INTERNATIONAL RAILWAY CONGRESS

FIFTH SESSION

LONDON : JUNE-JULY 1895

PROCEEDINGS

VOLUME 1

INTERNATIONAL
RAILWAY CONGRESS

5th, London. 1895.

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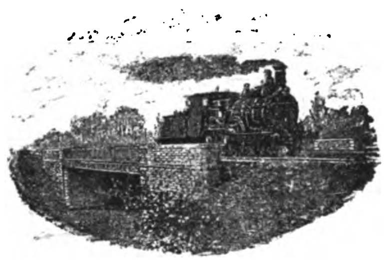
(ENGLISH EDITION)

VOLUME I



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PREFACE

In this edition a complete report of the Proceedings is given in English. There are, however, certain portions of the Proceedings which it has been found necessary to give in two languages. The sectional reports were originally drawn up in most cases in French, and accordingly the official French original is here preserved and printed in parallel columns, as was done in the daily journal of the meeting. Further, in order to economise, the list of delegates and other introductory matter has been printed in both languages to serve both for the French and English edition. Finally, it has seemed desirable to give certain of the speeches in their original words. Accordingly, the opening and closing ceremonies are reported both in French and English.

L. Weissenbruch,
Secretary
of the Executive Committee.

A. Dubois,
President.

BUREAU GÉNÉRAL — GENERAL OFFICIALS

DE LA CINQUIÈME SESSION — OF THE FIFTH SESSION

Président d'honneur (Honorary President) :

H. R. H. the PRINCE OF WALES.

Président (Acting President) :

Right Hon. Lord STALBRIDGE, Chairman of the London and North Western Railway and President of the Railway Companies' Association.

Vice-présidents (¹) :

Autriche-Hongrie (Austria-Hungary). — **Autriche.** — S. Exc. le Dr chevalier LÉON VON BILINSKI, conseiller intime I. R., chef de section au ministère I. R. du commerce, président de la direction générale I. R. des chemins de fer de l'État autrichien.

Hongrie. — JULES LUDVIGH, conseiller ministériel, membre de la Chambre des magnats, directeur-président des chemins de fer de l'État hongrois, membre de la Commission internationale du Congrès.

Belgique (Belgium). — A. DUBOIS, administrateur des chemins de fer de l'État belge, président de la Commission internationale permanente du Congrès.

Brésil (Brazil). — ROBERTO TROMPOWSKY LEITAO DE ALMEIDA, lieutenant-colonel du génie, chef de la Commission du ministère des travaux publics en Europe.

Chili. — VICTOR PRETOT FREIRE, ingénieur, inspecteur technique des matériaux en Europe.

Congo. — Le major ALBERT THYS, officier d'ordonnance du Roi des Belges, administrateur directeur général de la Compagnie du chemin de fer du Congo.

Danemark (Denmark). — TEGNER, directeur général des chemins de fer de l'État danois.

Égypte (Egypt). — S. Exc. BOGOS PACHA NUBAR, administrateur.

(¹) En vertu de l'article 12 des statuts du Congrès, le premier délégué de chaque Gouvernement est de droit vice-président. (Art. 12 of constitution of the Congress runs as follows : The delegate nominated first by each Government is *ex-officio* vice-president.)

Espagne (Spain). — E. Echegaray, ingénieur en chef au ministère des travaux publics.

États-Unis d'Amérique (United States of America). — James R. Roosevelt, secretary of the United States Embassy in London.

France. — Alfred Picard, inspecteur général des ponts et chaussées, président de la section des travaux publics, de l'agriculture, du commerce et de l'industrie au conseil d'État, vice-président du comité consultatif des chemins de fer, vice-président de la Commission internationale du Congrès.

Grande-Bretagne, empire des Indes et colonies (Great Britain, India and Colonies) :

A. Grande-Bretagne (Great Britain). — The Earl Cathcart.

B. Empire des Indes et colonies (India and Colonies). — **Indes (India).** — Col. R. A. Sargeaunt, R. E., Assoc. M. Inst. C. E., F. J. Inst., director-general of Indian Railways.

Canada. — Sir Charles Tupper, Bart., G. C. M. G., C. B., High Commissioner for Canada in London.

Natal. — Walter Peace, C. M. G., agent general for Natal in London.

Australie de l'Ouest (Western Australia). — Sir Malcolm Fraser, K. C. M. G, agent-general for Western Australia in London.

Australie du Sud (South Australia). — The Hon. Thomas Playford, agent general for South Australia in London.

Nouvelle-Galles du Sud (New South Wales). — Edward Miller Gard Eddy, chief commissioner of the New South Wales Government Railways.

Nouvelle-Zélande (New Zealand). — John Carruthers, Consulting Engineer to the Government of New Zealand in London.

Queensland. — Sir James Garrick, agent general for Queensland in London.

Tasmanie (Tasmania). — Sir Robert G. W. Herbert, G. C. B., agent general for Tasmania in London.

Italie (Italy). — Le comte Louis Ripa di Meana, inspecteur général des chemins de fer.

Japon (Japan). — Hikokichi Ijuin, secrétaire de légation du Japon à Londres.

Mexique (Mexico). — Luis Salazar, ingénieur.

Norvège (Norway). — C. Pihl, directeur pour le département de construction aux chemins de fer de l'État norvégien.

Pays-Bas (Holland). — J. J. van Kerkwijk, membre de la seconde Chambre des États-Généraux des Pays-Bas, membre de la Commission internationale du Congrès.

Portugal. — Bento Fortunato de Moura Continho d'Almeida d'Eça, ingénieur inspecteur de 1re classe et membre du conseil des travaux publics et des mines.

Roumanie (Roumania). — Duca, directeur général des chemins de fer de l'État roumain, professeur à l'École des ponts et chaussées de Bucharest, membre de la Commission internationale du Congrès et rapporteur.

Russie (Russia). — Alexandre Yermolow, conseiller privé, directeur de la chancellerie du ministre des voies de communication.

Serbie (Servia). — Milivoie Yossimovitch, inspecteur général des chemins de fer de l'État serbe.

Siam. — Xavier Olin, ancien ministre des travaux publics de Belgique.

Suède (Sweden). — Le comte Rodolphe Cronstedt, directeur général des chemins de fer de l'État.

Suisse (Switzerland). — Johann Tschiemer, inspecteur technique au département des postes et des chemins de fer.

Turquie (Turkey). — Le commandant Ghalib Bey, attaché naval de la légation de Turquie à Londres.

Secrétaire général (General Secretary) :

Sir Henry Oakley, general manager of the Great Northern Railway and secretary of the Railway Companies' Association.

Bureaux des sections. (Officials of the Sections.)

SECTION I.

Président. — Richard Jeitteles, conseiller I. et R. aulique, directeur général du chemin de fer du Nord Empereur Ferdinand d'Autriche, membre de la Commission internationale du Congrès.

Secrétaires principaux. — Debray, ingénieur en chef des ponts et chaussées de France, professeur à l'École nationale des ponts et chaussées, secrétaire général de la commission de méthodes d'essai des matériaux de construction.

E. Andrews, Resident Engineer, London and South Western Railway.

Secrétaires-rapporteurs. — Demoulin, inspecteur du matériel et de la traction des chemins de fer de l'Ouest français.

Leslie Robinson, Assiociate Member of the Institution of Civil Engineers.

SECTION II.

Président. — Kossuth, ingénieur, directeur de l'exploitation du deuxième compartiment des chemins de fer de la Méditerranée (Italie).

Secrétaires principaux. — Sauvage, ingénieur en chef des mines, ingénieur en chef adjoint du matériel et de la traction des chemins de fer de l'Ouest français.

Lieut. E. P. C. Girouard, Royal Engineers.

Secrétaires-rapporteurs. — de Fréminville, inspecteur du matériel roulant au chemin de fer de Paris à Orléans.

E. R. Dolby, Associate Member of the Institution of Civil Engineers, Member of the Institution of Mechanical Engineers, Whitworth Scholar.

Wildhagen, inspecteur principal de la Compagnie internationale des wagons-lits et des grands express européens.

SECTION III.

Président. — S. KERBEDZ, ingénieur, président du chemin de fer Vladicaucase.

Secrétaires principaux. — FRANÇOIS SCHÜLE, ingénieur du contrôle au département fédéral des chemins de fer suisses.

VICTOR GÉRARD, Continental Traffic Manager, London, Brighton and South Coast Railway.

Secrétaires-rapporteurs. — FAVRE, chef de la gare maritime de Calais du chemin de fer du Nord français.

VISINET, agent de la Compagnie des chemins de fer de l'Ouest français en Angleterre.

NIESSEN, agent of the London, Chatham and Dover Railway in Cologne.

Captain CHURCHWARD, agent of the London, Chatham and Dover Railway in Paris.

SECTION IV.

Président. — LÉON SAY, membre de l'Institut, vice-président des chemins de fer du Nord français.

Secrétaires principaux. — Cornel TOLNAY, inspecteur principal à l'inspection générale des chemins de fer et de la navigation au ministère du commerce de Hongrie.

C. J. OWENS, chief goods manager, London and South-Western Railway, Royaume-Uni.

Secrétaires-rapporteurs. — GUILLOUX, sous-inspecteur des services administratifs du chemin de fer du Nord français.

H. H. SPILLER, general Continental agent of the Midland Railway.

SECTION V.

Président. — The Right Hon. Sir ARTHUR OTWAY, Bart., director of the London, Brighton and South Coast Railway.

Vice-président. — GUSTAV BEHRENS, director of the Midland Railway.

Secrétaires principaux. — Le baron ALBERT DE FIERLANT, ingénieur, chef de service de l'exploitation à la Société générale de chemins de fer économiques belges.

Hon. T. C. FARRER, director of the Midland-Uruguay Railway.

Secrétaires-rapporteurs. — Le Dr. HARRY L. HIRSCHL, secrétaire du président de la Société autrichienne-hongroise des chemins de fer de l'État.

Captain GYE, R. N., agent of the South-Eastern Railway in Paris.

LISTE GÉNÉRALE DES DÉLÉGUÉS

GENERAL LIST OF DELEGATES

INTRODUCTION

Dans la liste des délégués que l'on trouvera ci-après, nous avons évité le plus possible les traductions pour ne pas grossir cet opuscule. Nous croyons donc utile de donner ici quelques mots d'explication qui aideront les délégués à traduire eux-mêmes les titres qui figurent à côté des noms.

Titres des fonctionnaires des chemins de fer anglais et américains.

Angleterre. — Les administrateurs (*directors*) ayant à leur tête un président (*chairman*) et un ou deux vice-présidents (*deputy chairmen*) forment le Conseil (*Board*). Le principal fonctionnaire est le directeur général (*general manager*) qui, outre la responsabilité dont il est chargé en ce qui concerne la direction de la ligne, les relations avec le gouvernement et d'autres compagnies, et toutes les autres négociations importantes, est spécialement à la tête du département du trafic (*traffic department*) qui réunit l'exploitation et le service commercial.

Directement sous ses ordres il y a : 1° le directeur en chef des marchandises ou chef du service commercial (*chief goods manager*) avec ses aides, le directeur en chef adjoint des marchandises (*assistant goods manager*), le directeur des charbons, etc. (*mineral manager*), le directeur du service extérieur des marchandises (*outdoor goods manager*) et les chefs de service régionaux des marchandises (*district goods mana-*

In order to save space we have avoided, as much as possible, giving translations of their titles in the following list of delegates. We have, however, thought it advisable to add a few words of explanation below which will enable delegates to translate the official titles for themselves.

Official Titles on English and American Railways.

England. — The *directors*, with at their head a *chairman* and one or two *deputy chairmen*, constitute the *Board*. The principal officer is the *general manager*, who in addition to a general responsibility for the management of the line as a whole, for negociations with the Government and other Companies, and all other important matters of policy, is more particularly at the head of the *traffic department*.

Directly under him are (1) the *chief goods manager*, with his *assistant goods manager*, *mineral manager*, *out-door goods manager* and *district goods manager;* and (2) the *superintendent of the line*, called also *general superintendent* and *traffic superintendent* and very frequently *superintendent* merely, with his *assistant superintendent*, *out-door superintendent*, and *district superintendents*.

gers), et 2° le surintendant de la ligne ou chef du mouvement (*superintendent of the line*, *general superintendent* ou *traffic superintendent*, et très fréquemment *superintendent*) avec son adjoint (*assistant superintendent*) son surintendant du service extérieur (*out-door superintendent*), et ses chefs de service régionaux (*district superintendents*).

A la tête du service de la voie (*engineering* ou *permanent way* ou *way and works department*) se trouve l'ingénieur en chef du service de la voie et des bâtiments (*engineer* ou *chief engineer* ou *civil engineer*) Il a généralement sous ses ordres un ingénieur en chef de l'entretien (*chief engineer of open lines*), un ou deux adjoints (*assistant engineers*) et un personnel d'ingénieurs régionaux ou divisionnaires (*divisional* ou *district engineers*).

Outre les ingénieurs faisant partie de leur personnel, plusieurs compagnies ont un ingénieur-conseil (*consulting-engineer*), ou une firme d'ingénieurs-conseils à laquelle elles s'adressent pour les affaires difficiles ou bien pour les aider à rédiger les demandes adressées au Parlement pour obtenir la concession de nouvelles lignes à construire.

A la tête du service de la traction et du matériel est le chef de la traction (*locomotive superintendent*) ou ingénieur en chef des constructions mécaniques (*chief mechanical engineer*). Il a sous ses ordres un ou plusieurs adjoints (*assistant locomotive superintendents*), un chef du service des ateliers (*works manager*) et deux ou plusieurs chefs de service régionaux (*divisional locomotive superintendents*). L'inspecteur en chef du matériel roulant (*carriage and wagon superintendent*) est parfois subordonné au chef de la traction et parfois il en est indépendant.

Les autres fonctionnaires supérieurs (*chief officers*) de la Compagnie, souvent appelés fonctionnaires du Conseil (*Board officers*) parce qu'ils dépendent directement du Conseil, sont les chefs de service suivants : le secrétaire (*secretary*) (qui est le représentant officiel de la Compagnie auprès des tribunaux et qui est l'instrument confidentiel du Conseil), l'avoué (*solicitor*), l'agent du domaine privé (*land and estate agent*), le chef comptable (*accountant*), le chef du service des magasins (*store keeper* ou *stores superintendent*), et parfois un chef du service des titres (*registrar*), un

At the head of the *engineering department*, also called *permanent way department* or *way and works department*, is the *engineer*, also called *chief engineer* and *civil engineer*. He generally has under him a *chief engineer of open lines*, one or more *assistant engineers*, and a staff of *divisional* or *district engineers*.

In addition to the *engineers* on their own staff, many Companies have a *consulting engineer* or sometimes a firm of engineers as *consultants*, who are called in to advise in difficult matters and to support applications to Parliament for power to construct new lines.

At the head of the *locomotive* or *rolling stock department* is the *locomotive superintendent*, sometimes called the *chief mechanical engineer*. He has under him one or more *assistant locomotive superintendents* and a *works manager*, and two or more *divisional locomotive superintendents*. The *carriage* and *wagon superintendent* is sometimes subordinate to the locomotive superintendent, sometimes an independent officer.

The other *chief officers* of the Company, frequently called *Board officers*, because they report directly to the *Board*, are the following *heads of departments : Secretary* (the official representative of the Company in lawsuits and in dealings with the Government and the confidential servant of the Board), *solicitor*, *land and estate agent*, *accountant*, *store keeper* or *stores superintendent*, and sometimes *registrar*, *cashier*, and *treasurer*.

caissier (*cashier*) et un trésorier (*treasurer*).

Les fonctionnaires suivants ont aussi des fonctions comportant une certaine indépendance, bien que leurs services soient souvent subordonnés à l'un ou à l'autre des services principaux : le chef du service des télégraphes (*telegraph superintendent*), le chef des services maritimes (*marine superintendent*), l'inspecteur en chef du service des signaux (*signal superintendent*) le directeur des hôtels et des buffets (*hotel and refreshment room manager*).

États-Unis. — Le président du conseil d'administration aux États-Unis est généralement appelé *president* (et non *chairman* comme en Angleterre). Parfois, cependant, il y a un *chairman* qui préside les séances du conseil, tandis qu'il existe aussi un *president* de la compagnie. Le président a sous ses ordres un ou plusieurs *vice-presidents*, qui sont ou ne sont pas membres du conseil. Chacun des vice-présidents est placé à la tête d'une ou de plusieurs branches du service. Le président et les vice-présidents sont donc les principaux fonctionnaires d'un chemin de fer américain et ils en représentent le pouvoir exécutif. Les principaux services placés sous leurs ordres sont :

Le secrétariat — dirigé par un secrétaire (*secretary*) — a la garde des archives à l'exclusion des pièces de comptabilité; il est chargé également de l'émission, du transfert, etc., des actions de la compagnie.

La trésorerie — dirigée par un trésorier (*treasurer*) — a la responsabilité de la caisse et du portefeuille, opère les recettes de toute nature et fait les payements d'après les ordres de tels ou tels fonctionnaires ou comités, conformément aux règlements.

Le service de la comptabilité — dirigé par un chef de la comptabilité (*comptroller* ou *general auditor*) — est chargé de la tenue de tous les registres et des comptes de la compagnie.

Le chef de ce service est généralement assisté par des comptables spéciaux des recettes des marchandises, des recettes des voyageurs, des dépenses, etc. (*auditors of freight receipts, passenger receipts, disbursements, etc.*). Il est d'habitude sous les ordres directs du président ou d'un vice président, mais c'est quelquefois l'un des vice-présidents lui-même et dans ce cas il

The following officers have also independent titles, though their departments are usually subordinate to one of the other principal departments : *Telegraph superintendent, marine superintendent, signal superintendent, hotel and refreshment room manager.*

United States. — The chairman of the Board of directors in the United States is generally called *president*. In some cases, however, these two functions are separate. The president is assisted by one or more *vice-presidents*, who may or may not be members of the Board. They each exercise general supervision over one or more Departments specially assigned to them. The president and vice-presidents are therefore the principal executive officers of an American railway. The chief departments under them are as follows :

The secretariat — with a *secretary* at its head — has charge of the records of the Company as distinguished from the accounts and is charged also with the issue, transfer, etc., of the Company's shares.

The treasury — with a *treasurer* at its head — is charged with the custody of the Company's money and securities, receives the cash from every source and distributes it under the direction of such officials or committees as the regulations of the Company provide.

The accounting department — in charge of a *comptroller* or *general auditor* — has charge of all the books and accounts of the Company.

He is usually assisted by *auditors* of special departments such as *freight receipts, passenger receipts, disbursements*, etc. He ordinarily reports to the president or to a vice-president, but in some cases is himself a vice-president and reports directly to the Board of directors.

dépend directement du conseil d'administration.

Ce qu'on appelle le SERVICE DU TRAFIC des chemins de fer américains ne comprend le plus souvent que l'exploitation commerciale. Il est dirigé par un chef du service commercial (*traffic manager*), ayant sous ses ordres un inspecteur principal (ou agent général) du service des marchandises (*general freight agent*) et un inspecteur principal (ou agent général) du service des voyageurs (*general passenger agent*) avec leurs adjoints (*assistants*) et leurs chefs de service divisionnaires (*divisional freight and passenger agents*). Dans quelques cas, c'est un vice-président qui est directement à la tête du service du trafic et parfois il cumule cette direction avec celle de l'administration générale de la compagnie.

THE TRAFFIC DEPARTMENT of American railways is usually concerned only with the commercial service. Its chief officers are *traffic manager* assisted by a *general freight agent* and a *general passenger agent* with their *assistants* and *divisional freight* and *passenger agents*. In some cases a vice-president is at the head of the traffic department and often combines that duty with that of direction of the operations or general management of the company as well.

LE SERVICE DE L'EXPLOITATION ou de la DIRECTION GÉNÉRALE (*Operating* ou *general management department*) comprend l'exploitation technique et est dirigé par un *directeur général* (*general manager*), qui est souvent aussi l'un des vice-présidents. Il a la direction générale des transports, du mouvement et de l'entretien de la voie, y compris les constructions nouvelles. Il a sous ses ordres un directeur général adjoint (*assistant general manager*), des chefs d'exploitation (*general superintendents*), un ingénieur en chef de la voie (*chief engineer*), un chef de service des télégraphes (*superintendent of telegraphs*), un ingénieur en chef de la traction (*superintendent of motive power*), un chef de service des ateliers (*superintendent of machinery*), etc. Les directeurs d'exploitation sont généralement chargés seulement du mouvement et de l'entretien de la voie d'une des grandes divisions du réseau et ils ont sous leurs ordres des chefs de service de l'exploitation divisionnaires ou régionaux (*division superintendents*), des chefs de section (*road masters*) ou des ingénieurs de l'entretien de la voie (*engineers of maintenance of way*), des chefs de dépôts (*master mechanics*), des chefs du mouvement ou agents chargés de l'expédition des trains (*train despatchers*), etc.

THE OPERATING OR GENERAL MANAGEMENT DEPARTMENT is ordinarily under the charge of the *general manager*, who is in very many cases also a vice-president of the company. He has general supervision of the transportation, traffic and maintenance including construction. He is generally assisted by an *assistant general manager*, *general superintendents*, *chief engineer*, *superintendent of telegraphs*, *superintendents of motive power and machinery*, etc. The general superintendents are usually in charge of grand divisions of the line with respect to transportation and maintenance only, being assisted by *division superintendents*, *road masters*, or *engineers of maintenance of way*, *master mechanics*, *train despatchers*, etc.

Les chefs du service commercial régionaux ou divisionnaires sont sous les ordres directs du chef du service commercial ou bien des chefs des services des marchandises et des voyageurs, et non des chefs de l'exploitation des grandes divisions.

Division traffic officials usually report direct to the head of the traffic department or to the heads of the freight and passenger departments and not to the divisional general superintendent or superintendents.

Titres et qualités des fonctionnaires des chemins de fer du continent.

Compagnies privées. — Comme en Angleterre comme aux États-Unis, le *conseil d'administration* est investi des pouvoirs les plus étendus pour l'administration de la Société, mais il délègue en général ces pouvoirs à un *comité exécutif* permanent de cinq à sept membres, qui font à tour de rôle un service hebdomadaire pour la vérification de la caisse centrale et des titres. Ce comité délègue à son tour ses pouvoirs au *directeur* ou *directeur général de la Compagnie* qui est l'autorité chargée d'exécuter les décisions du conseil ou les ordres du gouvernement.

Le gouvernement a, en général, une action de contrôle sur toutes les affaires des compagnies, mais l'étendue de cette autorité varie de pays à pays.

En France, le contrôle du gouvernement est exercé par un directeur du contrôle des chemins de fer au ministère des travaux publics, qui est indépendant de l'administration des chemins de fer de l'État. L'organisation de l'administration des chemins de fer de l'État est exactement semblable à celle des grandes compagnies, et elle est soumise à la même surveillance que celles-ci. La surveillance de chaque grand réseau forme elle-même un service de surveillance à la tête de laquelle se trouve *un inspecteur général des mines* ou *des ponts et chaussées* assisté de *quatre ingénieurs en chef* et d'*un inspecteur principal du contrôle de l'exploitation commerciale*, ainsi que d'*ingénieurs*, de *contrôleurs*, de *commissaires de surveillance*, etc., de chaque ligne.

En Russie, le directeur de chaque Compagnie (appelé aussi directeur de l'exploitation) est nommé par le gouvernement sur une liste de candidats présentés par le conseil et il est responsable, vis-à-vis du *ministre des voies de communication*, de l'état général de la voie, des ouvrages d'art, du matériel, etc.

Titles and Functions of Railway Officials on the Continent.

Private lines. — The Board (*Conseil d'administration*), as in England and in the United States, has full control of the management of the Company, but as a rule it delegates its power to a permanent Executive Committee (*Comité exécutif*) of from five to seven members, one of whom attends daily at the office according to a rota to examine the cash accounts and share registers. The Committee in its turn delegates its power to the manager (*directeur de la Compagnie*) or general manager (*directeur général de la Compagnie*) who is the executive officer charged with carrying out the decisions of the Board or the orders of the Government.

The Government has, as a rule, supreme control over the Company's affairs, but the extent of its authority varies from one country to another.

In France the Government control over all the Railways is exercised by a Railway Comptroller in the Ministry of Public Works (*directeur du contrôle des chemins de fer au Ministère des Travaux publics*) who is independent of the State Railways administration. The organisation of the State Railways is exactly the same as that of the great Companies, and it is subjected to the same control by the Ministry of Public Works as they are. The inspectorate (*surveillance*) of each great Company forms in itself an Inspecting Department, at the head of which there is an engineer having the rank of inspector general of the Mines or of the Roads and Bridges Department. He has as assistants four chief engineers (*ingénieurs en chef*), a principal inspector of commercial working (*inspecteur principal du contrôle de l'exploitation commerciale*), and a staff of engineers (*ingénieurs*), examiners (*contrôleurs*) and commissaries (*commissaires de surveillance*).

In Russia the manager of every Company (also called traffic manager) (*directeur de l'exploitation*) is nominated by the Government out of a list presented by the Board, and he is responsible to the Minister of communications (*voies de communication*), for the maintenance of the permanent way, works, rolling stock, etc.

En Autriche et en Italie, l'inspection générale des chemins de fer est divisée en cinq sections (constructions, mouvement et traction, exploitation commerciale, garanties et comptabilité et administration générale).

Chacune d'elles est dirigée par *un inspecteur général* assisté d'*inspecteurs en chef ou principaux* (ober inspectors), d'*inspecteurs* et de *commissaires*.

En Suisse, le contrôle relève d'une section spéciale du ministère des chemins de fer partagée en deux divisions, l'une administrative, l'autre technique. A la tête de chacune de celles-ci se trouve un *inspecteur* aidé d'*ingénieurs du contrôle*, etc.

En Belgique, le contrôle se fait peu sentir. Il est exercé par l'administration des chemins de fer de l'État qui est aussi chargée de l'octroi des concessions nouvelles et de la construction des nouvelles lignes.

En Hollande, où tous les chemins de fer sont exploités par des Compagnies, le contrôle est plus sévère.

Mais revenons à l'organisation des compagnies. Celle-ci souffre quelques exceptions et au chemin de fer Hollandais, par exemple, c'est un membre du conseil nommé *administrateur délégué* qui est le directeur de la Compagnie, tandis qu'un autre membre s'occupe du secrétariat et un autre du service de la trésorerie.

En Suisse, au lieu du directeur, il y a une *direction*, ou un *comité de direction*, composée d'un *président* et de plusieurs *membres* de la direction choisis obligatoirement ou non parmi les membres du Conseil et ayant chacun à conduire un département de l'administration centrale.

En Russie, certains conseils d'administration ont sous leur dépendance directe certains services, par exemple, le service commercial, le contrôle, l'économat, le contentieux.

Presque partout, les directions ou les directeurs disposent généralement d'une administration centrale très complète dont les principales subdivisions sont :

Administration centrale;

Exploitation;

In Austria and in Italy, the Railway inspectorate is divided into 5 sections (building, train movement, commercial service, guarantees and audit, general management).

Each of these is in charge of an inspector general (*inspecteur général*), who has under him chief inspectors (*inspecteurs en chef ou principaux*), inspectors and commissaries.

In Switzerland, the control is entrusted to a special section of the Railway Ministry, which has two departments, one administrative and the other technical. At the head of each department is an inspector (*inspecteur*), assisted by controlling engineers (*ingénieurs du contrôle*), etc.

In Belgium there is but little control over private lines and it is exercised by the State Railways Administration, which is responsible for granting charters for new lines and for their construction.

In Holland where all the railways belong to Companies the State control is more severe.

But to return to the organisation of the Companies there are some exceptions to the rules given above. On the Dutch Railways, for instance, a member of the Board is appointed managing director (*administrateur délégué*); he takes the place of general manager, while another member of the Board takes charge of the secretary's department, and another of the treasury.

In Switzerland, instead of a manager (*directeur*) there is a managing Committee, which consists of a president and several members of the Board, who in some Companies must be and in others need not be members of the Board, each having charge of a department of the Central Administration.

In Russia the « Boards » of some Companies have directly under them certain departments, for instance, the traffic, the audit, stores, solicitors' department.

Almost everywhere the directorates (*directions*) or the general managers (*Directeurs*) as the case may be, have under them a very complete central organisation. Its principal departments are :

Central Administration (*Administration centrale*).

Traffic (*exploitation*).

Traction et matériel;

Surveillance (de la voie) et *travaux* (ou *constructions nouvelles*).

Chacune de ces divisions, appelées en France des services centraux, a un chef qui a le titre d'*ingénieur en chef* (*chef d'exploitation, de la traction*, etc.), sauf l'administration centrale qui est dirigée par un *secrétaire général* et qui comprend, en outre, un *chef du contentieux*, un *inspecteur général de la comptabilité*, un *caissier en chef*, etc. Ces derniers fonctionnaires dépendent parfois directement du comité de direction ou exécutif.

Parfois les services centraux sont beaucoup plus nombreux. La Kaiser Ferdinands Nordbahn (Autriche) a en plus le *bureau central*, le *service commercial*, le *service financier*, le *service du matériel*, le *service des mines*, le *service des secours* le *contrôle des recettes et des dépenses* et le *bureau de la statistique*.

Les *services exécutifs* à l'extérieur, appelés en France *services régionaux*, sont presque toujours indépendants les uns des autres. Cependant, cette règle n'est pas tout à fait générale et aux chemins de fer Nord-Ouest autrichiens et Jonction Sud-Nord allemande, le mouvement, l'entretien et la traction forment des *inspections* sous les ordres d'un seul chef.

Au chemin de fer de la Méditerranée (Italie), le réseau est divisé, en ce qui concerne principalement le mouvement et la traction, en deux *compartiments d'exploitation* analogues aux grandes divisions des chemins de fer des États-Unis. Le directeur général, résidant à Milan, a sous ses ordres directs. outre l'*administration centrale*, une *agence commerciale*, une *division technique de l'exploitation* et une *délégation auprès du gouvernement* (à Rome). Les grands services centraux tels que celui de *l'entretien de la voie* et même de la *comptabilité* sont considérés dans ces conditions comme des services

Locomotive and rolling stock (*traction et matériel*).

Way and works or new works (*surveillance de la voie et travaux ou constructions nouvelles*).

Each of these departments, which in France are called « central service » has at its head an official with the title of « engineer in chief » (*ingénieur en chef*), traffic manager (*chef de l'exploitation*), locomotive superintendent (*chef de la traction*), etc., except the central administration, which is in charge of a general secretary (*secrétaire général*), and includes further a head of the law department (*chef du contentieux*) and a chief accountant (*inspecteur général de la comptabilité*), chief cashier (*caissier en chef*), etc. These latter officials are sometimes immediately under the executive Committee.

Sometimes the central departments are much more numerous. The Kaiser Ferdinands Nordbahn (Austria) has, in addition to those mentioned above, a central office, commercial branch (*service commercial*), financial branch (*service financier*), rolling stock department (*service du matériel*), mines department (*service des mines*), sick and accident fund (*service des secours*), audit of receipts and expenditure (*contrôle des recettes et des dépenses*), and statistical office (*bureau de la statistique*).

The outdoor executive services (*services exécutifs*) called in France district services (*services régionaux*) are almost always independent of one another. However, this rule is not universal, and on the North Western of Austria and the German South North Junction, the train movement, maintenance of way and works and the locomotive departments, are united to form inspectorates (*inspections*) each under a single head.

The system of the Mediterranean of Italy is divided, especially so far as train movement and the locomotive departments are concerned, into two traffic divisions (*compartiments d'exploitation*), similar to the grand divisions of the United States. The general manager, who has his headquarters at Milan, has under his immediate control, besides the central administration, a commercial agency, a technical traffic working department, and special representatives to deal with the government (at Rome). The main central departments, such as those of the permanent way, and even the accountants, are accorextérieurs, mais ils ont néanmoins eux-mêmes leurs chefs de service exécutifs aussi bien dans le premier compartiment que dans le second.

Quant aux titres des fonctionnaires de deuxième et de troisième rang, il est presque impossible de les expliquer ou d'en donner des équivalents anglais.

Au chemin de fer Grand Central Belge, le titre d'ingénieur chef de service est un grade qui ne comporte nullement la direction d'un service et qui équivaut à ce que, sur d'autres réseaux, on appelle ingénieur principal ou ingénieur en chef. Un inspecteur a, en France, le même rang qu'un chef de bureau et à l'État belge ou dans certains chemins de fer allemands, celui d'un chef de division.

Enfin, à l'Est français, les sous-directeurs de la traction s'appellent *ingénieurs en chef adjoints de la traction*, tandis qu'à l'État belge ils s'appellent *ingénieurs en chef inspecteurs de direction* de la traction.

Chemins de fer de l'État. — Les chemins de fer de l'État ont sur le continent une importance toujours grandissante. En Allemagne, sur 44,000 kilomètres, 28,000 sont exploités par l'État; en Autriche-Hongrie, sur 28,000 kilomètres, 16,000; en Belgique, sur 5,400 kilomètres, 3,200; en Danemark, sur 2,000 kilomètres, 1,700; en Russie, sur 31,600 kilomètres, 23,200; en Suède, sur 8,500 kilomètres, 3,100.

En France, comme nous l'avons déjà dit, le réseau d'État est exactement organisé sur le modèle d'une compagnie privée. Il possède donc un conseil d'administration qui est l'intermédiaire entre le directeur et le ministre des travaux publics, et qui a, à peu près, les mêmes pouvoirs que le conseil d'une grande compagnie. Un conseil analogue existe en Roumanie, mais le réseau d'État n'y est pas soumis au contrôle supplémentaire d'une administration distincte; en outre, le conseil communique avec le ministre par l'in-

dingly considered as district or divisional services (*services extérieurs*), but for all that they have at their head officials ranking as principal officers in both divisions of the system (*compartiments*).

As for the titles of the officers of the 2nd and 3rd class, it is almost impossible to explain them or to give their English equivalent.

On the Grand Central Belge the title engineer chief of department (*ingénieur chef de service*) in no way implies that the holder is at the head of a department, and is equivalent to what on other systems is called chief engineer (*ingénieur en chef ou principal*). Generally speaking, an inspector (*inspecteur*) ranks with a chief clerk (*chef de bureau*); while on the Belgian State Railway, and on certain German lines, he has a higher degree in order or dignity and ranks as a *chef de division*.

Finally on the Eastern of France the assistant locomotive superintendents are entitled *ingénieurs en chef adjoints de la traction*, while on the Belgian State Railway they are called *ingénieurs en chef inspecteurs de direction, de la traction*.

State Railways. — The State Railways on the Continent are constantly increasing in importance. In Germany out of 27,280 miles (44,000 kilometres) 17,360 miles (28,000 kilometres) are worked by the State; in Austro-Hungary out of 17,360 miles (28,000 kilometres) 9,920 miles (16,000 kilometres); in Belgium out of 3,349 miles (5,400 kilometres) 1,984 miles (3,200 kilometres); in Denmark out of 1,240 miles (2,000 kilometres), 1,055 miles (1,700 kilometres); in Russia out of 19,593 miles (31,600 kilometres) 14,384 miles (23,200 kilometres); in Sweden out of 5,271 miles (8,500 kilometres) 1,922 miles (3,100 kilometres).

In France, as has already been said, the State system is organised exactly on the same model as a private company. Accordingly it has a Board *Conseil d'administration*) interposed between the general manager and the Minister of Works, and which has, broadly speaking, the same powers as the Board of one of the great companies. A similar Board exists in Roumania, but the State Railway system is not there, as in France, subjected to the additional supervision by a separate organisation. Further, the Board termédiaire du directeur général et celui-ci peut en appeler au chef du département ministériel s'il y a divergence de vues.

A l'État belge, il n'y a pas de directeur général; en réalité, il y en a cinq qui ont le titre d'administrateurs et qui dirigent chacun spécialement un des services de l'administration centrale. Les directeurs de ces derniers services ont le titre de *directeur d'administration* ou d'ingénieur en chef directeur d'administration, s'ils sont ingénieurs.

En Hongrie, il y a cinq directions et le chef de la première (questions générales et exploitation) a le titre de directeur-président; mais, en dehors de l'administration des chemins de fer de l'État, il y a encore auprès du ministère du commerce, une section des chemins de fer dont l'une des subdivisions est l'inspection générale et la section des affaires commerciales s'occupe aussi des tarifs de transport.

D'autres chemins de fer de l'État en Danemark, en Suède, en Norvège, en Serbie, en Finlande, etc., ont un directeur général avec des pouvoirs étendus; mais nous avons encore à signaler d'une manière particulière les chemins de fer de l'État autrichien qui ont adopté en partie le principe de l'ancienne organisation allemande (récemment refondue d'une manière complète), avec cette différence que les grandes divisions du réseau en *directions d'exploitation* sont réunies sous les ordres d'*un président, chef de la direction générale*, ayant auprès de lui une administration centrale assez fortement constituée et composée de sept divisions dirigées par des *directeurs*. Les mêmes divisions se reproduisent à peu près dans chaque direction d'exploitation. Pour le service exécutif extérieur, il y a des *sections d'entretien* (de la voie), des *ateliers*, des *dépôts de machines* et des *offices d'exploitation*. Ceux ci n'ont pas et n'ont jamais eu une importance analogue à celle des institutions du même nom des chemins de fer prussiens qui étaient devenues de petites directions. Au contraire, ils sont situés dans les grandes stations et ce sont les chefs de ces stations qui les dirigent.

L'organisation des chemins de fer de l'État russe a quelque analogie avec celle de l'Autriche.

communicates with the Minister through the general manager, and this latter official may appeal to the Ministry if he differs from his Board.

On the Belgian State there is no general manager. In fact, there are five general managers who have the title of directors (*Administrateurs*), and each of whom has special charge of one of the departments of the Central Administration. The managers of these separate departments have the title of *Directeur d'administration*, or where they are engineers, the title of *Ingénieur en chef directeur d'administration.*

In Hungary there are five directorates, and the chief of the first of them (general and traffic questions) has the title of *directeur-président* but in addition to the management of the State Railways there is also at the Ministry of Commerce a railway section (one of whose special divisions is a general inspectorate), and besides the commercial section of this Ministry deals with the question of rates.

Other State Railways, in Denmark, Sweden, Norway, Servia, Finland, etc., have a general manager (*directeur général*) with large powers; but it is necessary to call special attention to the Austrian State Railways, which have partly adopted the principle of the original German organisation (which has recently been completely revolutionised) with this difference : that the great divisions of the system or traffic directorates (*directions d'exploitation*) are united under the orders of a president, chief of the general directorate, having at his disposal a very strongly constituted central staff composed of seven divisions, each in charge of a manager (*directeur*). The same divisions are, roughly speaking, reproduced in each traffic directorate. For the district out-door management there are maintenance sections (*sections d'entretien*) workshop sections, engine sheds, and traffic offices. These latter do not possess, and never have possessed, the same importance as the institutions which, till their abolition the other day, bore the same name on the Prussian Railways, and which had become petty directorates. On the contrary, in Austria they are situated at the main stations, and the Station superintendents are their heads.

The organisation of the Russian State Railways is not unlike that of Austria. The local

Les directions locales ont plus d'autonomie, bien qu'il y ait auprès de chacune d'elles un délégué du *contrôle de l'empire* chargé de l'examen des budgets, des recettes et des dépenses, de la surveillance de la gestion financière, etc.

L'administration centrale est formée d'*un conseil d'administration* composé d'un président, de sept délégués du ministère des voies de communication, d'un délégué de chacun des ministères des finances, de l'intérieur et des domaines de l'État, d'un représentant du contrôle de l'empire et de l'inspecteur général des chemins de fer (placé sous les ordres directs du ministre).

La surveillance des compagnies privées est confiée, sous les ordres du ministre des voies de communication, au *département des affaires de chemins de fer*. Le chef de ce département compose avec l'*adjoint* (ou substitut) *du ministre*, le président de la direction des chemins de fer de l'État, le chef du département des affaires de chemins de fer, du ministère des finances et quelques fonctionnaires des différents ministères, le *conseil des affaires de chemins de fer*, qui doit se prononcer sur toutes les grandes questions économiques. Les grandes questions techniques de construction et de travaux sont, en outre, soumises au *conseil des ingénieurs*, qui est un corps permanent et est composé de membres n'ayant pas d'autres fonctions.

Enfin, le ministère des finances, qui a dans ses attributions les questions de tarifs et les grandes questions commerciales, a un *département des affaires de chemins de fer* (au ministère des finances) pour les étudier, ainsi qu'*un conseil des affaires de tarifs*. Il y a en plus un comité des tarifs où les compagnies privées sont représentées et qui est présidé par le *directeur du département des affaires de chemins de fer du ministère des finances*.

manager of each line or system (*directeur local*) is more independent, but there is attached to each of them an official representing the Imperial control (*contrôle de l'Empire*), whose business it is to examine the accounts, receipts and expenditure, and generally to supervise the finance.

The central administration is formed of a Board composed of a president, seven representatives of the Ministry of Communications, one representative of the Ministry of Finance, one of the Ministry of the Interior and State Domains, one representative of the Imperial Control, and of the Inspector General of Railways which latter official reports direct to the Minister.

The supervision of the private Companies is entrusted, under the orders of the Minister of Communications, to the Railway Department; the head of this Department (*directeur*), together with the deputy Minister, the president of the State Railway directorate, the head of the Railway Matters Department from the Ministry of Finance and some other officials of various ministries compose the Railway Matters Council which deals with all important economic railway questions. The great questions of works and buildings are further under the control of an Engineering Council, which is a permanent body composed of members who devote their entire time to it.

Finally, the Finance ministry, which deals with questions of railway rates and important commercial matters, has also a Railway Matters Department, for investigation purposes, as also a Council to approve rates. There is also a tariff Committee, on which the private Companies are represented and which is presided over by the head of the Railway Matters Department from the Ministry of Finance.

N. B. — L'astérisque (*) indique qu'un délégué est déjà membre du Congrès en une autre qualité, laquelle est imprimée entre parenthèses. Tout nom répété n'entre plus en ligne de compte pour le calcul des délégations.

◆ = Inscrit sur la liste de présence.

N. B. — An asterisk (*) means that a delegate is already a member of the Congress in some other capacity, this latter being inserted in brackets. Members so marked are not included in the number allowed to their Company.

◆ = Registered as present.

I. — Membres de droit. (Ex officio delegates.)

A. — COMMISSION INTERNATIONALE PERMANENTE. (INTERNATIONAL PERMANENT COMMISSION.)

Président (*President*) :

◆A. **Dubois**, administrateur des chemins de fer de l'État belge.

Vice-présidents (*Vice-presidents*) :

◆Alfred **Picard**, inspecteur général des ponts et chaussées, président de la section des travaux publics, de l'agriculture, du commerce et de l'industrie au conseil d'État de France ;

◆Jules **Urban**, directeur général du chemin de fer Grand Central Belge, président de la Société générale belge de chemins de fer économiques.

Anciens présidents de session, membres permanents (*Past Presidents of sessions, permanent members*) :

François **Brioschi**, sénateur du royaume d'Italie (session de 1887);

◆Alfred **Picard**, précité (session de 1889);

Nicolas de **Petroff**, lieutenant général du génie, adjoint du ministre des voies de communication de Russie (session de 1892).

Membres (*Members*) :

◆Fredrik **Almgren**, administrateur des chemins de fer de l'État suédois ;

◆**Barabant**, directeur des chemins de fer de l'Est français ;

Borgnini, ingénieur, directeur général des chemins de fer de l'Adriatique ;

◆C. de **Burlet**, directeur général de la Société nationale belge des chemins de fer vicinaux ;

◆Amb. **Campiglio**, ingénieur, président de l'Union des chemins de fer italiens d'intérêt local, administrateur du chemin de fer du Nord de Milan ;

Colson, ingénieur en chef des ponts et chaussées, maître des requêtes au conseil d'État, directeur des chemins de fer au ministère des travaux publics de France ;

De Bruyn, ministre de l'agriculture et des travaux publics de Belgique, membre de la Chambre des représentants ;

◆**Dietler**, vice-président de la direction du chemin de fer du Gothard ;

◆**Duca**, directeur général des chemins de fer de l'État roumain, professeur à l'École des ponts et chaussées de Bucharest ;

◆Tony **Dutreux**, ingénieur civil, administrateur du chemin de fer Guillaume-Luxembourg ;

◆Sir Andrew **Fairbairn**, ancien membre du Parlement anglais, administrateur du Great Northern Railway (Angleterre);

◆**Griolet**, vice-président du conseil d'administration des chemins de fer du Nord français

◆**Heurteau**, directeur du chemin de fer d'Orléans ;

◆Richard **Jeitteles**, conseiller aulique, directeur général du chemin de fer du Nord autrichien Empereur Ferdinand ;

◆Louis **Lampugnani**, chef du trafic et du mouvement du premier compartiment des chemins de fer italiens de la Méditerranée ;

◆Max Edler von **Leber**, inspecteur en chef au corps I. R. du Contrôle des chemins de fer de l'Autriche ;

◆Jules **Ludvigh**, conseiller ministériel, membre de la Chambre des Magnats, directeur-président des chemins de fer de l'État hongrois ;

.Mathias **Massa**, ingénieur, directeur général des chemins de fer italiens de la Méditerranée

◆**Noblemaire**, directeur des chemins de fer de Paris à Lyon et à la Méditerranée ;

◆Louis de **Perl**, conseiller d'État actuel, directeur gérant de l'Union russe pour les relations internationales des chemins de fer ;

◆**Philippe**, inspecteur général des lignes Nord-belges ;

◆Le baron **Prisse**, directeur gérant honoraire du chemin de fer d'Anvers à Gand ;

◆**Ramaeckers**, secrétaire général du ministère des chemins de fer, postes et télégraphes de Belgique ;

◆**Schaar**, administrateur des chemins de fer de l'État belge ;

◆B. **Soumarokoff**, conseiller d'État actuel, ingénieur, directeur du département des chemins de fer de Russie ;

◆The Right Hon. Lord **Stalbridge**, président du conseil d'administration du London and North Western Railway (Angleterre) ;

◆de la **Tournerie**, inspecteur général des ponts et chaussées ;

◆**van Kerkwijk**, membre de la seconde Chambre des États-Généraux des Pays-Bas ;

◆**Werchovsky**, ingénieur, conseiller privé, membre du Conseil pour les affaires des chemins de fer de l'empire de Russie.

Secrétaire général (*General Secretary*) :

◆Auguste **De Laveleye**, ingénieur.

Secrétaire (*Secretary*) :

◆Louis **Weissenbruch**, ingénieur aux chemins de fer de l'État belge.

Trésorier (*Treasurer*) :

◆Édouard **Holemans**, chef de division aux chemins de fer de l'État belge.

Comité de direction de la Commission internationale.
(Executive Committee of the International Commission.)

Président : ◆A. **Dubois**. *Membres :* **Brioschi**, **De Bruyn**, ◆Sir Andrew **Fairbairn**, ◆**Griolet**, ◆Auguste **De Laveleye**, ◆**Ramaeckers**. *Secrétaire :* ◆Louis **Weissenbruch**. *Trésorier :* ◆E. **Holemans**.

Services spéciaux du Comité. (Executive Committee Staff.)

RÉDACTION DU *BULLETIN*. (EDITORIAL SUB-COMMITTEE.)

Président : ◆A. **Dubois**. *Membres :* ◆**Ramaeckers**, membre du comité de direction ; ◆L. **Weissenbruch**, secrétaire du comité de direction. *Secrétaire de la rédaction :* ◆A. **Huberti**, ingénieur, professeur à l'Université de Bruxelles.

SERVICE STÉNOGRAPHIQUE. (SHORTHAND STAFF.)

Lacomblé, chef du service sténographique à la Chambre et au Sénat de Belgique, *chef du service* ;
◆**Dehoul**, ◆**Demarteau**, ◆**Hombrecht**, ◆**Tambour** et ◆**Valkey**, *sténographes*.

B — SECTION ANGLAISE DE LA COMMISSION INTERNATIONALE.
(COMMISSION LOCALE D'ORGANISATION POUR LA CINQUIÈME SESSION.)

ENGLISH SECTION OF THE INTERNATIONAL COMMISSION.
(LOCAL ORGANISING COMMITTEE FOR THE FIFTH SESSION.)

Président (*President*) :

◆Sir Andrew **Fairbairn***, director Great Northern Railway (membre du Comité de direction du Congrès).

Vice-président (*Vice-President*) :

◆The Viscount **Emlyn**, deputy chairman Great Western Railway.

Membres (*Members*) :

◆G. J. **Armytage**, chairman, Lancashire and Yorkshire Railway;
◆Gustav **Behrens**, director, Midland Railway;
◆Sir **Courtenay Boyle**, K. C. B., secretary of the Board of Trade;
◆The Marquess of **Breadalbane**, K. G., director, Caledonian Railway;
◆John **Cleghorn**, director, North Eastern Railway;
◆J. C. **Colvill**, chairman, Great Southern and Western Railway of Ireland;
◆Sir Myles **Fenton**, general manager, South Eastern Railway;
◆J. S. **Forbes**, chairman, London Chatham and Dover Railway;
◆Lord Claud J. **Hamilton**, chairman, Great Eastern Railway;
◆Frederick **Harrison**, general manager, London and North Western Railway;
◆Henry **Lambert**, general manager, Great Western Railway;
◆G. W. **Maclure**, M. P., director, Manchester Sheffield and Lincolnshire Railway;
◆Sir Henry **Oakley**, general manager, Great Northern Railway;
◆The Right Hon. Sir Arthur **Otway**, Bart., director, London Brighton and South Coast Railway,
◆Wyndham **Portal**, chairman, London and South Western Railway;
◆Sir George **Russell**, Bart. M. P., director, South Eastern Railway;
◆Sir Charles **Scotter**, general manager, London and South Western Railway;
◆James **Thompson**, general manager, Caledonian Railway;
◆W. **Tipping**, director, London and North Western Railway;
◆G. H. **Turner**, general manager, Midland Railway;
◆The Marquess of **Tweeddale**, chairman, North British Railway.

Secrétaire (*Secretary*) :

◆W. M. **Acworth**.

Secrétaire adjoint (*Assistant Secretary*) :

◆**H. H. Orr**.

Comité de direction de la section anglaise.
(Executive Committee of the English Section.)

Président : ◆Sir Andrew **Fairbairn**. *Membres :* ◆The Viscount **Emlyn**, ◆The Right Hon. Sir Arthur **Otway**, Bart., ◆G. J. **Armytage**, ◆G. **Behrens**, ◆W. **Tipping**. *Secrétaire :* ◆W. M. **Acworth**. *Secrétaire adjoint :* ◆**H. H. Orr**.

C. — RAPPORTEURS NOMMÉS PAR LA COMMISSION INTERNATIONALE. (REPORTERS APPOINTED BY THE INTERNATIONAL COMMISSION.)

◆J. A. F. **Aspinall**, chief mechanical engineer, Lancashire and Yorkshire Railway;

◆W. **Ast**, conseiller de régence, directeur des voies et travaux du chemin de fer du Nord autrichien Empereur Ferdinand;

◆**Auvert**, ingénieur attaché au service central du matériel des chemins de fer de Paris à Lyon et à la Méditerranée;

◆**Belleroche**, ingénieur chef de service au chemin de fer Grand Central Belge;

◆A. von **Boschan**, ingénieur au chemin de fer du Nord autrichien Empereur Ferdinand;

◆**Bricka**, ingénieur en chef de l'exploitation des chemins de fer de l'État français, professeur du cours de chemins de fer à l'École des ponts et chaussées;

◆de **Burlet***, directeur général de la Société nationale belge des chemins de fer vicinaux (membre de la Commission internationale du Congrès);

H. **De Backer**, directeur général de la Société générale de chemins de fer économiques de Belgique.

Georges **De Laveleye**, membre du conseil d'administration du chemin de fer du Congo;

◆**Duca***, directeur général des chemins de fer de l'État roumain, professeur à l'École des ponts et chaussées de Bucharest (membre de la Commission internationale du Congrès);

◆F. **Harrison***, general manager, London and North Western Railway (membre de la section anglaise);

◆V. **Herzenstein**, ingénieur des voies de communication de Russie, vice-président de la Commission pour l'étude de la conservation des bois;

◆**Hodeige**, ingénieur principal aux chemins de fer de l'État belge;

◆**Hubert**, ingénieur en chef, directeur d'administration aux chemins de fer de l'État belge;

◆W. **Hunt**, chief engineer, Lancashire and Yorkshire Railway;

◆**Kowalski**, ingénieur en chef du service central de l'exploitation du chemin de fer de Bône-Guelma et prolongements;

◆Hy. **Lambert***, general manager, Great Western Railway (membre de la section anglaise);

◆Max Edler von **Leber***, inspecteur en chef au corps I. R. du Contrôle des chemins de fer de l'Autriche (membre de la Commission internationale du Congrès);

P. W. **Meik**, M. Inst. C. E.;

◆Lucien **Motte**, ingénieur principal aux chemins de fer de l'État belge;

◆A. C. **Humphreys-Owen**, M. P., chairman of the Montgomeryshire County Council, director Cambrian Railways;

◆A. C. **Park**, carriage superintendent, London and North Western Railway;

◆de **Perl***, conseiller d'État actuel, directeur gérant de l'Union russe pour les relations internationales des chemins de fer (membre de la Commission internationale du Congrès);

◆**Plocq**, ingénieur, chef de l'exploitation de la Société générale des chemins de fer économiques français;

◆J. **Richter**, adjoint du directeur de la ligne de Saint-Pétersbourg à Varsovie des chemins de fer de l'État russe;

◆Joseph **Rocca**, ingénieur, inspecteur de la direction générale des chemins de fer italiens de la Méditerranée;

◆**Sabouret**, ingénieur des ponts et chaussées, ingénieur principal du service central de la voie au chemin de fer de Paris à Orléans;

◆Eug. **Sartiaux**, chef des services électriques des chemins de fer du Nord français;

◆**Sauvage**, ingénieur en chef des mines, ingénieur en chef adjoint du matériel et de la traction des chemins de fer de l'Ouest français;

◆Léon **Scolari**, docteur en droit, chef de division à la direction générale des chemins de fer italiens de la Méditerranée;

◆**Terzi**, directeur du chemin de fer de Suzzara-Ferrara;

◆A. M. **Thompson** signal superintendent, London and North Western Railway;

◆G. H. **Turner***, general manager, Midland Railway (membre de la section anglaise);
◆R. H. **Twelvetrees**, chief goods manager, Great Northern railway;
◆J. L. **Wilkinson**, chief goods manager, Great Western Railway;
◆A. **Zanotta**, ingénieur, chef de section au service de l'entretien, surveillance et travaux des chemins de fer italiens de la Méditerranée.

D. — SECRÉTAIRES-RAPPORTEURS NOMMÉS PAR LA COMMISSION INTERNATIONALE. (SECRETARY-REPORTERS APPOINTED BY THE INTERNATIONAL COMMISSION.)

◆Capt. **Churchward**, agent of the London Chatham and Dover Railway in Paris;
◆**Demoulin**. inspecteur du matériel et de la traction des chemins de fer de l'Ouest français;
◆E. R. **Dolby**, Assoc. M. Inst. C. E., M. I. Mech. E. Wh. Sc.
◆**Favre**, chef de la gare maritime de Calais du chemin de fer du Nord français;
◆DE **Fréminville**, inspecteur du matériel roulant au chemin de fer de Paris à Orléans;
◆VICTOR **Gérard**, continental traffic manager, London, Brighton and South Coast Railway;
◆**Guilloux**, sous-inspecteur des services administratifs du chemin de fer du Nord français;
◆Capt. **Gye**, R. N., agent of the South Eastern Railway in Paris;
◆Le Dr HARRY L. **Hirschl**, secrétaire du président de la Société autrichienne-hongroise des chemins de fer de l'État;
◆**Niessen**, agent of the London, Chatham and Dover Railway at Cologne;
◆LESLIE **Robinson**, Associate Member of Institute of Civil Engineers;
◆**Sire**, agent de la Compagnie du chemin de fer du Nord français à Londres;
◆H. H. **Spiller**, general continental agent, Midland Railway;
◆E. **Uytborck**, agent of the South Eastern Railway in Brussels;
◆**Visinet**, agent de la Compagnie des chemins de fer de l'Ouest français en Angleterre;
◆**Wildhagen**, inspecteur principal de la Compagnie internationale des wagons-lits et des grands express européens.

II. — Membres délégués par les Gouvernements adhérents et les Administrations de chemins de fer participantes.

(Members appointed by Governments supporting, and by Railway Administrations subscribing to the Congress.)

A. — DÉLÉGUÉS DES GOUVERNEMENTS ADHÉRENTS. (MEMBERS APPOINTED BY GOVERNMENTS SUPPORTING THE CONGRESS.)

Argentine (République) (Argentine Republic).

Ministère de l'intérieur.

Autriche-Hongrie (Austria-Hungary).

Ministère du commerce d'Autriche :

◆S. Exc. le Dr chevalier LÉON VON **Bilinski**, conseiller intime I. et R., chef de section au ministère I. R. du commerce, président de la direction générale I. R. des chemins de fer de l'État autrichien.

◆MAX EDLER VON **Leber***, inspecteur en chef au corps I. R. du contrôle des chemins de fer de l'Autriche (membre de la Commission internationale du Congrès et rapporteur).

Ministère du commerce de Hongrie :

◆JULES **Ludvigh***, conseiller ministériel, membre de la Chambre des Magnats, directeur-président des chemins de fer de l'État hongrois (membre de la Commission internationale du Congrès);

◆CORNEL **Tolnay**, inspecteur principal à l'inspection générale des chemins de fer et de la navigation au ministère du commerce.

Belgique (Belgium).

Ministère des chemins de fer, postes et télégraphes et chemins de fer de l'État.

Commission internationale du Congrès :

◆A. **Dubois***, administrateur des chemins de fer de l'État belge, président de la Commission internationale du Congrès;

◆**Ramaeckers***, secrétaire général du ministère des chemins de fer, postes et télégraphes, membre du comité de direction du Congrès;

◆**Schaar***, administrateur des chemins de fer de l'État belge, membre de la Commission internationale du Congrès;

◆LOUIS **Weissenbruch***, ingénieur à l'Administration des chemins de fer de l'État belge, secrétaire du comité de direction du Congrès;

◆ÉDOUARD **Holemans***, chef de division à l'Administration des chemins de fer de l'État belge, trésorier du comité de direction du Congrès.

Rapporteurs :

◆**Hubert***, ingénieur en chef, directeur d'administration aux chemins de fer de l'État belge;

◆**Hodeige***, ingénieur principal aux chemins de fer de l'État belge;

◆LUCIEN **Motte***, ingénieur principal aux chemins de fer de l'État belge.

Autres délégués :

◆**Dethieu**, inspecteur général aux chemins de fer de l'État belge;

◆**Niels**, inspecteur de direction aux chemins de fer de l'État belge;

◆**De Busschere**, ingénieur en chef aux chemins de fer de l'État belge;

◆**Gerard**, ingénieur principal aux chemins de fer de l'État belge;

◆**Bruneel**, ingénieur principal aux chemins de fer de l'État belge.

Bolivie (Bolivia).

Ministère des travaux publics :

F. **Suarez**, consul général à Londres.

Brésil (Brazil).

Ministère des travaux publics, du commerce et de l'agriculture :

◆ROBERTO **Trompowsky Leitao de Almeida**, colonel du génie, chef de la Commission des achats en Europe.

Bulgarie (Bulgaria).

Ministère des travaux publics, voies et communications.

Chili.

Ministère de l'industrie, des travaux publics et de la colonisation :

◆VICTOR PRETOT **Freire**, ingénieur, inspecteur technique des matériaux en Europe.

Chine (China).

Le Tsung-li-Yamen.

Congo (État indépendant du).

Département des affaires étrangères :

◆Le major ALBERT **Thys**, officier d'ordonnance du Roi des Belges, administrateur directeur général de la Compagnie du chemin de fer du Congo;

GEORGES **De Laveleye***, administrateur de la Compagnie du chemin de fer du Congo (rapporteur);

◆EMILE **Delcommune**, commissaire de la Compagnie du chemin de fer du Congo.

Danemark (Denmark).

Ministère de l'intérieur et des travaux publics :

◆**Tegner**, directeur général des chemins de fer de l'État danois.

Égypte (Egypt).

Administration des chemins de fer, des télégraphes et du port d'Alexandrie :

◆S. EXC. BOGHOS PACHA **Nubar**, administrateur;

◆**Cotterill**, ingénieur, sous-chef du service technique.

Espagne (Spain).

Ministère du Fomento :

◆DON EDUARDO **Echegaray**, ingénieur-chef.

États-Unis d'Amérique (United States of America).

Secrétariat d'État :

◆JAMES R. **Roosevelt**, secretary of the United States Embassy in London.

France.

Ministère des travaux publics :

◆ALFRED **Picard***, inspecteur général des ponts et chaussées, président de la section des travaux publics, de l'agriculture, du commerce et de l'industrie au conseil d'État, vice-président du comité consultatif des chemins de fer (vice-président de la Commission internationale du Congrès);

◆**Linder**, inspecteur général des ponts et chaussées, vice-président du conseil général des mines;

◆**Orsel**, inspecteur général des mines, vice-président du comité de l'exploitation technique des chemins de fer;

Colson*, ingénieur en chef des ponts et chaussées, maître des requêtes au conseil d'État, directeur des chemins de fer au ministère des travaux publics (membre de la Commission internationale du Congrès);

Auzouy, chef du cabinet du ministre des travaux publics;

◆**Teissier**, auditeur au conseil d'État;

◆LÉON **Barthou**;

Massieu, inspecteur général des mines, chargé de la direction du contrôle des chemins de fer de l'Est;

◆**Salva**, inspecteur général des ponts et chaussées, chargé de la direction du contrôle du chemin de fer du Nord;

◆**Holtz**, inspecteur général des ponts et chaussées, chargé de la direction du contrôle des chemins de fer de Paris-Lyon-Méditerranée;

◆**Forestier**, inspecteur général des ponts et chaussées, chargé de la direction du contrôle du chemin de fer algérien;

◆**Lefebvre**, inspecteur général des ponts et chaussées, chargé de la direction du contrôle du chemin de fer d'Orléans;

◆**Le Chatelier**, ingénieur en chef des ponts et chaussées, chargé du service spécial du contrôle des lignes en construction ou en exploitation dans Paris;

◆**Worms de Romilly**, ingénieur en chef des mines, attaché au service du contrôle du réseau de la Méditerranée;

◆**Resal**, ingénieur en chef des ponts et chaussées, adjoint à la direction des chemins de fer au ministère des travaux publics;

◆**Chesneau**, ingénieur des mines, adjoint à la direction des chemins de fer au ministère des travaux publics.

Ministère du commerce, de l'industrie, des postes et des télégraphes :

◆Alfred **Picard***, ci-dessus désigné (voir *Ministère des travaux publics*);

◆**Chandèze**, directeur du commerce extérieur au ministère du commerce et de l'industrie, membre du comité consultatif des chemins de fer;

Delaunay-Belleville, président de la chambre de commerce de Paris, membre du comité consultatif des chemins de fer, directeur général de l'exploitation de l'Exposition universelle de 1900;

◆**Dervillé**, président du tribunal de commerce de la Seine, membre du comité consultatif des chemins de fer, directeur général adjoint de l'exploitation de l'Exposition universelle de 1900;

◆**Chardon**, auditeur de 1re classe au conseil d'État, secrétaire adjoint du comité consultatif des chemins de fer, secrétaire général de l'Exposition universelle de 1900;

◆**Fontaine**, ingénieur des mines, chargé des fonctions de sous-directeur de l'Office du travail;

◆**Romieu**, maître des requêtes au conseil d'État, professeur de législation des chemins de fer à l'École des sciences politiques;

◆André **Pelletan**, ingénieur, commissaire expert pour la vérification des marchandises présentées aux douanes;

◆**Goury du Roslan**, ingénieur des ponts et chaussées, délégué permanent de l'Office du travail;

◆**Pellé**, ingénieur des mines, ingénieur adjoint au chef de l'exploitation des chemins de fer de l'État;

◆**Gottschalk**, ingénieur civil, membre du comité consultatif et du comité de l'exploitation technique des chemins de fer;

◆**Pontzen**, ingénieur civil, membre du comité de l'exploitation technique des chemins de fer;

◆**Lagout**, ingénieur en chef des ponts et chaussées;

◆**Debray**, ingénieur en chef des ponts et chaussées, professeur à l'École nationale des ponts et chaussées, secrétaire général de la Commission des méthodes d'essai des matériaux de construction;

Flachon, chef adjoint du cabinet du Ministre des travaux publics.

Grande-Bretagne, empire des Indes et colonies (Great Britain, India and Colonies.)

A. — Grande-Bretagne (Great Britain).

Ministère du commerce (Board of Trade) :

◆James **Bryce**, president;

◆The Earl **Cathcart**;

◆The Right Honourable Lord **Balfour of Burleigh**;

◆The Right Honourable A. I. **Mundella**, M. P., F. R. S.;

◆Sir **Courtenay Boyle***, K. C. B., permanent secretary to the Board of Trade (membre de la section anglaise);

Francis J. S. **Hopwood**, C. M. G., assistant secretary, Board of Trade;

◆Sir MONTAGU **Ommanney**, K. C. M. G., Crown Agent for the Colonies;
◆Major-General C. S. **Hutchinson**, R. E., C. B.;
◆W. H. **Preece**, C. B., F. R. S., engineer in chief and electrician to the general post office;
◆Major F. A. **Marindin**, R. E., C. M. G., Board of Trade, inspecting officer of railways;
◆Lieutenant Colonel H. A. **Yorke**, R. E,. Board of Trade, inspecting officer of railways;
◆Major G. W. **Addison**, R. E., Board of Trade, inspecting officer of railways;
◆Major P. **Cardew**, R. E.;
◆Major C. M. G. **Bate**, R. E.;
◆Lieutenant E. P. C. **Girouard**, R. E.;
◆Lieutenant E. H. M. **Leggett**, R E.

B. — Empire des Indes et colonies (India and Colonies).

Secrétariat d'État pour l'empire des Indes (*Under Secretary of State for India*) :

◆Col. R. A. **Sargeaunt**, R. E., Assoc. M. Inst. C. E., F. J. Inst., director general of Indian Railways;
◆J. R. **Bell**, consulting engineer to the Government of India for State Railways.

Département des chemins de fer et canaux du Dominion du Canada (*Department of Railways and Canals of Canada*) :

◆Sir CHARLES **Tupper**, Bart., G. C. M. G., C. B , High Commissioner for Canada in London;
◆CONRADIN F. **Just**, secretary of the High Commissioner for Canada in London.

Ministère des travaux publics de la colonie du Cap (*Public Works Department of Cape of Good Hope*).

Agence générale de la colonie de Natal à Londres (*Agent general for Natal in London*) :

◆WALTER **Peace**, C. M. G., agent general for Natal in London.

Agence générale de l'Australie de l'Ouest (*Agent general for Western Australia*) :

◆Sir MALCOLM **Fraser**, K. C. M. G., agent general for Western Australia in London.

Agence générale de l'Australie du Sud à Londres (*Agent general for South Australia in London*) :

◆The Hon. THOMAS **Playford**, agent general for South Australia in London.

Agence générale de la colonie de la Nouvelle Galles du Sud à Londres (*Agent general for New South Wales in London*) :

◆EDWARD MILLER GARD **Eddy**, Chief Commissioner of the New South Wales Government Railways.

Agence générale de la colonie de la Nouvelle Zélande à Londres (*Agent general for New Zealand in London*) :

◆JOHN **Carruthers**, consulting engineer to the Government of New Zealand in London.

Agence générale de la colonie de Queensland à Londres (*Agent general for Queensland in London*) :

◆Sir JAMES **Garrick**, agent general for Queensland in London.

Agence générale de la colonie de Tasmanie à Londres (*Agent general for Tasmania in London*) :

Sir ROBERT G. W. **Herbert** G. C. B., agent general for Tasmania in London.

Agence générale de la colonie de Victoria à Londres (*Agent general for Victoria in London*).

Grèce (Greece).

Ministère de l'intérieur.

Italie (Italy).

Ministère des travaux publics :

FRANÇOIS **Brioschi***, sénateur du royaume d'Italie (membre du comité de direction du Congrès);
◆Le comte LOUIS **Ripa di Meana**, inspecteur général des chemins de fer;

Ottolenghi, inspecteur supérieur des chemins de fer;
◆**Rossi,** inspecteur supérieur des chemins de fer;
◆**Crosa,** inspecteur en chef des chemins de fer.

Japon (Japan).

Ministère des communications :

Hikokichi **Ijuin,** secrétaire de la légation du Japon à Londres.

Luxembourg (Luxemburg).

Direction générale des travaux publics.

Mexique (Mexico).

Secrétariat des communications et des travaux publics :

Luis **Salazar,** ingénieur;
◆Estanislao **Velasco,** ingénieur, chef du département des chemins de fer.

Norvège (Norway).

Ministère des travaux publics :

◆C. **Pihl,** directeur pour le département de construction aux chemins de fer de l'État;
C. E. **Krefting,** directeur pour le département de l'exploitation aux chemins de fer de l'État.

Pays-Bas (Holland).

Ministère du waterstaat, du commerce et de l'industrie :

◆J. J. **van Kerkwijk***, membre de la seconde Chambre des États-Généraux des Pays-Bas (membre de la Commission internationale du Congrès);
◆**Simon** (fils), membre du conseil de surveillance des chemins de fer.

Pérou (Peru).

Ministère de l'intérieur, de la police et des travaux publics.

Portugal.

Ministère des travaux publics, du commerce et de l'industrie :

◆Bento Fortunato de Moura Continho d'**Almeida d'Eça,** ingénieur, inspecteur de 1re classe et membre du conseil des travaux publics et des mines.

Roumanie (Roumania).

Ministère des travaux publics :

◆**Duca***, directeur général des chemins de fer de l'État, professeur à l'École des ponts et chaussées de Bucharest (membre de la Commission internationale du Congrès et rapporteur);
◆Ch. **Drago,** chef de service des ateliers et du matériel aux chemins de fer de l'État;
◆A. **Gafenco,** chef de service aux chemins de fer de l'État;
◆A. **Cottesco,** chef de service aux chemins de fer de l'État;
◆C. **Manesco,** chef de service aux chemins de fer de l'État;
◆A. **Saligny,** chef de service aux chemins de fer de l'État.

Russie (Russia).

Ministère des voies de communication :

◆ALEXANDRE **Yermoloff**, conseiller privé, directeur de la chancellerie du ministre des voies de communication ;

◆VLADIMIR **Werchovsky***, conseiller privé, ingénieur des ponts et chaussées, membre du conseil des chemins de fer (membre de la Commission internationale du Congrès) ;

◆BASILE **Soumarokoff***, conseiller d'État actuel, ingénieur des ponts et chaussées, directeur du département des chemins de fer (membre de la Commission internationale du Congrès);

◆LOUIS DE **Perl***, conseiller d'État actuel, attaché au ministère et gérant de l'Union russe pour les relations internationales des chemins de fer (membre de la Commission internationale du Congrès et rapporteur);

◆NICOLAS **Kopytkin**, conseiller d'État actuel, ingénieur des ponts et chaussées, inspecteur des trains impériaux ;

◆**Salkoff**, conseiller d'État actuel, ingénieur ;

◆JACQUES **Gordiéenko**, conseiller d'État, ingénieur des ponts et chaussées, professeur extraordinaire à l'Institut des voies de communication de l'Empereur Alexandre Ier ;

◆Le colonel ALFRED DE **Wendrich**, ingénieur militaire, membre du conseil des ingénieurs du ministère des voies de communication ;

◆BALTHAZAR FÉLIX **Souschinsky**, conseiller d'État, ingénieur attaché à la section technique du département des chemins de fer;

◆**Sytenko**, conseiller d'État, rédacteur en chef du Journal officiel du ministère des voies de communication ;

◆STANISLAS DE **Kounitsky**, conseiller de cour, ingénieur de cinquième classe au ministère des voiés de communication ;

◆**Proscouriakoff**, conseiller de cour, aide du gérant du laboratoire mécanique de l'Institut des ingénieurs des voies de communication de l'Empereur Alexandre Ier, ingénieur des voies de communication ;

◆V. **Herzenstein***, conseiller titulaire, ingénieur attaché au ministère des voies de communication (rapporteur).

Ministère des finances. Département des affaires de chemins de fer :

◆**Ratkoff-Rojnoff**, vice-directeur du département des affaires de chemins de fer ;

◆**Vilinski**, membre du comité des tarifs du ministère des finances ;

◆**Khitrovo**, fonctionnaire pour missions spéciales du département des affaires de chemins de fer du ministère des finances et représentant de ce ministère à l'Administration des chemins de fer de la Couronne.

Ministère de l'intérieur :

◆NICOLAS DE **Zwolinski**, conseiller honoraire, fonctionnaire au comité technique du ministère de l'intérieur.

Serbie (Servia).

Ministère des travaux publics :

◆MILIVOIE **Yossimovitch**, inspecteur général des chemins de fer de l'Etat serbe.

Siam.

Ministère des travaux publics :

◆XAVIER **Olin**, ancien ministre des travaux publics de Belgique.

Suède (Sweden).

Ministère de l'intérieur :

◆ Le comte Rodolphe **Cronstedt**, directeur général des chemins de fer de l'État;
◆ Fredrik **Almgren***, administrateur des chemins de fer de l'État suédois (membre de la Commission internationale du Congrès).

Suisse (Switzerland).

Département des postes et des chemins de fer :

◆ Johann **Tschiemer**, inspecteur technique;
◆ François **Schüle**, ingénieur du contrôle au département fédéral des chemins de fer.

Turquie (Turkey).

Ministère du commerce et des travaux publics :

◆ Le commandant **Ghalib Bey**, attaché naval à l'ambassade impériale de Turquie à Londres.

B. — DÉLÉGUÉS DES ADMINISTRATIONS PARTICIPANTES.
MEMBERS APPOINTED BY ADMINISTRATIONS SUBSCRIBING TO THE CONGRESS.

Allemagne (Germany).

Chemin de fer Sud-Est prussien (260 k., 3 dél.) :

Krueger, membre de la direction.

Chemin de fer de Weimar-Géra (69 k., 2 dél.) :

◆ Ernst **Kohl**, directeur, conseiller supérieur de construction.

Argentine (République) (Argentine Republic).

Buenos-Ayres Great Southern Railway (2,255 k. [1,401 milles]. 7 dél) :

◆ Frank **Parish**, chairman;
◆ John **Fair**, deputy chairman;
◆ R. J. **Neild**, director;
◆ H. C. **Allen**, secretary;
◆ H. H. **Loveday**, traffic superintendent;
◆ James **Livesey**, M. I. C. E., consulting engineer;
◆ A. **Giet**, accountant London office.

Central Argentine Railway (1,236 k. [768 milles] 5 dél.) :

◆ J. W. **Batten**, director;
◆ G. **Cooper**, director;
◆ F. **Neild**, director;
◆ Campbell P. **Ogilvie**, director;
◆ R. Campbell **Baines**, Mole superintendent.

Buenos-Ayres and Ensenada Port Railway (206 k [128 milles]. 3 dél.) :

Charles Buchanan **Ker**, director;
◆ William **Roberts**, director;
◆ T. D. **Brooke**, secretary.

Grand chemin de fer Central Sud-Américain (en construction, 2 dél.) :

◆Jules **Carlier**, administrateur;
A. J. de la **Fontaine**, ingénieur.

Autriche-Hongrie (Austria-Hungary).

A. — Autriche (Austria).

Chemins de fer de l'État (8,077 k., 8 dél.) :

◆S. Exc. le Dr. chevalier Leon von **Bilinski***, conseiller intime I. et R., chef de section au Ministère I. R. du commerce, président de la direction générale I. R. (délégué du gouvernement autrichien).
◆Le Dr. Ferdinand **Zehetner**, conseiller I. R. aulique, directeur administratif de la direction générale;
◆Gustav **Gerstel**, conseiller I. R. de régence, directeur du mouvement de la direction générale;
◆Le Dr. Chevalier Severin von **Kniaziolucki**, conseiller de la direction générale, chef de la section présidentielle de la direction générale;
◆Anton **Kuhnelt**, conseiller I. R. de régence, chef adjoint de la section commerciale de la direction générale;
◆Victor **Schutzenhofer**, conseiller I., chef adjoint de la section de la traction de la direction générale;
Alois **Stane**, conseiller de la direction générale, directeur adjoint de la construction de la direction générale;
◆Victor von **Koloszvary**, directeur de l'exploitation de la direction d'exploitation de Cracovie;
◆Theodor von **Scala**, directeur de l'exploitation de la direction d'exploitation de Villach.

Chemins de fer du Sud de l'Autriche (2,596 k., 8 dél.) :

◆Son Altesse Sérénissime le prince Egon **Hohenlohe**, président;
◆Oscar **Schüler**, directeur;
Le chevalier Max Bram von **Bardany**, conseiller I. R., directeur de l'exploitation.

Société autrichienne-hongroise des chemins de fer de l'État (1,376 k., 5 dél.) :

◆Le chevalier Theodore de **Taussig**, président;
◆Le chevalier Rodolphe de **Grimburg**, conseiller aulique, directeur;
◆Charles **Rimböck**, conseiller du gouvernement, chef du service financier;
◆Celestin **Rubricius**, conseiller du gouvernement, chef du service de l'exploitation;
◆François **Pauer**, inspecteur général et chef du service du matériel et de la traction;
◆Le Dr. Harry L. **Hirschl***, secrétaire (secrétaire-rapporteur).

Chemins de fer du Nord Empereur Ferdinand (1,295 k., 5 dél.) :

◆Son Exc. le margrave Alexander **Pallavicini**, conseiller intime I. et R. et chambellan, président;
◆Son Exc. le comte Philipp **Boos-Waldeck und Montfort**, conseiller intime I. et R. et chambellan, vice-président;
◆Joseph **Hönigsvald**, conseiller I. et R. de régence, administrateur;
◆Alfred von **Lenz**, administrateur;
◆Richard **Jeitteles***, conseiller I. et R. aulique, directeur général (membre de la Commission internationale du Congrès);
◆Wilhelm **Ast***, conseiller I. et R. de régence, directeur des voies et travaux (rapporteur);
◆Le Dr. Anton **Bezecny**, conseiller I. et R. de régence, secrétaire général;
◆Le chevalier Arthur von **Boschan***, ingénieur (rapporteur).

Chemins de fer Nord-Ouest autrichiens (940 k., 4 dél.) :

Le Dr. Emil **Sax**, administrateur;
◆ Le Dr. Alexander **Eger**, conseiller aulique, directeur;
◆ Wenzel **Hohenegger**, ingénieur, directeur des travaux;
◆ Le Dr. Max **Borowy**, secrétaire de la direction.

Jonction Sud-Nord allemande (280 k., 3 dél.) :

◆ Johann Freiherr von **Liebig**, administrateur;
◆ Louis **Löb**, administrateur;
E. **Prinzig**, administrateur.

Chemins de fer de Lemberg-Czernowitz-Jassy (581 k., 4 dél.) :

◆ E. A. **Ziffer**, ingénieur, président;
◆ Lord Eustace **Cecil**, administrateur;
L. M. **Rate**, administrateur;
◆ Max **Zingler**, secrétaire du bureau de Londres.

Chemins de fer du Nord de la Bohême (320 k., 3 dél.).

Chemin de fer de Vienne-Aspang (85 k., 2 dél.) :

◆ Franz **Grünebaum**, vice-président;
◆ Le chevalier Alfred Tunkler von **Treuimfeld**, directeur.

B. — Hongrie (Hungary).

Chemins de fer de l'Etat (7,395 k., 8 dél.) :

◆ Jules **Ludvigh***, conseiller ministériel, membre de la Chambre des Magnats, directeur-président (membre de la Commission internationale du Congrès, délégué du gouvernement hongrois);
◆ Sigismond **Thaly**, conseiller royal, chef d'exploitation;
◆ Emile **Stiffson**, inspecteur au service du mouvement;
◆ Sigismond **Abeles**, inspecteur au service de la traction;
◆ Ferdinand **Förster**, directeur de la fabrique de machines;
Henri **Fouquau**, secrétaire de la direction.

Chemin de fer Kaschau-Oderberg (446 k., 3 dél.) :

Pierre de **Rath**, ingénieur, directeur général;
◆ Adorjau **Hausser**, docteur en droit, inspecteur principal.

Chemins de fer unis d'Arad et de Csanad (325 k., 3 dél.) :

◆ Beni de **Boros**, conseiller royal, député au Parlement hongrois, directeur et ingénieur en chef;
◆ Bela de **Vasarhelyi**, directeur et administrateur;
◆ Laszlo de **Bohus**, directeur et administrateur.

Chemins de fer de la vallée de Szamos (221 k., 3 dél.) :

◆ Alexandre de **Schreiber**, membre de la direction;
Soltan de **Maleter**, directeur.

Chemin de fer d'intérêt local du Szilagysàg (109 k., 3 dél.) :

Coloman de **Gulacsy**, administrateur délégué;
Jules de **Posch**, administrateur;
Ambroise **Nemenyi**, administrateur.

Chemin de fer de Nagy Kikinda à Nagy-Becskerek (71 k., 2 dél.) :

Louis **Deutsch**, conseiller de direction ;
Le Dr. Stefan **Kepessy**, directeur-rapporteur.

Chemin de fer de Mohacs-Fünfkirchen (69 k., 2 dél.) :

Louis de **Ullmann**, directeur général ;
Emile de **Thaly**, directeur de l'exploitation.

Chemin de fer de Vinkorce à Brcka (51 k., 2 dél.) :

Le chevalier Ernest de **Lindheim**, administrateur ;
Coloman de **Gulacsy***, administrateur délégué (délégué du chemin de fer d'intérêt local du Szilagysàg).

Belgique (Belgium).

Chemins de fer de l'Etat (3,250 k., 8 dél.).

Commission internationale du Congrès :

◆A. **Dubois***, administrateur des chemins de fer de l'État belge, président de la Commission internationale du Congrès (délégué du gouvernement belge);
◆**Ramaeckers***, secrétaire général du ministère des chemins de fer, postes et télégraphes, membre du comité de direction du Congrès (délégué du gouvernement belge);
◆**Schaar***, administrateur des chemins de fer de l'État belge, membre de la Commission internationale du Congrès (id.);
◆Louis **Weissenbruch***, ingénieur aux chemins de fer de l'État belge, secrétaire du comité de direction du Congrès (id.);
◆Edouard **Holemans***, chef de division aux chemins de fer de l'État belge, trésorier du comité de direction du Congrès (id.).

Rapporteurs :

◆**Hubert***, ingénieur en chef, directeur d'administration aux chemins de fer de l'État belge (id.);
◆**Hodeige***, ingénieur principal aux chemins de fer de l'État belge (id.);
◆Lucien **Motte***, ingénieur principal aux chemins de fer de l'État belge (id.).

Autres délégués :

◆**Dethieu***. inspecteur général aux chemins de fer de l'État belge (id.);
◆**Niels***, inspecteur de direction aux chemins de fer de l'État belge (id.);
◆**De Busschere***, ingénieur en chef aux chemins de fer de l'État belge (id.);
◆Ernest **Gerard***, ingénieur principal aux chemins de fer de l'État belge (id.);
◆**Bruneel***, ingénieur principal aux chemins de fer de l'État belge (id.).

Chemin de fer Grand Central Belge (611 k., 4 dél.).

Délégués de droit :

◆Jules **Urban***, directeur général du chemin de fer Grand Central Belge, président de la Société générale belge de chemins de fer économiques (vice-président de la Commission internationale du Congrès);
◆Eugène **Belleroche***, ingénieur chef de service au chemin de fer Grand Central Belge (rapporteur).

Autres délégués :

◆**Montefiore-Levi**, sénateur, président ;
Maurice **Urban**, ingénieur en chef, directeur ;
◆Charles **Le Bon**, ingénieur en chef, directeur ;
◆Emile **Spruyt**, directeur.

Chemins de fer de la Flandre occidentale (182 k., 3 dél.) :

E. **Van den Bogaerde**, directeur gérant, chef de l'exploitation ;
◆ A. **Fraeys**, ingénieur, chef du service de la traction et du matériel ;
◆ F. **Lebbe**, ingénieur, chef du service des voies et travaux.

Chemin de fer du Nord français (lignes Nord-belges) (170 k., 3 dél.) :

◆ **Philippe***, inspecteur général (membre de la Commission internationale du Congrès);
Vallon, administrateur ;
◆ **Waru**, administrateur ;
◆ **Piéron**, ingénieur en chef des ponts et chaussées, ingénieur en chef des services actifs.

Chemin de fer de l'Est belge (135 k., 3 dél.) :

Édouard **Despret**, président ;
◆ Alphonse **Matthei**, directeur ;
Albert **Urban**, ingénieur, chef de service.

Chemin de fer du Nord de la Belgique (116 k., 3 dél.) :

Léon **Orban**, président ;
Ferdinand **Baeyens**, administrateur ;
◆ Gustave **Harten**, ingénieur, chef de service.

Chemin de fer de l'Entre-Sambre-et-Meuse (111 k., 3 dél.) :

◆ William **Austin**, président ;
◆ Edmond **Louis**, chef de service ;
◆ Charles **Hanrez**, ingénieur, chef de service.

Chemin de fer de Malines-Terneuzen (68 k., 2 dél.) :

◆ Al **Van den Broeck**, président ;
◆ Victor **Lamquet**, directeur gérant.

Chemin de fer de Braine-le-Comte à Gand (65 k., 2 dél.) :

Gustave **Boël**, administrateur directeur gérant ;
Louis **Boël**, secrétaire de la Compagnie.

Chemin de fer de Chimay (60 k., 2 dél.) :

◆ **Dognée**, administrateur ;
Baillet, directeur.

Chemin de fer de Gand-Eecloo-Bruges (48 k., 2 dél.) :

◆ Alfred **Neelemans**, administrateur ;
◆ Louis **Neelemans**, directeur gérant.

Chemin de fer de Tournai à Jurbise et de Landen à Hasselt (46 k., 2 dél.) :

◆ Le Dr Léopold **Barella**, administrateur ;
◆ Émile **Woyard**, inspecteur.

Chemin de fer de Gand à Terneuzen (41 k., 2 dél.) :

Jules **Cordeweener**, administrateur ;
Nestor **Wilmart**, directeur gérant.

Chemin de fer de Hasselt à Maeseyck (41 k., 2 dél.) :

◆ Léon **Collinet**, président ;
◆ Robert **Dresse**, secrétaire de la Compagnie.

Chemin de fer de Liége-Maestricht (30 k., 2 dél.) :

A. **Clermont**, directeur gérant.

Chemin de fer d'Anvers à Rotterdam (27 k., 2 dél.) :

Xavier **Neujean**, administrateur;
◆Léopold **Kirsch**, ingénieur, chef de service.

Chemin de fer de Termonde à Saint-Nicolas (22 k., 2 dél.) :

◆Armand **Dresse**, président;
◆A. **Ancion**, membre de la Chambre des représentants de Belgique, administrateur.

Chemin de fer d'Anvers à Gand (50 k., 2 dél.) :

◆**Verwilghen-Goris**, administrateur;
◆Edouard **Prisse**, directeur gérant.

Société nationale des chemins de fer vicinaux (1,144 k., 5 dél.) :

◆**Fris**, membre de la Chambre des représentants de Belgique, président;
◆C. de **Burlet** *, directeur général (membre de la Commission internationale du Congrès et rapporteur);
◆A. **Lebrun**, secrétaire général.

Chemins de fer secondaires (Compagnie générale des) (239 k., 3 dél.) :

◆Gustave **Michelet**, administrateur délégué;
◆P. **Liénart**, ingénieur en chef;
F. **Nonnenberg**, ingénieur en chef.

Railways économiques de Liége-Seraing et extensions (300 k., 3 dél.) :

◆**Dupont-Rucloux**, administrateur délégué;
◆Paul **Bourgeois**, directeur;
◆Ed. **De Cuyper**, directeur de l'exploitation.

Société générale de chemins de fer économiques (152 k., 3 dél.) :

E. **Urban**, ingénieur, administrateur;
◆G. **Kumps**, ingénieur, administrateur;
H. **De Backer***, ingénieur, directeur général (rapporteur).

Compagnie intern. des wagons-lits et des grands express européens (1,298 essieux à voy., 5 dél.) :

◆Georges **Nagelmackers**, directeur général;
A. **Lechat**, sous-directeur à Paris;
◆**Schrœder**, chef de direction;
◆**Gain**, ingénieur en chef;
◆A. **Neef**, inspecteur général.

◆**Wildhagen***, inspecteur principal (secrétaire-rapporteur).

Compagnie auxiliaire internationale de chemins de fer (3,296 essieux à marchandises, 3 dél.) :

◆Le baron E. de **Gienanth**, administrateur délégué;
E. **Funck**, administrateur;
Georges **De Laveleye***, administrateur (délégué du gouvernement du Congo et rapporteur).

Brésil (Brazil).

Brazil Great Southern Railway (982 k. [610 milles], 4 dél.) :

◆William John **Alt**, director;
Henry **Raincock**, director;
Laurence A. **Williams**, secretary.

Chemin de fer central de la Rép. des États-Unis du Brésil (730 k., 4 dél.) :

◆Roberto **Trompowsky Leitao de Almeida***, colonel du génie, chef de la commission des achats en Europe (délégué du gouvernement brésilien);
◆Arthur **Alvim**, ingénieur, ancien ingénieur en chef de la voie.

Compagnie générale de chemins de fer brésiliens (358 k., 3 dél.) :

◆Th. de **Joly**, président;
◆A. **Durieux**, administrateur;
◆Léon **Fontaine-De Laveleye**, administrateur.

Chemins de fer Sud-Ouest brésiliens (Compagnie des) (160 k., 3 dél.) :

F. **Philippson**, administrateur;
A. **Pocquet**, administrateur;
◆A. **Spée**, administrateur.

The Conde d'Eu Railway (142 k. [88 milles], 3 dél.) :

◆Gerard Philipp **Torrens**, chairman;
◆Henry Scott **Boys**, director;
◆Frank **Silverloch**, secretary.

Great Western of Brazil Railway (140 k. [87 milles], 3 dél.) :

◆Frank **Parish***, chairman (délégué du Buenos-Ayres Great Southern Railway);
◆A. P. **Youle**, vice-chairman;
◆Henry **Watts**, secretary.

Bulgarie (Bulgaria).

Chemins de fer de l'Etat (530 k., 4 dél.).

Chili.

Antofagasta (Chili) and Bolivia Railway (924 k. [574 milles], 4 dél.) :

◆E. M. **Underdown**, Q. C., chairman.

Colombie (Columbia).

Cartagena Magdalena Railway (106 k. [66 milles], 3 dél.) :

◆F. R. **Hart**, president;
◆F. **Newson**, general European agent.

Congo (État indépendant du).

Chemin de fer du Congo (Compagnie du) (80 k., 2 dél.) :

◆Le major Albert **Thys***, administrateur, directeur général (délégué du gouvernement du Congo);
◆Jean **Cousin**, administrateur, membre du comité permanent;
◆A. J. **Wauters**, secrétaire général.

Danemark (**Denmark**).

Chemins de fer de l'Etat (1,691 k., 5 dél.) :

◆**Westergaard**, chef du service de l'exploitation;
◆**Busse**, ingénieur en chef du matériel et de la traction;
Ernst, ingénieur en chef adjoint des chemins de fer en construction;
◆**Rimestad**, chef de bureau.

Chemin de fer de la Fionie méridionale (76 k., 2 dél.).

Chemin de fer de Lolland-Falster (72 k., 2 dél.) :

C. F. **Tietgen**, conseiller intime d'État, président;
◆C. **Larsen**, chef de l'exploitation.

Chemin de fer de l'Est de Seeland (47 kil., 2 dél.) :

C. F. **Tietgen***, conseiller intime d'État, président (délégué du chemin de fer de Lolland-Falster);
◆J. **Hansen**, secrétaire.

Égypte (**Egypt**).

Chemins de fer de l'État (1,544 k., 5 dél.) :

◆S. Exc. Boghos Pacha **Nubar***, administrateur (délégué du gouvernement égyptien).
◆**Cotterill***, ingénieur, sous-chef du service technique (id.).

Espagne (**Spain**).

Chemins de fer du Nord de l'Espagne (2,949 k., 8 dél.) :

Emile **Pereire**, président du Comité de Paris;
Rafael **Angulo**, membre du Comité de Paris;
Maurice **Bixio**, membre du Comité de Paris;
J. **Barat**, directeur;
A. **Biarez**, ingénieur en chef du service central à Paris;
Maurice **Pereire**, ingénieur attaché à la délégation à Paris;
◆Michel **Sala**, ingénieur de la voie.

Chemin de fer de Madrid à Saragosse et à Alicante (2,672 k., 8 dél.) :

Gustave **Bauer**, administrateur;
Cypriano Segundo **Montesino**, directeur général;
◆Charles **Grébus**, directeur général adjoint;
Albert **Levi-Alvares**, ingénieur conseil, secrétaire général du comité;
◆René **Lisle**, inspecteur général des services administratifs et financiers;
◆Joaquin L. de **Letona**, ingénieur en chef de la voie et des travaux;
◆Nathan **Süss**, ingénieur en chef de l'exploitation.

Chemins de fer andalous (883 k., 4 dél.).

Chemins de fer de Tarragone à Barcelone et à la France (718 k., 4 dél.) :

Claudio **Planas**, directeur gérant;
Manuel de **Aramburu y Pelayo**, ingénieur en chef des ponts et chaussées d'Espagne, chef de l'exploitation;
◆Eduardo **Maristany y Gibert**, ingénieur des ponts et chaussées d'Espagne, chef de la construction.

Chemins de fer de Madrid-Cacérès et Portugal et l'Ouest d'Espagne (Compagnie d'exploitation des) (505 k., 4 dél.).

Chemin de fer de Medina del Campo à Zamora et de Orense à Vigo (293 k., 3 dél.) ·

◆D. Domingo Juan **Sanllehy**, vice-président;
◆D. Antonio **Masso**, assistant du conseil.

Chemins de fer du Sud de l'Espagne (150 k., 3 dél.) :

◆Yvo **Bosch**, président du comité de Paris;
◆Émile **Cousin**, ingénieur.

Chemins de fer et mines de San Juan de las Abadesas (119 k., 3 dél.) :

Laureano de **Larramendi**, président;
Rodolfo **Juncadella**, secrétaire;
Domingo **Vehil**, ingénieur.

Chemin de fer de Medina del Campo à Salamanca (77 kil., 2 dél.) :

Pierre **Caillat**, administrateur délégué ;
Drouin, inspecteur général.

Chemin de fer de Valence et Aragon (30 k., 2 dél.) :

H. **Peemans**, administrateur;
◆Félix **Delhaye**, administrateur.

États-Unis d'Amérique (United States of America).

American Railway Association (228,465 k. [141,495 milles], 8 dél.) :

◆Henry S. **Haines**, president American Railway Association and vice-president Plant system;
◆Alfred **Walter**, president Delawarre, Susquehanna and Schuylkill Railroad;
◆William F. **Allen**, secretary American Railway Association and manager of the Official Railway Guide;
◆James T. **Harahan**, second vice-president Illinois Central Railroad;
◆Charles W. **Bradley**, general superintendent West Shore Railroad;
◆John C. **Kenly**, general manager Atlantic Coast line;
◆Jacob J. **Frey**, general manager Atchison Topeka and Santa-Fé Railroad;
◆Theodore **Voorhees**, first vice-president Philadelphia and Reading Railroad system.

Southern Pacific Railroad (10,739 k. [6,673 milles], 8 dél.) :

C. P. **Huntington**, president;
G. S. **Miles**, secretary of the president;
◆C. E. **Bretherton**, agent in London;
◆E. W. **Berryman**, agent for steamship lines;
A. N. **Towne**, third vice-president and general manager;
Julius **Kruttschnitt**, general manager Atlantic system;
William **Mahl**, general auditor.

Louisville and Nashville Railway (7,652 k. [4,755 milles], 8 dél.).

Pennsylvania Railroad (6,387 k. [3,967 milles], 8 dél.) :

◆Frank **Thomson**, first vice-president;
◆James **McCrea**, first vice-president Pennsylvania lines West of Pittsburg;
◆Theodore N. **Ely**, chief of motive power;
◆James L. **Taylor**, general European passenger agent.

Illinois Central Railroad (4,648 k. [2,888 milles], 8 dél.) :

◆James T. **Harahan***, second vice-president (délégué de l'American Railway Association);
◆W. Y. **Kehoe**, secretary of the second vice-president.

Denver and Rio Grande Railway (2,662 k. [1,654 milles], 8 dél.) :

◆George **Coppell**, chairman of Board of directors;
◆Edward T. **Jeffery**, president;
Charles C. **Beaman**, director and counsel;
John Lowber **Welsh**, director;
R. T. **Wilson**, director;
Howard **Gilliat**, London agent.

New York, New Haven and Hartford Railway (2,403 k. [1,493 milles], 8 dél.) :

◆Charles P. **Clark**, president;
◆F. S. **Curtis**, chief engineer;
◆John **Henney**, jun., superintendent motive power;
◆C. H. **Platt**, general superintendent New Haven system;
◆E. G. **Allen**, general superintendent Old Colony system;
◆S. A. **Gardner**, superintendent Fall River line;
◆C. C. **Elwell**, engineer maintenance of way, New York division;
◆J. G. **Parker**, secretary.

Cleveland Cincinnati Chicago and Saint-Louis Railway (2,288 k. [1,422 milles], 7 dél.).

Chesapeake and Ohio Railway (2,148 k. [1,335 milles], 7 dél.).

Lehigh Valley Railroad (1,732 k. [1,076 milles], 6 dél.) :

◆Chas. **Hartshorne**, vice-president;
◆Rollin H. **Wilbur**, general superintendent;
◆Israel W. **Morris**, general land agent.

Nashville Chattanooga and Saint-Louis Railway (1,547 k. [961 milles], 6 dél.) :

◆J. W. **Thomas**, jun., assistant general manager;
◆James **Cullen**, superintendent motive power.

New York Central and Hudson River Railroad (1,318 k. [819 milles], 5 dél.)

Chauncey M. **Depew**, president;
◆H. Walter **Webb**, third vice-president;
◆John M. **Toucey**, general manager;
William **Buchanan**, superintendent of motive power and rolling stock;
◆**Dudley**, engineer.

New York Ontario and Western Railway (768 k. [477 milles], 4 dél.)

◆Joseph **Price**, vice-president and director;
◆Harry **Pearson**, director;
◆Geo. von **Chauvin**.

Fitchburg Railroad (724 k. [450 milles], 4 dél.) :

◆Henry S. **Marcy**, president;
◆William L. **Chase**, director;
◆George **Heywood**, jun., director;
◆Dr George **Heywood**.

Pittsburgh and Western Railway (407 k. [253 milles], 3 dél.) :

◆W. H. **Addicks.**

Wilmington and Weldon Railroad (322 k. [200 milles], 3 dél.) :

◆John R. **Kenly***, general manager (délégué de l'American Railway Association).

Mobile and Birmingham Railway (262 k. [163 milles], 3 dél.) :

◆Thomas Frame **Thomson**, director;
◆Sir Douglas **Galton**, K. C. B., F. R. S., R. E., director;
◆Charles Bullen **Waller**.

West Virginia Central and Pittsburg Railway (245 k. [152 milles], 3 dél.) :

◆C. L. **Bretz**, general manager.

Richmond Fredericksburg and Potomac Railway (132 k. [82 milles], 3 dél.).

Arizona and South Eastern Railroad (89 k. [55 milles], 2 dél.) :

◆James **Douglas**, president.

Los Angeles Terminal Railway (80 k. [50 milles], 2 dél.) :

◆Geo. B. **Leighton**, president;
D. L. **Barnes**, consulting engineer.

Addison and Pennsylvania Railway (66 k. [41 milles], 2 dél.).

France, Algérie et colonies (France, Algeria and colonies).

A. — France.

Chemins de fer de l'État (2,743 k., 8 dél.) :

◆**Bouchard**, président;
◆**Lax**, administrateur;
◆**Benac**, secrétaire général;
◆**Matrot**, directeur;
◆**Bricka***, ingénieur en chef de l'exploitation (rapporteur);
◆**Fouan**, ingénieur en chef de la voie et des bâtiments;
◆**Parent**, ingénieur en chef du matériel et de la traction;
◆**Huguet**, ingénieur en chef attaché à la direction;
◆**Javary**, ingénieur des ponts et chaussées, attaché à la direction.

Chemins de fer de Paris à Lyon et à la Méditerranée (8,607 k., 8 dél.) :

◆**Noblemaire***, directeur (membre de la Commission internationale du Congrès);
◆**Amiot**, ingénieur en chef des mines, attaché à la direction;
◆René **Picard**, chef de l'exploitation;
◆**Berquet**, chef de l'exploitation adjoint;
◆**Luuyt**, sous-chef de l'exploitation;
◆**Chaperon**, chef de la 3e division de l'exploitation;
◆**Baudry**, ingénieur en chef du matériel et de la traction;
◆**Maréchal**, ingénieur principal, chef de la division du matériel;
◆**Kowalski**, ingénieur du service central de la traction;

◆**Auvert***, ingénieur attaché au service central du matériel (rapporteur).

Chemin de fer de Paris à Orléans (6,514 k., 8 dél.) :

◆**Bardoux**, administrateur;
◆**Schneider**, administrateur;
Vergé, administrateur;
◆**Heurteau***, directeur (membre de la Commission internationale du Congrès);
◆**Pader**, chef de l'exploitation, ou, à son défaut, **Nigond**, chef adjoint de l'exploitation;
◆**Brière**, ingénieur en chef de la voie;
◆**Carlier**, secrétaire général;
◆**Solacroup**, ingénieur en chef adjoint du matériel et de la traction;
◆G. **Michel**, attaché au secrétariat général;

◆**Sabouret***, ingénieur des ponts et chaussées, ingénieur principal du service central de la voie (rapporteur);
◆DE **Fréminville***, inspecteur du matériel roulant (secrétaire rapporteur).

Chemins de fer de l'Ouest (5,261 k., 8 dél.) :

◆EDW. **Blount**, administrateur;
◆Le marquis DU **Lau**, administrateur;
Marin, directeur;
◆**Clerc**, directeur des travaux;
◆**Moïse**, ingénieur en chef de la construction;
◆**Clérault**, ingénieur en chef du matériel et de la traction;
◆DE **Larminat**, chef de l'exploitation adjoint;
◆**Morandiere**, ingénieur des études;

◆**Sauvage***, ingénieur en chef des mines, ingénieur en chef adjoint du matériel et de la traction (rapporteur);
◆**Demoulin***, inspecteur du matériel et de la traction (secrétaire-rapporteur);
◆**Visinet***, agent commercial à Londres (secrétaire-rapporteur).

Chemins de fer de l'Est (4,727 k, 8 dél.) :

◆**Petsche**, administrateur;
◆Le marquis D'**Imécourt**, administrateur;
◆**Barabant***, directeur (membre de la Commission internationale du Congrès);
◆**Weiss**, chef adjoint de l'exploitation;
Fougère, chef du mouvement;
◆**Lancrenon**, ingénieur en chef adjoint du matériel et de la traction;
◆**Gerhardt**, ingénieur de la traction;
◆**Dufaux**, ingénieur principal de la voie.

Chemins de fer du Nord (3,650 k., 8 dél.):

◆LÉON **Say**, membre de l'Institut, vice-président;
◆**Griolet***, vice-président (membre du comité de direction du Congrès);
Hottinguer, administrateur;
◆**Sire***, agent de la Compagnie à Londres (secrétaire-rapporteur);
◆**Marie**, chef des services administratifs;
◆**Agnellet**, ingénieur en chef des ponts et chaussées, ingénieur en chef des études du matériel des voies et des bâtiments;
◆**De Fonbonne**, ingénieur principal de la traction;
◆**Kéromnès**, ingénieur principal des ateliers des machines de la Chapelle et d'Hellemmes;
◆**Aumont**, ingénieur des ponts et chaussées, ingénieur du matériel des voies;

◆EUG. **Sartiaux***, chef des services électriques (rapporteur);

◆**Guilloux***, sous-inspecteur des services administratifs (secrétaire-rapporteur);
◆**Favre***, chef de la gare maritime de Calais (secrétaire-rapporteur).

Chemin de fer du Midi (3,100 k., 8 dél.) :

◆**Aucoc**, président;
◆Georges **Picot**, administrateur;
◆**Blagé**, directeur;
◆**Maurer**, chef de l'exploitation;
◆**Herdner**, ingénieur du service central du matériel et de la traction;
◆**Choron**, ingénieur en chef de la voie et des lignes nouvelles;
Hausser, ingénieur en chef adjoint de la voie et des lignes nouvelles;
◆**Moffre**, ingénieur des ponts et chaussées, ingénieur principal attaché à la direction.

Chemin de fer de Ceinture de Paris (171 k., 3 dél.) :

Rœderer, directeur;
Dubois, sous-directeur;
◆**Hauet**, ingénieur de la voie.

Chemin de fer de l'Est de Lyon (94 k., 2 dél.) :

Victor **Stoclet**, administrateur;
Léon **Ulens**, administrateur.

Chemins de fer économiques (Société générale des) (1,180 k., 5 dél.) :

◆Albert **Ellissen**, administrateur;
◆Émile **Level**, directeur;
◆Ernest **Plocq***, ingénieur (rapporteur);
◆Georges **Level**, inspecteur attaché à la direction;
◆Henry **Vergé**.

Chemins de fer départementaux (880 k., 4 dél.):

◆**Zens**, administrateur, directeur;
◆**Coste**, ingénieur en chef adjoint à la direction;
◆**Chevalier**, ingénieur en chef des travaux et de la surveillance;
◆Albert **Zens**, secrétaire de la direction.

Chemins de fer du Sud de la France (540 k., 4 dél.) :

Joseph **Gay**, président;
René **Baulant**, administrateur délégué;
Georges **Cerbelaud**, ingénieur adjoint à la direction;
◆Alfred **Chassin**, ingénieur, directeur local des tramways de la Côte-d'Or.

Chemins de fer économiques du Nord (180 k., 3 dél.) :

◆Edouard **Empain**, administrateur délégué;
◆Victor **Mestreit**, directeur;
◆Armand **Rouffart**, ingénieur en chef des études et de la construction.

Chemins de fer régionaux des Bouches-du-Rhône (178 k., 3 dél.) :

Paul **Wallerstein**, président;
Delamarre, administrateur;
◆Édouard de **Traz**, administrateur.

Chemin de fer d'intérêt local du département des Landes (169 k., 3 dél.) :

Glasser, ingénieur en chef des ponts et chaussées;

◆**Moffre***, ingénieur des ponts et chaussées (délégué de la Compagnie du chemin de fer du Midi français);
◆**Piot**, secrétaire.

Compagnie Meusienne de chemins de fer (155 k., 3 dél.) :

◆**Pattin**, président;
◆**Gautier**, ancien élève de l'École polytechnique, administrateur;
◆**Merceron**, ingénieur, directeur.

Chemins de fer du Périgord (125 k., 3 dél.) :

Caze, président;
◆François **Empain**. administrateur;
De Wandre, directeur.

Société des voies ferrées du Dauphiné (58 k., 2 dél.) :

Émile **Francq**, administrateur délégué;
Léon **Devilaine**, ingénieur.

Chemin de fer de Saint-Quentin à Guise (40 k., 2 dél.) :

◆**Jourdain**, administrateur, directeur.

Chemin de fer de Guë à Menavcourt (36 k., 2 dél.) :

◆Jules **Guyard**, président;
◆René **Guyard**, administrateur.

Chemin de fer de Somain à la frontière belge (mines d'Anzin) (34 k., 2 dél.) :

A. **François**, directeur général;
de **Forcade**, secrétaire général.

Chemin de fer de Pithiviers (Loiret) à Toury (Eure-et-Loire) (31 k., 2 dél.) :

L. **Ravenez**, président;
◆A. **Poidatz**, administrateur.

Chemins de fer du Calvados (38 k., 2 dél.) :

◆**Orens**, ingénieur, directeur;
Benoit, ingénieur, chef de l'exploitation.

Chemin de fer de Chauny à Saint-Gobain (16 k., 2 dél.) :

Alfred **Biver**, directeur général;
◆E. **Jarriand**, sous-chef du secrétariat général.

Chemins de fer à voie étroite du Midi (10 k., 2 dél.).

B. — Algérie (Algeria).

Chemins de fer de l'Est algérien (887 k., 4 dél.) :

◆Albert **Dehaynin**, président;
◆Octave **Homberg** administrateur;
◆Le comte Paul **Durrieu**, administrateur;
◆**Mayer**, ingénieur en chef des ponts et chaussées, directeur.

Chemin de fer de Bône-Guelma et prolongements (réseau algérien) (794 k., 4 dél.) :

Y compris les lignes de Tunisie (358 k.).

Devès, président;
Schlemmer, administrateur;
◆**Allain-Launey**, administrateur;
◆Alfred **Kowalski***, ingénieur en chef du service central de l'exploitation (rapporteur)

Compagnie Franco-Algérienne (700 k , 4 dél.) :

Mauger, président;
H. **Lartigue**, administrateur, directeur général;
◆**Rowan**, ingénieur conseil;
◆Louis **Billema**, ingénieur du service central.

Chemins de fer de Paris à Lyon et à la Méditerranée (réseau algérien) (513 k., 4 dél.) :

Laugel, administrateur;
◆**Michel**, ingénieur en chef du matériel fixe et des approvisionnements de la voie;
◆**Étienne**, ingénieur attaché au service central de la voie;
◆**Desmure**, directeur de l'exploitation à Alger.

Chemins de fer de l'Ouest algérien (370 k., 3 dél) :

◆**Bordet**, administrateur délégué;
Peytel, administrateur délégué;
Cholet, directeur des services de la Compagnie en Algérie.

C. — **Colonies.**

Chemins de fer de Dakar à Saint-Louis (Sénégal) (264 k., 3 dél) :

◆Édouard de **Traz***, ingénieur, président (délégué des chemins de fer régionaux des Bouches-du-Rhône);
◆Alfred **Kowalski***, administrateur (délégué du chemin de fer de Bône-Guelma et rapporteur);
André de **Traz**, ingénieur, chef du service central.

Grande-Bretagne et Irlande (Royaume-Uni). Empire des Indes et Colonies. (The United Kingdom, India and its Colonies.)

A. — **Royaume-Uni (The United Kingdom).**

Great Western Railway (4,020 k. [2,498 milles], 8 dél.) :

◆The Viscount **Emlyn***, deputy chairman (vice-président de la section anglaise);
◆A. **Hubbard**, deputy chairman;
The Earl of **Cork**, director;
Col. the Hon. C. E. **Edgecumbe**, director;
◆W. **Robinson**, director;
◆C. G. **Mott**, director;
◆Henry **Lambert***, general manager (membre de la section anglaise et rapporteur);
◆T. J. **Allen**, superintendent of the line;
◆W. **Dean**, locomotive engineer;
◆J. C. **Inglis**, chief engineer;
◆J. E. **Spagnoletti**, consulting electrical engineer;
◆J. L. **Wilkinson***, chief goods manager (rapporteur).

London and North Western Railway (3,045 k. [1,892 milles], 8 dél.) :

◆The Right Hon. Lord **Stalbridge***, chairman (membre de la Commission internationale du Congrès);
◆J. P. **Bickersteth**, deputy chairman;
T. H. **Ismay**, director;
The Right Hon. D. R. **Plunket**, M. P., director;
His Grace the Duke of **Sutherland**, director;
W. **Tipping***, director (membre de la section anglaise);

◆F. **Harrison***, general manager (membre de la section anglaise et rapporteur);
◆Frank **Ree**, chief goods manager;
◆H. **Footner**, chief permanent way engineer;
◆George P. **Neele**, chief passenger superintendent;
◆C. A. **Park***, carriage superintendent (rapporteur);
◆F. **Stevenson**, chief civil engineer;
A. M. **Thompson***, signal superintendent (rapporteur);
◆F. W. **Webb**, chief mechanical engineer.

North Eastern Railway (2,555 k. [1,588 milles], 8 dél.):

Sir Joseph W. **Pease**, Bart., M. P, chairman;
◆Captain the Hon. C. **Duncumbe**, deputy chairman;
◆John **Cleghorn***, director (membre de la section anglaise);
Sir James **Kitson**, Bart., M. P., director;
◆Henry **Tennant**, director;
◆George S. **Gibb**, L. L. B., general manager;
◆J. Wolfe **Barry**, C. E. C. B.*, consulting engineer;
◆C. N. **Wilkinson**, secretary;
◆W. **Worsdell**, locomotive superintendent.

North British Railway (2,144 k. [1,332 milles], 7 dél.):

◆The Marquess of **Tweeddale***, chairman (membre de la section anglaise);
Sir Charles **Tennant**, deputy chairman;
J. G. A. **Baird**, M. P., director;
◆J. Parker **Smith**, M. P., director;
◆J. **Conacher**, general manager;
◆Jno. **Cathles**, secretary;
◆James **Carswell**, engineer;
◆M. **Holmes**, locomotive superintendent.

Midland Railway (2,092 k. [1,300 milles], 7 dél.):

◆Charles **Thomas**, deputy chairman;
◆Gustav **Behrens***, director (membre de la section anglaise);
W. U. **Heygate**, director;
◆H. T. **Hodgson**, director;
◆G. H. **Turner***, general manager (membre de la section anglaise et rapporteur);
◆T. G. **Clayton**, waggon and carriage superintendent;
◆S. W. **Johnson**, locomotive superintendent;
◆W. D. **Langdon**, telegraph superintendent;
◆J. A. **McDonald**, chief engineer;
◆H. H. **Spiller***, general continental agent (secrétaire rapporteur).

Caledonian Railway (1,676 k. [1,042 milles], 6 dél.).

J. C. **Bolton**, chairman;
◆The Marquess of **Breadalbane***, K. G., director (membre de la section anglaise);
◆J. C. **Bunten**, director;
◆Sir W. W. **Hozier**, Bart., director;
Sir Robert **Jardine**, Bart., director;
Wm. **McEwan**, M. P., director;
The Hon. G. R. **Vernon**, director;
◆James **Thompson***, general manager (membre de la section anglaise).

Great Eastern Railway (1,672 k. [1,039 milles], 6 dél.).

◆Lord Claud J. **Hamilton***, chairman (membre de la section anglaise);
Col. W. T. **Makins**, deputy chairman;
◆Sir H. W. **Tyler**, director;
◆W. **Birt**, general manager;
◆F. **Gooday**, continental traffic manager;
◆J. **Holden**. locomotive superintendent;
◆J. **Wilson**, engineer.

Great Northern Railway (1,505 k. [935 milles], 6 dél.).

The Right Hon. W. L. **Jackson**, M. P., chairman;
◆Lord **Hindlip**. deputy chairman;
◆Sir Andrew **Fairbairn***, director (membre du comité de direction de la Commission internationale et président de la section anglaise du Congrès);
F. W. **Fison**, director;
R. **Wigram**, director;
◆Sir Henry **Oakley***, general manager (membre de la section anglaise);
◆R. **Johnson**, engineer;
◆P. **Stirling**, locomotive engineer;
◆R. H. **Twelvetrees***, chief goods manager (rapporteur).

London and South Western Railway (1,416 k. [880 milles], 5 dél.):

◆W. S. **Portal***, chairman (membre de la section anglaise);
◆Lt.-col. the Hon. H. W. **Campbell**, deputy chairman;
Captain J. G. **Johnston**, director;
A. **Scott**, director;
◆Sir Charles **Scotter***, general manager (membre de la section anglaise);
◆C. J. **Owens**, chief goods manager;
◆E. **Andrews**, resident engineer.

Lancashire and Yorkshire Railway (1,094 k. [680 milles], 5 dél.):

◆G. J. **Armytage***, chairman (membre de la section anglaise);
◆W. **Tunstill**, deputy chairman;
◆H. **Bright**, director;
◆J. H. **Stafford**, general manager;
◆J. A. F. **Aspinall***, chief mechanical engineer (rapporteur);
◆C. W. **Bayley**, secretary;
◆Wm. **Hunt***, chief engineer (rapporteur);
◆W. B. **Worthington** assistant engineer.

Manchester Sheffield and Lincolnshire Railway (1,014 k. [630 milles], 5 dél.):

The Right Hon. the Earl of **Wharncliffe**, chairman;
◆Edward **Chapman**. deputy chairman;
◆J. **Maclure***, M. P., director (membre de la section anglaise);
◆William **Pollitt**, general manager;
◆Harry **Pollitt**, locomotive engineer;
◆Sir Douglas **Fox**.

Great Southern and Western Railway (975 k. [606 milles], 4 dél.):

◆J. C. **Colvill***, chairman (membre de la section anglaise);
◆Kennett **Bayley**, engineer in chief;

◆Robert G. **Colhoun**, traffic manager;
◆Henry A. **Ivatt**, locomotive engineer.

Great Northern Railway (Ireland) (842 k. [523 milles], 4 dél.):

◆James **Gray**, chairman;
◆Thomas **Robertson**, general manager;
W. H. **Mills**, chief engineer;
◆Henry **Plews**, secretary.

Glasgow and South Western Railway (771 k. [481 milles], 4 dél.):

◆Sir Renny **Watson**, chairman;
David **Guthrie**, deputy chairman;
◆David **Cooper**, general manager;
◆William **Melville**, civil engineer.

London, Brighton and South Coast Railway (767 k. [477 milles], 4 dél.):

◆The Right Hon. Lord **Cottesloe**, deputy chairman;
◆R. **Jacomb-Hood**, director;
◆The Right Hon. Sir Arthur **Otway***, Bart., director (membre de la section anglaise);
◆Allen **Sarle**, secretary and general manager;
◆Victor **Gerard***, continental traffic manager (secrétaire-rapporteur);

Midland Great Western of Ireland Railway (743 k. [462 milles], 4 dél.):

Sir Ralph Smith **Cusack**, chairman;
◆Captain Thomas James **Smyth**, director;
◆Joseph **Tatlow**, manager;
◆William George **Greene**, secretary.

Highland Railway (701 k. [436 milles], 4 dél.):

South Eastern Railway (679 k. [422 milles], 4 dél.):

◆Sir George **Russell***, Bart., M. P., chairman (membre de la section anglaise);
H. Cosmo O. **Bonsor**, M. P., deputy chairman;
The Right Hon. Lord **Hothfield**, director;
Col. J. J. **Mellor**, director;
◆Col. C. F. **Surtees**, director;
◆Sir Myles **Fenton***, general manager (membre de la section anglaise);
◆Capt. **Gye***, R. N., agent of the Company in Paris (secrétaire-rapporteur);
◆E. **Uytborck***, agent of the Company in Brussels (secrétaire-rapporteur).

Cambrian Railways (613 k. [381 milles], 4 dél.):

J. F. **Buckley**, chairman;
◆C. A. **Humphreys-Owen***, M. P., chairman of the Montgomeryshire County Council, director (rapporteur);
Lord Henry **Vane-Tempest**, director;
◆Alfred **Aslett**, secretary and general manager;
◆George **Owen**, engineer.

Great North of Scotland Railway (509 k. [316 milles], 4 dél.):

◆The Earl of **Kintore**, director;
◆W. **Moffatt**, general manager;
◆Patrick M. **Barnett**, engineer in chief;
◆William **Pickersgill**, locomotive superintendent.

Waterford and Limerick Railway (451 k. [280 milles], 3 dél.) :

◆Percy B. **Bernard**, chairman;
◆Lord Arthur **Butler**, director;
◆John J. **Murphy**, secretary.

Belfast and Northern Counties Railway (401 k. [249 milles], 3 dél.):

Edward J. **Cotton**, general manager;
◆Bowman **Malcolm**, locomotive engineer,
◆Berkley D. **Wise**, civil engineer.

North Staffordshire Railway (309 k. [192 milles], 3 dél.):

Thomas **Salt**, chairman;
◆W. D. **Phillipps**, general manager;
◆J. G. **Crosbie-Dawson**, engineer;

Great Northern and Midland joint lines Committee (293 k. [182 milles], 3 dél.):

◆ Sir John **Fowler**, Bart., consulting engineer;
◆Henry **Johnson**, continental agent;
Lord de **Ramsey**, director Great Northern Railway.

London, Chatham and Dover Railway (285 k. [177 milles], 3 dél.,

◆J. S. **Forbes***, chairman (membre de la section anglaise);
◆Wm. **Forbes**, continental and traffic manager;
◆John **Morgan**, secretary;
◆Capt. **Churchward***, agent of the Company at Calais (secrétaire-rapporteur);
◆**Niessen***, agent of the Company at Cologne (secrétaire-rapporteur).

Furness Railway (274 k. [171 milles], 3 dél.):

◆Henry **Cook**, secretary and manager;
◆F. J. **Ramsden**, assistant manager;
Frank **Stileman**, engineer in chief.

Cheshire Lines' Committee (220 k. [137 milles], 3 dél.):

F. P. **Cockshott**, superintendent of the line Great Northern Railway;
◆ J. M. **Cook**, excursion agent;
◆Colonel **Hutton** director, Manchester, Sheffield and Lincolnshire Railway.

Taff Vale Railway (193 k. [120 milles] 3 dél.):

Arthur Edward **Guest**, chairman;
R. L. **Grant Vassall**, deputy chairman;
◆A. **Beasley**, general manager.

Great Northern and Great Eastern Railway Companies' joint Committee (190 k. [118 milles] 3 dél.):

Sir Benjamin **Baker**, K. C. M. G., consulting engineer;
◆J. H. **Nettleship**, superintendent of the line Great Eastern Railway;
Frank C. **Shuttleworth**, director Great Northern Railway.

North London Railway (185 k. [115 milles], 3 dél.):

Oscar Leslie **Stephen**, chairman;
The Right Hon. David Robert **Plunket***, M. P., director (délégué du London and North Western Railway).
◆George Bolland **Newton**, general manager.

Midland and South Western Junction Railway (158 k. [98 milles], 3 dél.) :

◆W. E. Nicolson **Browne**, deputy chairman;
◆Sam. **Fay**, general manager;
◆Frank **Dawes**, solicitor.

Cork Bandon and South Coast Railway (151 k. [94 milles], 3 dél.) :

J. W. **Payne-Sheares**, J. P., chairman;
◆E. J O'.-B. **Croker**, general manager;
◆J. R. **Kerr**, C E., permanent way engineer.

London Tilbury and Southend Railway (131 k. [81 milles], 3 dél.) :

◆Arthur L. **Stride**, member of the Institute of Civil Engineers, managing director;
◆H. Cecil **Newton**, secretary;
◆Thomas **Whitelegg**, locomotive superintendent.

Belfast and County Down Railway (123 k. [76 milles], 3 dél.) :

Thomas J. **Brittain**, secretary;
James **Pinion**, general manager;
George P. **Culverwell**, engineer.

Hull Barnsley and West Riding Junction Railway (118 k. [73 milles], 3 dél. :

◆Lt. col. Gerard **Smith**, chairman;
◆Vincent Walker **Hill**, general manager;
◆Matthew **Stirling**, locomotive engineer.

Rhymney Railway (116 k. [72 milles]. 3 dél) :

◆John **Boyle**, chairman;
◆William **Austin***, deputy chairman (délégué du chemin de fer de l'Entre-Sambre-et-Meuse);
◆John Hudson **Smith**, director;
◆Cornelius **Lundie**, traffic manager.

Brecon and Merthyr Tydfil Junction Railway (109 k. [68 milles], 3 dél.) :

◆Henry Francis **Slattery**, chairman;
William Bailey **Hawkins**, deputy chairman;
◆Herbert Rhys. **Price**, secretary.

East and West Junction and Stratford-upon-Avon, Towcester and Midland Junction Railway (105 k. [65 milles], 3 dél) :

◆Thomas **Wilkins**, director;
◆William **Merrick**, general manager;
◆J. F. **Burke**, chief engineer.

Clogher Valley Railway (83 k. [52 milles], 2 dél.) :

◆Hugh de Fellenberg **Montgomery**, J. P. D. L., deputy chairman;
◆William **Irwin**, general manager.

Metropolitan Railway (83 k. [52 milles], 2 dél.) :

J. **Bell**, managing director;
G. H. **Whissell**, secretary.

Neath and Brecon Railway (64 k. [40 milles], 2 dél.) :

◆John Evan **Griffith**, general manager;
◆Charles **Talbot**, secretary and accountant.

Metropolitan District Railway (63 k. [39 milles], 2 dél.) :

◆Alfred **Powell**, manager;
◆George **Estall**, engineer and locomotive superintendent.

Tralee and Dingle Light Railway (60 k. [37 milles], 2 dél.) :

◆R. A. **Parkes**, manager;
◆George E. A. **Hickson**, engineer.

Isle of Man Railway (56 k. [35 milles], 2 dél.) :

◆G. H. **Wood**, secretary and general manager;
◆A. W. **Rixon**, solicitor.

Wrexham Mold and Connah's Quay Railway (56 k. [35 milles], 2 dél.) :

The Right Hon. Herbert **Gladstone**, M. P.;
Stuart **Wortley**, Q. C., M. P.

Manchester, Sheffield and Lincolnshire and Midland Railway Joint Committee (51 k. [32 milles] 2 dél.).

George E. **Paget**, chairman Midland Railway;
◆Alexander **Henderson**, director Manchester, Sheffield and Lincolnshire Railway.

Barry Railway (47 k. [29 milles], 2 dél.) :

◆Thomas Roe **Thompson**, director;
◆Richard **Evans**, manager.

Rhondda and Swansea Bay Railway (45 k. [28 milles], 2 dél.):

Sir John J. **Jenkins**, chairman;
Morgan B. **Williams**, deputy chairman.

Liverpool Overhead Railway (10 k. [6 milles], 2 dél.):

◆G. H. **Robertson**, director;
◆S. B. **Cottrell**, M. Inst. C. E., general manager and engineer.

Mersey Railway (6 k. [4 milles], 2 dél.) :

Albert George **Kitching**, chairman;
◆Francis **Fox**, director.

City and South London Railway (5 k. [3 milles], 2 dél.):

◆Thomas C. **Jenkin**, general manager;
◆Basil **Mott**, engineer.

B. — Empire des Indes et Colonies (India and Colonies).

East Indian Railway (2,927 k. [1,819 milles], 8 dél.) :

◆Lieutenant-general R. **Strachey**, R. E., C. S. I., L. L. D., chairman;
Bazett W. **Colvin**, deputy chairman;
Sir James L. **Mackay**, K. C. S. E., director;
Sir Alexander M. **Rendel**, K. C. S. E., consulting engineer;
◆W. S. **Rendel**, consulting engineer;
◆ F. E. **Robertson**, C.S.E., chief engineer;
◆ J. M. **Rutherford**, general traffic manager;
H. C. **Arbuthnott**, locomotive assistant to consulting engineer.

Atlantic and Lake Superior Railway (1,778 k. [1,105 milles], 6 dél.) :

◆Chas. Newhouse **Armstrong**, managing director ;
◆Edgar N. **Armstrong**, secretary;
◆Wm. **Burnside**, agent general for the United Kingdom.

Bengal and North Western Railway (1,217 k. [716 milles], 5 dél.) :

Lieut.-General C. H. **Dickens**, C. S. I., chairman;
◆D. J. **Robertson**, deputy chairman;
G. **Christian**, director;
G. W. **Allen**, C. I. E., director;
◆Lieut.-Colonel E. L. **Marryat**, secretary.

Quebec Central Railway (246 k. [153 milles], 3 dél.) :

◆Edward **Dent**, president ;
◆Edmund **Etlinger**, director;
◆Alexander **Bremner**, director.

Victoria Sidney Esquimaux and Nanaimo Railway of Canada (159 k. [99 milles], 3 dél.) :

Lieut.-col. **Kane**, agent general.

Victoria Government Railways (4,312 k. [2,679 milles], 8 dél.).

Cape Government Railways (3,988 k. [2,478 milles], 8 dél.).

New South Wales Government Railways (4,073 k. [2,531 milles], 8 dél.):

◆Edward Miller Gard **Eddy***, Chief Commissioner of the New South Wales Government Railways (délégué du gouvernement de la Nouvelle Galles du Sud).
◆Paul Bedford **Elwell**, electrical engineer of the New South Wales Government Railways.

New Zealand Government Railways (3,008 k. [1,869 milles], 8 dél.).

South Australia Government Railways (2,680 k. [1,666 milles], 8 dél.).

Tasmania Government Railways (676 k. [420 milles], 4 dél.).

Natal Government Railways (639 k. [397 milles], 4 dél.).

Grèce (Greece).

Chemins de fer de Pirée-Athènes-Péloponèse (553 k., 4 dél.) :

◆Aug. **Gillon**, ingénieur;
Const. D. **Nicolaidi**, ingénieur;
◆Arthur **Alvim***, ingénieur (délégué du chemin de fer Central de la République des États-Unis du Brésil).

Chemins de fer de Thessalie (204 k., 3 dél.).

Chemins de fer d'Attique (76 k., 2 dél).

Italie (Italy).

Chemins de fer Méridionaux (réseau de l'Adriatique) (5,513 k., 8 dél) :

Borgnini*, ingénieur, directeur général (membre de la Commission internationale du Congrès);
◆Le baron Charles de **Bottini**, ingénieur, chef du secrétariat général;
Charles **Ricchiardi**, ingénieur, chef de division au service de la traction ;

◆Louis **Alzona**, ingénieur, chef du service du mouvement et du trafic;
◆Ansano **Cajo**, ingénieur, chef du service de l'entretien;
◆Henry **Plancher**, ingénieur, sous-chef du service du matériel;
◆Henry **Cairo**, ingénieur, chef de division au service du mouvement et du trafic;
◆ Victor **Bavastro**, inspecteur central, agent commercial à l'étranger;
◆Eugène **Randich**, ingénieur, chef de section principal au service de l'entretien.

Chemins de fer de la Méditerranée (5,225 k., 8 dél.):

Massa*, ingénieur, directeur général (membre de la Commission internationale du Congrès);
Ratti, ingénieur, vice-directeur général;
◆**Kossuth**, ingénieur, directeur de l'exploitation du deuxième compartiment;
◆**Mantegazza**, ingénieur, directeur de l'entretien;
◆**Frescot**, ingénieur, directeur du matériel;
◆**Cornetti**, ingénieur, chef de la traction du premier compartiment;
◆**Lampugnani***, chef du trafic et du mouvement du premier compartiment (membre de la Commission internationale du Congrès);
◆Jean **Ferrari**, ingénieur, chef de l'entretien du deuxième compartiment;
◆**Colombo**, ingénieur, chef de division à la direction générale;
◆E. **Braschi**, chef du contentieux.

◆**Scolari***, docteur en droit, chef de division à la direction générale (rapporteur);
◆**Rocca***, ingénieur, inspecteur de la direction générale (rapporteur);
◆**Zanotta***, ingénieur, chef de section au service de l'entretien, surveillance et travaux (rapporteur).

Chemin de fer de la Sicile (1,010 k., 5 dél.);

◆Roberto **Varvaro**, administrateur;
Letterio **Bonanno**, administrateur;
◆Le comte **Miglioretti**, administrateur;
◆Enrico **Scialoja**, secrétaire général du conseil d'administration;
◆Charles **Grillo**, commissaire de la Société.

Chemins de fer sardes (413 k., 3 dél.):

◆Epaminonda **Segré**, administrateur;
◆Francis George **Whitwham**, administrateur;
◆Luigi **Conti Vecchi**, ingénieur, directeur.

Chemins de fer du Tessin (265 k., 3 dél.):

Édouard **Despret***, président (délégué du chemin de fer de l'Est belge);
◆Ulisse **Hennebuisse**, directeur de l'exploitation;
◆Joseph **Carlier**, ingénieur.

Chemin de fer du Nord de Milan (227 k., 3 dél.):

◆A. **Vaucamps**, administrateur;
◆Charles **Thonet**, ingénieur, directeur;
◆César **Rognoni**, ingénieur, inspecteur du service des voies et travaux.

Chemins de fer de la Sicile occidentale (*Palerme-Marsala-Trapani*) (200 k., 3 dél.):

◆Félix **Karo**, administrateur;
◆G. **Robbo**, administrateur délégué;
◆Jules **Cottrau**, chef du secrétariat.

Chemins de fer secondaires de la Sardaigne (600 k., 4 dél.).

◆Eugène **Pollone**, secrétaire d'administration ;
◆Charles **Busser**, ingénieur des constructions ;
◆Victor **Franzi**, ingénieur des constructions ;
◆Carlo **Esterle**, ingénieur, inspecteur.

Société vénitienne pour entreprises et constructions publiques (572 k., 4 dél.) :

◆Enrico **Cavo**, avocat, administrateur ;
◆Bartholomeo **Loleo**, avocat, administrateur ;
Ferdinando **Locatello**, ingénieur, directeur de l'exploitation.

Chemin de fer de l'Apennin central (135 k., 3 dél.) :

◆Auguste **Moyaux**, administrateur délégué ;
◆Albéric **Van Overbeke**, ingénieur principal ;
Léon **Moyaux**, ingénieur.

Chemin de fer de Suzzara-Ferrara (80 k., 2 dél.) :

◆A. **Spasciani**, ingénieur, président ;
◆Achille **Zavanella**, ingénieur, administrateur.

◆**Terzi***, directeur (rapporteur).

Chemin de fer de Reggio-Emilia (71 k., 2 dél.) :

◆Le Dr Antonio **Toso**, administrateur ;
◆Vittorio **Rol**, administrateur.

Chemin de fer de Sassuolo-Modena-Mirandola e Finale (69 k., 2 dél.) :

◆Leonardo **Loria**, ingénieur, administrateur ;
◆Pacifico **Levi**, avocat, secrétaire du conseil.

Chemins de fer secondaires romains (67 k., 2 dél.) :

◆Guilio **Navone**, avocat, administrateur ;
◆Giovanni **Strambio de Castillia**.

Chemins de fer économiques de Bari-Barletta et extensions (65 k., 2 dél.) :

C. **Blanchart**, ingénieur, secrétaire ;
◆J. **Borel**, ingénieur, directeur.

Chemin de fer de Crémone-Mantoue (63 k., 2 dél.).

Chemin de fer Central et tramways du Canavèse (59 k., 2 dél.) :

◆Adolphe **Pellegrini**, ingénieur, administrateur délégué.

Chemin de fer de Turin-Pignerol-Torre-Pellice (55 k., 2 dél.) :

◆**Cassinis**, ingénieur ;
◆**Pucci-Bandana**, ingénieur.

Chemin de fer de Naples-Ottaiano (50 k., 2 dél.) :

◆Antonio **Gattoni**, administrateur ;
◆Angelo **Basevi**, ingénieur, administrateur.

Chemin de fer de Chivasso à Ivrea (33 k., 2 dél.) :

◆Melchior **Pulciano**, ingénieur ;
◆Prosper **Peyrou**, ingénieur

Chemin de fer de Modena Vignola (26 k., 2 dél.) :

◆ANGELO **Guastalla**, avocat, président, administrateur délégué;
◆EMILE **Greiner**, administrateur.

Chemin de fer de Colle de Val d'Elsa Poggibonsi (8 k., 2 dél.) :

VITTORIO **Finzi**, président;
◆FERNAND **Courtois**, administrateur.

Tramways à vapeur interprovinciaux de Milan-Bergame-Crémone (164 k., 3 dél.) :

ISAAC **Stern**, administrateur;
◆**Maes**, ingénieur, directeur du chemin de fer de Valle Seriana et du tramway de Bergame-Soncino;
◆**Marsal**, ingénieur, directeur des chemins de fer économiques du Biellais.

Tramways à vapeur piémontais (160 k., 3 dél.) :

◆CHARLES **Dupuich**, administrateur;
◆GEORGES **Sassen**, directeur gérant;
◆GUSTAVE **Boty**, ingénieur.

Société anonyme nationale de tramways et de chemins de fer (136 k., 3 dél.) :

Le baron CONSTANZO **Cantoni**, président;
J. **Rusconi-Clerici**, ingénieur, administrateur;
◆ADOLPHE **Nathan**, ingénieur.

Tramway à vapeur de Biella à Vercelli (112 k., 3 dél.) :

◆VALÈRE **Mabille**, président;
◆HENRY **Sépulchre**, inspecteur général;
◆CHARLES **Roberti**, secrétaire de l'inspection générale.

Tramways siciliens (71 k., 2 dél.) :

LUCIEN **Guinotte**, sénateur, président;
◆**Ropsy-Chaudron**, administrateur.

Tramways et chemins de fer économiques de Rome, Milan, Bologne, etc. (69 k., 2 dél.) :

EMILE **Steens**, administrateur délégué;
◆LÉON **Vankeerberghen**, administrateur.

Tramways à vapeur de la province d'Alexandrie (69 k., 2 dél.) :

◆GUSTAVE **Melotte**, administrateur;
◆AIMÉ **Pacco**, ingénieur, administrateur.

Tramways de Turin (65 k., 2 dél.) :

◆J. **Jacobs**, ingénieur, président, administrateur de la Société générale de chemins de fer économiques;
◆ARTHUR **Gruslin**, ingénieur, directeur.

Tramways à vapeur de la province de Turin (62 k., 2 dél.) :

◆GUIDO **Bollero**, administrateur;
◆PAUL **Amoretti**, directeur.

Tramways à vapeur des provinces de Vérone et Vicence (57 k., 2 dél.) :

◆J. B. **Alessi**, administrateur;
◆E. **Wallaert**, administrateur.

Tramways de la province de Florence (45 k., 2 dél.) :

◆CESARE **Cesaroni**, administrateur;
◆ALESSANDRO **Panzarasa**, ingénieur électricien.

Tramways florentins (44 k., 2 dél.) :

◆Le baron ALBERT DE **Fierlant**, ingénieur, chef de service de l'exploitation à la Société générale de chemins de fer économiques;
◆ALBERT **Van der Straeten**, ingénieur, chef de service des voies et travaux à la Société générale de chemins de fer économiques.

Tramways à vapeur et chemins de fer économiques de la province de Pise (41 k., 2 dél.) :

◆F. BENEDETTO **Rognetta**, ingénieur, lieutenant-colonel d'artillerie, président;
◆EMILE **Rognetta**, avocat, secrétaire de la présidence.

Tramways napolitains (15 k , 2 dél.) :

◆C. **Bricourt**, administrateur;
◆E. **Vilers**, directeur.

Union des chemins de fer italiens d'intérêt local (522 k., 4 dél.) :

◆AMBROGIO **Campiglio***, président (membre de la Commission internationale du Congrès);
Pesaro, vice-président du chemin de fer Suzzara-Ferrara, membre du comité de l'Union;
◆**Camis**, ingénieur, membre du comité;
AUGUSTE **Ferrari**, président du chemin de fer de Novara-Seregno.

Association des tramways italiens (500 k., 3 dél.) :

G. **Bianchi**, ingénieur, président;
◆E. **Radice**, ingénieur, vice-président;
◆J. G. **Kessels**, ingénieur, secrétaire général.

Luxembourg (Luxemburg).

Chemins de fer Guillaume-Luxembourg (257 k., 3 dél.) :

◆TONY **Dutreux***, administrateur (membre de la Commission internationale du Congrès);
◆MAURICE **Letellier**, représentant de la Société à Luxembourg;
J. E. **Van de Wynckèle**, secrétaire du conseil.

Chemins de fer et Minières Prince Henri (163 k., 3 dél.) :

◆JULES **Wilmart**, administrateur;
J. B. **Dupont**, ingénieur, directeur;
E. **Diderich**, inspecteur chef de service.

Mexique (Mexico).

Chemin de fer de Hidalgo et Nord-Est (210 k., 3 dél.) :

Norvège (Norway).

◆*Chemins de fer de l'État* (1,510 kil., 6 dél.) :

◆C. **Pihl***, directeur pour le département de construction (délégué du gouvernement norvégien);
C. E. **Krefting***, directeur pour le département de l'exploitation (id.).

Chemin de fer de Christiania à Eidsvold (Norsk Hoved Jernbane) (68 k., 2 dél.).

Pays-Bas (Holland).

A. — Continent.

Chemins de fer de l'État néerlandais (Société pour l'exploitation des) (1,567 k., 6 dél.) :

J. H. **Nivel**, secrétaire ;
◆S. E. **Haagsma**, chef de division du service de la traction et du matériel ;
◆H. A. **Perk**, membre de la Commission militaire permanente des chemins de fer ;
◆H. **Spanjaard**, inspecteur principal.

Chemin de fer Hollandais (1,219 k., 5 dél.) :

R. van **Hasselt**, administrateur délégué ;
N. H. **Nierstrasz**, ingénieur, chef de l'exploitation ;
◆J. A. **Roessing van Iterson**, ingénieur en chef de la traction et du matériel ;
◆**De Bruyn**, ingénieur en chef des voies et travaux.

Chemin de fer Central néerlandais (102 k., 3 dél.) :

◆J. W. **Verloop**, ingénieur mécanicien.

Chemin de fer Brabant septentrional allemand (101 k., 3 dél.) :

J. M. **Voorhoeve**, président-directeur ;
J. B. **Zelis**, directeur.

Tramways néerlandais (94 k., 2 dél.) :

◆S. **Hamelink**, directeur ;
◆K. **Van Rijn**, commissaire.

Tramways à vapeur de Breskens-Maldegem (36 k., 2 dél.) :

◆**Gerritsen**, président ;
◆**Schotel**, commissaire.

B. — Colonies.

Chemins de fer de l'État aux Indes néerlandaises (1,147 k., 5 dél.)

Compagnie néerlandaise Sud-Africaine de chemins de fer (730 k., 4 dél.) :

R. W. J. C. van den **Wall Bake**, directeur ;
J. A. van **Kretschmar van Veen**, administrateur.

Chemins de fer des Indes néerlandaises (261 k., 3 dél.) :

◆G. F. **Lucardie**, administrateur.

Chemins de fer de l'Est de Batavia (57 k., 2 dél.).

Pérou (Peru).

Lima Railway (32 k. [19 1/2 milles], 2 dél.) :

◆Colonel Lawrence **Heyworth**, J. P., chairman and director ;
◆Sir Henry **Cartwright**, J. P., director.

Perse (Persia).

Chemins de fer et tramways en Perse (9 k., 2 dél.) :

◆Fernand **Guillon**, administrateur délégué ;
Gillet, chef de la comptabilité.

Portugal.

A. — Continent.

Chemins de fer de l'État (816 k., 4 dél.) :

◆Général José Joaquim de Paiva Cabral **Couceiro**, ingénieur inspecteur;
◆Le conseiller Joaquim Pires de **Souza Gomes**, ingénieur inspecteur;
◆Antonio José Antunes **Navarro**, ingénieur en chef de 1re classe;
◆Pedro Romano **Folque**, ingénieur en chef.

Chemins de fer portugais (Compagnie royale des) (1,023 k., 5 dél.) :

H. E. **Boyer**, administrateur, directeur;
Manuel A. d'**Espregueira**, ingénieur conseil;
Antonio de **Vasconcellos Porto**, ingénieur, chef de la construction;
◆Joao Ferreira de **Mesquita**, ingénieur adjoint du service du matériel et de la traction;
◆Antonio **Carrasco Bossa**, ingénieur adjoint du service de l'exploitation.

Chemin de fer de la Beira-Alta (253 k., 3 dél.) :

Henry **Durangel**, administrateur délégué;
Léon **Drouin***, inspecteur général (délégué du chemin de fer de Medina del Campo à Salamanca);
Le comte de **Gouvéa**, directeur.

Chemins de fer portugais (Compagnie nationale des) (101 k., 3 dél.) :

◆José Mesquita da **Rosa**, président;
◆Le Dr Antonio José **Gomes Lima**, directeur;
◆Manuel Emygdio da **Silva**, ingénieur conseil de la Compagnie.

B. — Colonies.

Chemins de fer de l'État (451 k., 3 dél.) :

◆Antonio Arthur da Costa Mendes de **Almeida**, capitaine du génie;
◆Angelo de **Sarrea Prado**, ingénieur civil;
◆Antonio Maria de **Avellar**, ingénieur civil.

Roumanie (Roumania).

Chemins de fer de l'État (2,399 k., 7 dél.) :

◆**Duca***, professeur à l'École des ponts et chaussées de Bucharest, directeur général (membre de la Commission internationale du Congrès, rapporteur et délégué du gouvernement roumain);
◆Ch. **Drago***, chef de service des ateliers et du matériel (délégué du gouvernement roumain);
◆A. **Gafenco***, chef de service (id.);
◆A. **Cottesco***, chef de service (id);
◆C. **Manesco***, chef de service (id.);
◆A. **Saligny***, chef de service (id.).

Russie (Russia).

Chemins de fer de l'État: Lignes Sud-Ouest russes (2,920 k.); lignes de Saint-Pétersbourg à Varsovie (1,288 k.), Nicolas (645 k.), de Polessié (1,507 k.), de Samara-Zlatooust et d'Orenbourg (1,504 k.), de Syzrane-Viazma (1,368 k.), de Libau-Romny (1,271 k.), de Catherine et de Donets (1,216 k.), de Kharkov-Nicolaïev (1,099 k.), d'Oural (1,085 k.), de Transcaucase (1,047 k.), de la Baltique, de Pskov-

Riga et du port de Saint-Pétersbourg (1,034 k.), de Riga-Orel (1,028 k.), de Moscou-Koursk et de Moscou-Nijni (991 k.), de Koursk-Kharkov-Azov (815 k.), de Lozovo-Sébastopol (686 k.) de Varsovie-Térespol, de Brest-Kholm, de Sedletz-Malkine et de Narev (535 k.), de Rjev-Viazma (124 k.), de Mourom (114 k.), de Baskountchak (77 k.), de Riga-Toukoum (58 k.), de Joukovo-Akoulitsk (45 k.), 8 + 5 + 4 + 6 + 6 + 5 + 5 + 5 + 5 + 5 + 5 + 5 + 5 + 4 + 4 + 4 + 4 + 3 + 3 + 2 + 2 + 2 = 97 délégués.

Administration centrale :

PAUL **Wassilevsky**, ingénieur, président;
◆NICOLAS **Antochine**, ingénieur;
◆ALEXANDRE **Plakida**, ingénieur, chef de la section technique;
◆SERGE **Grigorieff**, ingénieur;
◆NICOLAS **Bélélubsky**, ingénieur, professeur à l'Institut impérial des ingénieurs des voies de communication, membre du conseil des ingénieurs au ministère des voies de communication;
◆NICOLAS **Reitlinger**, secrétaire à l'administration de la caisse de retraite.

Lignes Sud-Ouest russes :

◆ARTHUR D'**Abramson**, ingénieur, chef du bureau technique du service de la voie et des bâtiments;
◆MAXIMILIEN **Filonenko**, ingénieur, chef du bureau du service du mouvement;
◆JAMES P. **Maginnis**, ingénieur.

Ligne de Saint-Pétersbourg à Varsovie :

◆PAUL **Rizzoni**, ingénieur, gérant des ateliers principaux;
◆J. **Richter***, adjoint du directeur (rapporteur).

Ligne Nicolas :

◆JOSEPH **Tourtsevitz**, ingénieur en chef du service de la voie et des bâtiments.

Ligne de Polessié :

◆SERGE **Batchmanoff**, ingénieur pour missions spéciales.

Ligne de Syzrane-Viazma :

PIERRE **Doumitrachko**, ingénieur en chef du service de la voie et des bâtiments.

Ligne de Libau-Romny :

◆VOLDEMAR **Grossman**, ingénieur en chef du service du matériel roulant et de la traction.

Ligne de Kharkov-Nicolaïev :

◆NICOLAS **Baldak**, ingénieur en chef du service du matériel roulant et de la traction.

Ligne du Transcaucase :

◆NICOLAS **Alfonsky**, ingénieur en chef adjoint du service de la voie et des bâtiments.

Ligne de la Baltique, de Pskov-Riga et du port de Saint-Pétersbourg :

◆DÉMÉTRIUS **Ivanoff**, ingénieur en chef du service de la voie et des bâtiments.

Ligne de Moscou-Koursk et de Moscou-Nijni :

◆NICOLAS **Chaufus**, ingénieur.

Ligne de Varsovie-Terespol, de Brest-Kholm, de Sedletz-Malkine et de Narev :

◆SIMÉON **Sklévitzky**, ingénieur, chef du service du mouvement.

Ligne de Riga-Orel :

M. **Pérévoznikoff**, ingénieur en chef du service du matériel roulant et de la traction.

Chemins de fer de l'Etat de Finlande (2,098 k., 7 dél.)

◆**Nordman**, directeur de la traction;
◆**Frosterus**, sous-directeur de l'entretien;
◆**Niklander**, sous-directeur du trafic;
◆**Engström**, sous-directeur de la traction.

Chemin de fer militaire transcaspien (1,433 k., 5 dél.).

Chemins de fer Sud-Est russes.
- *Ligne Koslov-Voronège-Rostov* (853 k., 4 dél.).
- *Ligne Griazi-Tsaritzyne* (746 k., 4 dél.).
- *Ligne Orel-Griazi* (308 k., 3 dél.).
- *Ligne de Livny* (61 k., 2 dél.).

◆Basile **Wrédensky**, ingénieur, directeur-administrateur.

Chemins de fer de Riazane-Ouralsk.

Ligne de Riazane-Saratov) 832 k., 4 dél.) :

J. E. **Adadourov**, président;
M. P. **Verschowsky**, directeur;
M. P. **Fédoroff**, directeur;
W. P. **Zouroff**, directeur.

Ligne de Tambov-Kamichine (475 k., 3 dél.) :

A. A. **Pomeranzoff**, directeur-candidat;
N. N. **Isnav**, agent du service de commerce.

Ligne de Pokrovsk-Ouralsk (423 k., 3 dél.) :

◆D. P. **Kandaouroff**, gérant de la Compagnie;
K. N. **Lazarew-Stanistchew**, ingénieur en chef.

Ligne de Rtistchevo-Serdobksk et Atkarsk-Petrovsk (173 k., 3 dél.) :

A. A. **Dobrowolski**, chef de l'exploitation;
S. W. **Ignatius**, chef du bureau technique.

Chemin de fer de Kiev-Voronège (1,768 k., 6 dél.) :

N. L. **Markoff**, président;
A. J. **Ghennert**, administrateur;
◆S. A. **Erine**, administrateur;
J. A. **Likhatchev**, administrateur suppléant et chef du service commercial;
◆S. J. **Sack**, ingénieur technologue;
◆D. S. **Ivachinzoff**, agent de la Société.

Chemins de fer de Vladicaucase (1,298 k., 5 dél.) :

◆S. **Kerbedz**, ingénieur, président;
◆R. **Salomé**, ingénieur, chef du bureau d'exploitation;
◆D. **Okoulitch**, ingénieur, chef de l'exploitation;
◆S. **Tchervinsky**, ingénieur, directeur des ateliers mécaniques;
V. **Goloubieff**, ingénieur.

Chemins de fer de Moscou-Brest (1,100 k., 5 dél.) :

◆**Krapiffka**, président;
Warschavsky, administrateur;
◆Emile **Danischewski**, chef de division du commerce et de l'exploitation;

◆**Liamine**, ingénieur des voies de communication, ingénieur en chef;
◆**Pschenetzky**, ingénieur technologue, adjoint du chef de traction.

Chemins de fer de Moscou-Jaroslav et Arkhangelsk (623 k., 4 dél.):

Sava **Mamontoff**, président;
Semen Petrovitch **Tchocoloff**, ingénieur de la construction.

Chemin de fer de Varsovie-Vienne (542 k., 4 dél.):

◆Etienne **Zielinski**, ingénieur, administrateur;
◆Alexandre **Wasiutynski**, ingénieur attaché à la direction;
◆Adam **Szawtowski**, sous-chef du mouvement;
◆Louis **Woyno**, sous-chef du service de la traction.

Chemins de fer de la Vistule (541 k., 4 dél.):

◆**Kozlowski**, vice-président;
◆**Sendzikowski**, ingénieur, administrateur directeur;
◆**Olkhine**, conseiller privé, administrateur directeur;
◆**Daragane**, ingénieur, directeur de l'exploitation.

Chemins de fer de Dombrova-Ivangorod (487 k., 3 dél.):

◆Jean de **Bloch**, conseiller d'État actuel, président;
Vladimir de **Lachtin**, conseiller d'État, ingénieur, directeur;
◆Stanislas **Olszewski**, ingénieur.

Chemins de fer de Fastov (304 k , 3 dél.):

◆L. I. **Poliakoff**, directeur;
I. W. **Drury**, directeur;
◆I. I. **Gorowitz**, secrétaire général de la direction.

Chemins de fer de Rybinsk-Bologoë (300 k., 3 dél.):

Alexandre de **Pourgold**, conseiller privé;
◆Jacques **Outine**, conseiller privé;
◆Constantin de **Yastchembski**, administrateur directeur.

Chemins de fer de Moscou-Kazane (248 k., 3 dél.):

◆Alexandre de **Meck**, directeur.

Chemins de fer de Chouia-Ivanovo (201 k., 3 dél.).

Chemins de fer de Novgorod (168 k., 3 dél.):

Paul de **Tanciev**, président;
Alexandre de **Kozlovski**, administrateur;
◆Henri de **Svientzitzki**, conseiller d'État, ingénieur, directeur.

Chemins de fer de Novotorchok (137 k., 3 dél.).

Chemins de fer de Saint-Pétersbourg-Irinorska (37 k., 2 dél.).

Chemins de fer de Borga-Kervo (33 k., 2 dél.):

C. G. **Standertskjöld**, ingénieur, directeur-président;
C. G. **Sanmark**, surintendant de l'Administration des industries de Finlande, directeur.

Chemin de fer de Lodz (28 k., 2 dél.) :

◆Jean de **Bloch***, conseiller d'État actuel, président (délégué des chemins de fer de Dombrova-Ivangorod);
◆Eugène **Kucharski**, chef du contrôle.

Chemin de fer de la ville de Kiev (23 k., 2 dél.) :

Brodsky, administrateur.

Chemin de fer de Tsarskoé-Sélo (26 k., 2 dél.) :

Léon **Warschawsky**, administrateur.

Première Société des chemins de fer secondaires en Russie (160 k., 3 dél.) :

Boleslas **Jalovietsky**, ingénieur des voies de communication;
Théodore **Yénakieff**, ingénieur des voies de communication;
◆A. **Nikitine**, ingénieur en chef.

Tramways d'Odessa (20 k., 2 dél.) :

◆P. **Hammelrath**, ingénieur, secrétaire du conseil d'administration;
◆Eugène **Bourson**, ingénieur.

Tramways de Moscou (9 k., 2 dél.) :

J. A. **Likhatchev***, administrateur (délégué du chemin de fer de Kiev-Voronège);
◆Fr. **Knauff**, administrateur.

Serbie (Servia).

Chemins de fer de l'Etat (540 k., 4 dél.) :

◆Milivoie **Yossimovitch***, inspecteur général (délégué du gouvernement serbe).

Suède (Sweden).

Chemins de fer de l'Etat (3,127 k., 8 dél.) :

◆Le comte Rodolphe **Cronstedt***, directeur général (délégué du gouvernement suédois);
◆Fredrik **Almgren***, administrateur (membre de la Commission internationale du Congrès, délégué du gouvernement suédois);
◆Victor **Klemming**, inspecteur du matériel;
◆A. **Roos** ingénieur en chef consultant des travaux de la voie;
◆Herman **Johansson**, ingénieur des études du matériel;
◆C. P. **Sandberg**, ingénieur consultant de la voie.

Chemins de fer de Norsholm-Westervik-Hultsfred (184 k., 3 dél.) :

◆Major P. **Petersson**, ingénieur des ponts et chaussées;
Capitaine A. G. **Stahle**, ingénieur des ponts et chaussées.

Chemin de fer de Nasstö-Oskarshamn (146 k., 3 dél) :

◆Fred. **Goslett**, directeur général.

Chemins de fer de Nora-Karlskoga (130 k., 3 dél.) :

◆C. **Collett**, ingénieur en chef, chef de l'exploitation.

Chemins de fer de Frövi-Ludvika et Banghammar-Kloten (120 k., 3 dél.) :

◆John **Johnson**, ingénieur, directeur général.

Chemin de fer de Palsboda-Finspong et Finspong-Norsholm (85 k., 2 dél.) :

◆ Oscar **Kamph**, ingénieur civil, chef de l'exploitation.

Suisse (Switzerland).

Chemins de fer du Jura-Simplon (1,052 k., 5 dél.) :

◆ Émile **Colomb**, directeur.

Chemin de fer Central suisse (394 k., 3 dél.) :

W. **Heusler**, vice-président du comité de direction;
J. **Mast**, membre du comité de direction;
J. **Flury**, membre du comité de direction.

Chemin de fer du Gothard (266 k., 3 dél.) :

Stoffel, président de la direction;
◆ **Dietler***, vice-président de la direction (membre de la Commission internationale du Congrès).

Chemin de fer suisse du Seethal (46 k., 2 dél.).

Chemin de fer à crémaillère de Viège à Zermatt (35 k., 2 dél.) :

◆ Ernest **Correvon**.

Chemin de fer d'Yverdon à Sainte-Croix (24 k., 2 dél.) :

◆ Ernest **Correvon***, vice-président (délégué du chemin de fer de Viège à Zermatt);
◆ John **Landry**, administrateur.

Chemin de fer de la Vallée de Birsig (13 k., 2 dél.) :

E. **Probst-Lotz**, président;
◆ Arnold **Gysin**, ingénieur, directeur de l'exploitation.

Chemin de fer de Glion aux Rochers de Naye (8 k., 2 dél.) :

◆ Georges **Masson**, président;
◆ Ami **Chessex**, vice-président.

Chemin de fer électrique de Sissach-Gelterkinden (3 k., 2 dél.).

Chemin de fer de Lausanne-Ouchy (2 k., 2 dél.) :

◆ J. J. **Mercier de Molin**, vice-président;
◆ E. **Francillon**, administrateur.

Chemin de fer funiculaire de Territet-Glion (1 k., 2 dél.).

◆ Auguste **Dupraz**, avocat, administrateur;
◆ Alexandre **Emery**, administrateur.

Tunisie (Tunis).

Chemin de fer Rubattino (Tunis-Bardo-La Goulette-Marsa (42 k., 2 dél.) :

◆ Le Prince Ruffo **Scilla**, administrateur;
◆ Francesco **Martorelli**, ingénieur, inspecteur général des chemins de fer italiens en retraite, gérant de la Société.

Turquie (Turkey).

Chemins de fer orientaux (Compagnie d'exploitation des) (1,264 k., 5 dél.) :

MAURICE **Bauer**, administrateur, membre du Comité de direction;
CHARLES **Morawetz**, administrateur;
◆J. **Goldberg**, ingénieur, secrétaire général;
◆Le D[r] G. DE **Adler**, conseil légal.

Chemins de fer ottomans de Beyrouth-Damas-Hauran (250 k., 3 dél.) :

◆**Allain-Launay***, administrateur (délégué du chemin de fer de Bône-Guelma)
◆D. **Pérouse**, ingénieur en chef des ponts et chaussées;
◆**Weisgerber**, ingénieur en chef des mines.

Uruguay.

Midland Uruguay railway (315 k. [196 milles], 3 dél.) :

◆C. G. **Mott***, chairman (délégué du Great Western Railway);
◆HON. J. C. **Farrer**, director;
◆Sir WM. L. **Young**, Bart., director.

Venezuela.

Chemins de fer vénézuéliens (Compagnie française des) (60 k., 2 dél.) :

◆ALBERT **Reynaud**, administrateur.

TABLE ALPHABÉTIQUE DES DÉLÉGUÉS

AVEC INDICATION DES SECTIONS AUX TRAVAUX DESQUELLES ILS ONT PRIS PART

ALPHABETICAL INDEX OF DELEGATES

INDICATING THE SECTIONS THEY ATTENDED

N. B. — L'absence est marquée par trois points (...) dans la dernière colonne. (... in the last col. means that the delegate was not present.)

NUMÉRO D'ORDRE. (NUMBER.)	NOM. (NAME.)	ADMINISTRATION DÉLÉGANTE. (DELEGATED BY.)	SECTIONS.
1	ABELES (Sigismond). . .	Chemins de fer de l'État (Hongrie) . . .	2
2	ABRAMSON (Arthur D') . .	Chemins de fer de l'État (lignes Sud-Ouest) (Russie)	1 & 5
3	ACWORTH (W. M.) . . .	Section anglaise	5
4	ADADOUROV (J. E.) . . .	Chemins de fer de Riazane-Ouralsk (ligne de Riazane-Saratov) (Russie)	...
5	ADDICKS (W. H.). . . .	Pittsburgh and Western Railway (États-Unis d'Amérique)	1 & 2
6	ADDISON (Major G. W.). .	Ministère du Commerce (*Board of Trade*) (Royaume uni de Gr.-Bret. et d'Irlande).	1, 2, 3, 4 & 5
7	ADLER (le Dr G. DE). . .	Compagnie d'exploitation des chemins de fer orientaux (Turquie).	4
8	AGNELLET	Chemin de fer du Nord (France). . . .	1 & 4
9	ALESSI (J. B.)	Tramways à vapeur des provinces de Vérone et Vicence (Italie)	5
10	ALFONSKY (Nicolas). . .	Chemins de fer de l'État (ligne de Transcaucase) (Russie)	1
11	ALLAIN-LAUNAY	Chemins de fer ottomans de Beyrouth Damas-Hauran (Turquie) et Chemins de fer de Bône-Guelma (Algérie). . . .	4
12	ALLEN (E. G.)	New York, New Haven, and Hartford Railway (États-Unis d'Amérique)	3
13	ALLEN (G. W)	Bengal and North Western Railway (Empire des Indes)	...
14	ALLEN (H. C)	Buenos-Ayres Great Southern Railway (République Argentine).	1, 2, 3 & 4
15	ALLEN (T. J.)	Great Western Railway (Grande-Bretagne).	3 & 4
16	ALLEN (William F.). . .	American Railway Association (Etats-Unis d'Amérique)	3 & 4
17	ALMEIDA (Antonio Arthur da Costa Mendes DE).	Chemins de fer de l'État dans les colonies (Portugal)	1

NUMÉRO D'ORDRE. (NUMBER.)	NOM. (NAME.)	ADMINISTRATION DÉLÉGANTE. (DELEGATED BY.)	SECTIONS.
18	ALMEIDA D'EÇA (Bento Fortunato de Moura Continho D').	Ministère des travaux publics, du commerce et de l'industrie (Portugal)	1
19	ALMGREN (Fredrik)	Commission internationale du Congrès et Ministère de l'intérieur (Suède)	2
20	ALT (William John)	Brazil Great Southern Railway (Brésil)	1
21	ALVIM (Arthur)	Chemin de fer Central de la République des États-Unis du Brésil (Brésil) et chemin de fer Pirée-Athènes-Péloponèse (Grèce).	1
22	ALZONA (Louis)	Chemins de fer Méridionaux (réseau de l'Adriatique) (Italie)	3 & 4
23	AMIOT	Chemins de fer de Paris à Lyon et à la Méditerranée (France)	4
24	AMORETTI (Paul)	Tramways à vapeur de la province de Turin (Italie)	2 & 5
25	ANCION (A.)	Chemin de fer de Termonde à Saint Nicolas (Belgique)	5
26	ANDREWS (E.)	London and South Western Railway (Grande-Bretagne)	1
27	ANGULO (Rafael)	Chemin de fer du Nord de l'Espagne	...
28	ANTOCHINE (Nicolas)	Administration centrale des chemins de fer de l'État (Russie)	2 & 3
29	ARAMBURU Y PELAYO (Manuel DE).	Chemins de fer de Tarragone à Barcelone et à la France (Espagne)	...
30	ARBUTHNOTT (H. C.)	East Indian Railway (Grande-Bretagne et colonies)	...
31	ARMSTRONG (Charles Newhouse).	Atlantic and Lake Superior Railway (Canada).	4
32	ARMSTRONG (Edgar N.)	Atlantic and Lake Superior Railway (Canada).	3
33	ARMYTAGE (G. J.)	Section anglaise et Lancashire and Yorkshire Railway (Grande-Bretagne)	1 & 2
34	ASLETT (Alfred)	Cambrian Railways (Grande-Bretagne)	1, 2, 3, 4 & 5
35	ASPINALL (J. A. F.)	Lancashire and Yorkshire Railway (Grande-Bretagne)	1 & 2
36	AST (Wilhelm)	Chemins de fer du Nord Empereur Ferdinand (Autriche)	1 & 3
37	AUCOC	Chemin de fer du Midi (France)	4
38	AUMONT	Chemin de fer du Nord (France)	1 & 4
39	AUSTIN (William)	Rhymney Railway (Grande-Bretagne) et chemin de fer de l'Entre-Sambre-et-Meuse (Belgique)	5
40	AUVERT	Chemins de fer de Paris à Lyon et à la Méditerranée (France)	2
41	AUZOUY	Ministère des travaux publics (France)	...
42	AVELLAR (Antonio Maria)	Chemins de fer de l'État dans les colonies (Portugal)	1 & 5
43	BAEYENS (Ferdinand)	Chemin de fer du Nord de la Belgique	...
44	BAÏDAC (Nicolas)	Chemins de fer de l'État (ligne de Kharkov-Nicolaïev) (Russie)	2 & 4
45	BAILLET	Chemin de fer de Chimay (Belgique)	...
46	BAINES (R. Campbell)	Central Argentine Railway (République Argentine)	4
47	BAIRD (J. G. A.)	North British Railway (Grande-Bretagne).	...
48	BAKER (sir Benjamin)	Great Northern and Great Eastern Railway Companies' Joint Committée (Grande-Bretagne)	...

NUMÉRO D'ORDRE. (NUMBER.)	NOM. (NAME.)	ADMINISTRATION DÉLÉGANTE. (DELEGATED BY.)	SECTIONS.
49	BALFOUR OF BURLEIGH (The Right Hon. Lord).	Ministère du Commerce (*Board of Trade*) (Royaume uni de Gr.-Bretagne et d'Irlande)	1, 2, 3, 4 & 5
50	BARABANT	Commission internationale du Congrès et Chemins de fer de l'Est (France) . . .	3 & 4
51	BARAT (T.)	Chemins de fer du Nord de l'Espagne . .	...
52	BARDANY (le Chevalier Max Bram von).	Chemins de fer du Sud de l'Autriche. . .	...
53	BARDOUX.	Chemins de fer de Paris à Orléans (France).	4
54	BARELLA (Dr Léopold) . .	Chemin de fer de Tournai à Jurbise et de Landen à Hasselt (Belgique)	4
55	BARNES (D. L.)	Los Angeles Terminal Railway (États-Unis d'Amérique)	...
56	BARNETT (Patrick M.) . .	Great North of Scotland Railway (Grande-Bretagne).	1 & 5
57	BARRY (J. Wolfe) . . .	North Eastern Railway (Grande-Bretagne).	1, 2, 3, 4 & 5
58	BARTHOU (Léon). . . .	Ministère des travaux publics (France) . .	...
59	BASEVI (Angelo). . . .	Chemin de fer de Naples-Ottaiano (Italie) .	5
60	BATCHMANOFF (Serge) . .	Chemins de fer de l'État (ligne de Polessié) (Russie)	1 & 4
61	BATE (Major C. M'G.) . .	Ministère du commerce (*Board of Trade*) (Royaume uni de Grande-Bretagne et d'Irlande).	1, 2 & 5
62	BATTEN (J. W.)	Central Argentine Railway (République Argentine)	1, 2, 3, 4 & 5
63	BAUDRY	Chemins de fer de Paris à Lyon et à la Méditerranée (France)	2
64	BAUER (Gustave). . . .	Chemin de fer de Madrid à Saragosse et à Alicante (Espagne)	...
65	BAUER (Maurice) . . .	Compagnie d'exploitation des chemins de fer orientaux (Turquie).	...
66	BAULANT (René). . . .	Chemins de fer du Sud de la France. . .	...
67	BAVASTRO (Victor) . . .	Chemins de fer méridionaux (réseau de l'Adriatique) (Italie).	3 & 4
68	BAYLEY (C. W.). . . .	Lancashire and Yorkshire Railway (Grande-Bretagne).	1, 2, 3 & 4
69	BAYLEY (Kennet) . . .	Great Southern and Western Railway (Grande-Bretagne)	1, 2 & 5
70	BEAMAN (Charles C.) . .	Denver and Rio Grande Railway (États-Unis d'Amérique)	...
71	BEASLEY (A.).	Taff Vale Railway (Grande-Bretagne) . .	3, 4 & 5
72	BEHRENS (Gustav) . . .	Section anglaise et Midland Railway (Grande-Bretagne)	3
73	BELELUBSKY (Nicolas) . .	Administration centrale des chemins de fer de l'État (Russie)	1 & 2
74	BELL (J.).	Metropolitan Railway (Grande-Bretagne).	...
75	BELL (J. R.).	Secrétariat d'État pour l'empire des Indes (Grande-Bretagne et colonies)	1, 2, 3 & 5
76	BELLEROCHE (Eugène) . .	Chemin de fer Grand Central Belge (Belgique).	2 & 5
77	BÉNAC	Chemins de fer de l'État (France). . . .	4
78	BENOIT	Chemins de fer du Calvados (France) . .	...
79	BERNARD (Percy B.). . .	Waterford and Limerick Railway (Grande-Bretagne).	2 & 4
80	BERQUET.	Chemins de fer de Paris à Lyon et à la Méditerranée (France)	3 & 4

NUMÉRO D'ORDRE. (NUMBER.)	NOM. (NAME.)	ADMINISTRATION DÉLÉGANTE. (DELEGATED BY.)	SECTIONS.
81	BERRYMAN (E. W.) . . .	Southern Pacific Railroad (États-Unis d'Amérique)	4
82	BEZECNY (le Dr Anton) . .	Chemins de fer du Nord Empereur Ferdinand (Autriche)	4 & 5
83	BIANCHI (G.).	Association des tramways italiens . . .	...
84	BIAREZ (A.)	Chemins de fer du Nord de l'Espagne . .	...
85	BICKERSTETH (J. P.). . .	London and North Western Railway (Grande-Bretagne).	2 & 5
86	BILINSKI (S. Exc. le Dr. Chevalier VON).	Ministère du commerce (Autriche) . . .	3 & 4
87	BILLÉMA (Louis). . . .	Compagnie Franco-Algérienne (Algérie). .	2
88	BIRT (W.)	Great Eastern Railway (Grande-Bretagne).	1, 2, 3, 4 & 5
89	BIVER (Alfred)	Chemin de fer de Chauny à Saint-Gobain (France)	...
90	BIXIO (Maurice)	Chemins de fer du Nord de l'Espagne . .	...
91	BLAGÉ	Chemins de fer du Midi (France). . . .	1 & 4
92	BLANCHART (C.)	Chemins de fer économiques de Bari-Barletta et extensions (Italie).	...
93	BLOCH (Jean DE)	Chemin de fer de Lodz et chemin de fer de Dombrova Ivangorod (Russie)	3 & 4
94	BLOUNT (Edw.)	Chemins de fer de l'Ouest (France) . . .	3
95	BOËL (Gustave)	Chemin de fer de Braine-le-Comte à Gand (Belgique)	...
96	BOËL (Louis).	Chemin de fer de Braine-le-Comte à Gand (Belgique)	...
97	BOHUS (Laszlo DE) . . .	Chemins de fer unis d'Arad et de Csanad (Hongrie).	5
98	BOLLERO (Guido). . . .	Tramways à vapeur de la province de Turin (Italie)	5
99	BOLTON (J. C.)	Caledonian Railway (Grande-Bretagne) . .	...
100	BONANNO (Letterio) . . .	Chemins de fer de la Sicile (Italie) . . .	...
101	BONSOR (H. Cosmo O.) . .	South Eastern Railway (Grande-Bretagne) .	...
102	BOOS WALDECK und MONTFORT (S. Ex. le Comte Philippe).	Chemins de fer du Nord Empereur Ferdinand (Autriche)	5
103	BORDET	Chemins de fer de l'Ouest algérien (Algérie).	4
104	BOREL (J.)	Chemins de fer économiques de Bari-Barletta et extensions (Italie).	5
105	BORGNINI.	Commission internationale du Congrès et chemins de fer méridionaux (réseau de l'Adriatique) (Italie).	...
106	BOROS (Beni DE). . . .	Chemins de fer unis d'Arad et de Csanad (Hongrie).	5
107	BOROWY (le Dr Max). . .	Chemin de fer Nord-Ouest autrichien et jonction Sud-Nord allemande (Autriche) . .	4
108	BOSCH (Yvo)	Chemins de fer du Sud de l'Espagne . . .	3
109	BOSCHAN (le Chevalier Arthur VON).	Chemins de fer du Nord Empereur Ferdinand (Autriche)	1 & 3
110	BOTTINI (le Baron Charles DE)	Chemins de fer méridionaux (réseau de l'Adriatique) (Italie).	3 & 4
111	BOTY (Gustave)	Tramways à vapeur piémontais (Italie) . .	5
112	BOUCHARD	Chemins de fer de l'État (France) . . .	4
113	BOURGEOIS (Paul) . . .	Railways économiques de Liége, Seraing et extensions (Belgique)	2 & 5
114	BOURSON (Eugène) . . .	Tramways d'Odessa (Russie)	2 & 3

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115	**Boyer** (H. E.)	Compagnie royale des Chemins de fer portugais	...
116	**Boyle** (sir Courtenay)	Section anglaise et Ministère du commerce (*Board of Trade*) (Royaume uni de Grande-Bretagne et d'Irlande)	4
117	**Boyle** (John)	Rhymney Railway (Grande-Bretagne)	1 & 4
118	**Boys** (Henry Scott)	The Conde d'Eu Railway (Brésil)	5
119	**Bradley** (Charles W.)	American Railway Association (États-Unis d'Amérique)	1, 2, 3 & 4
120	**Braschi** (E.)	Chemins de fer de la Méditerranée (Italie)	3 & 4
121	**Breadalbane** (The Marquess of)	Section anglaise et Caledonian Railway (Grande-Bretagne)	2 & 3
122	**Bremner** (M.)	Québec Central Railway (Canada)	1 & 2
123	**Bretherton** (C. E.)	Southern Pacific Railroad (États-Unis d'Amérique)	4
124	**Bretz** (C. L.)	West Virginia. Central and Pittsburg Railway (États-Unis d'Amérique)	3
125	**Bricka**	Chemins de fer de l'État (France)	1 & 3
126	**Bricourt** (C)	Tramways napolitains (Italie)	4
127	**Brière**	Chemins de fer de Paris à Orléans (France)	1
128	**Bright** (H.)	Lancashire and Yorkshire Railway (Grande-Bretagne)	1, 2, 3 & 4
129	**Brioschi** (François)	Comité de direction de la Commission internationale du Congrès et Ministère des travaux publics (Italie)	...
130	**Brittain** (Thomas J.)	Belfast and County Down Railway (Grande-Bretagne)	...
131	**Brodsky** (L.)	Chemin de fer de la ville de Kiev (Russie)	...
132	**Brooke** (T. D.)	Buenos-Ayres and Ensenada Port Railway (République Argentine)	3 & 4
133	**Browne** (W. E. Nicolson)	Midland and South Western Junction Railway (Grande-Bretagne)	1, 2, 3, 4 & 5
134	**Bruneel**	Ministère des chemins de fer, postes et télégraphes et chemins de fer de l'État (Belgique)	1 & 3
135	**Bryce** (James)	Ministère du commerce (*Board of Trade*) (Royaume uni de Gr.-Bret. et d'Irlande)	5
136	**Buchanan** (William)	New York Central and Hudson River Railroad (États-Unis d'Amérique)	...
137	**Buckley** (J. F.)	Cambrian Railways (Grande-Bretagne)	...
138	**Bunten** (J. C.)	Caledonian Railway (Grande-Bretagne)	4
139	**Burke** (J. F.)	East and West Junction and Stratford-upon-Avon Railway (Grande-Bretagne)	1, 2, 3, 4 & 5
140	**Burlet** (C. de)	Commission internationale du Congrès et Société nationale des chemins de fer vicinaux (Belgique)	5
141	**Burnside** (Wm.)	Atlantic and Lake Superior Railway (Canada)	3
142	**Busse**	Chemins de fer de l'Etat (Danemark)	1, 2 & 5
143	**Busser** (Charles)	Chemins de fer secondaires de la Sardaigne (Italie)	3
144	**Butler** (Lord Arthur)	Waterford and Limerick Railway (Grande-Bretagne)	2
145	**Caillat** (Pierre)	Chemin de fer de Medina del Campo à Salamanca (Espagne)	...
146	**Cairo** (Henry)	Chemins de fer méridionaux (réseau de l'Adriatique) (Italie)	3, 4 & 5

NUMÉRO D'ORDRE. (NUMBER.)	NOM. (NAME)	ADMINISTRATION DÉLÉGANTE. (DELEGATED BY.)	SECTIONS.
147	CAJO (Ansano)	Chemins de fer méridionaux (réseau de l'Adriatique) (Italie)	1
148	CAMIS	Union des chemins de fer italiens d'intérêt local (Italie)	4 & 5
149	CAMPBELL (Lt-Col. the Hon. H. W.)	London and South Western Railway (Grande-Bretagne)	3
150	CAMPIGLIO (Ambrogio)	Commission internationale du Congrès et Union des chemins de fer italiens d'intérêt local (Italie)	2 & 5
151	CANTONI (Baron Constanzo)	Société anonyme nationale de tramways et de chemins de fer (Italie)	...
152	CARDEW (Major P.)	Ministère du commerce (*Board of Trade*) (Royaume uni de Grande-Bretagne et d'Irlande)	1, 2, 3, 4 & 5
153	CARLIER	Chemins de fer de Paris à Orléans (France)	4
154	CARLIER (Joseph)	Chemins de fer du Tessin (Italie)	5
155	CARLIER (Jules)	Grand chemin de fer Central Sud-Américain (République Argentine)	5
156	CARRASCO BOSSA (Antonio)	Compagnie royale des chemins de fer portugais	3 & 5
157	CARRUTHERS (John)	Agence générale de la colonie de la Nouvelle-Zélande à Londres (Grande-Bretagne et colonies)	2
158	CARSWELL (James)	North British Railway (Grande-Bretagne)	1, 2 & 5
159	CARTWRIGHT (Sir Henry)	Lima Railway (Pérou)	4
160	CASSINIS	Chemin de fer de Turin, Pignerol Torre-Pellice (Italie)	5
161	CATHCART (the Earl)	Ministère du commerce (*Board of Trade*) (Royaume uni de Grande-Bretagne et d'Irlande)	5
162	CATHLES (Jno.)	North British Railway (Grande-Bretagne)	1, 3 & 4
163	CAVO (Enrico)	Société vénitienne pour entreprises et constructions publiques (Italie)	4
164	CAZE	Chemins de fer du Périgord (France)	...
165	CECIL (Lord Eustace)	Chemins de fer de Lemberg-Czernowitz-Jassy (Autriche)	1, 2, 3, 4 & 5
166	CERBELAUD (Georges)	Chemins de fer du Sud de la France	...
167	CESARONI (Cesare)	Tramways de la province de Florence (Italie)	2
168	CHANDÈZE	Ministère du commerce, de l'industrie, des postes et des télégraphes (France)	4
169	CHAPERON	Chemins de fer de Paris à Lyon et à la Méditerranée (France)	2 & 3
170	CHAPMAN (Edward)	Manchester, Sheffield and Lincolnshire Railway (Grande-Bretagne)	4
171	CHARDON	Ministère du commerce, de l'industrie, des postes et des télégraphes (France)	4
172	CHASE (William L.)	Fitchburg Railroad (États-Unis d'Amérique)	3 & 4
173	CHASSIN (Alfred)	Chemins de fer du Sud de la France	5
174	CHAUFUS (Nicolas)	Chemins de fer de l'État (ligne de Moscou-Koursk et de Moscou-Nijni) (Russie)	1, 3 & 4
175	CHAUVIN (Geo. VON)	New-York, Ontario and Western Railway (États-Unis d'Amérique)	3
176	CHESNEAU	Ministère des travaux publics (France)	1, 2 & 3
177	CHESSEX (Ami)	Chemin de fer de Glion aux Rochers de Naye (Suisse)	5

NUMÉRO D'ORDRE. (NUMBER.)	NOM. (NAME.)	ADMINISTRATION DÉLÉGANTE. (DELEGATED BY.)	SECTIONS.
178	Chevalier	Chemins de fer départementaux (France)	1, 3, 4 & 5e
179	Cholet	Chemins de fer de l'Ouest algérien (Algérie).	...
180	Choron	Chemins de fer du Midi (France).	1
181	Christian (G.)	Bengal and North Western Railway (Empire des Indes)	...
182	Churchward (Captain).	London Chatham and Dover Railway (Grande-Bretagne)	3
183	Clark (Charles P.)	New York, New Haven and Hartford Railway (États-Unis d'Amérique)	4
184	Clayton (C. G.).	Midland Railway (Grande-Bretagne).	2
185	Cleghorn (John).	Section anglaise et North Eastern Railway (Grande-Bretagne)	1 & 2
186	Clerault.	Chemins de fer de l'Ouest (France)	2
187	Clerc.	Chemins de fer de l'Ouest (France)	1
188	Clermont (A.)	Chemin de fer de Liége-Maestricht (Belgique).	...
189	Cockshott (F. P.)	Cheshire Lines Committee (Grande-Bretagne)	...
190	Colhoun (Robert G.)	Great Southern and Western Railway (Grande-Bretagne)	4
191	Collet (C.)	Chemins de fer de Nora-Karlskoga (Suède).	5
192	Collinet (Léon).	Chemin de fer de Hasselt à Maeseyck (Belgique).	5
193	Colomb (Émile)	Chemins de fer du Jura Simplon (Suisse).	2 & 3
194	Colombo	Chemins de fer de la Méditerranée (Italie)	1
195	Colson	Commission internationale du Congrès et Ministère des travaux publics (France)	...
196	Colvill (J. C.)	Section anglaise et Great Southern and Western Railway (Grande-Bretagne).	4
197	Colvin (Bazett W.).	East Indian Railway (Grande-Bretagne et colonies)	...
198	Conacher (J.)	North British Railway (Grande-Bretagne).	3
199	Conti Vecchi (Luigi)	Chemins de fer Sardes (Italie).	1 & 2
200	Cook (Henry)	Furness Railway (Grande-Bretagne).	3 & 4
201	Cook (J. M.).	Cheshire Lines Committee (Grande-Bretagne)	3
202	Cooper (David)	Glasgow and South Western Railway (Grande-Bretagne)	3 & 4
203	Cooper (G.)	Central Argentine Railway (Rép. Argentine).	4
204	Coppell (George)	Denver and Rio Grande Railway (Etats-Unis d'Amérique)	1, 2, 3, 4 & 5
205	Cordeweener (Jules)	Chemin de fer de Gand à Terneuzen (Belgique)	...
206	Cork (the Earl of)	Great Western Railway (Grande-Bretagne).	...
207	Cornetti.	Chemins de fer de la Méditerranée (Italie)	2
208	Correvon (Ernest)	Chemin de fer d'Yverdon à Ste-Croix et chemin de fer de Viège à Zermatt (Suisse).	4 & 5
209	Coste.	Chemins de fer départementaux (France).	4 & 5
210	Cotterill	Gouvernement et chemins de fer de l'État (Égypte)	1 & 5
211	Cottesco (A.)	Ministère des travaux publics et chemins de fer de l'État (Roumanie)	3
212	Cotteslor (the Right Hon. Lord).	London, Brighton and South Coast Railway (Grande-Bretagne)	3
213	Cotton (Edward T.).	Belfast and Northern Counties Railway (Royaume uni de Gr.-Bretagne et d'Irlande)	...
214	Cottrau (Jules).	Chemins de fer de la Sicile occidentale (Palerme, Marsala, Trapani) (Italie)	4

NUMÉRO D'ORDRE. (NUMBER.)	NOM. (NAME.)	ADMINISTRATION DÉLÉGANTE (DELEGATED BY.)	SECTIONS.
215	COTTRELL (S. B.). . . .	Liverpool Overhead Railway (Gr.-Bretagne).	1
216	COUCEIRO (Jose Joaquim de Paiva Cabral). . . .	Chemins de fer de l'État (Portugal) . . .	3 & 5
217	COURTOIS (Fernand) . . .	Chemin de fer de Colle de Val d'Elsa Poggibonsi (Italie)	2
218	COUSIN (Emile)	Chemins de fer du Sud de l'Espagne . . .	1 & 5
219	COUSIN (Jean)	Compagnie du chemin de fer du Congo . .	1 & 5
220	CROKER (E. T. O'B). . .	Cork Bandon and South Coast Railway (Royaume uni de Gr.-Bret. et d'Irlande).	4 & 5
221	CRONSTEDT (C^te Rodolphe) .	Ministère de l'intérieur et chemins de fer de l'État (Suède)	1
222	CROSA.	Ministère des travaux publics (Italie). . .	1 & 5
223	CROSBIE-DAWSON (J. G.). .	North Staffordshire Railway (Royaume uni de Grande-Bretagne et d'Irlande) . . .	1
224	CULLEN (James)	Nashville, Chattanooga and S^t-Louis Railway (Etats-Unis d'Amérique)	2 & 3
225	CULVERWELL (George P). .	Belfast and County Down Railway (Royaume uni de Grande-Bretagne et d'Irlande) . .	...
226	CURTIS (F. S.)	New York, New Haven and Hartford Railway (Etats-Unis d'Amérique)	1
227	CUSACK (Sir Ralph Smith) .	Midland Great Western of Ireland Railway (Royaume uni de Gr.-Bret. et d'Irlande).	...
228	DANISCHEWSKI (Emile) . .	Chemin de fer de Moscou-Brest (Russie). .	3
229	DARAGANE	Chemin de fer de la Vistule (Russie) . . .	1, 3 & 4
230	DAWES (Frank)	Midland and South Western Junction Railway (Grande-Bretagne)	3, 4 & 5
231	DEAN (W.)	Great Western Railway (Grande-Bretagne).	2
232	DE BACKER (H.)	Société générale de chemins de fer économiques (Belgique)	...
233	DEBRAY	Ministère du commerce, de l'industrie, des postes et des télégraphes (France) . . .	1
234	DE BRUYN	Commission internationale du Congrès . .	...
235	DE BRUYN (C.)	Chemin de fer Hollandais (Pays-Bas) . . .	1
236	DE BUSSCHERE	Ministère des chemins de fer, postes et télégraphes et ch. de fer de l'État (Belgique) .	1, 3, 4 & 5
237	DE CUYPER (Ed.) . . .	Railways économiques de Liége-Seraing et extensions (Belgique)	1, 2, 3 & 5
238	DEHAYNIN (Albert) . . .	Chemins de fer de l'Est algérien	4
239	DELAMARRE	Chemins de fer régionaux des Bouches-du-Rhône (France)	...
240	DELAUNAY-BELLEVILLE . .	Ministère du commerce, de l'industrie, des postes et des télégraphes (France) . . .	...
241	DE LAVELEYE (Auguste) .	Commission internationale du Congrès . .	4
242	DE LAVELEYE (Georges). .	Département des affaires étrangères de l'État indépendant du Congo et Compagnie auxiliaire internationale de chemins de fer (Belgique).	...
243	DELCOMMUNE (Emile) . .	Département des affaires étrangères de l'Etat indépendant du Congo.	2
244	DELHAYE (Félix). . . .	Chemin de fer de Valence et Aragon (Espagne)	5
245	DEMOULIN.	Chemins de fer de l'Ouest (France) . . .	2
246	DENT (Edward)	Quebec Central Railway (Canada)	5
247	DEPEW (Chauncey M.) . .	New York Central and Hudson River Railroad (Etats-Unis d'Amérique)	...
248	DERVILLÉ.	Ministère du commerce, de l'industrie, des postes et des télégraphes (France). . .	4

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249	DESMURE	Chemins de fer de Paris à Lyon et à la Méditerranée (réseau algérien)	3 & 4
250	DESPRET (Edouard)	Chemin de fer de l'Est belge (Belgique) et chemins de fer du Tessin (Italie)	...
251	DETHIEU	Ministère des chemins de fer, postes et télégraphes et chemins de fer de l'Etat (Belgique)	1 & 5
252	DEUTSCH (Louis)	Chemin de fer de Nagy-Kikinda à Nagy-Becskerek (Hongrie)	...
253	DEVÈS	Chemin de fer de Bône-Guelma et prolongements (réseau algérien)	...
254	DEVILAINE (Léon)	Société des voies ferrées du Dauphiné (France)	...
255	DICKENS (Lt-Général C. H.)	Bengal and North Western Railway (Empire des Indes)	...
256	DIDERICH (E.)	Chemin de fer Prince-Henri (Luxembourg)	4
257	DIETLER	Commission internationale du Congrès et chemin de fer du Gothard (Suisse)	1 & 2
258	DOBROWOLSKI (A. A.)	Chemin de fer de Riazane-Ouralsk (ligne de Rtistchevo-Serdobksk et Atkarsk-Petrovsk) (Russie)	...
259	DOGNÉE	Chemin de fer de Chimay (Belgique)	4
260	DOLBY (E. R.)	Commission internationale du Congrès (secrétaire-rapporteur)	1 & 2
261	DOUGLAS (James)	Arizona and South Eastern Railroad (États-Unis d'Amérique)	5
262	DOUMITRACHKO (Pierre)	Chemins de fer de l'État (ligne de Syzrane-Viazma) (Russie)	...
263	DRAGO (Th.)	Ministère des travaux publics et chemins de fer de l'État (Roumanie)	2
264	DRESSE (Armand)	Chemin de fer de Termonde à Saint-Nicolas (Belgique)	5
265	DRESSE (Robert)	Chemin de fer de Hasselt à Maeseyck (Belgique)	5
266	DROUIN (Léon)	Chemin de fer de Medina del Campo à Salamanca (Espagne) et chemin de fer de la Beira-Alta (Portugal)	...
267	DRURY (T. W.)	Chemin de fer de Fastov (Russie)	...
268	DUBOIS (A.)	Commission internationale du Congrès, Ministère des chemins de fer, postes et télégraphes et chem. de fer de l'État (Belgique)	4 & 5
269	DUBOIS	Chemin de fer de Ceinture de Paris (France)	...
270	DUCA	Commission internationale du Congrès, Ministère des travaux publics et chem. de fer de l'État (Roumanie)	4
271	DUDLEY	New-York Central and Hudson River Railroad (Etats-Unis d'Amérique)	1, 2 & 5
272	DUFAUX	Chemins de fer de l'Est (France)	1 & 3
273	DUNCOMBE (Captain the Hon. C.)	North Eastern Railway (Grande-Bretagne)	2 & 5
274	DUPONT (T. B.)	Chemin de fer Prince-Henri (Luxembourg)	...
275	DUPONT-RUCLOUX	Railways économiques de Liége-Seraing et extensions (Belgique)	1, 2, 3 & 5
276	DUPRAZ (Auguste)	Chemin de fer funiculaire de Territet-Glion (Suisse)	4 & 5
277	DUPUICH (Charles)	Tramways à vapeur Piémontais (Italie)	5
278	DURANGEL (Henry)	Chemins de fer de la Beira-Alta (Portugal)	...

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279	DURIEUX (A).	Compagnie générale de chemins de fer brésiliens (Brésil)	...
280	DURRIEU (le Comte Paul)	Chemins de fer de l'Est algérien (Algérie).	2 & 4
281	DUTREUX (Tony).	Commission internationale du Congrès et chemin de fer Guillaume-Luxembourg (Luxembourg)	1
282	ECHEGARAY (Eduardo)	Ministère du fomento (Espagne)	3
283	EDDY (Edward Miller Gard).	New South Wales Government (Grande-Bretagne et colonies)	1, 2, 3, 4 & 5
284	EDGECUMBE (Col. the Hon. C. E.).	Great Western Railway (Grande-Bretagne).	...
285	EGER (le Dr Alexander).	Chemin de fer Nord-Ouest autrichien et jonction Sud-Nord allemande (Autriche).	4
286	ELLISSEN (Albert)	Société générale des chemins de fer économiques (France).	5
287	ELWELL (C. C.)	New York, New Haven and Hartford Railway (États-Unis d'Amérique)	1
288	ELWELL (Paul Bedford)	New South Wales Government Railways (Grande-Bretagne et colonies)	2, 3 & 5
289	ELY (Théodore N.)	Pennsylvania Railroad (Ét.-Unis d'Amérique)	1, 2, 3, 4 & 5
290	EMERY (Alexandre)	Chemin de fer funiculaire de Territet-Glion (Suisse)	5
291	EMLYN (the Viscount)	Section anglaise et Great Western Railway (Grande-Bretagne)	1, 2, 3, 4 & 5
292	EMPAIN (Edouard)	Chemins de fer économiques du Nord (France)	5
293	EMPAIN (François)	Chemins de fer du Périgord (France)	5
294	ENGSTRÖM	Chemins de fer de l'Etat de Finlande (Russie)	2 & 5
295	ERINE (S.A.).	Chemin de fer de Kiev-Voronège (Russie).	3, 4 & 5
296	ERNST.	Chemins de fer de l'Etat (Danemark)	...
297	ESPREGUEIRA (Manuel A. d').	Compagnie royale des chemins de fer portugais.	...
298	ESTALL (George).	Metropolitan District Railway (Gr.-Bretagne)	1 & 2
299	ESTERLE (Carlo)	Chemins de fer secondaires de la Sardaigne (Italie)	1
300	ETIENNE	Chemins de fer de Paris à Lyon et à la Méditerranée (réseau algérien)	1
301	ETLINGER (Edm.).	Quebec Central Railway (Canada).	1
302	EVANS (Richard).	Barry Railway (Royaume uni de Grande-Bretagne et d'Irlande)	4 & 5
303	FAIR (John)	Buenos-Ayres Great Southern Railway (République Argentine).	4
304	FAIRBAIRN (sir Andrew).	Commission internationale du Congrès et Great Northern Railway (Gr.-Bretagne).	1
305	FARRER (Hon. T. C.)	Midland Uruguay Railway (Uruguay)	5
306	FAVRE	Chemin de fer du Nord (France)	3
307	FAY (Sam)	Midland and South Western Railway (Grande-Bretagne)	3 & 5
308	FÉDOROFF (M. L.)	Chemins de fer de Riazane-Ouralsk (ligne de Riazane-Saratov) (Russie)	...
309	FENTON (sir Myles)	Section anglaise et South Eastern Railway (Grande-Bretagne)	3
310	FERRARI (Auguste)	Union des chemins de fer italiens d'intérêt local (Italie)	...
311	FERRARI (Jean)	Chemins de fer de la Méditerranée (Italie)	1
312	FERREIRA DE MESQUITA (Joao)	Compagnie royale des chem. de fer portugais.	1 & 2
313	FIERLANT (le Bon Albert DE)	Tramways florentins (Italie)	5

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314	FILONENKO (Maximilien) .	Chemins de fer de l'État (lignes Sud-Ouest) (Russie)	3
315	FINZI (Vittorio)	Chemin de fer de Colle de Val d'Elsa Poggibonsi (Italie)	...
316	FISON (F.W.)	Great Northern Railway (Grande Bretagne).	...
317	FLACHON	Ministère du commerce, de l'industrie, des postes et des télégraphes (France) . . .	...
318	FLURY (J.)	Chemin de fer Central suisse	...
319	FOCQUET (A.).	Compagnie des chemins de fer Sud-Ouest brésiliens (Brésil)	...
320	FOLQUE (Pedro Romano) .	Chemins de fer de l'État (Portugal) . . .	1
321	FONBONNE (DE)	Chemin de fer du Nord (France)	2
322	FONTAINE.	Ministère du commerce, de l'industrie, des postes et des télégraphes (France) . . .	4
323	FONTAINE-DELAVELEYE (Léon)	Compagnie générale de chemins de fer brésiliens (Brésil)	3, 4 & 5
324	FONTAINE (A. J. DE LA) . .	Grand chemin de fer Central-Sud-Américain (République Argentine)	...
325	FOOTNER (H.)	London and North Western Railway (Grande-Bretagne).	1, 3 & 5
326	FORBES (J.-S.)	Section anglaise et London, Chatham and Dover Railway (Grande Bretagne) . . .	4
327	FORBES (Wm)	London, Chatham and Dover Railway (Grande-Bretagne)	3
328	FORCADE (DE)	Chemin de fer de Somain à la frontière belge (mines d'Anzin) (France).	...
329	FORESTIER	Ministère des travaux publics (France). .	3 & 5
330	FÖRSTER (Ferdinand) . .	Chemins de fer de l'État (Hongrie) . . .	1 & 2
331	FOUAN	Chemins de fer de l'État (France)	1
332	FOUGÈRE	Chemins de fer de l'Est français. . . .	...
333	FOUQUAU (Henri) . . .	Chemins de fer de l'État (Hongrie) . . .	4
334	FOWLER (Sir John) . . .	Great Northern and Midland Joint Lines Committee (Grande-Bretagne)	1
335	FOX (Sir Douglas) . . .	Manchester, Sheffield and Lincolnshire Railway (Grande-Bretagne)	1, 2 & 5
336	FOX (Francis)	Mersey Railway (Grande Bretagne) . . .	1, 2 & 5
337	FRAEYS (A.)	Chemins de fer de la Flandre occidentale (Belgique).	1 & 2
338	FRANCILLON (E.). . . .	Chemin de fer de Lausanne-Ouchy (Suisse).	4 & 5
339	FRANÇOIS (A.)	Chemin de fer de Somain à la frontière belge (France)	...
340	FRANCQ (Emile)	Soc. des voies ferrées du Dauphiné (France).	...
341	FRANZI (Victor)	Chemins de fer secondaires de la Sardaigne (Italie).	3
342	FRASER (Sir Malcolm) . .	Gouvernement de l'Australie de l'Ouest (Grande-Bretagne et colonies)	4
343	FREIRE (Victor Pretot) . .	Ministère de l'industrie, des travaux publics et de la colonisation (Chili)	1 & 2
344	FREMINVILLE (DE) . . .	Chemin de fer de Paris à Orléans (France).	1 & 2
345	FRESCOT	Chemins de fer de la Méditerranée (Italie) .	2
346	FREY (Jacob J.)	American Railway Association (États-Unis d'Amérique)	1 & 3
347	FRIS	Société nationale des Chemins de fer vicinaux (Belgique).	4 & 5
348	FROSTERUS	Chemins de fer de l'État de Finlande (Russie).	1

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349	Funck (E.)	Compagnie auxiliaire internationale de chemins de fer (Belgique)	...
350	Gafenco (A.)	Ministère des travaux publics et chemins de fer de l'État (Roumanie)	2 & 4
351	Gain	Compagnie internationale des wagons-lits et des grands express européens (Belgique).	2
352	Galton (Sir Douglas)	Mobile and Birmingham Railway (États-Unis d'Amérique)	5
353	Gardner (S. A.)	New York, New Haven and Hartford Railway (États-Unis d'Amérique)	3
354	Garrick (Sir James)	Agence générale de la colonie de Queensland (Grande-Bretagne et colonies)	5
355	Gattoni (Antoni)	Chemin de fer de Naples-Ottaiano (Italie)	5
356	Gautier	Compagnie Meusienne de chemins de fer (France)	5
357	Gay (Joseph)	Chemins de fer du Sud de la France.	...
358	Gerard	Ministère des chemins de fer, postes et télégraphes et chemins de fer de l'État (Belgique)	2
359	Gérard (Victor)	London, Brighton and South Coast Railway (Grande-Bretagne)	3
360	Gerhardt	Chemins de fer de l'Est (France)	2
361	Gerritsen	Tramways à vapeur de Breskens Maldegem (Pays-Bas)	5
362	Gerstel (Gustav)	Chemins de fer de l'État (Autriche)	3
363	Ghalib-Bey (le Commandant).	Ministère du commerce et des travaux publics (Turquie)	2
364	Ghennert (Arcady J.)	Chemin de fer de Kiev-Voronège (Russie)	1, 4 & 5
365	Gibb (George S.)	North Eastern Railway (Grande-Bretagne)	1, 2, 3, 4 & 5
366	Gienanth (Le baron E. de).	Compagnie auxiliaire internationale de chemins de fer (Belgique)	2 & 3
367	Giet (A.)	Buenos-Ayres Great Southern Railway (République Argentine)	4
368	Gillet	Chemins de fer et Tramways en Perse	...
369	Gilliat (Howard)	Denver and Rio-Grande Railway (États-Unis d'Amérique)	...
370	Gillon (Aug)	Chemins de fer de Pirée, Athènes, Péloponèse (Grèce)	1
371	Girouard (Lieut[nt] E. P. C).	Ministère du commerce (*Board of Trade*) (Royaume uni de Gr.-Bretagne et d'Irlande)	2
372	Gladstone (The Right Hon. Herbert).	Wrexham Mold and Connah's Quay Railway (Grande-Bretagne)	...
373	Glasser	Chemins de fer d'intérêt local du département des Landes (France)	...
374	Goldberg (J.)	Compagnie d'exploitation des chemins de fer orientaux (Turquie)	1, 3 & 4
375	Goloubieff (V.)	Chemin de fer Vladicaucase (Russie)	...
376	Gomes Lima (le D[r] Antonio Jose).	Compagnie nationale des chemins de fer portugais.	3 & 5
377	Gooday (F.)	Great Eastern Railway (Grande-Bretagne)	3
378	Gordiéenko (Jacques)	Ministère des voies de communication (Russie)	1 & 3
379	Gorowitz (J.)	Chemins de fer de Fastov (Russie)	4
380	Goslett (Fred)	Chemin de fer de Nassiö-Oskarshamn (Suède)	1 & 2
381	Gottschalk	Ministère du commerce, de l'industrie, des postes et des télégraphes (France)	2, 3 & 5

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382	GOURY DU ROSLAN . . .	Ministère du commerce, de l'industrie, des postes et des télégraphes (France). . .	3 & 4
383	GOUVÉA (le Comte DE) . .	Chemins de fer de la Beira-Alta (Portugal).	...
384	GRANT VASSALL (R. L.) .	Taff Vale Railway (Grande-Bretagne) . .	...
385	GRAY (James)	Great Northern Railway (Ireland) (Royaume uni de Grande-Bretagne et d'Irlande) . .	4
386	GRÉBUS (Charles). . . .	Chemin de fer de Madrid à Saragosse et à Alicante (Espagne)	2 & 4
387	GREENE (William George) .	Midland Great Western of Ireland Railway (Royaume uni de Grande-Bretagne et d'Irlande).	3
388	GREINER (Emile). . . .	Chemin de fer de Modena-Vignola (Italie) .	2 & 5
389	GRIFFITH (John Evan) . .	Neath and Brecon Railway (Grde-Bretagne).	1, 2, 3 & 4
390	GRIGORIEFF (Serge) . . .	Administration centrale des chemins de fer de l'État (Russie)	1 & 3
391	GRILLO (Charles). . . .	Chemins de fer de la Sicile (Italie) . . .	4
392	GRIMBURG (le Chevalier Rodolphe DE).	Société autrichienne-hongroise des chemins de fer de l'État (Autriche)	1, 2, 3 & 4
393	GRIOLET	Commission internationale du Congrès et chemin de fer du Nord (France) . . .	4 & 5
394	GROSMAN (Voldemar) . .	Chemins de fer de l'État (ligne de Libau-Romny) (Russie).	2
395	GRÜNEBAUM (Franz). . .	Chemin de fer de Vienne-Aspang (Autriche).	1 & 5
396	GRUSLIN (Arthur) . . .	Tramways de Turin (Italie)	2 & 5
397	GUASTALLA (Angelo). . .	Chemin de fer de Modena-Vignola (Italie) .	5
398	GUEST (Arthur Edward) .	Taff Vale Railway (Grande-Bretagne) . .	...
399	GUILLON (Fernand) . . .	Chemins de fer et tramways en Perse . .	5
400	GUILLOUX.	Chemin de fer du Nord (France). . . .	4
401	GUINOTTE (Lucien) . . .	Tramways siciliens (Italie)	...
402	GULACSY (Coloman DE) . .	Chemin de fer d'intérêt local du Szilagysag (Hongrie).	...
403	GUTHRIE (David). . . .	Glasgow and South Western Railway (Grande-Bretagne)	...
404	GUYARD (Jules)	Chemin de fer de Gué à Menaucourt (France).	5
405	GUYARD (René)	Chemin de fer de Gué à Menaucourt (France).	5
406	GYE (Capt.)	South Eastern Railway (Grande-Bretagne).	3
407	GYSIN (Arnold)	Chemin de fer de la vallée de Birsig (Suisse).	5
408	HAAGSMA (S. E.) . . .	Société pour l'exploitation des chemins de fer de l'État néerlandais (Pays-Bas) . . .	2
409	HAINES (Henry S.) . . .	American Railway Association (États-Unis d'Amérique)	4 & 5
410	HAMELINK (S.)	Tramways néerlandais (Pays-Bas) . . .	5
411	HAMILTON (Lord Claud J.) .	Section anglaise et Great Eastern Railway (Grande-Bretagne)	1, 2, 3, 4 & 5
412	HAMMELRATH (P.) . . .	Tramways d'Odessa (Russie)	5
413	HANREZ (Charles) . . .	Chemin de fer de l'Entre-Sambre-et-Meuse (Belgique)	3
414	HANSEN (J.)	Chemin de fer de l'Est de Seeland (Danemark).	3
415	HARAHAN (James T.) . .	American Railway Association et Illinois Central Railroad (États-Unis d'Amérique).	1 & 3
416	HARRISON (F.)	Section anglaise et London and North Western Railway (Grande-Bretagne) . . .	3 & 4
417	HART (F. R.)	Cartagena Magdalena Railway (Colombie) .	2 & 4
418	HARTEN (Gustave) . . .	Chemin de fer du Nord de la Belgique . .	1
419	HARTSHORNE (Chas.) . .	Lehigh Valley Railroad (États-Unis d'Amérique).	1, 2, 3, 4 & 5

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456	HUBERT	Ministère des chemins de fer, postes et télégraphes et chemins de fer de l'État (Belgique)	2 & 5
457	HUBERTI (Alphonse)	Commission internationale du Congrès (Comité de rédaction du *Bulletin*)	1 & 3
458	HUGUET	Chemins de fer de l'État (France)	4
459	HUMPHREYS OWEN (C. A.)	Cambrian Railways (Grande-Bretagne)	...
460	HUNT (WM.)	Lancashire and Yorkshire Railway (Grande-Bretagne)	1, 2 & 5
461	HUNTINGTON (C. P.)	Southern Pacific Railroad (États-Unis d'Amérique)	...
462	HUTCHINSON (Major General C. S.)	Ministère du commerce (*Board of Trade*) (Royaume uni de Grande-Bretagne et d'Irlande)	1, 2, 3, 4 & 5
463	HUTTON (Colonel)	Cheshire Lines Committee (Gr.-Bretagne)	5
464	IGNATIUS (S. W.)	Chemins de fer de Riazane-Ouralsk, ligne de Rtistchevo-Serdobksk et Atkarsk-Petrovsk (Russie)	...
465	IJUIN (Hikokichi)	Ministère des communications (Japon)	4
466	IMECOURT (le Marquis D')	Chemins de fer de l'Est (France)	4
467	INGLIS (J. C.)	Great Western Railway (Grande-Bretagne)	1, 2 & 5
468	IRWIN (William)	Clogher Valley Railway (Grande-Bretagne)	3 & 5
469	ISMAY (C. H.)	London and North Western Railway (Grande-Bretagne)	...
470	ISNAV (N. N.)	Chemins de fer de Riazane-Ouralsk, ligne de Tambov-Kamichine (Russie)	...
471	IVACHINZOFF (D. S.)	Chemin de fer de Kiev Voronège (Russie)	4 & 5
472	IVANOFF (Demetrius)	Chemins de fer de l'État (ligne de la Baltique, de Pskov-Riga et du port de Saint-Pétersbourg) (Russie)	1
473	IVATT (Henry A.)	Great Southern and Western Railway (Grande-Bretagne)	1 & 2
474	JACKSON (the Right Hon. W. L.)	Great Northern Railway (Grande-Bretagne)	...
475	JACOBS (T.)	Tramways de Turin (Italie)	5
476	JACOMB-HOOD (R.)	London, Brighton and South Coast Railway (Grande-Bretagne)	1 & 5
477	JALOVIETSKI (Boleslas)	Première Société des chemins de fer secondaires en Russie	...
478	JARDINE (Sir Robert)	Caledonian Railway (Grande-Bretagne)	...
479	JARRIAND (E.)	Chemin de fer de Chauny à Saint-Gobain (France)	4
480	JAVARY	Chemins de fer de l'État (France)	4
481	JEFFERY (Edward T.)	Denver and Rio Grande Railway (États-Unis d'Amérique)	4
482	JEITTELES (Richard)	Commission internationale du Congrès et chemin de fer du Nord Empereur Ferdinand (Autriche)	1 & 5
483	JENKIN (Thomas C.)	City and South London Railway (Grande-Bretagne)	2, 3, 4 & 5
484	JENKINS (Sir John J.)	Rhondda and Swansea Bay Railway (Grande-Bretagne)	...
485	JOHANSSON (Herman)	Chemins de fer de l'État (Suède)	1 & 2
486	JOHNSON (Henry)	Great Northern and Midland joint lines Committee (Grande-Bretagne)	3

NUMÉRO D'ORDRE. (NUMBER.)	NOM. (NAME.)	ADMINISTRATION DÉLÉGANTE. (DELEGATED BY.)	SECTIONS.
487	Johnson (John)	Chemin de fer Frövi-Ludvika et Bangham-mar Kloten (Suède).	1, 2 & 3
488	Johnson (R.).	Great Northern Railway (Grande-Bretagne).	1 & 5
489	Johnson (S. W.). . . .	Midland Railway (Grande-Bretagne) . .	2
490	Johnston (Captain J. G.) .	London and South Western Railway (Grande-Bretagne).	...
491	Joly (Ch. de)	Compagnie générale de chemins de fer brésiliens (Brésil)	4
492	Jourdain	Chemin de fer de Saint-Quentin à Guise (France)	5
493	Juncadella (Rodolfo) . .	Chemins de fer et mines de San Juan de las Abadesas (Espagne).	...
494	Just (Conradin F.) . . .	Département des chemins de fer et canaux du Dominion du Canada	4 & 5
495	Kamph (Oscar)	Chemin de fer de Palsboda-Finspong et Finspong-Norsholm (Suède)	3
496	Kandaouroff (D. P) . .	Chemins de fer de Riazane-Ouralsk, ligne de Pokrovsk-Ouralsk (Russie)	3 & 4
497	Kane (Lieut.-Col.) . . .	Victoria Sidney Esquimaux and Nanaimo Railway of Canada	...
498	Karo (Félix).	Chemins de fer de la Sicile occidentale (Italie)	1 & 2
499	Kehoe (W. Y.)	Illinois Central Railway (États-Unis d'Amérique).	1 & 3
500	Kenly (John R.) . . .	American Railway Association (États-Unis d'Amérique)	3 & 4
501	Kepessy (le Dr Stefan). .	Chemin de fer de Nagy-Kikinda à Nagy-Becskerek (Hongrie)	...
502	Ker (Charles Buchanan) .	Buenos-Ayres and Ensenada Port Railway (République Argentine).	...
503	Kerbedz (S).	Chemin de fer Vladicaucase (Russie). . .	3
504	Kéromnes	Chemin de fer du Nord (France). . . .	2
505	Kerr (J. R.).	Cork, Bandon and South Coast Railway (Royaume uni de Grande-Bretagne et d'Irlande).	1 & 5
506	Kessels (T. G.)	Association des Tramways italiens (Italie) .	5
507	Khitrovo	Ministère des finances (département des affaires de chemins de fer) (Russie) . .	1 & 5
508	Kintore (the Earl of) . .	Great North of Scotland Railway (Grande-Bretagne).	4
509	Kirsch (Léopold) . . .	Chemin de fer d'Anvers à Rotterdam (Belgique).	1 & 3
510	Kitching (Albert George) .	Mersey Railway (Grande-Bretagne)	...
511	Kitson (Sir James) . . .	North Eastern Railway (Grande-Bretagne) .	...
512	Klemming (Victor) . . .	Chemins de fer de l'État (Suède)	2
513	Knauff (Fr.)	Tramways de Moscou (Russie)	5
514	Kniaziolucki (le Dr Chevalier Severin von).	Chemins de fer de l'État (Autriche) . . .	4
515	Kohl (Ernst).	Chemin de fer de Weimar Géra (Allemagne).	1
516	Koloszvary (Victor von) .	Chemins de fer de l'État (Autriche) . . .	3 & 4
517	Kopytkin (Nicolas). . .	Ministère des voies de communication (Russie)	2
518	Kossuth	Chemins de fer de la Méditerranée (Italie) .	1, 2, 3, 4 & 5
519	Kounitsky (Stanislas de) .	Ministère des voies de communication (Russie)	1, 2, 3 & 5

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520	KOWALSKI (Alfred Marie)	Chemin de fer de Bône-Guelma et prolongements (Algérie) et chemin de fer de Dakar à Saint-Louis (Sénégal)	1, 4 & 5
521	KOWALSKI (Charles)	Chemins de fer de Paris à Lyon et à la Méditerranée (France)	2, 3 & 5
522	KOZLOVSKI (Alexandre DE)	Chemins de fer de Novgorod (Russie)	...
523	KOZLOWSKI (Ladislas)	Chemins de fer de la Vistule (Russie)	4e
524	KRAPIFFKA	Chemins de fer de Moscou-Brest (Russie)	1 & 4
525	KREFTING (C. E.)	Ministère des travaux publics et chemins de fer de l'État (Norvège)	...
526	KRETSCHMAR VAN VEEN (J.A. VAN).	Compagnie néerlandaise sud-africaine de chemins de fer (Pays-Bas et colonies)	...
527	KRUEGER	Chemins de fer Sud-Est prussien (Allemagne).	...
528	KRUTTSCHNITT (Julius)	Southern Pacific Railroad (États Unis d'Amérique)	...
529	KUCHARSKI (Eugène)	Chemin de fer de Lodz (Russie)	3 & 4
530	KÜHNELT (Anton)	Chemins de fer de l'État (Autriche)	4 & 5
531	KUMPS (G.)	Société générale de chemins de fer économiques (Belgique)	1, 3 & 5
532	LACHTIN (Vladimir DE)	Chemins de fer de Dombrova Ivangorod (Russie)	...
533	LAGOUT	Ministère du commerce, de l'industrie, des postes et des télégraphes (France)	5
534	LAMBERT (Henry)	Section anglaise et Great Western Railway (Grande-Bretagne)	3, 4 & 5
535	LAMPUGNANI	Commission internationale du Congrès et chemins de fer de la Méditerranée (Italie).	3
536	LAMQUET (Victor)	Chemin de fer de Malines-Terneuzen (Belgique)	1, 2, 3 & 4
537	LANCRENON	Chemins de fer de l'Est (France)	2
538	LANDRY (John)	Chemin de fer d'Yverdon à Ste-Croix (Suisse).	4 & 5
539	LANGDON (W. D.)	Midland Railway (Grande-Bretagne)	3
540	LARMINAT (DE)	Chemins de fer de l'Ouest (France)	3
541	LARRAMENDI (Laureano DE).	Chemins de fer et mines de San Juan de las Abadesas (Espagne)	...
542	LARSEN (C.)	Chem. de fer de Lolland-Falster (Danemark).	3
543	LARTIGUE (H.)	Compagnie franco-algérienne (Algérie)	...
544	LAU (le Marquis DU).	Chemins de fer de l'Ouest (France)	2
545	LAUGEL	Chemins de fer de Paris-Lyon-Méditerranée (réseau algérien)	...
546	LAX	Chemins de fer de l'État (France)	4 & 5
547	LAZAREW-STANISTCHEW (K. N.).	Chemins de fer de Riazane-Ouralsk (ligne de Pokrovsk-Ouralsk (Russie)	...
548	LEBBE (F.)	Chemins de fer de la Flandre occidentale (Belgique)	1 & 2
549	LEBER (Max Edler VON).	Commission internationale du Congrès et Ministère du commerce (Autriche)	1 & 5
550	LE BON (Charles)	Chemin de fer Grand Central Belge (Belgique).	1
551	LE BRUN (A.)	Société nationale des chemins de fer vicinaux (Belgique)	1 & 5
552	LECHAT (A.)	Compagnie internationale des wagons-lits et des grands express européens (Belgique).	...
553	LE CHATELIER	Ministère des travaux publics (France)	2 & 4
554	LEFEBVRE	Ministère des travaux publics (France)	3
555	LEGGETT (Lieutent E. H. M.)	Ministère du commerce (*Board of Trade*) (Royaume uni de Gr.-Bretagne et d'Irlande).	1 & 5

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556	Leighton (Geo B.)	Los Angeles Terminal Railway (États-Unis d'Amérique)	2 & 5
557	Lenz (Alfred von)	Chemins de fer du Nord Empereur Ferdinand (Autriche)	1 & 2
558	Letellier (Maurice)	Chemins de fer Guillaume-Luxembourg (Luxembourg)	3 & 4
559	Letona (Joaquin L. Lopez de).	Chemins de fer de Madrid à Saragosse et à Alicante (Espagne)	1 & 5
560	Level (Émile)	Société générale des chemins de fer économiques (France)	5
561	Level (Georges)	Société générale des chemins de fer économiques (France)	3 & 5
562	Levi (Pacifico)	Chemin de fer Sassuolo-Modena-Mirandola et Finale (Italie)	5
563	Lévi-Alvarès (Albert)	Chemin de fer de Madrid à Saragosse et à Alicante (Espagne)	...
564	Liamine	Chemins de fer de Moscou-Brest (Russie).	1, 3 & 4
565	Liebig (Johann Freiherr von).	Chemin de fer Nord-Ouest autrichien et jonction Sud-Nord allemande (Autriche).	4
566	Liénart (P.)	Compagnie générale des chemins de fer secondaires (Belgique)	5
567	Likhatchev (T. A.)	Chemin de fer de Kiev-Voronège et Tramways de Moscou (Russie)	...
568	Linder	Ministère des travaux publics (France)	2 & 3
569	Lindheim (le Chevalier Ernest de).	Chemin de fer de Vinkovce à Brcka (Hongrie).	...
570	Lisle (René)	Chemin de fer de Madrid à Saragosse et à Alicante (Espagne)	3 & 4
571	Livesey (James)	Buenos-Ayres Great Southern Railway (République Argentine)	1 & 2
572	Löb (Louis)	Chemin de fer Nord-Ouest autrichien et jonction sud-nord allemande (Autriche)	4
573	Locatello (Ferdinando)	Société vénitienne pour entreprises et constructions publiques (Italie)	...
574	Loleo (Bartholoméo)	Société vénitienne pour entreprises et constructions publiques (Italie)	4
575	Loria (Leonardo)	Chemin de fer Sassuolo-Modena-Mirandola et Finale (Italie)	1
576	Louis (Edmond)	Chemin de fer de l'Entre-Sambre-et Meuse (Belgique)	4
577	Loveday (H. H.)	Buenos-Ayres Great Southern Railway (République Argentine)	3, 4 & 5°
578	Lucardie (G. F.)	Société des chemins de fer des Indes néerlandaises	5
579	Ludvigh (Jules)	Commission internationale du Congrès, Ministère du commerce et chem. de fer de l'État (Hongrie)	3 & 4
580	Lundie (Cornelius)	Rhymney Railway (Grande-Bretagne)	1, 2, 3, 4 & 5
581	Luuyt	Chemins de fer de Paris à Lyon et à la Méditerranée (France)	3
582	Mabille (Valère)	Tramways à vapeur de Biella à Vercelli (Italie)	2 & 5
583	Mackay (Sir James)	East Indian Railway (Grande-Bretagne et colonies)	...
584	McCrea (James)	Pennsylvania Railroad (États-Unis d'Amérique)	1, 2, 3, 4 & 5

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585	McDonald (J. A.)	Midland Railway (Grande-Bretagne).	1
586	McEwan (Wm.).	Caledonian Railway (Grande-Bretagne)	...
587	Maclure (J.).	Section anglaise et Manchester, Sheffield and Lincolnshire Railway (Grande-Bretagne).	1, 2, 3, 4 & 5
588	Maes	Tramways à vapeur interprovinciaux de Milan-Bergame-Crémone (Italie)	5
589	Maginnis (James P)	Chemins de fer de l'État (lignes Sud-Ouest) (Russie)	1 & 3
590	Mahl (William).	Eastern Pacific Railroad (États-Unis d'Amérique).	...
591	Makins (Col. W. E.)	Great Eastern Railway (Grande-Bretagne)	...
592	Malcolm (Bowman).	Belfast and Northern Counties Railway (Royaume uni de Gr.-Bretagne et d'Irlande)	2 & 5
593	Maléter (Soltan de)	Chemins de fer de la vallée de Szamos (Hongrie)	...
594	Mamontoff (Sawa)	Chemins de fer de Moscou-Jaroslav et Arkhangelsk (Russie)	...
595	Manesco (C.).	Ministère des travaux publics et chemins de fer de l'État (Roumanie)	3 & 4
596	Mantegazza.	Chemins de fer de la Méditerranée (Italie).	1
597	Marcy (Henry S.)	Fitchburg Railroad (États-Unis d'Amérique).	3 & 4
598	Maréchal	Chemins de fer de Paris à Lyon et à la Méditerranée (France)	2
599	Marie	Chemin de fer du Nord (France)	3, 4 & 5
600	Marin	Chemins de fer de l'Ouest (France)	...
601	Marindin (Major F. A.).	Ministère du commerce (*Board of Trade*) (Royaume uni de Grande-Bretagne et d'Irlande).	1, 2, 3, 4 &
602	Maristany y Gibert (Ed.).	Chemins de fer de Tarragone à Barcelone et à la France (Espagne)	4
603	Markoff (N. L.).	Chemin de fer de Kiev-Voronège (Russie)	...
604	Marryat (Lieut.-Col. E. L.)	Bengal and North Western Railway (Empire des Indes).	3 & 5
605	Marsal	Tramways à vapeur interprovinciaux de Milan-Bergame-Crémone (Italie)	5
606	Martorelli (Francesco)	Chemin de fer Rubattino (Tunis-Bardo La Goulette, Marsa) (Tunisie).	3 & 5
607	Massa	Commission internationale du Congrès et chemins de fer de la Méditerranée (Italie).	...
608	Massieu	Ministère des travaux publics (France)	...
609	Masso (Antonio).	Chemins de fer de Medina del Campo à Zamora y de Orense à Vigo (Espagne)	3
610	Masson (Georges)	Chemin de fer de Glion aux Rochers de Naye (Suisse)	4
611	Mast (J.).	Chemin de fer Central suisse	...
612	Matrot	Chemins de fer de l'État (France).	3 & 4
613	Matthei (Alphonse).	Chemin de fer de l'Est belge (Belgique)	2 & 4
614	Mauger	Compagnie Franco-algérienne (Algérie).	...
615	Maurer	Chemins de fer du Midi (France).	3
616	Mayer	Chemins de fer de l'Est algérien (Algérie)	4
617	Meck (Alexandre de)	Chemins de fer de Moscou-Kazane (Russie).	4 & 5
618	Meik (P. W.)	Commission internationale du Congrès (Rapporteur)	...
619	Mellor (Colonel J. J.)	South Eastern Railway (Grande-Bretagne)	...
620	Melotte (Gustave)	Tramways à vapeur de la province d'Alexandrie (Italie)	5

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621	Melville (William). . .	Glasgow and South Western Railway (Grande-Bretagne).	1 & 3
622	Mercerон	Compagnie Meusienne de chemins de fer (France)	5
623	Mercier de Molin (J. J.).	Chemin de fer de Lausanne Ouchy (Suisse).	4 & 5
624	Merrick (William). . .	East and West Junction and Stratford-upon-Avon Railway (Grande-Bretagne) . . .	1, 2, 3 & 4
625	Mestreit (Victor) . . .	Chemins de fer économiques du Nord (France)	5
626	Michel (G.)	Chemins de fer de Paris à Orléans (France).	4
627	Michel (Jules)	Chemins de fer de Paris à Lyon et à la Méditerranée (réseau algérien). . . .	1
628	Michelet (Gustave). . .	Compagnie générale des chemins de fer secondaires (Belgique)	5
629	Miglioretti (le C^te^ Albert).	Chemins de fer de la Sicile (Italie) . . .	4
630	Miles (G. S.).	Southern Pacific Railroad (Etats-Unis d'Amérique)	...
631	Mills (W. H.)	Great Northern Railway Ireland (Royaume uni de Grande-Bretagne et d'Irlande) . .	...
632	Moffatt (W.)	Great North of Scotland Railway (Grande-Bretagne)	4 & 5
633	Moffre	Chemins de fer d'intérêt local du département des Landes (France)	1, 2 & 3
634	Moïse.	Chemins de fer de l'Ouest (France) . . .	1 & 4
635	Montefiore Lévi . . .	Chemin de fer Grand Central Belge . . .	4
636	Montesino (Cyp. Segundo).	Chemin de fer de Madrid à Saragosse et à Alicante (Espagne)	...
637	Montgomery (Hugh de Fellenberg).	Clogher Valley Railway (Grande-Bretagne).	5
638	Morandière	Chemins de fer de l'Ouest (France) . . .	2^e^
639	Morawetz (Charles) . .	Compagnie d'exploitation des chemins fer Orientaux (Turquie)	...
640	Morgan (John)	London, Chatham and Dover Railway (Grande-Bretagne)	3
641	Morris (Israel W.) . . .	Lehigh Valley Railroad (États-Unis d'Amérique).	4
642	Mott (Basil).	City and South London Railway (Grande-Bretagne).	2
643	Mott (C. G.).	Great Western Railway (Grande-Bretagne) et Midland Uruguay Railway (Uruguay).	2 & 5
644	Motte (Lucien)	Ministère des chemins de fer, postes et télégraphes et chemins de fer de l'État (Belgique)	1 & 3
645	Moyaux (Auguste) . . .	Chemins de fer de l'Apennin Central (Italie).	5
646	Moyaux (Léon)	Chemins de fer de l'Apennin Central (Italie).	...
647	Mundella (the Right Hon. A. I.).	Ministère du commerce (*Board of Trade*) (Royaume uni de Grande-Bretagne et d'Irlande).	2 & 5
648	Murphy (John J.) . . .	Waterford and Limerick Railway (Grande-Bretagne).	4
649	Nagelmackers (Georges) .	Compagnie internationale des wagons-lits et des grands express européens (Belgique).	3 & 4
650	Nathan (Adolphe) . . .	Société anonyme nationale de tramways et de chemins de fer (Italie)	1
651	Navarro (Antonio Jose Antunes).	Chemins de fer de l'État (Portugal) . . .	4 & 5
652	Navone (Guilio). . . .	Chemins de fer secondaires romains (Italie).	

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653	NEEF (A.)	Compagnie internationale des wagons-lits et des grands express européens (Belgique).	3
654	NEELE (George P.). . .	London and North Western Railway (Grande-Bretagne).	1, 2, 3, 4 & 5
655	NEELEMANS (Alfred). . .	Chemin de fer de Gand-Eecloo-Bruges (Belgique)	1
656	NEELEMANS (Louis). . .	Chemin de fer de Gand-Eecloo-Bruges (Belgique)	3
657	NEILD (F.)	Central Argentine Railway (République Argentine)	3 & 4
658	NEILD (R. J.).	Buenos-Ayres Great Southern Railway (République Argentine).	4 & 5
659	NEMÉNYI (Ambroise) . .	Chemin de fer d'intérêt local du Szilagysag (Hongrie).	...
660	NETTLESHIP (I. J.) . . .	Great Northern and Great Eastern Railway Companies' Joint Committee (Grande-Bretagne).	1, 2 & 4
661	NEUJEAN (Xavier) . . .	Chemin de fer d'Anvers à Rotterdam (Belgique).	...
662	NEWSON (F.).	Cartagena Magdalena Railway (Colombie) .	4
663	NEWTON (George Bolland).	North London Railway (Grande-Bretagne).	3
664	NEWTON (H. Cecil) . . .	London, Tilbury and Southend Railway (Grande-Bretagne)	3, 4 & 5
665	NICOLAIDI (Const. P.) . .	Chemins de fer de Pirée-Athènes-Péloponèse (Grèce)	...
666	NIELS.	Ministère des chemins de fer, postes et télégraphes et chemins de fer de l'État (Belgique).	3 & 4
667	NIERSTRASZ (N. K.). . .	Chemin de fer Hollandais (Pays-Bas) . .	...
668	NIESSEN	London, Chatham and Dover Railway (Grande-Bretagne)	3
669	NIGOND	Chemins de fer de Paris à Orléans (France).	3
670	NIKITINE (A.).	Première Société des chemins de fer secondaires en Russie	5
671	NIKLANDER	Chemins de fer de l'État de Finlande (Russie).	3
672	NIVEL (J. K.).	Société pour l'exploitation des chemins de fer de l'État néerlandais (Pays-Bas) . . .	...
673	NOBLEMAIRE	Commission internationale du Congrès et chemins de fer de Paris à Lyon et à la Méditerranée (France)	4
674	NONNENBERG (F.)	Compagnie générale des chemins de fer secondaires (Belgique)	...
675	NORDMAN.	Chemins de fer de l'État de Finlande (Russie).	2
676	NUBAR (S. Exc. Boghos Pacha).	Gouvernement et administration des chemins de fer, des télégraphes et du port d'Alexandrie (Egypte)	2 & 3
677	OAKLEY (Sir Henry). . .	Section anglaise et Great Northern Railway (Grande-Bretagne)	1, 2, 3, 4 & 5
678	OGILVIE (Campbell P.) . .	Central Argentine Railway (République Argentine)	2
679	OKOULITCH (B.)	Chemin de fer Vladicaucase (Russie). . .	3 & 4
680	OLIN (Xavier).	Ministère des travaux publics (Siam). . .	4
681	OLKHINE	Chemins de fer de la Vistule (Russie) . .	1 & 4
682	OLSZEWSKI (Stanislas) . .	Chemin de fer de Dombrova-Ivangorod (Russie)	2 & 3

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683	Ommanney (Sir Montagu)	Ministère du commerce (*Board of Trade*) (Royaume uni de Grande-Bretagne et d'Irlande)	5
684	Orban (Léon)	Chemin de fer du Nord de la Belgique	...
685	Orens	Chemins de fer du Calvados (France)	5
686	Orr (H. H.)	Section anglaise	5
687	Orsel	Ministère des travaux publics (France)	3
688	Ottolenghi	Ministère des travaux publics (Italie)	...
689	Otway (the Right Hon. Sir Arthur).	Section anglaise et London, Brighton and South Coast Railway (Grande-Bretagne)	4
690	Outine (Jacques)	Chemins de fer de Rybinsk-Bologoë (Russie).	3 & 4
691	Owen (George)	Cambrian Railways (Grande-Bretagne)	1, 2, 3 & 4
692	Owens (C. J.)	London and South Western Railway (Grande-Bretagne)	3, 4 & 5
693	Pacco (Aimé)	Tramways à vapeur de la province d'Alexandrie (Italie)	5
694	Pader	Chemins de fer de Paris à Orléans (France).	3
695	Paget (G. E.)	Manchester, Sheffield and Midland Joint Committee (Grande-Bretagne)	...
696	Pallavicini (Son Exc. le Margrave Alexander).	Chemins de fer du Nord Empereur Ferdinand (Autriche)	5
697	Panzarasa (Alessandro)	Tramways de la province de Florence (Italie).	2
698	Parent	Chemins de fer de l'État (France)	2
699	Parish (Frank)	Buenos-Ayres Great Southern Railway (République Argentine)	1, 2, 3, 4 & 5
700	Park (C. A.)	London and North Western Railway (Grande-Bretagne)	2
701	Parker (J. G.)	New York, New Haven and Hartford Railway (États-Unis d'Amérique)	5
702	Parkes (R. A.)	Tralee and Dingle Light Railway (Grande-Bretagne)	1, 3 & 5
703	Pattin	Compagnie Meusienne de chemins de fer (France)	5
704	Pauer (François)	Société autrichienne-hongroise des chemins de fer de l'État (Autriche)	2
705	Payne-Sheares (T. W.)	Cork, Bandon and South Coast Railway (Royaume uni de Grande-Bretagne et d'Irlande)	...
706	Peace (Walter)	Agence générale de la colonie de Natal (Grande-Bretagne et colonies)	1, 2, 3, 4 & 5
707	Pearson (Harry)	New York, Ontario and Western Railway (États-Unis d'Amérique)	3 & 4
708	Pease (Sir Jos. W.)	North Eastern Railway (Grande-Bretagne).	...
709	Peemans (H.)	Chemin de fer de Valence et Aragon (Espagne)	...
710	Pellé	Ministère du commerce, de l'industrie, des postes et des télégraphes (France)	5
711	Pellegrini (Adolphe)	Chemin de fer central et tramways du Canavèse (Italie)	3 & 5
712	Pelletan (André)	Ministère du commerce, de l'industrie, des postes et des télégraphes (France)	2 & 4
713	Pereire (Emile)	Chemins de fer du Nord de l'Espagne	...
714	Pereire (Maurice)	Chemins de fer du Nord de l'Espagne	...
715	Perévoznikoff (M.)	Chemins de fer de l'Etat, ligne de Riga-Orel (Russie)	2 & 3

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716	PERK (H. A.).	Société pour l'exploitation des chemins de fer de l'État néerlandais (Pays-Bas)	3 & 5
717	PERL (Louis DE)	Commission internationale du Congrès et Ministère des voies de communication (Russie)	3 & 4
718	PÉROUSE (D.).	Chemins de fer ottomans de Beyrouth-Damas-Hauran (Turquie)	3 & 5
719	PESARO	Union des chemins de fer italiens d'intérêt local (Italie)	...
720	PETERSSON (Major P.)	Chemins de fer de Norsholm-Westervik-Hultsfred (Suède)	2
721	PÉTROFF (Nicolas DE)	Commission internationale du Congrès	...
722	PETSCHE	Chemin de fer de l'Est (France)	1 & 3
723	PEYROU (Prosper)	Chemin de fer de Chivasso à Ivréa (Italie).	4
724	PEYTEL	Chemins de fer de l'Ouest algérien (Algérie).	...
725	PHILIPPE	Commission internationale du Congrès et chemins de fer du Nord français (lignes Nord belges) (Belgique).	3
726	PHILIPPSON (F.).	Compagnie des chemins de fer Sud-Ouest brésiliens (Brésil)	...
727	PHILLIPPS (W. D)	North Staffordshire Railway (Grande-Bretagne).	1 & 3
728	PICARD (Alfred)	Commission internationale du Congrès, Ministère des travaux publics et Ministère du commerce (France)	4
729	PICARD (René)	Chemins de fer de Paris à Lyon et à la Méditerranée (France)	3
730	PICKERSGILL (William)	Great North of Scotland Railway (Grande-Bretagne).	2
731	PICOT (Georges)	Chemins de fer du Midi (France).	4
732	PIERON	Chemins de fer du Nord français (lignes Nord belges) (Belgique).	3 & 4
733	PIHL (C.).	Ministère des travaux publics et chemins de fer de l'Etat (Norvège)	1 & 5
734	PINION (James)	Belfast and County Down Railway (Royaume-Uni de Grande-Bretagne et d'Irlande)	...
735	PIOT	Chemins de fer d'intérêt local du département des Landes (France).	4
736	PLAKIDA (Alexandre)	Administration centrale des chemins de fer de l'Etat (Russie)	1 & 5
737	PLANAS (Claudio)	Chemins de fer de Tarragone à Barcelone et à la France (Espagne)	...
738	PLANCHER (Henry)	Chemins de fer méridionaux (réseau de l'Adriatique) (Italie).	2
739	PLATT (C. H.)	New York, New Haven and Hartford Railway (Etats-Unis d'Amérique)	3
740	PLAYFORD (The Hon. Thom.)	Agence générale de l'Australie du Sud (Grande-Bretagne et colonies)	5
741	PLEWS (Henry)	Great Northern Railway (Grande-Bretagne).	4
742	PLOCQ (Ernest)	Société générale des chemins de fer économiques (France)	3 & 5
743	PLUNKET (The Right Hon. D. R.).	North London Railway et London and North Western Railway (Grande-Bretagne)	...
744	POIDATZ (A.).	Chemin de fer de Pithiviers (Loiret) à Toury (Eure-et-Loire) (France)	5

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745	POLIAKOFF (L T.) . . .	Chemin de fer de Fastov (Russie) . . .	4
746	POLLITT (Harry). . . .	Manchester, Sheffield and Lincolnshire Railway (Grande-Bretagne)	1, 2 & 3
747	POLLITT (William) . . .	Manchester, Sheffield and Lincolnshire Railway (Grande-Bretagne)	1, 2, 3 & 4
748	POLLONE (Eugène) . . .	Chemins de fer secondaires de la Sardaigne (Italie)	5
749	POMERANZOFF (A. A.). . .	Chemins de fer de Riazane-Ouralsk (ligne de Tambov-Kamichine) (Russie) . . .	...
750	PONTZEN	Ministère du commerce, de l'industrie, des postes et des télégraphes (France). . .	2, 3 & 5
751	PORTAL (W. S)	Section anglaise et London and South Western Railway (Grande-Bretagne) . .	4
752	POSCH (Jules DE). . . .	Chemin de fer d'intérêt local du Szilagysag (Hongrie).	...
753	POURGOLD (Alexandre DE) .	Chemins de fer de Rybinsk-Bologoë (Russie).	...
754	POWELL (Alfred). . . .	Metropolitan District Railway (Grande-Bretagne).	3 & 4
755	PREECE (H. W.). . . .	Ministère du commerce (*Board of Trade*) (Royaume uni de Grande-Bretagne et d'Irlande).	3
756	PRICE (Herbert Rhys) . .	Brecon and Merthyr Tydfil Junction Railway (Grande-Bretagne)	3, 4 & 5
757	PRICE (Joseph)	New York, Ontario and Western Railway (Etats-Unis d'Amérique)	4
758	PRINZIG (Édouard) . . .	Chemin de fer Nord-Ouest autrichien . .	...
759	PRISSE (le Baron) . . .	Commission internationale du Congrès . .	1, 2, 3, 4 & 5
760	PRISSE (Édouard) . . .	Chemin de fer d'Anvers à Gand (Belgique) ..	1, 2 & 3
761	PROBST-LOTZ (E.). . . .	Chemin de fer de la vallée de Birsig (Suisse)	...
762	PROSCOURIAKOFF. . . .	Ministère des voies de communication (Russie)	1 & 4
763	PSCHENETZKY	Chemins de fer de Moscou-Brest (Russie) .	1, 2 & 3
764	PUCCI-BANDANA	Chemin de fer de Turin-Pignerol-Torre-Pellice (Italie)	1
765	PULCIANO (Melchior) . .	Chemin de fer de Chivasso à Ivréa (Italie) .	1
766	RADICE (E.)	Association des tramways italiens (Italie) .	2 & 5
767	RAINCOCK (Henry) . . .	Brazil Great Southern Railway (Brésil). .	...
768	RAMAECKERS.	Commission internationale du Congrès, Ministère des chemins de fer, postes et télégraphes et chem de fer de l'État (Belgique)	3, 4 & 5
769	RAMSDEN (F. J.). . . .	Furness Railway (Grande Bretagne). . .	3 & 4
770	RAMSEY (Lord DE) . . .	Great Northern and Midland joint lines' Committee (Grande-Bretagne)	...
771	RANDICH (Eugène) . . .	Chemins de fer méridionaux (réseau de l'Adriatique) (Italie).	1
772	RATE (L. M.)	Chemins de fer de Lemberg-Czernowitz-Jassy (Autriche)	...
773	RATH (Pierre DE) . . .	Chemin de fer Kaschau-Oderberg (Hongrie).	...
774	RATKOFF-ROJNOFF . . .	Ministère des finances (département des affaires de chemins de fer) (Russie) . .	...
775	RATTI.	Chemins de fer de la Méditerranée (Italie) .	...
776	RAVENEZ (L.).	Chemins de fer de Pithiviers (Loiret) à Toury (Eure-et-Loire) (France) . . .	...

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777	REE (Frank)	London and North Western Railway (Grande-Bretagne)	1, 2, 3, 4 & 5
778	REITLINGER (Nicolas)	Administration centrale des chemins de fer de l'Etat (Russie)	4
779	RENDEL (Sir Alex. M.)	East Indian Railway (Grande-Bretagne et colonies)	...
780	RENDEL (W. S.)	East Indian Railway (Grande-Bretagne et colonies)	1 & 2
781	RESAL	Ministère des travaux publics (France)	1
782	REYNAUD (Albert)	Compagnie française des chemins de fer vénézuéliens (Venezuela)	4
783	RICCHIARDI (Charles)	Chemins de fer méridionaux (réseau de l'Adriatique) (Italie)	...
784	RICHTER (J.)	Chemins de fer de l'Etat (ligne de Saint-Pétersbourg à Varsovie) (Russie)	3, 4 & 5
785	RIMBOCK (Charles)	Société autrichienne-hongroise des chemins de fer de l'Etat (Autriche)	4
786	RIMESTAD	Chemins de fer de l'Etat (Danemark)	4
787	RIPA DI MEANA (le Cte Louis)	Ministère des travaux publics (Italie)	3
788	RIXON (A. W.)	Isle of Man Railway (Royaume uni de Grande-Bretagne et d'Irlande)	5
789	RIZZONI (Paul)	Chemins de fer de l'Etat (lignes de Saint-Pétersbourg à Varsovie) (Russie)	2
790	ROBBO (G.)	Chemins de fer de la Sicile occidentale (Palerme, Marsala, Trapani) (Italie)	3
791	ROBERTI (Charles)	Tramways à vapeur de Biella à Vercelli (Italie)	5
792	ROBERTS (William)	Buenos Ayres and Eusenada Port Railway (République Argentine)	1, 2, 3, 4 & 5
793	ROBERTSON (D. J.)	Bengal and North Western Railway (Empire des Indes)	4
794	ROBERTSON (F. E.)	East Indian Railway (Grande-Bretagne et colonies)	1, 4 & 5
795	ROBERTSON (G. H.)	Liverpool Overhead Railway (Grande-Bretagne)	3
796	ROBERTSON (Thomas)	Great Northern Railway (Ireland) (Royaume uni de Grande-Bretagne et d'Irlande)	4
797	ROBINSON (Leslie)	Commission internationale du Congrès (secrétaire-rapporteur)	2 & 5
798	ROBINSON (W.)	Great Western Railway (Grande-Bretagne)	4
799	ROCCA	Chemins de fer de la Méditerranée (Italie)	4
800	ROEDERER	Chemin de fer de ceinture de Paris (France)	...
801	ROESSING VAN ITERSON (T. A.)	Chemin de fer Hollandais (Pays-Bas)	2
802	ROGNETTA (Emile)	Tramways à vapeur et chemins de fer économiques de la province de Pise (Italie)	4
803	ROGNETTA (F. Benedetto)	Tramways à vapeur et chemins de fer économiques de la province de Pise (Italie)	1
804	ROGNONI (César)	Chemin de fer du Nord de Milan (Italie)	1
805	ROL (Vittorio)	Chemin de fer de Reggio-Emilia (Italie)	4
806	ROMIEU	Ministère du commerce, de l'industrie, des postes et des télégraphes (France)	3, 4 & 5
807	ROOS (Alex.)	Chemins de fer de l'Etat (Suède)	1
808	ROOSEVELT (James R.)	Secrétariat d'État (Etats-Unis d'Amérique)	1, 2, 3, 4 & 5
809	ROPSY-CHAUDRON	Tramways siciliens (Italie)	5
810	ROSA (José Mesquita DA)	Compagnie nationale des chemins de fer portugais	5

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811	Rossi	Ministère des travaux publics (Italie)	2
812	Rouffart (Armand)	Chemins de fer économiques du Nord (France)	5
813	Rowan	Compagnie Franco-Algérienne (Algérie)	5
814	Rubricius (Célestin)	Société autrichienne hongroise des chemins de fer de l'Etat (Autriche)	3
815	Rusconi-Clerici (J.)	Société anonyme nationale de tramways et de chemins de fer (Italie)	...
816	Russell (Sir George)	Section anglaise et South Eastern Railway (Grande-Bretagne)	4
817	Rutherford (M.)	East Indian Railway (Grande-Bretagne et colonies)	3
818	Sabouret	Chemins de fer de Paris à Orléans (France)	1
819	Sack (S. T.)	Chemin de fer de Kiev-Voronège (Russie)	1, 2 & 5
820	Sala (Michel)	Chemins de fer du Nord de l'Espagne	1
821	Salazar (Luis)	Secrétariat des communications et des travaux publics (Mexique)	...
822	Saligny (A.)	Ministère des travaux publics et chemins de fer de l'Etat (Roumanie)	1
823	Salkoff	Ministère des voies de communication (Russie)	1 & 3
824	Salomé (R.)	Chemin de fer Vladicaucase (Russie)	1, 3 & 4
825	Salt (Thomas)	North Staffordshire Railway (Grande-Bretagne)	...
826	Salva	Ministère des travaux publics (France)	1 & 3
827	Sandberg (C. P.)	Chemins de fer de l'Etat (Suède)	1
828	Sanlleh y (D. Domingo Juan)	Chemin de fer de Medina del Campo à Zamora y de Orense à Vigo (Espagne)	4
829	Sanmark (C. G.)	Chemins de fer de Borga-Kervo (Russie)	...
830	Sargeaunt (Col. R. A.)	Secrétariat d'Etat pour l'empire des Indes (Grande-Bretagne et colonies)	4
831	Sarle (Allen)	London, Brighton and South Coast Railway (Grande-Bretagne)	3 & 4
832	Sarrea Prado (Angelo de)	Chemins de fer de l'Etat dans les colonies (Portugal)	3 & 5
833	Sartiaux (Eugène)	Chemin de fer du Nord (France)	2 & 3
834	Sassen (Georges)	Tramways à vapeur piémontais (Italie)	5
835	Sauvage	Chemins de fer de l'Ouest (France)	2
836	Sax (D[r] Emile)	Chemin de fer Nord-Ouest autrichien	...
837	Say (Léon)	Chemin de fer du Nord (France)	4
838	Scala (Theodor von)	Chemins de fer de l'État (Autriche)	3
839	Schaar	Commission internationale du Congrès, Ministère des chemins de fer, postes et télégraphes et chem. de fer de l'État (Belgique)	2
840	Schlemmer	Chemin de fer de Bône-Guelma et prolongements (réseau algérien)	...
841	Schneider (A.)	Chemin de fer de Paris à Orléans (France)	4
842	Schotel	Tramways à vapeur de Breskens-Maldegem (Pays-Bas)	5
843	Schreiber (Alexandre de)	Chemins de fer de la vallée de Szamos (Hongrie)	4
844	Schroeder	Compagnie internationale des wagons-lits et des grands express européens (Belgique)	3
845	Schüle (François)	Département des postes et des chemins de fer (Suisse)	1 & 3
846	Schüler (Oscar)	Chemins de fer du Sud de l'Autriche	5

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847	SCHUTZENHOFER (Victor) .	Chemins de fer de l'État (Autriche). . .	2
848	SCIALOJA (Enrico) . . .	Chemins de fer de la Sicile (Italie) . . .	3 & 4
849	SCILLA (le prince Ruffo). .	Chemin de fer Rubattino (Tunis-Bardo-la Goulette Marsa) (Tunisie)	4 & 5
850	SCOLARI	Chemins de fer de la Méditerranée (Italie) .	4
851	SCOTT (A.)	London and South Western Railway (Grande-Bretagne).	...
852	SCOTTER (Sir Charles) . .	Section anglaise et London and South Western Railway (Grande-Bretagne) . . .	3
853	SEGRÉ (Epaminonda) . .	Chemins de fer sardes (Italie).	3
854	SENDZIKOWSKI	Chemins de fer de la Vistule (Russie) . .	1 & 4
855	SEPULCHRE (Henry) . .	Tramways à vapeur de Biella à Vercelli (Italie)	5
856	SHUTTLEWORTH (Frank C.).	Great Northern and Great Eastern Railway Companies joint committee (Gr.-Bretagne).	...
857	SILVA (Manuel Emygdio DA).	Compagnie nationale des chemins de fer portugais.	3 & 5
858	SILVERLOCH (Frank). . .	The Conde d'Eu Railway (Brésil) . . .	4
859	SIMON (Fils)	Ministère du waterstaat, du commerce et de l'industrie (Pays-Bas)	1 & 4
860	SIRE	Chemin de fer du Nord (France) . . .	3
861	SKLÉVITZKY (Siméon) . .	Chemins de fer de l'État, lignes de Varsovie-Terespol, de Brest-Kholm, de Sedletz-Malkine et de Narev (Russie)	3 & 4
862	SLATTERY (Henry Francis).	Brecon and Merthyr Tydfil Junction Railway (Grande-Bretagne)	4
863	SMITH (Lieutenant-Colonel Gérard).	Hull Barnsley and West Riding Junction Railway (Grande-Bretagne).	4 & 5
864	SMITH (John Hudson) . .	Rhymney Railway (Grande-Bretagne) . .	2
865	SMITH (J. Parker) . . .	North British Railway (Grande-Bretagne) .	3
866	SMYTH (Captain Thomas James).	Midland Great Western of Ireland Railway (Royaume uni de Grande-Bretagne et d'Irlande).	4
867	SOLACROUP	Chemins de fer de Paris à Orléans (France).	2
868	SOUMAROKOFF (Basile) . .	Commission internationale du Congrès et Ministère des voies de communication (Russie)	2, 3, 4 & 5
869	SOUSCHINSKY (Balthasar Félix).	Ministère des voies de communication (Russie)	2
870	SOUZA GOMES (le Conseiller Joaquim Pires de).	Chemins de fer de l'État (Portugal). . .	3 & 5
871	SPAGNOLETTI (J. E.). . .	Great Western Railway (Grande-Bretagne).	2
872	SPANJAARD (H.)	Compagnie pour l'exploitation des chemins de fer de l'État néerlandais (Pays-Bas) .	3
873	SPASCIANI (A.)	Chemins de fer de Suzzara-Ferrara (Italie) .	5
874	SPEE (A.).	Compagnie des chemins de fer Sud-Ouest brésiliens (Brésil)	5
875	SPILLER (H H.). . . .	Midland Railway (Grande-Bretagne). . .	3
876	SPRUYT (Emile). . . .	Chemin de fer Grand Central Belge (Belgique).	3 & 4
877	STAFFORD (J. H.) . . .	Lancashire and Yorkshire Railway (Grande-Bretagne).	2, 3 & 4
878	STAHLE (Capitaine A. G.) .	Chemins de fer de Norsholm-Westervik-Hultsfred (Suède)	...

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879	STALBRIDGE (the Right Hon. Lord).	Commission internationale du Congrès et London and North Western Railway (Grande-Bretagne)	1 & 2
880	STANDERTSKJOLD (C. G.)	Chemins de fer de Borga Kervo (Russie)	...
881	STANE (Aloïs)	Chemins de fer de l'État (Autriche)	...
882	STEENS (Emile)	Tramways et chemins de fer économiques de Rome, Milan, Bologne, etc. (Italie)	...
883	STEPHEN (O. L.)	North London Railway (Grande-Bretagne).	...
884	STERN (Isaac)	Tramways à vapeur interprovinciaux de Milan-Bergame-Crémone (Italie)	...
885	STEVENSON (F.)	London and North Western Railway (Grande-Bretagne)	1, 2, 3 & 4
886	STIFFSON (Emile)	Chemins de fer de l'État (Hongrie)	3 & 4
887	STILEMAN (Frank)	Furness Railway (Grande-Bretagne)	...
888	STIRLING (Matthew)	Hull Barnsley and West Riding Junction Railway (Grande-Bretagne)	1 & 2
889	STIRLING (P.)	Great Northern Railway (Grande-Bretagne).	...
890	STOCLET (Victor)	Chemin de fer de l'Est de Lyon (France)	...
891	STOFFEL	Chemin de fer du Gothard (Suisse)	...
892	STRACHEY (Lieutnt génl R.)	East Indian Railway (Grande-Bretagne et colonies)	3 & 4
893	STRAMBIO DE CASTILLIA (Giovanni)	Chemins de fer secondaires romains (Italie).	4
894	STRIDE (Arthur L.)	London Tilbury and Southend Railway (Grande-Bretagne)	1, 3 & 4
895	SUAREZ (J.)	Ministère des travaux publics (Bolivie)	...
896	SURTEES (Colonel C. F.)	South Eastern Railway (Grande-Bretagne).	1 & 5
897	SÜSS (Nathan)	Chemin de fer de Madrid à Saragosse et à Alicante (Espagne)	2 & 3
898	SUTHERLAND (His Grace the Duke of).	London and North Western Railway (Grande-Bretagne)	...
899	SVIENTZITZKI (Henri DE)	Chemin de fer de Novgorod (Russie)	3 & 5
900	SYTENKO	Ministère des voies de communication (Russie)	1 & 3
901	SZAWTOWSKI (Adam)	Chemin de fer de Varsovie-Vienne (Russie)	3 & 4
902	TALBOT (Charles)	Neath and Brecon Railway (Grande-Bretagne)	3
903	TANCIEV (Paul DE)	Chemin de fer de Novgorod (Russie)	...
904	TATLOW (Joseph)	Midland Great Western of Ireland Railway (Royaume uni de Grande-Bretagne et d'Irlande)	4
905	TAUSSIG (le Chevalier Théodore DE).	Société autrichienne-hongroise des chemins de fer de l'Etat (Autriche)	4
906	TAYLOR (James L.)	Pennsylvania Railroad (États-Unis d'Amérique)	1, 2, 3 & 4
907	TCHERVINSKY (S.)	Chemin de fer Vladicaucase (Russie)	2 & 4
908	TCHOCOLOFF (Petrovitch)	Chemin de fer de Moscou-Iaroslav et Arkhangelsk (Russie)	...
909	TEGNER	Ministère de l'intérieur et des travaux publics (Danemark)	4
910	TEISSIER	Ministère des travaux publics (France)	3, 4 & 5
911	TENNANT (Sir Charles)	North British Railway (Grande-Bretagne)	...
912	TENNANT (Henry)	North Eastern Railway (Grande-Bretagne)	2, 3 & 5
913	TERZI	Chemin de fer de Suzzara-Ferrara (Italie)	5
914	THALY (Emile DE)	Chemin de fer de Mohacs-Fünfkirchen (Hongrie)	...

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915	THALY (Sigismond) . . .	Chemin de fer de l'État (Hongrie) . . .	2 & 3
916	THOMAS (Charles) . . .	Midland Railway (Grande-Bretagne). . .	3
917	THOMAS (J. W.). . . .	Nashville, Chattanooga, and St-Louis Railway (États-Unis d'Amérique)	1, 2 & 3
918	THOMPSON (A. M.) . . .	London and North Western Railway (Grande-Bretagne)	...
919	THOMPSON (James) . . .	Section anglaise et Caledonian Railway (Grande-Bretagne)	1, 2, 3, 4 & 5
920	THOMPSON (Thomas Roe) .	Barry Railway (Grande-Bretagne) . . .	4
921	THOMSON (Frank) . . .	Pennsylvania Railroad (Etats-Unis d'Amérique).	1, 2, 3, 4 & 5
922	THOMSON (Thomas Frame) .	Mobile and Birmingham Railway (Etats-Unis d'Amérique)	3 & 5
923	THONET (Charles) . . .	Chemin de fer du Nord de Milan (Italie). .	1, 2 & 5
924	THYS (Albert)	Département des affaires étrangères du Congo.	2, 3 & 5
925	TIETGEN (C. F.)	Chemin de fer de Lolland-Falster et chemin de fer de l'Est de Seeland (Danemark). .	...
926	TIPPING (W.).	Section anglaise et London and North Western Railway (Grande-Bretagne) . .	4
927	TOLNAY (Cornel). . . .	Ministère du commerce (Hongrie) . . .	1
928	TORRENS (Gerard Philip.) .	Conde d'Eu Railway (Brésil)	2
929	TOSO (le Dr Antonio). . .	Chemin de fer de Reggio-Emilia (Italie). .	4
930	TOUCEY (John M.) . . .	New York Central and Hudson River Railroad (Etats-Unis d'Amérique)	1, 2 & 3
931	TOURNERIE (DE LA) . . .	Commission internationale du Congrès . .	1
932	TOURTSEVITZ (Joseph) . .	Chemins de fer de l'État (ligne Nicolas) (Russie)	1 & 3
933	TOWNE (A. N.)	Southern Pacific Railroad (États-Unis d'Amérique).	...
934	TRAZ (André DE). . . .	Chemin de fer de Dakar à St-Louis (Sénégal).	...
935	TRAZ (Edouard DE) . . .	Chemins de fer régionaux des Bouches-du-Rhône (France)	3
936	TREUIMFELD (le Chevalier Alfred Tunkler VON).	Chemin de fer de Vienne-Aspang (Autriche).	5
937	TROMPOWSKI LEITAO DE ALMEIDA (Roberto).	Ministère des travaux publics, du commerce et de l'agriculture (Brésil)	2
938	TSCHIEMER (Johann). . .	Département des postes et des chemins de fer (Suisse)	1 & 3
939	TUNSTILL (W.)	Lancashire and Yorkshire Railway (Grande-Bretagne).	1, 2, 3 & 4
940	TUPPER (Sir Charles) . .	Département des chemins de fer et canaux du Dominion du Canada	5
941	TURNER (G. H.)	Section anglaise et Midland Railway (Grande-Bretagne).	3
942	TWEEDDALE (The Marquess OF).	Section anglaise et North British Railway (Grande-Bretagne)	4
943	TWELVETREES (R. H.) . .	Great Northern Railway (Grande-Bretagne).	3
944	TYLER (Sir H. W.). . .	Great Eastern Railway (Grande-Bretagne) .	2
945	ULENS (Léon)	Chemin de fer de l'Est de Lyon (France). .	...
946	ULLMANN (Louis DE) . .	Chemin de fer de Mohacs Fünfkirchen (Hongrie).	...
947	UNDERDOWN (E. M). . .	Antofagasta (Chili) and Bolivia Railway (Chili).	1 & 2
948	URBAN (Albert)	Chemin de fer de l'Est belge (Belgique) . .	...

NUMÉRO D'ORDRE. (NUMBER.)	NOM. (NAME.)	ADMINISTRATION DÉLÉGANTE. (DELEGATED BY.)	SECTIONS.
949	URBAN (E.)	Société générale de chemins de fer économiques (Belgique)	...
950	URBAN (Jules)	Commission internationale du Congrès et chemin de fer Grand Central Belge (Belgique).	5
951	URBAN (Maurice)	Chemin de fer Grand Central Belge (Belgique)	...
952	UYTBORCK	South Eastern Railway (Grande-Bretagne).	3
953	VALLON	Chemin de fer du Nord français (lignes Nord belges) (Belgique)	...
954	VAN DEN BOGAERDE (E.)	Chemins de fer de la Flandre occidentale (Belgique)	...
955	VAN DEN BROECK (Al.)	Chemin de fer de Malines-Terneuzen (Belgique)	1, 2, 3, 4 & 5
956	VAN DER STRAETEN (Albert)	Tramways florentins (Italie)	1
957	VAN DE WYNCKELE (J. E.)	Chemins de fer Guillaume-Luxembourg (Luxembourg)	...
958	VANE-TEMPEST (Lord Henry)	Cambrian Railways (Grande-Bretagne)	...
959	VAN HASSELT (Robert)	Chemin de fer Hollandais (Pays-Bas).	3 & 4
960	VANKEERBERGHEN (Léon)	Tramways et chemins de fer économiques de Rome-Milan-Bologne (Italie)	5
961	VAN KERKWIJK (J. J.)	Commission internationale du Congrès et Ministère du waterstaat, du commerce et de l'industrie (Pays-Bas)	5
962	VAN OVERBEKE (Albéric)	Chemin de fer de l'Apennin Central (Italie).	5
963	VAN RYN (K.)	Tramways néerlandais (Pays-Bas)	5
964	VARVARO (Roberto).	Chemins de fer de la Sicile (Italie)	4 & 5
965	VASARHELYI (Béla DE)	Chemins de fer unis d'Arad et de Csanad (Hongrie)	5
966	VASCONCELLOS PORTO (Antonio DE).	Compagnie royale des chemins de fer portugais.	...
967	VAUCAMPS (A.)	Chemin de fer du Nord de Milan (Italie).	5
968	VEHIL (Domingo)	Chemins de fer et mines de San Juan de las Abadesas (Espagne).	...
969	VELASCO (Estanislao)	Secrétariat des communications et des travaux publics (Mexique).	3 & 5
970	VERGÉ	Chemins de fer de Paris à Orléans (France).	...
971	VERGÉ (Henry)	Société générale des chemins de fer économiques (France).	5
972	VERLOOP (J. W.).	Chemin de fer Central néerlandais (Pays-Bas).	2
973	VERNON (the hon. G. R.)	Caledonian Railway (Grande-Bretagne)	...
974	VERSCHOWSKY (M. P.)	Chemins de fer de Riazane-Ouralsk (ligne de Riazane-Saratov) (Russie)	...
975	VERWILGHEN-GORIS	Chemin de fer d'Anvers à Gand (Belgique).	3, 4 & 5
976	VILERS (E.)	Tramways napolitains (Italie).	2 & 5
977	VILINSKI	Ministère des finances (département des affaires de chemins de fer) (Russie)	4 & 5
978	VISINET	Chemins de fer de l'Ouest (France).	3
979	VOORHEES (Théodore)	American Railway Association (États-Unis d'Amérique)	1 & 4
980	VOORHOEVE (J. M.)	Chemin de fer Brabant septentrional allemand (Pays-Bas)	...
981	WALLAERT (E.)	Tramways à vapeur des provinces de Vérone et Vicence (Italie)	5
982	WALL BAKE (R. W. I. C. VAN DEN).	Compagnie néerlandaise Sud-Africaine de chemins de fer (Pays-Bas et colonies)	...

NUMÉRO D'ORDRE. (NUMBER.)	NOM. (NAME.)	ADMINISTRATION DÉLÉGANTE. (DELEGATED BY.)	SECTIONS.
983	WALLER (Charles Bullen)	Mobile and Birmingham Railway (États-Unis d'Amérique)	3
984	WALLERSTEIN (Paul)	Chemins de fer régionaux des Bouches-du-Rhône (France)	...
985	WALTER (Alfred)	American Railway Association (États-Unis d'Amérique)	2 & 3
986	WANDRE (DE)	Chemins de fer du Périgord (France)	...
987	WARSCHAVSKY	Chemins de fer de Moscou-Brest (Russie)	...
988	WARSCHAWSKY (Léon)	Chemins de fer de Tsarskoé-Selo (Russie)	...
989	WARU	Chemin de fer du Nord français (lignes Nord belges) (Belgique)	4
990	WASIUTYNSKI (Alexandre)	Chemin de fer de Varsovie Vienne (Russie)	1 & 3
991	WASSILEVSKY (Paul)	Administration centrale des chemins de fer de l'État (Russie)	...
992	WATSON (Sir Renny)	Glasgow and South Western Railway (Grande-Bretagne)	4
993	WATTS (Henry)	Great Western of Brazil Railway (Brésil)	1
994	WAUTERS (A. J.)	Compagnie du chemin de fer du Congo	4
995	WEBB (F. W.)	London and North Western Railway (Grande-Bretagne)	5
996	WEBB (H. Walter)	New York Central and Hudson River Railroad (États Unis d'Amérique)	3
997	WEISGERBER	Chemins de fer ottomans de Beyrouth-Damas-Hauran (Turquie)	1
998	WEISS	Chemins de fer de l'Est (France)	3 & 5
999	WEISSENBRUCH (Louis)	Commission internationale du Congrès, Ministère des chemins de fer, postes et télégraphes et chem. de fer de l'État (Belgique)	1 & 4
1000	WELSH (John Lowber)	Denver and Rio Grande Railway (Etats-Unis d'Amérique)	...
1001	WENDRICH (le Colonel Alfred DE)	Ministère des voies de communication (Russie)	3, 4 & 5
1002	WERCHOVSKY (Vladimir)	Commission internationale du Congrès et Ministère des voies de communication (Russie)	1 & 4
1003	WESTERGAARD	Chemins de fer de l'État (Danemark)	3 & 4
1004	WHARNCLIFFE (the Right Hon. the Earl of)	Manchester, Sheffield and Lincolnshire Railway (Grande-Bretagne)	...
1005	WHISSELL (G. H.)	Metropolitan Railway (Grande-Bretagne)	...
1006	WHITELEGG (Thomas)	London, Tilbury, and Southend Railway (Grande-Bretagne)	2 & 4
1007	WHITWHAM (Fr. George)	Chemins de fer sardes (Italie)	3, 4 & 5
1008	WIGRAM (R.)	Great Northern Railway (Grande-Bretagne)	...
1009	WILBUR (Rollin H.)	Lehigh Valley Railroad (États-Unis d'Amérique)	2 & 4
1010	WILDHAGEN	Compagnie internationale des wagons-lits et des grands express européens (Belgique)	2
1011	WILKINS (Thomas)	East and West Junction and Stratford-upon-Avon Railway (Grande-Bretagne)	3
1012	WILKINSON (C. N.)	North Eastern Railway (Grande-Bretagne)	1 & 3
1013	WILKINSON (J. L.)	Great Western Railway (Grande-Bretagne)	3 & 4
1014	WILLIAMS (Laurence A.)	Brazil Great Southern Railway (Brésil)	...
1015	WILLIAMS (Morgan B.)	Rhondda and Swansea Bay Railway (Grande-Bretagne)	...
1016	WILMART (Jules)	Chemin de fer Prince-Henri (Luxembourg)	5
1017	WILMART (Nestor)	Chemin de fer de Gand à Terneuzen (Belgique)	...

NUMÉRO D'ORDRE. (NUMBER.)	NOM. (NAME.)	ADMINISTRATION DÉLÉGANTE. (DELEGATED BY.)	SECTIONS.
1018	Wilson (J.)	Great Eastern Railway (Grande-Bretagne).	5
1019	Wilson (R. T.)	Denver and Rio Grande Railway (États-Unis d'Amérique)	...
1020	Wise (Berkley D.)	Belfast and Northern Counties Railway (Royaume uni de Gr.-Bretagne et d'Irlande).	1 & 5
1021	Wood (G. H.)	Isle of Man Railway (Royaume uni de Grande-Bretagne et d'Irlande	3 & 5
1022	Worms de Romilly	Ministère des travaux publics (France)	2
1023	Worsdell (W.)	North Eastern Railway (Grande-Bretagne).	2
1024	Worthington (W. B)	Lancashire and Yorkshire Railway (Grande-Bretagne).	1, 2 & 5
1025	Wortley (Stuart)	Wrexham Mold and Connah's Quay Railway (Grande-Bretagne)	...
1026	Woyard (Émile).	Chemin de fer de Tournai à Jurbise et de Landen à Hasselt (Belgique)	4
1027	Woyno (Louis)	Chemin de fer de Varsovie-Vienne (Russie).	2
1028	Wrédensky (Basile).	Chemins de fer Sud-Est (Russie)	3
1029	Yastchembski (Constantin de).	Chemin de fer de Rybinsk-Bologoë (Russie).	4 & 5
1030	Yénakieff (Théodore)	Première Société des chemins de fer secondaires en Russie.	...
1031	Yermoloff (Alexandre).	Ministère des voies de communication (Russie)	4
1032	Yorke (Lieutenant-Colonel H. A.).	Ministère du commerce (*Board of Trade*) (Royaume uni de Grande-Bretagne et d'Irlande).	1, 2, 3, 4 & 5
1033	Yossimovitch (Milivoie)	Ministère des travaux publics (Serbie)	1, 4 & 5
1034	Youle (A. P.)	Great Western of Brazil Railway (Brésil)	5
1035	Young (Sir Wm L).	Midland Uruguay Railway (Uruguay)	3
1036	Zanotta	Chemins de fer de la Méditerranée (Italie).	1 & 3
1037	Zavanella (Achille)	Chemin de fer de Suzzara-Ferrara (Italie).	5
1038	Zehetner (le Dr Ferdinand).	Chemins de fer de l'État (Autriche)	4
1039	Zelis (J. B.).	Chemin de fer Brabant septentrional allemand (Pays-Bas).	...
1040	Zens (Albert)	Chemins de fer départementaux (France).	5
1041	Zens (P.).	Chemins de fer départementaux (France).	5
1042	Zielinski (Étienne)	Chemin de fer de Varsovie-Vienne (Russie).	4
1043	Ziffer (E. A.)	Chemins de fer de Lemberg, Czernowitz, Jassy (Autriche).	1 & 5
1044	Zingler (Max)	Chemins de fer de Lemberg, Czernowitz, Jassy (Autriche).	5
1045	Zouroff (W. L.)	Chemins de fer de Riazane-Ouralsk (Ligne de Riazane-Saratov) (Russie)	...
1046	Zwolinski (Nicolas de)	Ministère de l'intérieur (Russie)	4 & 5

DISPOSITIONS

STATUTAIRES & RÉGLEMENTAIRES

DU CONGRÈS INTERNATIONAL DES CHEMINS DE FER (1)

BUT ET DÉFINITION.

ARTICLE PREMIER. — Le *Congrès international des chemins de fer* est une association permanente ayant pour but de favoriser les progrès des chemins de fer.

ART. 2. — L'Association se compose d'Administrations de chemins d'État et d'Administrations concessionnaires ou exploitantes de chemins de fer d'intérêt public qui ont fait acte d'adhésion.

Les Gouvernements adhérant à l'Association se font représenter par des délégués.

COMMISSION INTERNATIONALE PERMANENTE.

ART. 3. — L'Association est représentée par une Commission internationale qui est élue par le Congrès. Cette Commission a son siège à Bruxelles.

Les fonctions de ses membres sont honorifiques.

ART. 4. — La Commission est chargée d'examiner les demandes d'adhésion des Administrations de chemins de fer faites en conformité des articles 1 et 2 et de statuer à leur sujet. Ne seront pas considérées comme Administrations de chemins de fer celles qui n'ont

(1) Pour les dispositions formant règlement des sessions, voir spécialement les articles 10 à 16.

CONSTITUTION

AND BYE-LAWS

OF THE INTERNATIONAL RAILWAY CONGRESS (1)

OBJECT AND SCOPE.

1. — The *International Railway Congress* is a permanent association established to promote the progress and development of railways.

2. — It is composed of railway administrations which have formally joined whether state or private and either owning or working lines for public traffic.

Governments joining are represented by delegates.

PERMANENT INTERNATIONAL COMMISSION.

3. — The Congress is represented by a permanent International Commission which it elects. The office of this Commission is at Brussels and its members give their services gratuitously.

4. — It is the duty of the Commission to consider and decide upon the application for membership of the Congress made by railway administrations in accordance with articles 1st and 2nd. Administrations whose primary object is not the working of railways will not

(1) For the bye-laws of the sessions see specially articles 10 to 16.

pas en vue l'exploitation de chemins de fer en ordre principal. La Commission peut, pour les admissions nouvelles, déterminer un minimum de développement kilométrique ou d'autres conditions d'admission pour chaque catégorie de chemins de fer (1).

En outre, la Commission est chargée d'or-

(1) *Conditions d'admission arrêtées par la Commission internationale, dans sa séance du 29 juillet 1893, en exécution de l'article 4 des statuts revisés à Saint-Pétersbourg en 1892.*

I. — Pour pouvoir être admise à participer à l'Association du Congrès, toute Administration de chemins de fer devra adresser au président de la Commission internationale une demande portant l'engagement de se conformer aux prescriptions des statuts. La demande devra être accompagnée des documents nécessaires pour qu'il soit possible de se rendre compte de la nature et de la situation de l'entreprise.

II. — La demande ne pourra pas être prise en considération :

1° Si le chemin de fer n'est pas d'intérêt public, c'est-à-dire s'il n'a pas donné lieu à un acte de concession de l'autorité publique compétente (à moins qu'il n'appartienne à l'Etat) et s'il n'a pas ouvert un service public ;

2° Si la traction des véhicules n'a pas lieu par des moyens mécaniques ;

3° Si l'Administration adhérente n'a pas en vue l'exploitation des chemins de fer en ordre principal, c'est-à-dire notamment si la partie du capital consacrée à des chemins de fer n'est pas plus forte que celle affectée à un autre but (exploitation de services de navigation, de tramways à traction par chevaux, d'usines, hôtels, etc.);

4° Si le chemin de fer n'a pas un développement minimum de 50 kilomètres pour les lignes à traction par locomotives ordinaires ou de 25 kilomètres pour les lignes exploitées par un mode spécial de traction mécanique.

Le minimum de 50 kilomètres sera appliqué aux lignes mixtes, en faisant entrer en ligne de compte les sections à crémaillère pour le double de leur longueur.

Le même minimum sera appliqué aux lignes en voie de construction, avec cette réserve que ces lignes ne pourront être admises à participer au Congrès avant d'avoir 25 kilomètres en exploitation par la vapeur ou la moitié par mode de traction spécial.

III. — Tout chemin de fer admis après la date du 31 août 1892 qui cessera de remplir les conditions précédentes, ou tout chemin de fer qui entrera en liquidation ou en faillite, cessera *ipso facto* de faire partie de l'Association. Il en sera de même de tout chemin de fer qui n'aura plus payé ses cotisations depuis plus de deux exercices.

IV. — Tout chemin de fer ayant été rayé, sur sa demande ou autrement, de la liste des participants au Congrès, ne pourra être réadmis que moyennant le payement des cotisations correspondant aux exercices écoulés depuis la dernière session du Congrès.

be regarded as railway administrations. In admitting new adherents the Commission may lay down for each class of lines a minimum mileage or other qualification (1).

Further, it is the duty of the Commission

(1) *Regulations for admission to membership of the Congress laid down by the Commission on July 29, 1893, in accordance with the article 4 of the constitution as amended in Saint-Petersburg in 1892.*

I. — Every Railway Administration desirous of admission to membership of the Congress must address to the president of the International Commission a formal application to that effect. The application, which carries with it an obligation to submit to the rules of the Congress, must be accompanied by such documents as may be required to establish the nature and position of the administration.

II. — No application can be entertained unless :

1. The Railway is public, that is to say (except where it belongs to the State), has been authorised by Act or charter of the public authority having jurisdiction in the matter, and is open for public traffic;

2. Is worked by mechanical means;

3. The Administration applying for admission is primarily a Railway Administration and more especially, the portion of the capital devoted to Railway purposes is larger than that directed to any other object (steamboat services, horse tramways, mines and works, hotels, etc.);

4. The Railway has, in the case of lines worked by locomotives, a minimum length of 32 miles (50 kilometres) or of lines worked by any special means of mechanical traction, a minimum length of 16 miles (25 kilometres).

This minimum of 32 miles (50 kilometres) will be applicable to mixed systems, a section of rack railway being reckoned, however, as twice its actual length.

The same minimum will apply to lines in course of construction, provided however that such lines shall not be admitted to membership of the Congress until 16 miles (25 kilometres) worked by locomotives or half that length worked by special mechanical means shall be actually open for traffic.

III. — Any Railway admitted to membership after August 31/92 which shall cease to comply with the foregoing requirements or any Railway which shall go into liquidation or become bankrupt shall *ipso facto* cease to be a member of the Congress. The same rule shall apply to a Railway which for two years in succession shall have failed to pay its subscriptions.

IV. — A Railway which at its own request or for any other cause has ceased to be a member of the Congress, shall before readmission be required to pay up the back subscriptions which would have been due from it since the last session of the Congress.

ganiser les sessions du Congrès, de désigner les questions à examiner, d'en préparer l'étude, de faire rédiger et de publier les comptes rendus dés débats, de dresser le budget, de fixer les cotisations en conformité de l'article 17, de surveiller la gestion des finances et, généralement, de faire procéder à tous les travaux, études et publications qu'elle juge utiles dans l'intérêt de l'œuvre poursuivie par l'Association.

Art. 5. — La Commission internationale se compose des anciens présidents de session, membres de droit, et de 33 membres élus.

Son bureau comprend : 1 président, 2 vice-présidents, 1 secrétaire général, 1 secrétaire et 1 trésorier.

Les membres élus sont, autant que possible, choisis dans les différentes nationalités des adhérents. En aucun cas, il ne peut y avoir plus de 9 membres élus appartenant à la même nationalité.

Lorsque le lieu de réunion d'une session du Congrès est déterminé, la Commission internationale peut s'adjoindre, à titre temporaire, des membres choisis dans le pays où la prochaine assemblée doit être tenue.

La Commission nomme son secrétaire et son trésorier. Ils n'ont, en cette qualité, que voix consultative.

Art. 6. — La Commission internationale élit dans son sein les membres de son bureau dans la première séance qui suit une session du Congrès.

La Commission se réunit sur la convocation du président, aussi souvent que l'intérêt de l'Association l'exige, et au moins une fois par an.

Elle doit être convoquée lorsque cinq de ses membres le demandent. Les séances de la Commission sont présidées par le président. En cas d'empêchement, le président est remplacé par un des vice-présidents.

Les résolutions de la Commission sont prises à la majorité des voix des membres

to organise the Congress meetings, to prepare a programme of questions for discussion and be responsible for their preliminary treatment, to publish reports of the discussions, to draw up a balance sheet, to fix, subject to article 17, the amount of the annual subscriptions, to be responsible for the finances and generally to set on foot any investigations and issue any reports and other publications which will in its judgment further the objects for which the Congress is established.

5. — The International Commission is composed of ex-presidents of the sessions of the Congress, who are members *ex officio*, and 33 elected members.

Its officers are a president, two vice-presidents, a general secretary, a secretary and a treasurer.

The elected members are as far as possible chosen to represent the different nations. Under no circumstance shall any one nation have more than nine representatives.

When the place of meeting for a session of the Congress has been fixed the International Commission is empowered to coopt as temporary members representatives of the country where the meeting is to be held.

The commission appoints its secretary and its treasurer. As such they have no right to vote.

6. — The International Commission at its first meeting after a session of the Congress elects its president, vice-presidents and general secretary from amongst its own number.

The commission is summoned by the president to meet when the business of the Congress requires it, but in any case at least once a year.

Any five members may require a meeting to be summoned. The president takes the chair, or in his absence one of the vice-presidents.

Questions are decided by the votes of the majority of members present. If the votes présents. En cas de partage, la voix du membre qui préside est prépondérante.

Les délibérations de la Commission sont constatées par des procès-verbaux. Elles ne sont valables que si neuf membres au moins y prennent part.

Si, dans une première réunion, ce nombre n'est pas atteint, il pourra être délibéré à la réunion suivante, convoquée à quinze jours d'intervalle, quel que soit le nombre de membres présents.

ART. 7. — Les 33 membres élus par la Commission internationale sont renouvelés par tiers à chaque session.

Elle fixe, dans sa première séance après ce renouvellement, l'ordre de sortie de ses membres lors des élections suivantes (1).

Les membres sortants sont rééligibles.

La Commission a, en tout temps, la faculté de se compléter par la désignation provisoire de membres choisis parmi les délégués des adhérents. Dans ce cas, il est procédé à l'élection définitive lors de la plus prochaine session.

COMITÉ DE DIRECTION.

ART. 8. — Dans la première séance qui suit une session, la Commission délègue sept de ses membres, qui forment un Comité de direction.

Le Comité de direction est composé du président, du secrétaire général et de cinq membres.

Le secrétaire et le trésorier de la Commission y sont adjoints, avec voix consultative.

Le mandat des membres du Comité de direction a une durée égale à l'intervalle de deux sessions du Congrès. Il peut être renouvelé.

Le Comité se réunit au moins tous les trois mois. Il peut être convoqué extraordinaire-

(1) *Disposition transitoire :* Pour la première fois, toute la Commission internationale sera élue à la session du Congrès de 1887.

are equal the chairman has a casting vote.

Minutes are kept of the proceedings of the Commission. Nine members are required to form a quorum.

If at a first meeting this number is not present an adjournment of a fortnight shall take place, and at the meeting so adjourned no quorum is necessary for the transaction of business.

7. — One-third of the 33 elected members of the International Commission retire and are replaced each session.

At its first meeting after this replacement the Commission settles the order of retirement of the rest of the members (1).

Retiring members are re-eligible.

The Commission has at any time power to fill vacancies by the provisional election of members who must be delegates. Such members hold office till the next meeting of the Congress.

EXECUTIVE COMMITTEE.

8. — At its first meeting after a session of the Congress the Commission nominates 7 of its members to form an executive Committee.

The executive Committee consists of the president, the general secretary of the Commission and five members.

The secretary and the treasurer of the Commission are members of the Committee, but without the right to vote.

The members of the executive Committee hold office for a period equal to the interval between two sessions of Congress. They are re-eligible.

The executive Committee meets at least every three months. It may be summoned

(1) *Temporary provision :* At the outset the whole of the International Commission shall be elected at the Congress in 1887.

ment sur l'initiative du président ou à la demande de trois membres.

ART. 9. — Le Comité est chargé spécialement de l'expédition des affaires courantes, de la gestion des finances, ainsi que de la surveillance et de la direction de tous les travaux, études et publications, de la rédaction du *Bulletin*, de la conservation de la bibliothèque et des archives. Il fait imprimer entièrement ou partiellement les mémoires et les documents destinés au Congrès qu'il lui paraît nécessaire de distribuer pour éclairer les discussions. Il se tient à la disposition des adhérents pour leur fournir les renseignements spéciaux qui lui seraient demandés.

Le Comité nomme et révoque le personnel.

L'exécution des décisions du Comité est confiée à son bureau (1).

(1) *Règlement d'ordre intérieur du Comité de direction.*

I et II. — (Voir les articles 8 et 9 des statuts.)

III. — Le Comité se réunit à son local ordinaire, rue de Louvain, 11, à Bruxelles, sur convocation du président, et, autant que possible, le dernier samedi d'un mois.

En cas d'empêchement du président, le Comité désigne un de ses membres pour le remplacer (*).

Les convocations énoncent l'ordre du jour.

IV. — La présence de trois membres suffit pour délibérer valablement.

Les procès-verbaux des séances sont adressés à tous les membres du Comité.

V. — Les affaires soumises au Comité sont traitées en observant la division du travail du Congrès. (Voir article 13 des statuts.)

Les questions importantes sont envoyées à l'examen d'un membre rapporteur.

VI. — Le Comité peut faire appel au concours des spécialistes. Il peut les rémunérer.

VII. — La correspondance est signée par le président ou par le secrétaire délégué par lui.

VIII. — Le président, aidé du secrétaire du Comité, dirige spécialement la publication du *Bulletin*, étant entendu que les articles à insérer sont toujours soumis à l'appréciation préalable d'un membre désigné par lui pour faire partie du Comité de rédaction.

En cas de différend, l'affaire est soumise à l'appréciation du Comité de direction.

Les travaux relatifs aux questions du programme

(*) M. Ramaeckers a été désigné dans la séance du 27 janvier 1894.

specially either by the president on his own authority or on the requisition of three members.

9. — The Committee is responsible in particular for the management of current affairs, and financial business; also for superintending and managing investigations, reports and publications, for the editing of the *Bulletin* and the care of the library and archives. It decides as to printing in whole or in part the reports and other documents submitted to the Congress, whose circulation it regards as necessary to facilitate the discussions. It is the duty of the Committee to furnish to members of the Congress such special information as they may require.

The Committee has the right of appointing and dismissing the staff.

The officers carry out the instructions of the Committee (1).

(1) *Bye-laws of the executive committee.*

I and II. — (Arts. 8 and 9 of the constitution.)

III. — The Executive Committee meets at its office, rue de Louvain, 11, Brussels, when summoned by the president, as far as possible on the last Saturday in the month.

The Committee appoints one of its members to take the chair in the absence of the president (*).

The business to be transacted is specified in the summons.

IV. — The quorum of the Committee is three.

Minutes of the meeting are sent to all members of the Committee.

V. — The business of the Committee is divided under the same heads as the proceedings of the Congress (see art. 13 of the constitution).

Questions of importance are referred to some member of the Committee for report.

VI. — The Committee may engage and pay for expert assistance.

VII. — Letters are signed by the president or by the secretary acting under his authority.

VIII. — The president with the assistance of the secretary of the Committee is specially responsible for the publication of the *Bulletin*, but articles to be inserted are always previously approved by another member appointed by the president to form one of the editorial committee.

In case of difference the matter is referred to the decision of the executive Committee.

Where papers referring to questions on the programme

(*) Mr. Ramaeckers was appointed at the meeting of January 27, 94.

SESSIONS DU CONGRÈS.

Art. 10. — Le Congrès se réunit tous les deux ans. Dans chaque session, il désigne le lieu et la date de la session suivante.

En cas d'empêchement imprévu, la Commission internationale peut modifier ces dispositions.

Art. 11. — Ont le droit de prendre part aux sessions du Congrès :

1° Les membres de la Commission internationale;

2° Les délégués désignés par les adhérents;

3° Les secrétaires et le trésorier, ainsi que les secrétaires de section nommés par la Commission ou par son Comité et chargés de l'exposé des questions du programme.

Les Gouvernements fixent eux-mêmes le nombre de leurs délégués.

Les Administrations de chemins de fer peuvent nommer des délégués au nombre de 8 au plus, suivant l'étendue de leur réseau, savoir :

2 délégués pour les exploitations ne dépassant pas 100 kilomètres,

SESSIONS OF THE CONGRESS.

10. — The Congress meets every two years. At each meeting it fixes the time and place of the following meeting.

In case of unforeseen hindrance, the International Commission may alter the arrangements.

11. — The following have a right to take part in the meetings :

1. The members of the International Commission.

2. Delegates appointed by the adherents.

3. The secretaries and the treasurer, as also the secretaries of the sections nominated by the Commission or the executive Committee to report on the questions in the programme.

Governments are entitled to send as many delegates as they think proper.

Railway administrations are entitled to nominate 8 delegates as a maximum, according to the length of their system, as follows : —

For lines not more than 62 miles (100 kilometres) 2 delegates.

peuvent être imprimés directement sous la responsabilité de leurs auteurs.

Il en est de même de la sténographie revue par les orateurs.

IX. — Le trésorier tient la comptabilité des dépenses et des recettes.

La Commission internationale étant spécialement chargée de surveiller la gestion des finances en vertu de l'article 4 des statuts, son secrétaire général procède à une vérification de la caisse et des écritures a chaque séance du Comité.

Les recouvrements de fonds sont faits au nom de la Commission internationale, et les quittances à talon sont visées par le secrétaire général de la Commission.

Le trésorier présente un état de la situation de la caisse à chaque séance du Comité.

Les fonds productifs d'intérêt sont placés à la Caisse d'épargne et de retraite sous la garantie de l'Etat. Ils ne peuvent être retirés qu'au nom de la Commission internationale sur deux signatures : celle du trésorier et celle du secrétaire général ou du président de la Commission internationale.

X. — Le Comité fixe les traitements du personnel dans les limites du budget arrêté par la Commission.

are printed the responsibility rests with their authors.

The same rule applies to the reports of debates revised by the speakers.

IX. — The treasurer keeps accounts of receipts and expenditure.

In accordance with article 4 of the constitution, the financial management of the Congress is in the hands of the International Commission. Accordingly at each meeting of the Committee the general secretary of the Commission examines the receipts and the vouchers.

Subscriptions are made payable to the International Commission, and the receipts corresponding thereto are checked by its general secretary.

The treasurer submits a summary balance sheet at each meeting of the Committee.

Money other than cash in hand is deposited in the government Savings Bank in the name of the Commission. Its withdrawal requires two signatures, that of the treasurer and that of the general secretary or the president of the Commission.

X. — Within the limits of the budget voted by the Commission, the Committee fixes the salaries of the staff.

3 délégués pour les exploitations ne dépassant pas 500 kilomètres, et

1 délégué en plus par groupe de 500 kilomètres ou par fraction de 500 kilomètres en plus.

ART. 12. — A l'ouverture de chaque session, le bureau de la Commission internationale remplit les fonctions de bureau provisoire, et le Congrès procède immédiatement à l'élection de son bureau, composé :

1° D'un ou de plusieurs présidents d'honneur;

2° D'un président;

3° De vice-présidents;

4° Des présidents de section, en conformité de l'article 14;

5° D'un secrétaire général;

6° De secrétaires.

Le premier délégué de chaque Gouvernement est de droit vice-président.

Tous les membres du bureau sont nommés pour une session.

L'élection a lieu dans les conditions indiquées à l'article 16, alinéa 6.

Les fonctions des membres du bureau sont déterminées par les règles en usage dans les assemblées délibérantes pour la direction des débats.

ART. 13. — A l'ouverture de chaque session et après la formation du bureau, le Congrès se divise en sections (voies et travaux, traction et matériel, exploitation, questions d'ordre général, etc.).

Un membre peut s'inscrire à la fois dans plusieurs sections.

Le Congrès peut aussi constituer des commissions spéciales.

ART. 14. — Chaque section nomme son président, son secrétaire principal et ses secrétaires. Les présidents de section sont, de droit, membres du bureau de la session.

Les sections et les commissions se dissolvent à la fin de chaque session.

ART. 15. — Les discussions du Congrès

For lines not more than 311 miles (500 kilometres) 3 delegates.

And one additional delegate for each additional 311 miles (500 kilometres) or fraction thereof.

12. — At the opening of each session the officers of the International Commission hold office temporarily while the Congress elects its own officers as follows : —

1. One or more honorary presidents (*président d'honneur*).

2. An acting president (*président*).

3. Vice-presidents.

4. Presidents of the different sections in accordance with art. 14.

5. A general secretary.

6. Secretaries.

The delegate nominated first by each Government is *ex officio* vice-president.

All the officers are appointed for the duration of the session.

The election takes place according to the rules laid down in article 16, paragraph 6.

The duties of the officers are those laid down by the rules of deliberative assemblies for the conduct of their proceedings.

13. — At the opening of each session, and after the appointment of the officers, the Congress divides into sections (way and works, locomotives and rolling stock, traffic, general, etc.).

A member may enter his name in more than one section.

The Congress may also appoint special Committees.

14. — Each section appoints its own president, its own chief secretary, and its secretaries. The presidents of each section are, in virtue of their position, officers of the Congress.

The sections and the Committees cease with the termination of each session.

15. — The discussions of the Congress are

portent sur les questions inscrites au programme de la session.

Ce programme est arrêté par la Commission internationale; il y est tenu compte des indications résultant des délibérations du précédent Congrès et de ses sections.

La Commission reçoit les propositions des adhérents; un rapporteur désigné par la Commission rédige un exposé sommaire et sans conclusions des éléments de chaque question, ainsi que l'analyse des documents qui lui ont été transmis.

Art. 16. — Les discussions ont lieu en français ou dans la langue du pays où se tient le Congrès. Des interprètes traduisent en français les discours prononcés dans une autre langue.

Les procès verbaux et les comptes rendus sont rédigés en français, mais les orateurs ont le droit d'exiger la reproduction de leurs déclarations originales en regard de la traduction.

Les discussions ont lieu d'abord en sections.

Les bureaux des sections rédigent un résumé des débats formulant les diverses opinions émises dans la section. Après approbation par la section, ces résumés sont présentés à l'assemblée plénière et insérés dans le procès-verbal, en y ajoutant, s'il y a lieu, la mention des opinions nouvelles émises au sein de l'assemblée plénière.

Le Congrès n'émet de votes qu'en ce qui concerne les questions relatives au règlement ou se rattachant à l'organisation de l'institution.

Les votes sur ces questions spéciales ont lieu à la majorité des membres assistant au Congrès. Il est procédé au vote par assis et levé; s'il existe un doute sur le résultat du vote, il est passé au scrutin. Le vote par appel nominal n'a lieu que s'il en est fait la demande par douze assistants.

confined to the questions set down on the programme of the meeting.

This programme is drawn up by the International Commission, with the help of suggestions made at the meetings of the previous Congress and its sections.

The Commission receives suggestions from adherents. The reporter appointed by the Commission prepares a brief outline of each question without expressing conclusions, and also a summary of the contents of the documents which have reached him.

16. — The discussions take place in French or in the language of the country in which the Congress is held. Speeches in any other language are translated into French.

The minutes and reports are drawn up in French, but the speakers are entitled to claim that their original words shall be printed alongside of the translation.

The subjects are discussed in the first place in the sections.

The officials of the respective sections draw up an abstract of the discussions, setting forth the various opinions expressed in the section. After receiving the approval of the section, these abstracts are submitted to the general meeting and inserted in the minutes, there being added, if necessary, a statement of any new opinions expressed at the general meeting itself.

The Congress does not vote except on questions of management or organisation.

On these special questions the votes of the majority of the members present are taken by sitting and rising. If there is any doubt the votes are counted. A call of the roll can only be made if at least a dozen members demand it.

COTISATIONS, REVISION DES STATUTS, ETC.

ART. 17. — Les frais des sessions, de la Commission internationale et du Comité sont à charge d'une caisse alimentée :

1° Par les cotisations annuelles des adhérents;

2° Par des subventions et autres libéralités.

Les cotisations annuelles des adhérents se composent :

a) Pour les gouvernements, d'une allocation fixée par eux-mêmes;

b) Pour les Administrations de chemins de fer, d'une part fixe de 100 francs, plus une part variable proportionnelle à l'étendue de leur réseau. Cette cotisation variable, destinée à couvrir le budget de l'Association, ne peut dépasser 25 centimes par kilomètre.

L'année sociale commence le 15 avril.

ART. 18. — Les cotisations donnent le droit aux adhérents de recevoir gratuitement les comptes rendus des sessions à un nombre d'exemplaires indiqué par le nombre de leurs délégués augmenté d'une unité.

Les autres publications sont envoyées aux Administrations adhérentes en raison de leur importance, calculée d'après les bases de l'article 11, et des abonnements à prix réduits peuvent être accordés.

ART. 19. — La Commission internationale présente, à chaque session du Congrès, un rapport sur l'administration des finances. Le Congrès nomme deux commissaires chargés de la vérification des comptes.

ART. 20. — Toute proposition de revision des statuts doit être présentée à la Commission internationale, avec motifs à l'appui, trois mois au moins avant l'ouverture de la session, de façon à pouvoir être portée par la Commission à la connaissance des adhérents un mois au moins avant cette ouverture. La proposition, avant sa prise en considération par le

SUBSCRIPTIONS, REVISION OF THE CONSTITUTION, ETC.

17. — The cost of the meetings of the International Commission and the executive Committee are defrayed by a fund formed of:

1. The annual subscriptions of adherents.

2. Subsidies and other casual receipts.

The annual subscriptions of adherents consist of :

a) In the case of governments an amount fixed by themselves;

b) In the case of railway administrations a fixed sum of £ 4 ($ 20), plus a sum proportionate to the length of the system. This variable sum necessary to meet the expenses of the Congress may not exceed 2 1/2 d. (5 cents) per mile.

The financial year begins on the 15th April.

18. — The subscriptions entitle each adherent to receive as many reports of the proceedings as the number of its delegates, *plus* one.

Any other publications of the Congress are sent to the subscribing administrations in numbers based upon their mileage in conformity with article 11; and subscriptions may be permitted at a reduced rate.

19. — The International Commission presents at each session of the Congress a report on the financial position. The Congress appoints two auditors to pass the accounts.

20 — Every proposal for a revision of the constitution must be submitted to the International Commission with the reasons for its adoption at least three months before the date fixed for the opening of the session, so that it may be brought by the Commission to the knowledge of the adherents at least one month before that date. No proposition can be taken

Congrès, doit être appuyée par la Commission ou par vingt-cinq membres.

Art. 21. — Les adhérents s'efforcent de faciliter les réunions du Congrès et la mission de la Commission internationale.

into consideration by the Congress unless it is supported either by the Commission or by 25 members.

21. — The adherents pledge themselves to promote the meetings of the Congress and the mission of the International Commission.

INSTRUCTIONS

POUR

MM. les Présidents, les Secrétaires principaux, les Rapporteurs et les Secrétaires-Rapporteurs des sections.

L'expérience des sessions précédentes ayant montré qu'il était nécessaire d'apporter une certaine uniformité dans la marche et la direction des discussions des sections, le Comité de direction de la Commission internationale a cru devoir faire rédiger les instructions suivantes pour servir de guide à MM. les présidents, les secrétaires et les rapporteurs des sections.

I. — Composition des bureaux.

a) En vertu de l'article 14 des statuts, chaque section nomme son président, son secrétaire principal et ses secrétaires. Comme il importe que les fonctions de présidents et de secrétaires principaux soient équitablement réparties entre les diverses nationalités représentées au Congrès et que les candidats puissent se préparer à les remplir, la Commission internationale soumet à la ratification des sections les candidatures choisies à l'avance.

b) La Commission internationale désigne, en outre, un ou plusieurs ***secrétaires-rapporteurs*** par section afin d'aider les rapporteurs

INSTRUCTIONS

FOR

the Presidents, Secretaries, Reporters and Secretary Reporters of Sections.

The experience of previous sessions having shown the necessity of adopting some kind of system in the work and discussions of the different sections, the Executive Committee of the International Commission has deemed it expedient to draw up the following instructions to assist the presidents, secretaries and reporters of sections in carrying out their duties.

1. — Election of officers.

a) According to article 14 of the statutes, each section shall appoint its own president, secretary and assistant secretaries. As it is advisable that the functions of the presidents and secretaries should be fairly distributed among the different nationalities represented at the Congress, and also that candidates should be enabled to prepare themselves for carrying out the said functions, the International Commission will submit the names of candidates selected beforehand, for ratification by the various sections.

b) The International Commission will also name one or more *secretary reporters* for each section. They will be required to assist the à résumer leurs exposés dans les deux langues (français et anglais).

Le président de chaque section présente à la ratification de l'assemblée la nomination des autres secrétaires qu'il désire s'adjoindre comme collaborateurs.

II. — Usage des langues.

a) En vertu de l'article 16 des statuts, « les « discussions ont lieu en français ou dans la « langue du pays où se tient le Congrès. Des « interprètes traduisent en français les dis- « cours prononcés dans une autre langue ».

b) En ce qui concerne la 5e session, la Commission internationale a, en outre, décidé que tous les discours et les communications en français seraient traduits ou résumés en anglais Les secrétaires-rapporteurs voudront bien, à cet effet, prêter leur concours au président et au secrétaire principal de chaque section.

III. — Travaux des sections.

a) *Fixation de l'ordre du jour de chaque section.* — Au début de la session, le président de chaque section déterminera, d'accord avec l'assemblée, l'ordre du jour des séances, de manière à fixer, aussi exactement qu'il est possible de le faire, le jour où sera abordée la discussion de chacune des questions soumises à la section seule ou réunie à d'autres.

b) *Résumé du rapport par le rapporteur.* — Pour entamer l'étude d'une question, le président donnera la parole au rapporteur qui fera connaître à la section la substance de son exposé. Le rapporteur est instamment prié de ne pas lire son rapport *in extenso*, mais de le résumer d'une manière concise en insistant sur les points principaux qui y sont développés et en faisant bien ressortir les opinions différentes exprimées dans leurs réponses au questionnaire détaillé par les chemins de fer participant à l'Association ainsi que les con-

reporters in summarizing their reports in French and English.

The president will submit, for the approval of the meeting, the names of other assistant secretaries whom he may desire to assist him.

II. — Languages used.

a) According to article 16 of the statutes, « discussions take place in French or in the « language of the country in which the Con- « gress is held. Speeches in any other lan- « guage are translated into French. »

b) With regard to the 5th session, the International Commission has decided that all speeches and communications in French shall be translated or abstracted into English. Secretary-reporters will therefore accordingly afford all the assistance in their power to the president and secretary of each section, with this object.

III. — Work of sections.

a) *Arrangement of programme of the sittings of each section.* — At the opening of the session, the president of each section shall decide with the approval of the meeting, the programme of the sittings, in order to fix, as far as possible, the day when shall be discussed each of the questions submitted to the section alone or meeting jointly with another.

b) *The reporter's summary of his report.* — To open a discussion, the president shall request the reporter to give the section a summary of his report. The reporter is particularly requested not to read his report *in extenso*, but only to give an abstract of it, dwelling on the main points which are enlarged upon in his report, and laying stress on the answers given to the detailed list of questions by the railway companies who are members of the Congress, calling attention to the different opinions expressed by the said clusions proposées. Pour bien atteindre ce résultat, il conviendra, avant d'énoncer les conclusions, de rappeler brièvement les considérations générales les plus importantes déjà indiquées au cours du résumé, afin que celles-ci, jointes aux conclusions, constituent un tout complet par lui-même. Autant que possible, le rapporteur ne devra pas parler plus d'une demi-heure.

c) *Discussion.* — Le résumé de l'exposé étant terminé, le président ouvrira la discussion. Si, comme cela arrive assez souvent, une certaine hésitation se produit parmi les délégués présents et si aucun d'eux ne demande la parole immédiatement, le président ne se hâtera pas de déclarer les conclusions adoptées. Il s'efforcera, au contraire, de provoquer les discussions en attirant l'attention des membres sur les points du rapport qu'il jugera de nature à soulever des objections, et il fera tous ses efforts pour obtenir des déclarations intéressantes et des renseignements de la part des personnes qu'il soupçonnera avoir spécialement étudié la question.

Le président veillera à ce que les prescriptions relatives à l'usage des langues soient observées.

d) *Clôture de la discussion.* — En cas de discussion sur la durée des débats, la clôture sera prononcée par l'assemblée à la majorité des deux tiers des membres présents. La discussion étant close, les conclusions ainsi que les amendements qui auraient pu y être présentés au cours des débats seront mis aux voix et adoptés à la majorité des membres présents.

e) *Lecture du rapport de section et des projets de conclusions à la séance plénière.* — Le président ou le secrétaire principal de la section aidé, s'il y a lieu, par les secrétaires, fera précéder le texte des conclusions qui doit être soumis aux délibérations de l'assemblée plénière, d'un résumé de la discussion désigné sous le nom de *rapport de section.* Ce rapport, qui devra refléter le plus exactement

companies and the conclusions to be drawn. In order to achieve this object it is advisable to begin with a statement of the conclusions arrived at, and then to point out briefly the more important views already mentioned in the summary, so that they may, jointly with the conclusions, form a complete statement. It is desirable that reporters, should, as far as possible, limit their opening speeches to half-an-hour.

c) *The discussion.* — When the reporter has concluded his remarks, the president shall open the discussion If, as is frequently the case, the delegates present hesitate to come forward and state their views, the president shall not hastily declare that the conclusions are adopted by the meeting. He shall, on the contrary, invite discussion by calling the attention of those present to certain features in the report which he may consider open to criticism, and he shall endeavour as far as possible to obtain interesting remarks and information from delegates present whom he may think specially qualified to give an opinion on the subject in question.

The president shall, moreover, see that the regulation regarding the languages employed is duly observed.

d) *Closure of the discussion.* — A majority of two-thirds of members present shall at any time have power to declare a discussion at an end, should any question arise as to its duration. When a discussion is closed, the conclusions and also any amendments that may have been proposed, will be put to the vote in the ordinary manner.

e) *Presentation of conclusion to the general meeting.* — The president or the secretary, with the help, if necessary, of the assistant secretaries, shall draw up a résumé of the discussion (called a *sectional report*) as an introduction to the conclusions which are to be submitted to the general meeting. This report shall give, as far as possible, the general drift of the discussion and shall indipossible l'allure de la discussion, reproduira les arguments principaux développés et indiquera les personnes qui les ont fait valoir.

Le rapport de section a une grande importance parce qu'il tient les membres de l'assemblée générale qui n'ont pas assisté aux séances de section au courant de l'état de la question. S'il est bien fait, si, sans être trop développé, il résume d'une manière nette et concise l'ensemble de la discussion, il peut, dans bien des cas, éviter qu'un débat épuisé se renouvelle inutilement en séance plénière.

Il est bien difficile, sinon impossible, de tracer le plan précis d'un tel travail.

On trouvera dans les comptes rendus des sessions antérieures de nombreux exemples de rapports rédigés avec grand talent et peignant admirablement la physionomie des discussions. Mais la plupart d'entre eux résument les opinions sans citer les noms des personnes qui les ont émises. L'assemblée plénière a cependant le droit d'être complètement éclairée sur ce qui s'est passé en sections.

Nous proposerons le modèle suivant :

QUESTION XIII-B DE LA 3e SESSION.

INFLUENCE QUE PEUT AVOIR, SUR LES CONDITIONS ÉCONOMIQUES DE L'EXPLOITATION, L'AUGMENTATION DU TONNAGE DES WAGONS A MARCHANDISES.

Rapports des 2e et 3e sections réunies.

« Le rapporteur, Mr. Pol Lefèvre, fait ressortir la tendance assez générale des Administrations de chemins de fer en Autriche, Allemagne, Hollande et Suisse, à augmenter la capacité de leurs wagons plats et, particulièrement, à porter de 10 à 15 tonnes, par voie de transformation, la capacité de leurs wagons découverts à deux essieux. Il rapporte ce fait que l'Etat prussien a transformé 2,260 wagons à houille de 10 tonnes en wagons de 12.5 et de 15 tonnes avec une dépense de 38 fr. 93 c. (£ 1-10-10) par wagon. Dans ces conditions, la réforme ne peut manquer, d'après

cate the principal arguments used, with the names of the speakers.

The sectional report is of great importance, as it will keep those members who have been unable to attend all the meetings of the sections informed on the matter under discussion. If this report is carefully drawn up, not too burdened with detail, but giving a concise and general idea of the discussion, it will in many cases avoid, in general meeting, the useless discussion of a subject which has been fully threshed out.

It is extremely difficult, if not impossible, to draw out an exact plan of a task such as this.

In the proceedings of former sessions will be found numerous examples of reports, drawn up with great ability, which reproduce admirably the character of the discussions. Most of the reports, however, state the various opinions without appending the names of their authors. The general meeting should certainly be informed of all that has taken place in sections.

The following is submitted as a specimen :

QUESTION XIII-B OF THE 3rd SESSION.

THE EFFECT WHICH THE INCREASE IN THE TONNAGE OF GOODS WAGONS WOULD HAVE ON THE COST OF RAILWAY WORKING.

Reports of the 2nd and 3rd sections, meeting jointly.

« The reporter, Mr. Pol Lefèvre, demonstrates that Railway Administrations in Austria, Germany, Holland and Switzerland, generally tend to increase the tonnage capacity of their lowsided goods wagons, and especially to convert their 10-ton into 15-ton 4 wheeled open goods wagons. He states that the Prussian State Railways have converted 2,260 10-ton coal trucks into 12 1/2 and 15-ton at a cost of £ 1·10 10 (38 fr. 93 c) per truck. Under these circumstances, he considers that the conversion cannot fail to be an advantageous one, the old 10-ton wagons being used as le rapporteur, d'être avantageuse, les anciens wagons de 10 tonnes étant utilisés comme par le passé sans grand inconvénient lorsqu'ils ne trouvent pas un chargement de 15 tonnes. En revanche, quand on obtient de l'aliment pour 15 tonnes, on conçoit tout ce que l'on peut gagner, par tonne, au point de vue des dépenses de construction et d'entretien du matériel, des dépenses de manutention, de classement et de triage, de traction, etc. La capacité par tonne des voies de service est également augmentée dans une forte proportion.

« Une note pleine d'intérêt de M. Ely, l'ingénieur en chef de la traction du Pennsylvania Railroad, montrait qu'en Amérique on avait été beaucoup plus loin, le tonnage de 30 tonnes y étant adopté depuis longtemps pour les wagons à houille. Il en est résulté une réduction de 566 kilogrammes (1,245.2 livres) à 368 kilogrammes (809.6 livres) du poids mort par tonne offerte (31.8 p. c.), de 566 fr. 75 c. (£ 22-8-11) à 373 francs (£ 14-15-10) de la dépense de construction par tonne de capacité (33 8 p. c.), de 48 (18"8) à 26 (10"2) centimètres de la longueur par tonne offerte (45.6 p. c.).

« Mr. Frescot (Méditerranée italienne), dont la Compagnie a cependant depuis longtemps des wagons de 12 tonnes, a objecté à l'augmentation de ce tonnage que, dans l'état actuel des règlements, les lignes secondaires de son réseau ne pourraient supporter le poids de 12 1/2 tonnes par essieu dont pourraient les charger des wagons de 15 tonnes à deux essieux. Son Administration a cherché cependant à diminuer le poids mort des wagons par l'emploi de l'acier.

« Plusieurs orateurs ont ensuite parlé tour à tour pour et contre la réforme : défavorable lorsque le trafic est plus spécialement agricole ou sujet à transbordement, d'après les uns ; utile pour le trafic des matières pondéreuses et sans effet nuisible dans le cas contraire, d'après les autres.

« Citons parmi les témoignages favorables, ceux des chemins de fer hollandais (Mr. Verloop) et russes.

« Mr. Kerbedz, vice-président du chemin de fer Vladicaucase, a fait connaitre que l'augmentation de la capacité avait parfaitement réussi sur son réseau, grâce à quelques avantages accordés aux expéditeurs. Mais l'assemblée a été impressionnée

before, without any inconvenience, when a 15-ton load is not forthcoming. On the other hand, when the 15-ton loads can be obtained, the resulting economy per ton is obvious, not only from the point of view of construction and maintenance of the rolling stock, but also of handling, classification, sorting, haulage, etc. The tonnage capacity of the lines is also materially increased.

« In a very interesting note Mr. Ely, chief of motive power of the Pennsylvania Railroad, showed that in the United States they had gone still further, a tonnage of 30 tons having been adopted for coal trucks, which resulted in the following reductions : —

« From 1,245·2 lbs (566 kilograms) to 809·6 lbs (368 kilograms) dead load per ton (31·8 p. c.), from £ 22 8·11 (566 fr. 75 c.) to £ 14·15·10 (373 francs) in construction cost per ton capacity (33·8 p. c.), and from 18·8" (48 centimetres) to 10·2" (26 centimetres) in the length per ton capacity (45·6 p. c.).

« Mr. Frescot (Mediterranean Railway, Italy), whose company adopted 12-ton wagons long ago, nevertheless objected to an increase in tonnage on account of the regulations at present in force for their secondary lines, which he added were such that the latter could not support the weight of 12 1 2 tons per axle which would follow upon the adoption of 15-ton wagons. His company sought, he added, to diminish the dead weight by the use of steel.

« Several speakers then followed, taking opposite views to one another, some opposing the change where traffic is chiefly agricultural or subject to transhipment, others favouring the transformation for bulky goods traffic and considering it harmless where traffic is not bulky.

« The Dutch Railways (Mr. Verloop) and the Russian were favourable to the change.

« Mr. Kerbedz, Deputy Chairman of the Vladicaucasus Railway, pointed out that an increase in the tonnage capacity of wagons had worked very successfully on his Company's line, thanks to certain advantages offered to consignors. A par un discours de Mr. A. Sartiaux, ingénieur en chef de l'exploitation du Nord français, mettant en doute la possibilité de la transformation des wagons de 10 tonnes de son réseau en wagons de 15 tonnes, et déclarant que cette réforme serait contraire aux désirs du commerce.

« L'assemblée s'est donc bornée à admettre le projet de conclusions suivant, qu'elle soumet à l'assemblée plénière :

PROJET DE CONCLUSIONS.

« En raison des conditions essentiellement « différentes qui régissent le trafic des divers « réseaux, il n'est pas possible d'indiquer une « règle générale pour fixer le tonnage à donner « aux véhicules à marchandises en vue de réali- « ser les meilleures conditions économiques de « l'exploitation.

« Il incombe aux services chargés de la con- « struction du matériel, de rechercher tous les « moyens ayant pour but de diminuer le poids « mort dans des proportions compatibles avec la « nature du trafic, avec la sécurité et avec un bon « entretien. »

speech by Mr. A. Sartiaux, general manager of the Northern of France, was very effective. Mr. Sartiaux doubted if it would be possible to convert 10-ton into 15-ton wagons on his line, and declared that such a change would not meet business requirements.

« The meeting therefore confined itself to passing the following resolution, which was submitted to the general meeting : —

CONCLUSIONS PRESENTED.

« In consideration of the different conditions « under which various railway companies work « their lines, it is impossible to lay down any « general law governing the tonnage of goods « wagons with a view to economical working.

« The Departments connected with the con- « struction of rolling stock should seek, by all « possible means, to reduce the dead weight of « wagons, so far as is compatible with the kind « of traffic, with safety and with proper mainte- « nance. »

OUVERTURE SOLENNELLE

Le 26 juin 1895, à 3 heures de relevée,

DANS LA SALLE DES CÉRÉMONIES DE L'INSTITUT

Le prince de Galles ayant accepté de faire l'ouverture de la 5e session en qualité de président d'honneur, prend place sur l'estrade, ayant à sa droite Mr. Bryce, le président du « Board of Trade », et à sa gauche Mr. Dubois, le président de la Commission internationale. Sur l'estrade se trouvait aussi la suite du prince, ainsi que les deux vice-présidents de la Commission, les membres du comité exécutif de la Commission permanente, les membres du bureau de la section anglaise, Lord Stalbridge, président de la Railway Companies' Association, et Sir Henry Oakley, secrétaire.

Le prince de Galles, dont l'arrivée est accueillie par de vifs applaudissements, s'exprime en ces termes :

« Messieurs,

« Je m'acquitte aujourd'hui d'une mission aussi agréable qu'importante en procédant à l'ouverture de la cinquième session du Congrès des chemins de fer. Je remplis cette tâche au nom de la Reine, qui prend l'intérêt le plus vif à la discussion de questions qui touchent de si près aux intérêts de ses États. Je la remplis également en mon nom personnel, heureux de l'occasion qui m'est offerte d'adresser ici aux administrations de chemins

OPENING CEREMONY

June 26, 1895, at three o'clock, in the

RECEPTION HALL AT THE IMPERIAL INSTITUTE

The Prince of Wales graciously consented, as honorary president, to formally open the Fifth Session of the Congress. Mr. Bryce, president of the Board of Trade, was seated on the right of His Royal Highness on the platform; Mr. Dubois, president of the International Commission, being seated on the left; the two vice-presidents of the Commission, the members of the Executive Committee of the Permanent Commission; the president, vice-president, and secretary of the English Section; Lord Stalbridge, president, and Sir Henry Oakley, secretary of the Railway Companies' Association, being also on the platform near the Prince.

The Prince of Wales, whose arrival was enthusiastically welcomed, expressed himself as follows : —

« Gentlemen,

« I have to discharge to-day the very pleasing and the very important duty of declaring open the Fifth International Railway Congress. I fulfil this duty on behalf of the Queen, who takes the greatest interest in the discussion of matters so closely affecting the welfare of her dominions. I do so on my own behalf, being glad of the opportunity of expressing my deep appreciation to the Railway authorities, both at home and abroad, for their unfailing cour-de fer de l'Angleterre et de l'étranger, tous mes remerciements pour l'inépuisable obligeance avec laquelle elles m'ont toujours facilité mes nombreux voyages. Et, enfin, je remplis cette tâche au nom des grandes compagnies de chemins de fer de ce pays, dont la gestion est confiée à un groupe d'hommes de la plus haute compétence et du plus grand talent et qui m'ont demandé de vouloir bien être leur interprète en cette occasion. Je souhaite donc la bienvenue en Angleterre, berceau des chemins de fer, aux délégués des États du continent et, chose unique jusqu'à présent dans les annales du Congrès, à ceux des deux Amériques. (*Applaudissements.*)

« Soixante-dix ans se sont écoulés depuis la construction de notre premier chemin de fer, entre Stockton et Darlington. Cinq ans plus tard, en 1830, fut inaugurée dans des circonstances qui prirent un caractère tragique, la première ligne ouverte au transport des voyageurs sous le contrôle du Parlement et avec un capital souscrit par le public. Cette intéressante solennité, riche de promesses pour l'avenir, fut attristée par un accident qui eut pour conséquence la mort de M. Huskisson. Pendant les soixante années qui suivent, les chemins de fer se sont développés dans le monde entier, et la réunion de ce jour montre bien l'intérêt que nous inspire cette industrie remarquable qui, plus que toute autre, a provoqué l'accumulation des richesses et l'extension du commerce du monde, et qui a puissamment contribué à resserrer les liens d'amitié entre les nations et à établir la bonne entente universelle.

« L'institution du Congrès des chemins de fer a été fondée en 1885, un assez grand nombre d'hommes appartenant aux chemins de fer les plus importants ayant été réunis à l'occasion du jubilé des chemins de fer belges.

« Des sessions ont été tenues depuis à Milan en 1887 et à Paris en 1889, et la dernière qui s'est réunie à Saint-Pétersbourg en 1892 restera inoubliable par l'accueil splendide qui fut fait aux délégués et le puissant patronage

tesy, and for the facilities which they have invariably afforded me on the occasion of my many journeys; and I perform it finally in the name of the great Railway Companies of this country, which are governed by a body of gentlemen of the highest ability and skill, who have asked me to be their spokesman on this occasion. I welcome to England, the birthplace of railways, the delegates from the Continental States, and representatives, I think for the first time in the history of these congresses, from the two continents of America. (*Applause.*)

« Nearly seventy years ago the first railway that was constructed in the world — that between Stockton and Darlington — was opened. Five years later — in 1830 — under circumstances of the most tragic kind, the first railway constructed under parliamentary powers, and by money publicly subscribed, was inaugurated for passenger traffic between Manchester and Liverpool, and a ceremony of great interest and of greater promise was marred by the lamentable accident which led to the death of Mr. Huskisson. In the sixty years which have since elapsed the development of railways has progressed throughout the world, and we have fitly met here to-day to show our interest in that celebrated industry which, probably more than any other, has enhanced the wealth and fostered the commerce of the world, and has tended to promote international friendship and universal goodwill. (*Cheers.*)

« The Railway Congress had its origin in 1885, when a number of leading railway men met in Brussels to celebrate the jubilee of the Belgian railways.

« Sessions have since been held in Milan in 1887, and in Paris in 1889, and the last Congress, which assembled in St. Petersburg, in 1892, was made memorable by the splendid hospitality and great encouragement given to qui lui fut accordé par feu l'empereur de Russie. (*Applaudissements.*) Je crains, messieurs, que nous ne puissions vous offrir ni les beautés de l'Italie, ni les plaisirs de Paris, ni la réception magnifique qui a caractérisé la réunion précédente ; mais nous pouvons vous montrer Manchester, Liverpool, Cardiff et Crewe, ces grands centres industriels qui, je l'espère, vous offriront d'utiles enseignements et des exemples d'un travail fécond.

« Je me permets de dire même cela à nos amis des États-Unis (pays qui possède plus de la moitié du développement kilométrique du monde entier), ainsi qu'aux représentants des Indes et de nos colonies, qui ont aidé au développement des chemins de fer avec une activité et un succès qui méritent les plus chaudes félicitations. Le programme des discussions, si intéressant qu'il soit pour ceux qui, comme vous, sont compétents dans tous les détails techniques, aura également de l'attrait pour le public.

« Vous aurez à examiner non seulement le problème de l'accélération de la vitesse des trains de voyageurs, mais encore les moyens d'augmenter le confort par l'usage des voitures à intercirculation et par le perfectionnement du chauffage et de l'éclairage. Vous aurez également à examiner les moyens d'augmenter la sécurité des voyageurs par les perfectionnements apportés aux signaux, par les enclenchements des aiguilles, le calage des ponts tournants, etc.

« La traction électrique vous présente un champ relativement peu exploré jusqu'ici. Enfin, en vous occupant des chemins de fer économiques, vous serez en mesure de nous fournir des renseignements sur une question dont l'intérêt va croissant dans notre pays, et qui, en ce moment, est soumise aux délibérations de notre Parlement.

« Dans l'étude de toutes ces questions, vous apporterez non seulement votre grand savoir, mais vous serez, j'en suis convaincu, mus par

it by the late lamented Emperor of Russia. (*Applause.*) Gentlemen, I fear that we cannot promise you the beauty of Italy, the gaiety of Paris, or the magnificent reception which was accorded to you on the last occasion upon which you met; but we can show you in Manchester, Liverpool, Cardiff, and Crewe great centres of industry, from which I hope you will be able to derive useful knowledge, and in which you will be able also to see examples of the most beneficial work.

« I venture to say this even to our friends from the United States (a country which owns nearly half the railway mileage of the world) as well as to the representatives of India and our colonies, who have helped forward the work of railway development with a speed and a success which I think deserve the utmost commendation. (*Applause.*) The programme of discussions, interesting as it is to those who, like yourselves, know how to appreciate technical details, will be of interest likewise to the public.

« You will be asked to consider not only the acceleration of passenger trains, but the means of promoting the comfort of passengers by the use of vestibule or corridor cars, and by improved methods of heating and lighting. You will be also asked to consider arrangements for adding to the safety of the travelling public in such matters as signalling, interlocking, and the security of bridges.

« Electrical traction will present a field for your inquiries as yet comparatively unexplored, and on the subject of light railways you will be able to give us information on a question which is of growing interest in this country, and in the discussion of which our Parliament is at present engaged.

« To all these subjects you will bring, not only profond knowledge, but a desire, I am sure, to exchange information which must le désir d'échanger des enseignements dont tous ceux qui prendront part à vos discussions feront grand profit.

« Permettez-moi, pour finir, de vous souhaiter une fois encore la bienvenue au nom de notre Souveraine, au nom des compagnies anglaises et en mon nom personnel, et d'exprimer le désir sincère de voir cette session servir non seulement à reculer les limites des connaissances techniques, mais encore à créer de nombreuses et durables amitiés dont les années à venir feront connaître tout le prix. » (*Applaudissements vifs et prolongés.*)

Mr. Dubois, *président de la Commission internationale permanente :*

« Monseigneur,

« Que ma première parole exprime notre gratitude envers Votre Altesse Royale, qui nous fait l'honneur insigne d'inaugurer notre session, et qui daigne nous marquer ainsi le prix qu'Elle attache à l'institution du Congrès des chemins de fer et l'intérêt qu'Elle porte à ses travaux. Nous offrons à Votre Altesse Royale l'hommage respectueux de notre profonde reconnaissance et nous serions heureux que cet hommage adressé à l'héritier du trône pût remonter jusqu'à l'Auguste Souveraine qui, depuis cinquante-huit ans, préside aux destinées de la grande nation à laquelle nous devons aujourd'hui une large et cordiale hospitalité.

« Le gouvernement de Sa Très Gracieuse Majesté, qui a bien voulu nous accorder son puissant patronage, a droit aussi à nos remerciements. Je prie M. le président du Board of Trade de vouloir bien accepter ceux que j'ai l'honneur de lui adresser.

« Lorsque la proposition fut faite à Saint-Pétersbourg, en 1892, de tenir à Londres la session suivante du Congrès, cette proposition, à laquelle les délégués anglais donnèrent un appui aussi chaleureux qu'empressé, fut approuvée par un vote unanime et

be of advantage to all who take part in your discussions.

« Let me, in conclusion, once more welcome you on behalf of the Sovereign, the railway companies, and myself, and express the earnest hope that this Congress may be the means, not only of extending scientific and technical knowledge, but of founding also many pleasant and enduring friendships which will be valued in years to come. » (*Loud and prolonged applause.*)

Mr. Dubois, *president of the Permanent International Commission : —*

« Your Royal Highness,

« My first words must express our gratitude to your Royal Highness for doing us the signal honour of inaugurating our Session and of condescending to show in this manner the value your Royal Highness attaches to the institution of the Railway Congress and the interest your Royal Highness takes in our work. We would express to you the respectful homage of our profound gratitude, and we shall be happy if this homage addressed to the heir to the throne reaches the August Sovereign who has for fifty-eight years presided over the destinies of the great nation to which we are indebted to-day for their generous and cordial hospitality.

« The government of Her Most Gracious Majesty, which has been good enough to lend us its powerful support, has also a claim on our gratitude. I would beg the president of the Board of Trade to accept the thanks which I have the honour of expressing to him.

« When it was proposed at St. Petersburg in 1892 to hold the next session of the Congress in London, the English delegates supported the motion in a manner as cordial as it was sincere, and the resolution was passed unanimously and, I might almost say, with en quelque sorte d'acclamation. Il ne pouvait en être autrement, car la proposition répondait véritablement à un désir intime de tous les adeptes du Congrès. Ne devait-il pas être dans les vœux de tous de se voir, un jour prochain, réunis familialement dans ce pays que l'on a souvent appelé le berceau des chemins de fer, et dans lequel, depuis près de trois quarts de siècle, les ingénieurs du monde entier ont pu venir à toute époque recueillir des enseignements précieux sur la construction et l'exploitation des voies ferrées?

« Et puisque j'évoque en ce moment le souvenir de cette mission d'éducateurs qu'ont remplie les ingénieurs anglais, puis-je me permettre d'ajouter quelques mots personnels? A moi qui suis Belge, et qui dois à cette qualité la part que l'on m'a fait l'honneur de m'attribuer dans la gestion d'une œuvre belge par ses origines et par son foyer permanent, il m'est agréable de rappeler dans cette circonstance solennelle ce que durent à l'Angleterre les hommes d'État et les ingénieurs qui, sous l'impulsion d'un grand prince que la Belgique vénère et dont l'Angleterre aussi garde la mémoire, entreprirent il y a soixante et quelques années de doter leur patrie d'un ensemble de voies ferrées. La Belgique reconnaissante s'est associée avec empressement aux manifestations grandioses et touchantes à la fois qui ont marqué, il y a quatorze ans, la célébration du centenaire de l'illustre George Stephenson.

« C'est avec une grande satisfaction et une confiance absolue que la commission commença la préparation de la cinquième session. Elle ne tarda pas à trouver un grand allégement de sa tâche dans le concours plein d'initiative, de dévouement et de générosité que lui apporta une section locale d'organisation constituée par l'Association des compagnies de chemins de fer du Royaume-Uni et formée de leurs représentants pris parmi les plus autorisés. Cette section fut complétée par l'adjonction d'un délégué du Board of Trade

acclamation. It could not be otherwise, for, in fact, the proposal answered to the cherished desire of all the leading spirits of the Congress. Was it not natural that it should be the wish of all to meet one day in familiar intercourse in the country which has often been called the cradle of railways, and to which for nearly three-quarters of a century the engineers of the whole world have always been able to come and learn invaluable lessons both in the construction and in the working of railways?

« And while I am reminded of the position which English engineers have always held as pioneers, may I be allowed to allowed to add a few personal words? To me, who am a Belgian, and who owe to that fact the place of honour which has been conferred on me in the administration of a work which is Belgian both in its origin and in its permanent home, it is pleasant to remember on this memorable occasion how great was the debt owed to England by the statesmen and engineers who, under the guidance of a great king, whom Belgium reveres and whom England has not yet forgotten, undertook some sixty years back to endow Belgium with a complete system of railways. Belgium in gratitude joined with eagerness in the splendid, and at the same time touching, demonstrations which fourteen years ago marked the celebration of the centenary of the illustrious George Stephenson.

« It was with great satisfaction and absolute confidence that the Commission began the preparations for the fifth session. The Commission at once found its task greatly lightened by the energetic, unselfish, and generous support given by the local organising Committee which was appointed by the English Railway Companies' Association, and composed of some of its most influential members. The local Committee was completed by a representative of the Board of Trade, and it appointed as its secretary the author of et elle choisit comme secrétaire l'auteur de publications sur les railways anglais et écossais qui sont honorablement connues de tous les hommes de chemins de fer.

« Nous avons été heureux de voir placé à la tête de la section locale un des membres les plus aimés de la Commission permanente, l'un de nos coopérateurs de la première heure et de tous les instants qui porte dignement un nom célèbre dans l'histoire de l'industrie et de la science.

« La Commission, mettant à profit les leçons de l'expérience et se conformant à des désirs qui ont été généralement manifestés, a restreint plus qu'on ne l'avait fait jusqu'ici le nombre des questions à débattre au cours de la session.

« Les discussions qui ont été préparées par des rapports bien étudiés, dus à des spécialistes d'une compétence éprouvée, pourront dès lors recevoir toute l'ampleur dont elles sont susceptibles. Elles fourniront, nous en nourrissons l'espoir, des contributions importantes à la solution des problèmes nombreux et complexes que soulèvent la construction et l'exploitation des voies ferrées.

« Au nombre des questions qui méritent le plus d'attirer l'attention, je citerai celles qui ont pour objet :

« Le renforcement des voies;

« La construction des ponts métalliques;

« Les locomotives à grande vitesse;

« La traction électrique;

« Les signaux;

« Les manœuvres et les manutentions dans les gares;

« Le règlement international des réclamations;

« La généralisation du système décimal;

« Les facilités à accorder aux lignes à faible trafic;

« L'affermage des lignes secondaires.

« Ainsi les assises de Londres auront été largement fructueuses à l'égal de leurs devan-

works on the Railways of England and Scotland which every railway man knows and values.

« We rejoiced to see placed at the head of the Local Section one of the most esteemed members of the permanent Committee, our earliest and most constant supporters, one who worthily upholds the dignity of a name famous in the history of industry and of science.

« The Committee, profiting by the lesson of experience, and conforming to the wishes which have been generally expressed, has restricted the number of questions for discussion on this occasion beyond what has been the case heretofore.

« The carefully considered reports contributed by specialists of acknowledged competence will accordingly receive the most exhaustive discussion which their subject may require. They will furnish, we venture to hope, important contributions to the solution of numerous and complex problems which arise in the construction and working of railways.

« Among the questions which deserve special attention I will mention the following :—

« The strengthening of the permanent way.

« The construction of iron bridges.

« Express locomotives.

« Electric traction.

« Signals.

« Methods of station working.

« International rules for the settlement of disputes.

« The universal adoption of the decimal system.

« The relaxation of normal requirements for light railways.

« Their working by leasing Companies.

« Thus the London meeting will have been as fruitful as its predecessors in Brussels, cières de Bruxelles, Milan, Paris et Saint-Pétersbourg, et nous aimons à penser qu'il nous sera permis d'en clore le procès-verbal en y inscrivant ce témoignage :

« Par dix années d'efforts, de travaux poursuivis avec zèle, méthode et persévérance, le Congrès des chemins de fer a démontré sa raison d'être et prouvé sa vitalité. Il a sa place aujourd'hui marquée en bon rang parmi les institutions qui servent utilement la cause du progrès et de la civilisation ; il vivra, il est indestructible! »

Mr. Bryce,

« Altesse royale, mylords et messieurs,

« S. A. R. le prince de Galles a souhaité la bienvenue aux délégués du Congrès dans des termes dont la cordialité doit nous avoir tous frappés. Ce n'est pas un mince honneur pour le Congrès que l'héritier du trône qui, j'ose le dire, s'est toujours associé d'une façon si intime pour le plus grand bien du pays à toutes les entreprises et à toutes les solennités nationales, ait daigné accepter d'être le président d'honneur de cette session et de marquer, par sa présence, la sympathie qu'il porte à l'institution du Congrès. (*Applaudissements.*) Son Altesse Royale a dit tout ce qu'il fallait dire pour exprimer les sentiments de sympathie et d'intérêt avec lesquels ceux qui, dans ce pays, ont la conscience de la grande importance des questions de chemins de fer, prendront part à vos délibérations.

« Nous reconnaissons tout l'intérêt et la valeur, pour nous-mêmes et pour tous les pays, de réunions de personnes de la plus haute compétence qui viennent échanger les résultats d'une expérience consommée acquise dans les conditions les plus variées.

« Le véritable art et la vraie science sont toujours généreux. Ce qui distingue l'homme

Milan, Paris and St. Petersburg, and we venture to hope that in closing our report we shall be justified in writing this epitaph upon it : —

« By ten years of effort, of zealous, methodical and persevering work, the Railway Congress has justified its existence and proved its vitality. It has to-day a recognised and honoured position among those useful institutions which serve the cause of progress and civilisation; it will live; it is indestructible. »

Mr. Bryce,

« May it please your Royal Highness, my Lords, and Gentlemen,

« His Royal Highness the Prince of Wales has welcomed the delegates to this Congress in terms whose cordiality must have impressed you all. It is no slight honour to this Congress that the Heir to the Throne, who, if I may be permitted to say so, has so closely, and with so much benefit to the country, associated himself with all undertakings and occasions of national interest, has honoured the Congress by becoming its honorary president, and given it the countenance of his presence and sympathy on this occasion. (*Applause.*) His Royal Highness has said all that need be said to express the sentiment of sympathy and interest with which those who in this country are aware of the great importance of railway questions view and will follow the deliberations of this Congress.

« We recognise not only the interests but the value to ourselves, and to other countries not less, of gatherings of this nature gatherings of experts, where the fullest knowledge is brought together, and where the results of the ripest experience gained under a variety of conditions are interchanged.

« True science and true art are always generous. The note of the scientific man, as well scientifique aussi bien que l'artiste, qui s'est dévoué à son art parce qu'il l'aime, c'est qu'il désire faire partager les connaissances qu'il possède pour augmenter le fonds commun et pour faire faire un pas en avant au progrès général.

« Aux délégués étrangers qui sont ici réunis j'ose dire — et j'ose le dire non seulement en mon nom personnel mais au nom de celui, quel qu'il soit, qui pourrait occuper la position de président du *Board of Trade* — que le gouvernement de Sa Majesté fera tous ses efforts pour rendre leur visite à la fois agréable et intéressante. (*Très bien.*) Ils trouveront bien des choses dignes d'attirer leur attention dans les chemins de fer de la Grande-Bretagne, bien qu'il ne soit pas douteux que la situation de nos railways ne soit relativement un peu moins importante qu'il y a trente ans, quand notre première ère de la construction des chemins de fer tirait à sa fin. Nous avons donné le signal du départ et maintenant on peut admettre que nous avons terminé la construction ou presque terminé la construction de nos grandes lignes principales. D'après les meilleurs chiffres que j'ai pu obtenir, le capital total engagé dans les chemins de fer de la Grande-Bretagne est de 25 milliards de francs (1,000 millions de livres sterling), soit d'un sixième du capital total engagé dans les chemins de fer du monde entier. Le nombre de voyageurs transportés annuellement dans ce pays est, en chiffres ronds, de 900 millions, le nombre de tonnes transportées annuellement est de 330 millions (325 millions de tonnes anglaises), le nombre d'employés de chemins de fer est à peu près de 400,000. Notre kilométrage total est seulement de 34,000 kilomètres (21,000 milles), tandis que celui de toutes les possessions de Sa Majesté Britannique est de 113,000 kilomètres (70,000 milles) et celui du monde entier est de 644,000 kilomètres (400,000 milles), dont à peu près la moitié se rapporte aux États-Unis et à l'Amérique du Nord, comme vous l'a dit Son Altesse Royale. La

as of the artist who follows his art because he loves it, is that of wishing to communicate the knowledge he possesses to enlarge the general store and to advance the general progress.

« To the Foreign delegates who are here present I will venture to say that so far as Her Majesty's Government can (and this I will venture to say on behalf of whoever may occupy the position of president of the Board of Trade) Her Majesty's Government will do its best to make their visit both pleasant and profitable. (*Hear, hear.*) They will find much that is interesting in British Railways, although no doubt the position of British Railways is relatively somewhat less important than it was 30 years ago, when our first great era of railway construction was drawing to its close. We had the start, and now we may be taken to have completed the making, or nearly completed the making, of our great trunk lines. According to the best figures I have been able to obtain, the total capital invested in British Railways is about one thousand millions sterling (25,000,000,000 francs) being about one sixth of the total capital invested in railways in the world. The number of passengers carried, speaking again in round figures, annually in this country is 900,000,000; the number of tons carried annually is 325,000,000 (330,000,000 metric tons); the number of the railway employes is about 400,000. Our total mileage however is only 21,000 miles (34,000 kilometres) as against 70,000 miles (113,000 kilometres) in the whole of Her Majesty's Dominions, and as against 400,000 miles (644,000 kilometres) in the world at large nearly one half of which, as your Royal Highness has submitted, is to be found in the United States and North America. Britain is a comparatively small area, and our lines are short if they be compared with some of the great lines of Russia, or that great Canadian Pacific line which nearly reaches 3,000 miles (4,800 kilo-

Grande-Bretagne est un pays comparativement petit et nos lignes sont peu étendues si on les compare à quelques-unes des grandes lignes de la Russie ou au Grand Canadian Pacific, qui atteint presque 4,800 kilomètres (3,000 milles). Cependant nous pouvons montrer ici à nos visiteurs étrangers quelque chose qui sera plein d'intérêt pour eux; nous pouvons leur montrer des travaux de génie remarquables, tels que le grand pont du Forth et le tunnel de la Severn; nous pouvons leur montrer un service des trains singulièrement complet et bien organisé, qui donne des facilités qui ne sont données nulle part à une population très dense et qui, j'ose l'affirmer, combine la vitesse et la sécurité à un degré qui n'a pas été atteint jusqu'ici. Et je n'omettrai pas de remarquer, à propos de la sécurité, que dans ce pays le gouvernement et les compagnies de chemins de fer se sont beaucoup occupés de la question de la sécurité du personnel des chemins de fer et que nous espérons que cette question qui, sans aucun doute, a toutes les sympathies étrangères, comme elle a la sympathie de la Grande-Bretagne, aura une place dans vos discussions.

« Si nous avons beaucoup de choses à vous montrer, nous avons aussi bien des choses à apprendre de nos visiteurs étrangers. Des systèmes divers d'exploitation sont représentés ici. La France, par exemple, bien que la plupart de ses chemins de fer soient dans les mains de compagnies privées, a vu son gouvernement prendre une part active dans les progrès de ses chemins de fer. En Russie, l'exploitation des chemins de fer appartient presque entièrement à l'État. En Italie, les chemins de fer ont été affermés par l'État et forment des entreprises privées. L'Autriche-Hongrie a essayé les deux systèmes et sera capable de nous donner des renseignements précieux sur leurs résultats.

« D'un autre côté, la Belgique, aussi bien que la France et l'Italie, pourront nous enseigner beaucoup de choses hautement intéressantes et importantes relativement à la question à

metres). Nevertheless we can show our foreign visitors something here which will be full of interest to them. We can show them remarkable engineering works, such as the great Forth Bridge and the Severn Tunnel; we can show them a singularly complete and highly organised service of trains which gives facilities not elsewhere given for a very dense population, and which I think I may say combines speed with safety in a manner hitherto unprecedented. And I will not omit to notice, *apropos* of the question of safety, that in this country we have been much occupied, both the Government and the Railway Companies, with the question of the safety of the railway work people, and that we hope that that question which I have no doubt engages foreign sympathy, as well as it does British sympathy, will find a place among your deliberations.

« If we have much to show, we have also, gentlemen, much to learn from our foreign visitors. Various systems of railway management are represented here. France, for instance, although most of her railways are in the hands of private companies, has seen her government take a very active share in the work of railway development. In Russia, the railway management nearly entirely belongs to the State. In Italy, the railways have been leased by the State as private undertakings. Austria-Hungary is trying both schemes and will be able to give us valuable information as to their results.

« On the other hand from Belgium, as well as from France and Italy, we may learn much that is highly interesting and important upon the question to which your Royal laquelle Votre Altesse royale a fait allusion, celle de la construction et de l'exploitation économiques des chemins de fer légers, lesquels pourront non seulement donner quelque aide à l'agriculture, mais aussi faire quelque chose pour activer la vie dans nos villages et pour essayer d'introduire dans les bourgs et les districts ruraux de notre pays quelques-unes des industries actuellement trop concentrées dans nos grandes villes. La Suisse, avec son bureau international de chemins de fer qui prononce des sentences sur les litiges entre les chemins de fer, pourra nous donner un exemple de la manière dont une institution de cette espèce pourrait fonctionner dans un but plus industriel et plus commercial. Non seulement les États-Unis pourront nous enseigner beaucoup de choses utiles, en ce qui concerne la traction électrique, qui y a atteint, je pense, un plus grand développement que partout autre part de ce côté de l'Atlantique, mais nous aurons aussi beaucoup de renseignements intéressants à obtenir des hommes qui sont à la tête de ces grands réseaux de chemins de fer qui traversent, sur plus de la moitié de sa profondeur, le grand continent et qui ont des relations fréquentes et souvent si délicates avec les autorités civiles des districts qu'ils parcourent et sur la prospérité desquels ils ont une influence si directe. Quelques-unes de ces questions, Votre Altesse Royale et vous, messieurs, vous ne les trouverez point à l'ordre du jour du Congrès; cependant, elles sont, je pense, pleines d'intérêt pour nous et nous profiterons de l'occasion que nous donne la présence des délégués étrangers pour apprendre quelque chose sous ce rapport. Nous profiterons de l'occasion que nous donne la réunion de tant de gens capables et expérimentés pour nous faire ouvrir les trésors de renseignements que chaque contrée peut nous apporter.

« Ce que les chemins ont fait à la fois pour les convenances privées et le plaisir de chacun de nous, ainsi que pour la prospérité commerciale de nos pays respectifs, mes paroles

Highness has referred, — the question of cheaper construction and the working of light railways, which may not only give some measure of aid to agriculture but may also do something to quicken life in our villages, and to endeavour to bring some of the industries, now too much concentrated in great towns, into the villages and rural districts of our country. Switzerland again with its International Railway Bureau, which is engaged in the settlement of railway controversies, may give us an example of how an international system of that kind may be worked in a wider industrial and commercial field. From the United States we may learn, not only a great deal that is valuable with regard to electric traction, which has been carried to a higher point there I think than anywhere on this side of the Atlantic, but we shall also have many interesting data from the gentlemen who are in control of those great railway systems which stretch more than half way across the great continent, and which are brought into frequent and sometimes very delicate relation with the civil authorities of the districts they traverse, and whose prosperity they so materially affect. Some of these topics, your Royal Highness and gentlemen. will not be found in the Agenda of the Congress; nevertheless they are, I think, full of instruction for us, and we shall value the opportunity which the presence of foreign delegates will give us of learning something about them; we shall value the opportunity which the meeting of so many capable and experienced men affords of learning what stores of knowledge each country has to contribute.

« How much railways have done both for the private convenience and pleasure of all of us, and for the commercial prosperity of our respective countries, it needs no words of mine to seraient insuffisantes pour le dire, mais j'aurais voulu, si possible, m'étendre un peu sur les résultats futurs du développement des chemins de fer. Le sujet cependant est trop vaste. L'accroissement de moyens de communication par terre, qui sont déjà rapides et économiques, ont changé toutes les traditions du commerce, de la politique et de la civilisation sous toutes ses formes. Il y a un vers d'un fameux poète ancien qui m'a frappé et dans lequel il est question des fils du dieu du feu qui, en créant des routes, ont dompté la terre; et nous pouvons dire, messieurs, que dans la dernière moitié de ce siècle les routes de fer et les enfants du dieu du feu ont changé la face de la terre. Ils ont créé un énorme développement du trafic et non seulement du trafic par terre, mais aussi du trafic maritime; car en apportant à bon marché les matières premières et les objets manufacturés au bord de la mer, ils ont accru immensément le développement des transports par eau. Ils ont permis aux peuples civilisés de connaître beaucoup mieux qu'ils ne pouvaient le faire auparavant, les caractères et les mœurs les uns des autres et de prouver plus complètement comment le bien-être de chacun est lié au bien-être de tous. Dans l'Inde, ils ont fait beaucoup, ils font et ils feront encore davantage pour effacer ces distinctions de caste qui y étaient devenues plus fortes que les différences de nationalité en Europe. Ils ont ouvert l'Afrique qui était, il y a peu de temps, inexplorée et inconnue; ils pénètrent dans les déserts de l'Asie; ils ont rendu le monde entier d'aujourd'hui virtuellement plus étroit que celui que connaissaient nos ancêtres il y a vingt ans.

« Votre Altesse Royale et vous, messieurs, vous trouverez ces résultats bien vastes et il y en a que l'on ne peut encore apercevoir qu'à moitié parce que nous ne pouvons les percevoir que comme un mirage à travers les brouillards de l'avenir; mais ils ajoutent de la dignité et de l'importance même à ces détails de l'art de l'ingénieur et de la conduite du

say. But I should have liked, had it been possible, to dwell a little upon the wider and further results of railway extension, — the subject, however, is too vast. The growth of a means of land communication which is at once rapid and cheap has changed all the traditions of commerce, of politics of government, and I may say, of civilisation in all its forms. There is a striking line in a famous ancient poet in which he speaks of the sons of the Fire God who in making roads have made the wild earth tame; and we may say gentlemen, that within the last half century iron roads and the children of the Fire God have changed the face of our earth. They have induced an enormous development of trade, and not only of land trade but of ocean trade also; for the cheap bringing of the products and of manufactures to the sea board has immensely increased the development of water carriage also. They have enabled the civilised Peoples to know, far better than they previously could, the characters and habits of life of one another, and to realise more fully how the welfare of each is bound up with the welfare of all. In India they have done much, and are doing, and will do, still more to break down those distinctions of caste which there have been even stronger than the differences of nationality in Europe. They are opening up Africa, so lately unexplored and unknown; they are penetrating the deserts of Asia; they are making the whole great world of our time virtually smaller than that little world which our ancestors knew 20 centuries ago.

« These, your Royal Highness and Gentlemen, are vast results; they are results which are still only half perceived as they loom on as through the mists of the future: but they add dignity and importance even to those details of engineering and traffic management with which the sections of this Congress will be concerned; and they make trafic dont les sections du Congrès auront à s'occuper et ils nous font percevoir quelles conséquences immenses et d'une portée considérable peuvent avoir dans les siècles à venir les efforts que vous faites et les efforts qui seront faits par cette vaste armée de travailleurs du chemin de fer du monde entier que les membres du Congrès représentent.

« Messieurs, je n'ajouterai qu'un seul mot. Ces grands résultats que nous prévoyons nous font admirer votre habileté et votre énergie; ils nous associent intimement à vos visées et à vos aspirations. Ils nous donnent d'autant plus de raison de nous réjouir de vous voir parmi nous dans la capitale de l'empire britannique, et de vous souhaiter de tout notre cœur le succès et la prospérité de votre œuvre. » (*Applaudissements.*)

(*S. A. R. le prince de Galles se retire avec sa suite; l'assemblée, debout, l'accompagne de ses applaudissements dans un mouvement unanime de respectueuse sympathie.*)

Quelques instants après, la séance est reprise sous la présidence de Mr. Dubois.

Mr. Dubois propose la nomination de Lord Stalbridge comme président et de Sir Henry Oakley comme secrétaire général de la session. (*Acclamations.*)

(*Lord Stalbridge, accompagné de Sir Henry Oakley, prend place au bureau.*)

Lord Stalbridge. — « Messieurs, je ne veux pas abuser de vos moments, car après les éloquents discours de S. A. R. le prince de Galles et du président du « Board of Trade », il me reste peu de chose à vous dire, si ce n'est de vous souhaiter la bienvenue au nom des chemins de fer anglais. Déjà ils l'ont fait, l'un comme occupant le rang le plus élevé dans ce pays, et le président du Board of Trade au nom du gouvernement. C'est au nom d'un intérêt privé que les Compagnies de chemins

us feel what immense and for reaching consequences may in the centuries to come hang upon the efforts you are making, and hang also upon those which are being made by that vast army of railway workers throughout the world whom the delegates here present represent.

« Gentlemen, I will say only one word more. While these consequences which we foresee lead us to admire your skill and your energy, they associate us very closely with your aims and your aspirations, and give us further reasons for rejoicing to see you here among us in the capital of the British Empire, and for wishing, as we heartily wish to-day, success and prosperity to your labours. » (*Applause.*)

(*H. R. H. the Prince of Wales left the Hall amidst applause, accompanied by his suite, all present rising.*)

A few minutes afterwards the proceedings were continued under the presidency of Mr. Dubois.

Mr. Dubois proposed the nomination of Lord Stalbridge as acting president, and of Sir Henry Oakley as general secretary of the session. (*Cheers.*)

(*Lord Stalbridge took the chair, accompanied by Sir Henry Oakley.*)

Lord Stalbridge. — « Gentlemen, — I will detain you but a very few moments, for after the eloquent speeches of his Royal Highness the Prince of Wales and the President of the Board of Trade, to which you have just listened, little remains for me to say, except to welcome you on behalf of the railway companies of this country. You are assured of your welcome from those two gentlemen — the highest in the land and the President of the Board of Trade as representing the de fer le font à leur tour, de tout cœur, à votre arrivée à Londres.

« Je sais que ce n'est pas à mes qualités personnelles que je dois l'honneur d'occuper le poste élevé que vous avez bien voulu me confier aujourd'hui, mais parce que j'ai été choisi par mes collègues comme représentant un chemin de fer que j'ose appeler l'un des premiers du pays, sinon du monde entier.

« Mes prédécesseurs, dans ce fauteuil, ont toujours été des hommes renommés pour des connaissances techniques plus étendues que je ne puis prétendre posséder; leurs noms sont bien connus dans les annales de l'exploitation des chemins de fer; mais, comme vous le savez bien, en Angleterre les administrateurs de chemins de fer ne sont pas choisis à cause de leurs connaissances des détails techniques, mais pour d'autres raisons. Pour les détails techniques de l'exploitation des railways, nous nous reposons sur ces hommes habiles, experts dans la profession, sur lesquels nous devons nous reposer et qui sont capables de nous assister, et auxquels nous confions l'exploitation technique du réseau entier. C'est sur leur intelligence et leur énergie que nous nous reposons, et j'ai la confiance que dans les visites et dans les excursions que vous allez faire, vous pourrez juger par vous-mêmes de leur talent et de leur habileté; car vous pouvez être assurés d'une chose, c'est que rien ne sera négligé par les compagnies de chemins de fer pour faire votre séjour dans cette île aussi intéressant et aussi agréable que possible. (*Applaudissements.*) Vous ne devez pas nous en vouloir si le temps n'est pas parfait, parce que, comme vous le savez, l'Angleterre est proverbiale pour l'inconstance de son climat. En ce moment, nous avons certainement du beau temps, et je crains que dans ce bâtiment vous ne trouviez qu'il ne règne une chaleur un peu plus forte que celle à laquelle beaucoup

Government — and the railways companies, as being in this country a private interest, now welcome you most heartily on this your first appearance in London.

« I feel that the honourable position in which you have been good enough to place me today is not owing to any special knowledge or ability of my own, but it is in consequence of my having been elected by my colleagues to take the chair of one which I think I may modestly call, at least one of the leading railways of this country, if not of the world.

« My predecessors in this chair have always been famous for more technical knowledge than I can pretend to possess; their names are well known in the annals of railway working; but, as you are very well aware, in England directors are not chosen on account of their knowledge of technical details, but they are chosen for other reasons. For the technical details in the working of the railway we depend upon those able gentlemen experts in the profession on whom we must depend, and to whom we look for the actual technical working of the whole line. It is upon their skill and energy that we depend, and I trust that in the visits and excursions you will shortly make you will be able to judge for yourselves of their skill and ability; for you may rest assured of this : that nothing shall be wanting on the part of the railway companies to make your stay in this Island as interesting and as agreeable as possible. (*Applause.*) You must not blame us if the weather is not perfect, because, as you are aware, England is proverbial for the fickleness of her climate. At present we are having certainly fine weather, and I am afraid that in this building you may feel it a little warmer than even some of you, gentlemen, are accustomed to; but still I trust that the weather will be such as to render your excursions over our country agreeable and pleasant.

de vous, messieurs, ne sont accoutumés ; j'espère, cependant, que le temps sera tel qu'il rendra vos excursions à travers le pays agréables et amusantes.

« Comme vous l'a très bien dit Mr. Bryce, nous sommes fiers d'avoir été le berceau de la locomotive; car je pense qu'il est universellement admis que George Stephenson, s'il n'a fait aucune découverte remarquable, a été le premier à adapter la vapeur aux besoins de la locomotive, si l'on peut s'exprimer ainsi, et l'on nous pardonnera de tirer quelque fierté de ce que ce don fait à la civilisation soit dû à l'esprit inventif d'un Anglais; mais les Anglais se réjouissent surtout de ce que ces résultats bienfaisants ne sont pas restés confinés dans leurs îles, et de ce que le monde civilisé tout entier a profité des fruits de son génie, de son énergie et de sa persévérance, en présence des grandes difficultés de l'époque. Maintenant, beaucoup de nos amis étrangers admireront, j'ose le dire, la haute pression à laquelle les railways anglais sont toujours exploités. S'il est une chose que les Anglais voudraient pouvoir faire et ne peuvent faire, c'est de fermer les portes d'une station cinq ou dix minutes avant le départ du train, ce qui est une coutume très fréquente à l'étranger; mais vous verrez les gens arriver à la gare au dernier moment avant l'heure du départ réglementaire, avec leurs bagages et tout le reste; toutefois, l'habitude et l'habileté de nos employés permettent de faire face à cela et je pense que vous serez surpris de la ponctualité avec laquelle nos trains les plus chargés quittent leur point de départ dans la métropole et dans les autres grandes villes à l'heure réglementaire.

« Je voudrais vous exposer quelques faits relatifs aux chemins de fer anglais et que Mr. Bryce n'a fait qu'effleurer. Je voudrais établir une comparaison et je suis à même de le faire avec les résultats d'il y a cinquante ans. Cette comparaison entre 1843 et 1893 mérite bien d'attirer quelques instants votre attention. Mr. Bryce a dit que le nombre de

« Now, as Mr. Bryce has truly said, we pride ourselves upon being the home of the locomotive; for I think it is universally admitted that George Stephenson was the one man who without making any remarkable discovery, if one may say so, was the one to adapt steam for locomotive purposes; and it is a pardonable pride with us that this boon to civilisation sprang from the brain of an Englishman. But Englishmen rejoice in the knowledge that its beneficent results are not confined to these Islands, but that the whole civilised world has shared in the fruits of his genius, energy, and perseverance, in the face of great difficulties at the time. Now many of our foreign friends will I dare say admire the high pressure at which English railways are always worked. If there is one thing more than another that Englishmen would like to do and cannot do, it is to shut the doors of a station five or ten minutes before the train leaves, which is very frequently the habit abroad; but you will see people come up to the station at the very moment before the train is advertised to leave, with their baggage and everything else; but habit and custom and the skill of our employes is enabled to deal with that, and I think you will be surprised at the punctuality with which our heavily loaded trains leave the termini and stations in the Metropolis and other large towns at the advertised moment.

« I should like to lay before you a few facts on which Mr. Bryce touched lightly with regard to English Railways. And I would just compare them, and I am enabled to do so, with what was the result exactly 50 years ago. The comparisons between 1843 and 1893 are well worthy of your attention for a few moments. Mr. Bryce said that the number of voyageurs du Royaume-Uni est à peu près de 900 millions, mais il a complètement oublié qu'à côté de ces 900 millions de voyageurs, il n'y a pas moins de 1,574,000 cartes d'abonnement émises pour des parties plus ou moins longues de l'année, chacune desquelles, d'après notre estimation, est employée en moyenne 250 à 300 fois ; de telle sorte que si vous voulez bien multiplier 1,574,000 par 250 et ajouter le résultat aux 900 millions, vous aurez une idée réelle du nombre de voyageurs que nous transportons dans ce pays. (*Applaudissements.*)

« Les recettes du trafic des voyageurs se sont élevées à 757,925,000 francs (£ 30,317,000); le tonnage des marchandises (je parle de l'année 1893) s'est élevé à 298 millions de tonnes (293,290,000 tonnes anglaises), avec une recette de 1,024,850,000 francs (£ 40,994,000); vous voyez ainsi que notre trafic des marchandises rapporte à peu près 250 millions de francs (£ 10 millions) de plus que notre trafic des voyageurs. Les recettes totales des chemins de fer du Royaume-Uni, y compris les rentes et les recettes diverses, se sont élevées à 2,015,797,300 francs (£ 80,631,892) et les dépenses d'exploitation ont atteint 1,142,377,975 francs (£ 45,695,119), ou 57 p. c. des recettes totales; la différence, représentant la recette nette, s'est élevée à 873,419,325 francs (£ 34,936,773), ce qui serait suffisant pour payer en moyenne un intérêt annuel de 3.59 p. c. du capital. Le nombre total de kilomètres parcourus par les trains dans le Royaume-Uni a été de 519,452,460 (322,841,802 milles) et le nombre total de machines possédé par les différentes compagnies était de 18,032, de telle sorte que chaque machine a parcouru en moyenne 29,806 kilomètres (17,903 milles) dans l'année; on peut dire aussi que si l'on additionne les parcours effectués par toutes les machines en quarante minutes on obtient un parcours total égal au tour du monde. Ce sont des chiffres considérables, mais ils sont insignifiants si nous les comparons à ceux des che-

passengers in the United Kingdom was something like 900,000,000 but there he totally forgot that besides those 900,000,000 passengers there were no less than 1,574,000 season tickets issued for varying periods during the year, each of which was, according to our computation, used between 250 and 300 times; so that if you will kindly multiply 1,574,000 by 250, and add that to the 900,000,000 you will then have a real idea of the number of passengers that we do carry in this country. (*Applause.*)

« The receipts for passenger traffic amounted to £ 30,317,000 (757,925,000 francs); the tonnage of goods and mineral traffic (I am speaking of the year 1893) amounted to 293,290,000 tons (298,000,000 metric tons), the receipts from which amounted to £ 40,994,000 (1,024 millions 850,000 francs); so that you will see that our goods traffic brings in more by some £ 10,000,000 (250,000,000 francs) than our passenger traffic in this country. The total receipts of the railways in the United Kingdom, including rents and other items amounted to £ 80,631,892 (2,015,797,300 francs) and the working expenditure came to £ 45,695,119 (1,142,377,975 francs) or 57 per cent of the total receipts. The balance representing the net profit amounted to £ 34,936,773 (873 millions 419,325 francs), or sufficient to pay on an average 3·59 per cent per annum on the paid up capital. The total number of miles travelled by trains in the United Kingdom was 322,841,802 (519,452,460 kilometres); and the total number of engines possessed by the various companies was 18,032 so that each engine ran on the average 17,903 miles (29,806 kilometres) in the year. Taking the whole of the engines collectively it may be said that they run once round the world in every forty minutes. Those are large figures, but if we look at the railways of the civilised world, why those figures are absolutely dwarfed. Some three or four years ago it was computed that the amount of money mins de fer du monde civilisé. On a calculé, il y a trois ou quatre ans, que le capital engagé dans les chemins de fer du monde était approximativement de 150,000 millions de francs (6,000 millions sterling), et que les recettes de l'exploitation étaient à peu près de 12,500 millions de francs (500 millions sterling) par an. Le total du kilométrage des railways du monde nous a été donné par Mr. Bryce ; je ne vous en reparlerai donc plus, mais il y a un fait curieux, c'est qu'il y a dans le monde environ 120,000 locomotives en feu, et si l'on peut admettre que chacune d'elles parcourt en moyenne 32,180 kilomètres (20,000 milles) par an, nous obtiendrons un parcours de 3,861,600,000 kilomètres (2,400,000,000 milles) par an, soit vingt-six fois la distance entre la terre et le soleil. Ces chiffres sont absolument trop grands pour que l'intelligence humaine puisse les saisir. Mais on doit s'émerveiller que tout ce développement de l'industrie des chemins de fer a été l'œuvre d'une seule génération, car c'est un fait peu douteux qu'il y a encore beaucoup de personnes qui peuvent se souvenir d'avoir voyagé en coche ou en diligence avant l'existence des chemins de fer. L'un des vice-présidents du London and North Western Railway, Mr. Cawkwell, avait 23 ans lorsque le chemin de fer de Liverpool à Manchester, le premier railway ouvert au transport public des voyageurs, fut inauguré en 1830. Mais il y a un autre sujet auquel Mr. Bryce a fait allusion et sur lequel je voudrais vous donner quelques chiffres, et, s'il y a un sujet et s'il est un motif pour lequel les hommes qui sont chargés de l'exploitation des chemins de fer en Europe ou au dehors peuvent s'adresser de légitimes congratulations, c'est que grâce au génie inventif de leurs ingénieurs et à la multiplication des appareils de signaux et d'enclenchements construits dans un but de sécurité, les accidents qui ont coûté la vie à des voyageurs sur les chemins de fer ont été, dans les dernières années, réduits presque au minimum.

invested in the railways of the world was approximately six thousand millions sterling (150,000 millions of francs), and that the traffic receipts were nearly five hundred millions sterling (12,500 millions of francs) per annum. The total mileage of the railways of the world Mr. Bryce has given you, so I will not go over that again; but this is a curious fact : that there are in the world about 120,000 locomotive engines in steam, and if it may be assumed that each of those runs on the average 20,000 miles (32,180 kilometres) in the year we shall get a train mileage of about 2,400,000,000 of miles (3,871,600,000 kilometres) in the year, or 26 times the distance between the Earth and the sun. These figures are almost too vast for the human intellect to grasp; but the most marvellous reflection is, that all this development of railway enterprise has been the work of a single generation; for it is an undoubted fact that there are many persons living who can remember travelling by coach or stage wagon before the railways existed. One of the Deputy Chairmen of the London and North Western Railway, Mr. Cawkwell, was twenty-three years of age when the Liverpool and Manchester Railway, the first public passenger railway made, was opened for traffic in 1830. But there is another subject to which Mr. Bryce alluded, and on which I should just like to give you a very few figures, and that is, that it there is one legitimate subject of congratulation amongst those who are responsible for the working of railways whether in Europe or abroad, it is, that owing to the inventive genius of their engineers, and the multiplication of the signalling and interlocking appliances designed for safety, the loss of life amongst passengers travelling by railway has been reduced in recent years to almost a minimum.

« Dans l'année 1870, sur les chemins de fer du Royaume-Uni, il a été tué un voyageur sur 4,700,000 et il a été blessé un voyageur sur 280,000 par des accidents de trains; en 1893, malgré le grand accroissement de la vitesse des trains et l'encombrement plus grand des chemins de fer provenant de l'augmentation du trafic, il n'a été tué qu'un voyageur sur 8,237,000 — c'est-à-dire à peu près la moitié — et il n'a été blessé qu'un voyageur sur 715,000. Il est donc un fait que, s'il faut en juger seulement par la statistique, là où un homme est le plus en sûreté, c'est dans une voiture d'un train express.

« Maintenant, messieurs, je vais enfin arriver à la comparaison promise. Cinquante ans auparavant, en 1843, treize ans après l'ouverture du premier chemin de fer public, les recettes de l'exploitation des chemins de fer du Royaume-Uni, au lieu d'être de plus de 2,000 millions de francs (80 millions sterling), comme en 1893, étaient seulement de 112 1/2 millions de francs (4 1/2 millions sterling) à peu près. Le nombre de tonnes transportées n'était pas noté à cette époque, mais le nombre de voyageurs était d'environ 23 1/2 millions. Le capital dépensé pour tous les chemins de fer ouverts au trafic à cette époque était de 1,637,500,000 francs (65,500,000 sterling), et le kilométrage des chemins de fer, qui s'élève aujourd'hui à 32,200 kilomètres (20,000 milles), était alors de moins de 3,220 kilomètres (2,000 milles).

« Telle est la comparaison rapide qu'il m'a été possible de vous donner pour la dernière période de cinquante ans; mais qui peut prévoir ce que l'homme qui aura l'honneur d'occuper dans cinquante ans le poste que j'ai en ce moment, sera mis à même de vous dire? Prendra-t-il un ballon pour quitter son fauteuil ou montera-t-il dans un train marchant à la vitesse de 240 kilomètres (150 milles) à l'heure et quel sera le moteur futur du monde? Actuellement, pour autant que les ingénieurs puissent le dire, l'électricité semble destinée à jouer un rôle très important sous ce rapport;

« In the year 1870 on the railways of the United Kingdom, 1 passenger in about 4,700,000 was killed, and 1 in about 280,000 was injured by accidents to trains; but in 1893, notwithstanding the great increase in the speed of the trains, and the more crowded state of the railways arising from the growth of traffic, only 1 passenger in every 8,237,000 was killed — that is, nearly half what it was before —and 1 in 715,000 was injured. It is a fact that, judging from statistics alone, the safest place that a man can be in is in a carriage on an express train.

« Now, gentlemen, I would just give you this comparison : that just 50 years ago, in 1843, thirteen years after the opening of the first public railway, the total traffic receipts on the railways of the United Kingdom instead of being more than eighty millions sterling (2,000 millions of francs), as they were in 1893, were only about four and a half millions (112 1/2 millions of francs). The number of tons carried was not at that time recorded, but the number of passengers carried was about 23 1/2 millions — the paid up capital of all the railways at that time opened for traffic was 65 1/2 millions sterling (1,637,500,000 francs) and the mileage of the railways which has now grown to 20,000 miles (32,200 kilometres) was then less than 2,000 miles (3,200 kilometres).

« Such is the short comparison I have been able to give you for the last 50 years; but who can tell what the gentleman who will occupy the honourable position, which I at this moment hold, 50 years hence will be enabled to say ? Will he take a balloon then to leave this place, or will he go on the rails at the rate of 150 miles (240 kilometres) an hour, or what will be the future motor of the world ? At present, so for as engineers can say, electricity seems to be bound to play a very important part with regard to that; but with regard to that, what is to mais à ce propos, quelle sera la force motrice, si vous me permettez d'employer ce mot, qui produira l'électricité? Sera-ce encore le charbon? Nous constatons que la consommation du charbon dans ce pays s'accroît avec une grande rapidité. Je trouve qu'en 1854, qui est la première année pour laquelle on ait recueilli des statistiques complètes à ce sujet, l'extraction totale du charbon dans le Royaume-Uni était de 65,696,000 tonnes (64,661,000 tonnes anglaises). En 1893, l'extraction totale a été de 166,954,000 tonnes (164,325,000 tonnes anglaises). Eh bien, je suis heureux de vous dire que nous ne sommes pas inquiets en ce moment de la diminution de nos gisements de charbon; il n'est point douteux que dans les pays qui ont été ouverts récemment, — je fais plus particulièrement allusion au Japon, — de vastes mines de charbon ont été trouvées, et au fur et à mesure que le monde s'ouvrira davantage, on découvrira qu'il y a encore des dépôts ignorés de charbon, qui est, en somme, du soleil en bouteille pour l'usage futur du monde.

« Les chemins de fer, comme vous le savez, messieurs, étendent partout de nouvelles lignes. L'Afrique présentera, sans aucun doute, prochainement, avant que de nombreuses années se soient écoulées, le même aspect, sous le rapport des chemins de fer, que le continent américain présente actuellement. Il est certain que ces réunions du Congrès, si utiles qu'elles aient été dans le passé, seront encore plus utiles dans l'avenir, et que vos délibérations aideront matériellement à l'extension des chemins de fer, qui, pour autant que nous puissions le dire à l'heure actuelle, sont la grande force civilisatrice du monde, car partout où l'on voit apparaître la civilisation, un chemin de fer la précède ou la suit. (*Applaudissements.*)

« Je suis certain que les délibérations du Congrès n'auront pas une importance moindre que celles des précédents. J'ai la confiance que vous tirerez quelque profit des excursions qui ont été soigneusement organisées en vue

be the motive power (if I may use that word) to produce electricity? Is it to be coal? because we find that the consumption of coal in this country is increasing very rapidly. I find that in 1854, which is the earliest year for which complete mineral statistics were recorded, the total output of coal in the United Kingdom was 64,661,000 tons (65 millions 696,000 metric tons). In 1893, the total output was 164,325,000 tons (166 millions 954,000 metric tons). Well, I am glad to say that we are not anxious at this moment as to the diminution of our deposits of coal; but there is no doubt that in countries which have been opened up lately, — I can allude more particularly to Japan — large coal fields have been found; and the more that the world is opened up the more it will be found that there are deposits of coal, which is really bottled sunshine when all is said and done, in various parts of the world stored up for the future use of the world.

« Railways as you know, gentlemen, are increasing everywhere. Africa will shortly present, before many years are over, the same aspect of Railways over it, doubtless, that the American continent presents now; and there is no doubt whatever that these congress meetings, useful as they have been in the past, will be still more useful in the future, and that your deliberations will aid materially in the spread of railways throughout the world, which, so far as we can tell at this present moment are the great civilising power of the world; for wherever civilisation is found to go a railway is bound either to precede or follow. (*Applause.*)

« I feel certain that the deliberations of this session will not be of less importance than those which have preceded it. I trust that you will take advantage of the excursions which have been carefully laid out for you to de vous faire voir nos grands centres de l'industrie des chemins de fer, et j'espère, quand nous nous séparerons, que les délégués emporteront un bon souvenir de l'hospitalité des Compagnies du Royaume-Uni. Je puis vous assurer que nous ferons tout ce qui est possible pour rendre votre visite agréable, et j'espère le prouver.

« J'ai maintenant un autre devoir à remplir, c'est de prier les délégués présents de se rendre dans les locaux des sections pour y élire leurs présidents et faire les premiers pas nécessaires pour inaugurer leurs travaux. » (*Applaudissements.*)

Mr. Dubois. — « Les membres du Congrès sont priés de se rendre dans leurs sections respectives pour y procéder à la nomination du président et des secrétaires principaux de chacune des sections. »

— La séance est levée à 4 heures.

see our great centres of railway industry, and I trust that when we meet to say good bye some ten days or a fortnight hence I shall find that there has been a feeling of satisfaction expressed by the delegates generally at the reception which they have been accorded by the railway companies of this country. I can assure you that we shall do our best to make your visit pleasant and agreeable, and I trust it will prove so.

« I have now only one other duty to perform, and that is to ask the delegates present to adjourn to their various rooms, and there to elect their Presidents and lay the steps for the future business of this Congress. » (*Applause.*)

Mr. Dubois. — The members of the Congress are requested to adjourn to their various sections for the purpose of electing the President and principal secretaries of each section.

— The proceedings terminated at 4 o'clock.

Ordre du jour des sections

—	SECTION I. — VOIES ET TRAVAUX. (WAY AND WORKS.)	SECTION II. — TRACTION ET MATÉRIEL. (LOCOMOTIVES AND ROLLING-STOCK
Lundi, 1er juillet (Monday, July 1) — *Matin*, 10 heures (*Morning*, 10 o'clock).	I. Renforcement des voies. (Strengthening of Permanent Way.)	V. Chaudières. (Boilers.)
Lundi, 1er juillet (Monday, July 1) — *Après-midi*, 2 heures. (*Afternoon*, 2 o'clock).	I. Renforcement des voies. (Strengthening of Permanent Way.)	V. Chaudières. (Boilers.)
Mardi, 2 juillet (Tuesday, July 2) — *Matin*, 10 heures (*Morning*, 10 o'clock).	I. Renforcement des voies. (Strengthening of Permanent Way.)	VI. Locomotives des trains à grand vitesse. (Express Locomotives.)
Mardi, 2 juillet (Tuesday, July 2) — *Après-midi*, 2 heures. (*Afternoon*, 2 o'clock).	II. Points spéciaux de la voie. (Places in Permanent Way, &c)	VII. Voitures des trains à grand vitesse. (Express Rolling-stock.) *Avec la section III, dans la salle de séances plénières.* (*With Section III, in East Conferens Hall.*)
Mercredi, 3 juillet, *Matin*, 10 heures (Wednesday, July 3, *Morning*, 10 o'clock)	II. Points spéciaux de la voie. (Places in Permanent Way, &c) III. Bifurcations. (Junctions.)	VII. Voitures des trains à grand vitesse. (Express Rolling-stock). *Avec la section III, dans la salle n°* — *Salle des chemins de fer économiques.* (*With Section III, in Room No.* *Light Railway Room.*)
Jeudi, 4 juillet (Thursday, July 4) — *Matin*, 10 heures. (*Morning*, 10 o'clock).	IV. Ponts métalliques. (Metallic Bridges.)	VIII. Traction électrique. (Electric Traction.)
Jeudi, 4 juillet (Thursday, July 4) — *Après-midi*, 2 heures (*Afternoon*, 2 o'clock).	Séance plénière. (General Meeting.)	Séance plénière (General Meeting.)
Vendredi, 5 juillet (Friday, July 5) — *Matin*, 10 heures (*Morning*, 10 o'clock).	XVI. Système décimal. (Decimal System). *Avec la section IV, dans la salle n° 12.* (*With Section IV, in Room No. 12.*)	IX. Accélération des transports d marchandises. (Acceleration of Merchandise. *Avec la section III, dans la salle des séances plénières.* (*With Section III, in East Conferenc Hall.*)
Vendredi, 5 juillet (Friday, July 5) — *Après-midi*, 2 heures. (*Afternoon*, 2 o'clock).	Séance plénière. (General Meeting.)	Séance plénière. (General meeting.)
Samedi, 6 juillet, *Matin*, 10 heures (Saturday, July 6, *Morning*, 10 o'clock)	IV. Ponts métalliques. (*Suite et fin.*) (Metallic Bridges). (*End.*)	VIII. Traction électrique. (*Suite e fin.*) (Electric traction). (*End.*)
Lundi, 8 juillet (Monday, July 8) — *Matin*, 10 heures (*Morning*, 10 o'clock.	...	XX. Freins des chemins de fer éco nomiques. (Brakes for Light Railways.) *Avec la section V, dans la salle n°* (*With Section V, in Room No.*
Lundi, 8 juillet (Monday, July 8) — *Après-midi*, 2 heures. (*Afternoon*, 2 o'clock).	Séance plénière. (General Meeting.)	Séance plénière. (General Meeting.)
Mardi, 9 juillet, *Matin* (Tuesday, July 9, *Morning*) — 10 heures (10 o'clock)	Séance plénière. (General Meeting.)	Séance plénière. (General Meeting.)
Mardi, 9 juillet, *Matin* (Tuesday, July 9, *Morning*) — 11 1/2 heures (11.30 o'clock)	Séance de clôture. (Closing Ceremony.)	Séance de clôture. (Closing Ceremony)

Programme of the Sectional Meetings.)

SECTION III. — EXPLOITATION. (TRAFFIC)	SECTION IV. — ORDRE GÉNÉRAL. (GENERAL.)	SECTION V. — CHEMINS DE FER ÉCONOMIQUES. (LIGHT RAILWAYS.)
XI. Signaux. **(Signals.)** **XI. Signaux.** **(Signals.)**	**XIII. Organisation.** **(Organisation.)** **XIV. Règlement des litiges.** **(Settlement of disputes.)**	**XIX. Dépôts des chemins de fer économiques.** **(Light Railway Shops.)** **XIX. Dépôts des chemins de fer économiques.** **(Light Railway Shops.)**
X. Manœuvres de gare. **(Station Working.)** **VII. Voitures des trains à grande vitesse.** **(Express Rolling-stock.)** *Avec la section II, dans la salle des séances plénières, à 3 h. 30.* *(With Section II, in East Conference Hall, at 3.30 o'clock.)*	... ...	**XVIII. Affermage de l'exploitation des chemins de fer économiques.** **(Leasing.)** **XVIII. Affermage de l'exploitation des chemins de fer économiques.** **(Leasing.)**
VII. Voitures des trains à grande vitesse. **(Express Rolling-stock.)** *Avec la section II, dans la salle n° 8. — Salle des chemins de fer économiques.* *(With Section II, in Room No. 8, Light Railway Room.)*	**XVII-B. Facilités à accorder aux chemins de fer à faible trafic.** **(Relaxation of requirements.)** *Avec la section V, dans la salle des séances plénières.* *(With Section V, in East Conference Hall.)*	**XVII-B. Facilités à accorder aux chemins de fer à faible trafic.** **(Relaxation of requirements.)** *Avec la section IV, dans la salle des séances plénières.* *(With Section IV, in East Conference Hall.)*
X. Manœuvres de gare. *(Suite et fin.)* **(Station Working).** *(End.)* **Séance plénière.** **(General Meeting.)**	**XVII-B. Facilités à accorder aux chemins de fer à faible trafic.** **(Relaxation of requirements.)** *Avec la section V, dans la salle des séances plénières.* *(With Section V, in East Conference Hall.)* Séance plénière. (General Meeting.)	**XVII-B. Facilités à accorder aux chemins de fer à faible trafic.** **(Relaxation of requirements.)** *Avec la section IV, dans la salle des séances plénières.* *(With Section IV, in East Conference Hall.)* Séance plénière. (General Meeting.)
IX. Accélération des transports de marchandises. **(Acceleration of Merchandise.)** *Avec la section II, dans la salle des séances plénières.* *(With Section II, in East Conference Hall.)* **Séance plénière.** **(General Meeting.)**	**XVI. Système décimal.** **(Decimal system.)** *Avec la section I, dans la salle n° 12.* *(With Section I, in Room No. 12.)* **Séance plénière.** **(General Meeting.)**	**XVIII. Affermage de l'exploitation des chemins de fer économiques.** *(Fin).* **(Leasing.)** *(End.)* **Séance plénière.** **(General Meeting.)**
XII. Factage et camionnage. **(Cartage and Delivery.)**	**XVII-A. Affluents de transports.** **(Contributive traffic.)** *Avec la section V, dans la salle des séances plénières.* *(With Section V, in East Conference Hall.)*	**XVII-A. Affluents de transports.** **(Contributive traffic.)** *Avec la section IV, dans la salle des séances plénières.* *(With Section IV, in East Conference Hall.)*
XV. Cadran de vingt-quatre heures. **(The Twenty-four Hours' Day.)** *Avec la section IV, dans la salle des séances plénières.* *(With Section IV, in East Conference Hall.)* **Séance plénière.** **(General Meeting.)**	**XV. Cadran de vingt-quatre heures.** **(The Twenty-four Hours' Day).** *Avec la section III, dans la salle des séances plénières.* *(With Section III, in East Conference Hall.)* **Séance plénière.** **(General Meeting.)**	**XX. Freins des chemins de fer économiques.** **(Brakes for Light Railways.)** *Avec la section II, dans la salle n° 8.* *(With Section II, in Room No. 8.)* **Séance plénière.** **(General Meeting.)**
Séance plénière. **(General Meeting.)** **Séance de clôture.** **(Closing Ceremony.)**	**Séance plénière.** **(General Meeting.)** **Séance de clôture.** **(Closing Ceremony.)**	**Séance plénière.** **(General Meeting.)** **Séance de clôture.** **(Closing Ceremony.)**

LISTE DES DOCUMENTS

publiés en vue de la cinquième session.

LIST OF THE PAPERS

published for the Fifth Session.

I. Ordre de publication (As issued).

N° du tiré à part. (Number of the separate issue.)	NUMÉRO de la question. (NUMBER of the question.)	TITRE DE LA QUESTION. (TITLE OF THE QUESTION.)	DOCUMENTS.
Brun. (Brown)		**En français (In French) :**	
1	V	Chaudières, foyers et tubes à fumée des locomotives.	Exposé, par Mr. Ed. Sauvage.
1bis	V	Chaudières, foyers et tubes à fumée des locomotives.	Addenda, par le même.
2	XX	Freins des chemins de fer économiques.	Exposé, par Mr. Plocq.
3	III	Bifurcations	— par Mr. A. Zanotta.
4	XIX	Dépôts des chemins de fer économiques.	— par Mr. Terzi.
5	XI	Signaux.	1er exposé (pays de langue non anglaise), par Mr. Lucien Motte.
6	XIII	Organisation des services	1er exposé (pays de langue non anglaise), par Mr. G. Duca.
7	XV	Cadran de vingt-quatre heures. . .	Exposé, par Messrs. Scolari et Rocca.
8	II	Points spéciaux de la voie	— par Mr. Sabouret.
9	XVI	Système décimal.	— par Mr. Wilkinson.
10	...	L'histoire, l'organisation et les résultats du Congrès international des chemins de fer.	Note, par Mr. A. Dubois.
11	XIII	Organisation des services	2e exposé (pays de langue anglaise), par Mr. Fred. Harrison.
12	XVII-A	Affluents de transports et chemins de fer à faible trafic.	Exposé, par Mr. H. De Backer.
13	X	Manœuvres de gare	2e exposé des littéras A et B, (pays de langue anglaise), par Mr. George H. Turner.
14	XI	Signaux	2e exposé (pays de langue anglaise), par Mr. Thompson. 1re note par Mr. Raynar Wilson. 2e note par l'Administration des chemins de fer de la Méditerranée (Italie).
15	XIV	Règlement des litiges	Exposé, par Mr. Louis de Perl. Note, par Mr. Chas. J. Owens.
16	XVIII	Affermage de l'exploitation des chemins de fer économiques.	Exposé, par Mr. C. de Burlet. Note, par Mr. W. M. Acworth.
17	I	Renforcement des voies en vue de l'augmentation de la vitesse des trains.	2e exposé (pays de langue anglaise), pr Mr. W. Hunt. 1er exposé (pays de langue non anglaise), par Mr. W. Ast. Addenda au 2e exposé (pays de langue anglaise), par Mr. W. Hunt.

N. B. — Le numérotage des tirés à part français et celui des tirés à part anglais sont différents. (The numbering of the separate issues in French and English is not the same.)

N° du tiré à part. (Nummer of the separate issue).	NUMÉRO de la question. (NUMBER of the question.)	TITRE DE LA QUESTION. (TITLE OF THE QUESTION.)	DOCUMENTS.
Bras. (Brass)			
18 Suite à 13.	X	Manœuvres de gare	Exposé du littéra A (pays de langue non anglaise), par Mr. J. de Richter.
			1re note sur le littéra A, par l'Administration des chemins de fer méridionaux (réseau de l'Adriatique.
19	IX	Accélération du transport des marchandises.	Exposé, par Mr. H. Lambert.
20	IV	Construction des ponts métalliques	Exposé, par Mr. Max Edler von Leber.
21	X	Manœuvres de gare	1er exposé du littéra B (pays de langue non anglaise), par Messrs. Eug. Sartiaux et A. von Boschan.
22	VII	Voitures des trains à grande vitesse.	Exposé, par Mr. C.-A. Park.
23	XVII-B	Facilités à accorder aux chemins de fer à faible trafic.	Exposé, par Messrs. A.-C. Humphreys-Owen et P.-W. Meik.
			1re note, par Mr. E.-A. Ziffer.
			2e note, par le même.
24	VIII	Traction électrique	Exposé, par Mr. Auvert.
			1re note, par l'Administration des chemins de fer de l'Ouest français.
			2e note, par l'Administration du chemin de fer du Nord.
			3e note, par Mr. Ernest Gerard.
25	XII	Factage et camionnage	Exposé, par Mr. Twelvetrees.
			1re note, par l'Administration des chemins de fer de l'Etat belge.
			2e note, par l'Administration des chemins de fer de l'Ouest français.
26	VI	Locomotives des trains à grande vitess	Exposé, par Mr. John-A. Aspinall.
27	XI	Signaux	3e note, par Mr. Theo.-N. Ely.
			4e — par l'American Railway Association (Messrs. A.-W. Sullivan et F.-A. Delano).
			5e note, par Mr. Robert Pitcairn.
			6e — par Mr. A.-T. Dice.
28	XVII-B	Facilités à accorder aux chemins de fer à faible trafic.	3e note, par Mr. Thomas-C. Farrer.
29	X	Manœuvres de gare	1re note sur le littéra B, par Mr. Wilhelm Ast.
			2e — sur le littéra B, par l'Administration des chemins de fer du Nord Empereur Ferdinand.
30	...	Le développement des chemins de fer dans le Dominion du Canada.	Note, par l'honorable Sir Charles Tupper.
31	Formulaire A.	Les bris des rails d'acier	Exposé, par Mr. Bricka.
32	— B.	L'entretien courant des traverses métalliques comparé à celui des traverses en bois.	Exposé, par Mr. Kowalski.
33	— C.	La durée des traverses en bois des différentes essences non injectées ou injectées d'après les divers procédés.	Exposé, par Mr. V. Herzenstein.
34	— E.	Les foyers des locomotives	Exposé, par Mr. Hodeige.
35	— F.	Les chaudières des locomotives	Exposé, par Mr. Belleroche.
36	— G.	Le graissage des véhicules	Exposé, par Mr. Hubert.

N. B. — Le numérotage des tirés à part français et celui des tirés à part anglais sont différents. (The numbering of the separate issues in French and English is not the same.)

Number of the separate issue. (N° du tiré à part.)	NUMBER of the question. (NUMÉRO de la question.)	TITLE OF THE QUESTION. (TITRE DE LA QUESTION.)	DOCUMENTS.
Red. (Rouge.)			**In English (En anglais):**
1	XX	Brakes for light railways	Report, by Mr. Plocq.
			Addenda, by the same.
2	V	Boilers, fire-boxes and tubes. . . .	Report, by Mr. Ed. Sauvage.
3	XVI	Decimal system	— by Mr. J.-L. Wilkinson.
4	XIX	Light railway shops.	— by Mr. Terzi.
5	XV	The twenty-four hours day	— by Messrs. Scolari and Rocca.
6	XIII	Organisation	2nd report (for English speaking countries), by Mr. Harrison.
7	X	Station working	2nd report on parts A and B (for English speaking countries), by Mr. Turner.
8	XI	Signals	2nd report (for English speaking countries), by Mr. Thompson.
			1st note, by Mr. Raynar Wilson.
9	I	Strengthening of permanent way in view of increased speed of trains.	2nd report (for English speaking countries), by Mr. William Hunt.
			Addenda by the same.
10	VI	Express locomotives	Report, by Mr. Aspinall.
11	II	Places in permanent way requiring special attention.	— by Mr. Sabouret.
12	XIII.	Organisation	1st report (for non English speaking countries), by Mr. Duca.
13	VII	Rolling stock for express trains. . .	Report, by Mr. C.-A. Park.
14	III	Junctions	— by Mr. Zanotta.
15	...	The history, organisation and results of the International Railway Congress.	Note, by Mr. A. Dubois.
16	IX	Acceleration of transport of merchandise.	Report, by Mr. H. Lambert.
17	XII	Cartage and delivery	Report, by Mr. Twelvetrees.
			1st note, by the Belgian State Railways Administration.
			2nd note, by the Western Railways of France Administration.
18	XI (See also N° 8)	Signals	1st Report (for non English speaking countries), by Mr. Motte.
			2nd note, by the Mediterranean Railway Company (Italy).
			3rd note, by Mr. Theo.-N. Ely.
			4th — by the American Railway Association (Messrs. A.-W. Sullivan and F.-A. Delano).
			5th note, by Mr. Robert Pitcairn.
			6th — by Mr. A.-T. Dice.

N. B. — Le numérotage des tirés à part français et celui des tirés à part anglais son différents. (The numbering of the separate issues in French and English is not the same.)

Number of the separate issue. (N° du tiré à part.)	NUMBER of the question. (NUMÉRO de la question.)	TITLE OF THE QUESTION. (TITRE DE LA QUESTION.)	DOCUMENTS.
Red. (Rouge.)			
19	XVII-A	Light feeder lines.	Report, by Mr. De Backer.
20	XIV	Settlement of disputes	— by Mr. de Perl.
21	XVIII	The working of light railways by leasing companies.	— by Mr. de Burlet.
			Note by Mr. M.-W. Acworth.
22	IV	Construction and tests of metallic bridges.	Report, by Mr. Max Edler von Leber.
23	X	Station working. (Methods of accelerating the shunting of trucks.)	1st report on Part A (for non English speaking countries), by Mr. J. de Richter.
	X	Station working. (Employment of mechanical and electrical appliances in shunting.)	1st report on Part B (for non English speaking countries), by Messrs. Eug. Sartiaux and A. von Boschan.
			1st note, on Part B, by Mr. Ast.
			2nd — — by the Administration of the « Kaiser Ferdinand Nordbahn » (railway).
24	...	Railway progress in the Dominion of Canada.	Memorandum, by the Hon. Sir Charles Tupper.
25	I	Strengthening of permanent way in view of increased speed of trains.	Report, by Mr. Ast.
26	XVII-B	Relaxation of normal requirements for light railways.	Report, by Messrs. Humphreys-Owen and P.-W. Meik.
			1st note, by Mr. E.-A. Ziffer.
			2nd — —
			3rd — by the Hon. Thomas C. Farrer.
27	VIII	Electric traction.	Report, by Mr. Auvert.
			1st note, by the Western of France Railway.
			2nd — by the Northern of France Railway.
			3rd — by Mr. Ernest Gerard.
28	XIV (See also N° 8).	Settlement of disputes	Note, by Mr. Chas. J. Owens.

N. B. — Le numérotage des tirés à part français et celui des tirés à part anglais sont différents. (The numbering of the separate issues in French and English is not the same.)

II. Dans l'ordre des questions. (As the questions are inserted in the agenda for discussion.)

NUMÉRO de la question. (NUMBER of the question.)	TITRE DE LA QUESTION. (TITLE OF THE QUESTION.)	DOCUMENTS.	ANNÉE ET PAGE du *Bulletin*. (YEAR AND PAGE of the *Bulletin*.)	NUMÉRO du tiré à part. (NUMBER of the separate issue.)
		En français (In French) :		
I	Renforcement des voies en vue de l'augmentation de la vitesse des trains. (Strengthening of permanent way in view of the increased speed of trains.)	2e exposé (pays de langue anglaise), par Mr. W. Hunt.	1895, vol. IX, p. 1037.	17 brun (brown).
		1er exposé (pays de langue non anglaise), par Mr. W. Ast.	1895, vol. IX, p. 1161.	Id.
		Addenda au 2e exposé (pays de langue anglaise), par Mr. W. Hunt.	1895, vol. IX, p. 1898.	Id.
		In English (En anglais) :		
		2nd report (for English speaking countries), by Mr. William Hunt.	1895, vol. IX, p. 1113.	9 red (rouge).
		Addenda to the 2nd report (for English speaking countries), by the same.	1895, vol. IX, p. 1910.	Id.
		1st report (for non English speaking countries), by Mr. Ast.	...	25 red (rouge).
		En français (In French) :		
II	Points spéciaux de la voie. (Places in permanent way requiring special attention.)	Exposé, par Mr. Sabouret	1895, vol. IX, p. 473.	8 brun (brown).
		In English (En anglais) :		
		Report, by Mr. Sabouret	...	11 red (rouge).
		En français (In French) :		
III	Bifurcations . . . . . . (Junctions.)	Exposé, par Mr. A. Zanotta	1894, vol. VIII, p. 959.	3 brun (brown).
		In English (En anglais) :		
		Report, by Mr. Zanotta	...	14 red (rouge).
		En français (In French) :		
IV	Construction et épreuves des ponts métalliques. (Construction and tests of metallic bridges.)	Exposé, par Mr. Max Edler von Leber . .	1895, vol. IX, p. 1635.	20 brun (brown).
		In English (En anglais) :		
		Report, by Mr. Edler von Leber	...	22 red (rouge).
		En français (In French) :		
V	Chaudières, foyers et tubes à fumée des locomotives. (Boilers, fire-boxes and tubes.)	Exposé, par Mr. Ed. Sauvage	1894, vol. VIII, p. 641.	1 brun (brown).
		Addenda à l'exposé par le même.	1895, vol. IX, p. 589.	1*bis* sans couverture (without cover).
		In English (En anglais) :		
		Report, by Mr. Ed. Sauvage	...	2 red (rouge).
		En français (In French) :		
VI	Locomotives des trains à grande vitesse. (Express locomotives.)	Exposé, par Mr. John A.-F. Aspinall . . .	1895, vol. IX, p. 2321.	26 brun (brown).
		In English (En anglais) :		
		Report, by Mr. Aspinall	1895, vol. IX, p. 1369.	10 red (rouge).

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NUMÉRO de la question. (NUMBER of the question.)	TITRE DE LA QUESTION. (TITLE OF THE QUESTION.)	DOCUMENTS.	ANNÉE ET PAGE du *Bulletin*. (YEAR AND PAGE of the *Bulletin*.)	NUMÉRO du tiré à part. (NUMBER of the separate issue.)
		En français (In French) :		
VII	Voitures des trains à grande vitesse.	Exposé, par Mr. C.-A. Park	1895, vol. IX, p. 1975.	22 brun (brown).
	(Rolling-stock for express trains.)	**In English (En anglais) :**		
		Report, by Mr. C.-A. Park	1895, vol IX, p. 1847.	13 red (rouge).
		En français (In French) :		
VIII	Traction électrique. . . .	Exposé, par Mr. Auvert	1895, vol. IX, p. 2035.	24 brun (brown).
	(Electric traction.	1re note, par l'Administration des chemins de fer de l'Ouest français	1895, vol. IX, p. 2147.	Id.
		2e note, par l'Administration du chemin de fer du Nord français.	1895, vol. IX, p. 2196.	Id.
		3e note, par Mr. Ernest Gerard	1895, vol. IX, p. 2202.	Id.
		In English (En anglais) :		
		Report, by Mr. Auvert	...	27 red (rouge).
		1st note, by the Western of France Railway.	...	Do.
		2nd — by the Northern of France Railway.	...	Do.
		3rd — by Mr. Ernest Gerard	...	Do.
		En français (In French) :		
IX	Accélération des transports de marchandises.	Exposé, par Mr. H. Lambert	1895, vol. IX, p. 1735.	19 brun (brown).
	(Acceleration of transport of merchandise.)	**In English (En anglais) :**		
		Report, by Mr. H. Lambert.	1895, vol. IX, p. 2215.	16 red (rouge).
		En français (In French) :		
X	Manœuvres de gare : *Littéra A.*	2e exposé des littéras A et B (pays de langue anglaise), par Mr. George-H. Turner.	1895, vol. IX, p. 70:.	13 brun (brown).
	Moyens d'accélérer les manœuvres de gare.	1er exposé du littéra A (pays de langue non anglaise), par Mr. J. de Richter.	1895, vol. IX, p. 1563.	18 brun (brown).
	Littéra B. Emploi des moyens mécaniques et électriques dans les manœuvres de gare.	1re note sur le littéra A, par l'Administration des chemins de fer Méridionaux (ou réseau adriatique).	1895, vol. IX, p. 1632.	Id.
	(Station working :	1er exposé du littéra B (pays de langue non anglaise), par Messrs. Eug. Sartiaux et A. von Boschan.	1895, vol. IX, p. 1783.	21 brun (brown).
	Part A. Methods of accelerating the shunting of trucks in station working.	1re note sur le littéra B, par Mr. Wilhelm Ast.	1894, vol. VIII, p. 4.	29 brun (brown).
		2e — par l'Administration des chemins de fer Nord Empereur Ferdinand.	1895, vol. IX, p. 2499.	Id.
	Part B. Employment of mechanical and electrical appliances in station working.)	**In English (En anglais) :**		
		2nd report (for English speaking countries), by Mr. Turner.	1895, vol IX, p. 765.	7 red (rouge).
		1st report on Part A (for non English speaking countries), by Mr. de Richter.	...	23 red (rouge).
		1st report on Part B (for non English speaking countries), by Messrs. Eug. Sartiaux and A. von Boschan.	...	Do.
		1st note on Part B, by Mr. Ast.	...	Do.
		2nd — — by the Administration of the « Kaiser Ferdinand Nordbahn » Railway.	...	Do.

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NUMÉRO de la question. (NUMBER of the question.)	TITRE DE LA QUESTION. (TITLE OF THE QUESTION.)	DOCUMENTS.	ANNÉE ET PAGE du *Bulletin*. (YEAR AND PAGE of the *Bulletin*.)	NUMÉRO du tiré à part. (NUMBER of the separate issue.)
		En français (In French) :		
XI	Signaux. . . . . (Signals.)	1er exposé (pays de langue non anglaise), par Mr. Lucien Motte.	1894, vol. VIII, p. 1042.	5 brun (brown).
		2e exposé (pays de langue anglaise), par Mr. Thompson.	1895, vol. IX, p. 824.	14 brun (brown).
		1re note, par Mr. Raynar Wilson.	1894, vol. VIII, p. 894.	Id.
		2e note, par l'Administration des chemins de fer de la Méditerranée (Italie).	1895, vol. IX, p. 378.	Id.
		3e note, par Mr. Théo.-N. Ely	1895, vol. IX, p. 2421.	27 brun (brown)
		4e note, par l'American Railway Association (Messrs. A.-W. Sullivan et Frédéric-A. Delano).	1895, vol. IX, p. 2436.	Id.
		5e note, par Mr. Robert Pitcairn	1895, vol. IX, p. 2588.	Id.
		6e note, par Mr. A.-T. Dice.	1895, vol. IX, p. 2622.	Id.
		In English (En anglais) :		
		2nd report (for English speaking countries), by Mr. Thompson.	1895, vol. IX, p. 881.	8 red (rouge).
		1st note, by Mr. Raynar Wilson	1894, vol. VIII, p. 895.	Do.
		1st report (for non English speaking countries), by Mr. Motte.	...	18 red (rouge).
		2nd note, by the Mediterranean Railway Company (Italy).	..	Do.
		3rd note, by Mr. Theo.-N. Ely	1895, vol. IX, p. 2447.	Do.
		4th — by the American Railway Association (Messrs. A.-W. Sullivan and F.-A. Delano).	1895, vol. IX, p. 2461.	Do.
		5th note by Mr. Robert Pitcairn	1895, vol. IX, p. 2588	Do
		6th — by Mr. A.-T. Dice.	1895, vol. IX, p. 2624.	Do.
		En français (In French) :		
XII	Factage et camionnage . . (Cartage and delivery.)	Exposé, par Mr. Twelvetrees.	1895, vol. IX, p. 2243.	25 brun (brown).
		1re note, par l'Administration des chemins de fer de l'Etat belge.	1895, vol. IX, p. 2267.	Id.
		2e note, par l'Administration des chemins de fer de l'Ouest français.	1895, vol. IX, p. 2278.	Id.
		In English (En anglais) :		
		Report, by Mr. Twelvetrees	1895, vol. IX, p. 22 3.	17 red (rouge).
		1st note, by the Belgian State Railways Administration.	1895, vol. IX, p 2305.	Do.
		2nd note, by the Western Railway of France Administration.	1895, vol. IX, p. 2317.	Do.
		En français (In French) :		
XIII	Organisation des services. . (Organisation.)	1er exposé (pays de langue non anglaise), par Mr. G. Duca.	1895, vol. IX, p. 141.	6 brun (brown).
		2e exposé (pays de langue anglaise), par Mr. Fred. Harrison.	1895, vol. IX, p. 613.	11 brun (brown).
		In English (En anglais) :		
		2nd report (for English speaking countries), by Mr. Fred. Harrison.	1895, vol. IX, p. 636.	6 red (rouge).
		1st report (for non English speaking countries), by Mr. Duca.	...	12 red (rouge).

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NUMÉRO de la question. (NUMBER of the question.)	TITRE DE LA QUESTION. (TITLE OF THE QUESTION.)	DOCUMENTS.	ANNÉE ET PAGE du *Bulletin.* (YEAR AND PAGE of the *Bulletin.*)	NUMÉRO du tiré à part. (NUMBER of the separate issue.)
		En français (In French) :		
XIV	Règlement des litiges . . . (Settlement of disputes.)	Exposé, par Mr. Louis de Perl	1895, vol. IX, p. 932.	15 brun (brown).
		Note, par Mr. Chas. I. Owens.	1894, vol. VIII, p. 902.	Id.
		In English (En anglais) :		
		Report, by Mr. de Perl	...	20 red (rouge).
		Note by Mr. Chas. J. Owens.	1895, vol. IX, p. 903.	28 red (rouge).
		En français (In French) :		
XV	Cadran de vingt-quatre heures (The twenty-four hours day.)	Exposé, par Messrs. Scolari et Rocca . . .	1895, vol IX, p. 434.	7 brun (brown).
		In English (En anglais) :		
		Report, by Messrs. Scolari and Rocca . . .	...	5 red (rouge).
		En français (In French) :		
XVI	Système décimal. . . . . (Decimal system.)	Exposé, par Mr. J. L. Wilkinson	1895, vol. IX, p. 491.	9 brun (brown).
		In English (En anglais) :		
		Report, by Mr. J.-L. Wilkinson	1895, vol. IX, p. 501.	3 red (rouge).
		En français (In French) :		
XVII-A	Affluents de transports. . . (Light feeder lines.)	Exposé, par Mr. H. De Backer	1895, vol. IX, p. 656.	12 brun (brown).
		In English (En anglais) :		
		Report, by Mr. de Backer	...	19 red (rouge).
		En français (In French) :		
XVII-B	Facilités à accorder aux chemins de fer à faible trafic. (Contributive traffic.)	Exposé, par Messrs. A. C. Humphreys-Owen et P.-W. Meik.	1895, vol. IX, p. 1918.	23 brun (brown).
		1re note, par Mr. E.-A. Ziffer.	1894, vol. VIII, p. 229.	Id.
		2e — par le même	1894, vol. VIII, p. 711.	Id.
		3e — par Mr Thomas C. Farrer. . . .	1895, vol. IX, p. 2545.	23 brun (brown).
		In English (En anglais) :		
		Report, by Messrs. A.-C. Humphreys-Owen and P.-W. Meik.	1895, vol. IX, p. 1947.	26 red (rouge).
		1st note, by Mr. E. A. Ziffer.	...	Do.
		2nd — —	...	Do.
		3rd — by the Hon. Thomas C. Farrer. . .	1895, vol. IX, p. 2545.	Do.
		En français (In French) :		
XVIII	Affermage de l'exploitation des chemins de fer économiques. (The working of light railways by leasing companies.)	Exposé, par Mr. C. de Burlet.	1895, vol. IX, p. 954	16 brun (brown).
		Note, par Mr. W.-M. Acworth	1894, vol. VIII, p. 798.	Id.
		In English (En anglais) :		
		Report, by Mr. de Burlet	...	21
		Note, by Mr. W.-M. Acworth.	1894, vol. VIII, p. 799.	red (rouge).

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NUMÉRO de la question. (NUMBER of the question.)	TITRE DE LA QUESTION. (TITLE OF THE QUESTION)	DOCUMENTS.	ANNÉE ET PAGE du *Bulletin*. (YEAR AND PAGE of the *Bulletin*.)	NUMÉRO du tiré à part. (NUMBER of the separate issue.)
		En français (In French) :		
XIX	Dépôts des chemins de fer économiques. (Light railway shops.)	Exposé, par Mr. Terzi	1895, vol. IX, p. 133.	4 brun (brown).
		In English (En anglais) :		
		Report, by Mr. Terzi	...	4 red (rouge).
		En français (In French) :		
XX	Freins des chemins de fer économiques. (Brakes for light railways.)	Exposé, par Mr. Plocq	1894, vol. VIII, p. 916.	2 brun (brown).
		Complément à l'exposé, par le même	1895, vol. IX, p. 386.	Id.
		In English (En anglais) :		
		Report, by Mr. Plocq	...	1 red (rouge).
		Addendum, by the same	...	Do.
		En français (In French) :		
...	L'histoire, l'organisation et les résultats du Congrès international des chemins de fer.	Note, par Mr. A. Dubois	1895, vol. IX, p. 511.	10 brun (brown).
		In English (En anglais) :		
	(The history, organisation and results of the International Railway Congress.)	By Mr. A. Dubois	...	15 red (rouge).
		En français (In French) :		
...	Le développement des chemins de fer dans le Dominion du Canada.	Note, par l'honorable Sir Charles Tupper	1895, vol. IX, p. 2471.	30 brun (brown)
		In English (En anglais) :		
	(Railway progress in the Dominion of Canada.)	By the Hon. Sir Charles Tupper	1895, vol. IX, p. 2485.	24 red (rouge).

ANNEXE au questionnaire. (APPENDIX to the list of questions for discussion.)	TITRE DE LA QUESTION. (TITLE OF THE QUESTION.)	DOCUMENTS.	ANNÉE ET PAGE du *Bulletin*. (YEAR AND PAGE of the *Bulletin*.)	NUMÉRO du tiré à part. (NUMBER of the separate issue.)
		En français (In French) :		
A	Renseignements techniques sur les bris des rails d'acier. (Technical information on the breaking of steel rails.)	Rapport, par Mr. Bricka Traduction anglaise non encore publiée. (English translation not yet ready.)	1895, vol. IX, pag. 580.	31 brun (brown).
		En français (In French) :		
B	Renseignements techniques sur l'entretien courant des traverses métalliques comparé à celui des traverses en bois. (Technical information on the current cost of metallic compared with wooden sleepers.)	Rapport, par Mr. Kowalski Traduction anglaise non encore publiée (English translation not yet ready.)	1895, vol. IX, pag. 3169.	32 brun (brown).

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ANNEXE au questionnaire. (APPENDIX to the list of questions for discussion.)	TITRE DE LA QUESTION. (TITLE OF THE QUESTION.)	DOCUMENTS.	ANNÉE ET PAGE du *Bulletin* (YEAR AND PAGE of the *Bulletin*.)	NUMÉRO du tiré à part. (NUMBER of the separate issue.)
		En français (In French) :		
C	Renseignements techniques sur la durée des traverses en bois des différentes essences non injectées ou injectées d'après les divers procédés. (Technical information on the life of wooden sleepers of different kinds, not pickled or pickled according to various processes.)	Rapport, par Mr. V. Herzenstein . . . . Traduction anglaise non encore publiée. (English translation not yet ready.)	1895, vol IX, pag. 2889.	33 brun (brown).
		En français (In French) :		
D	Renseignements techniques sur les essieux coudés des locomotives (Technical information on locomotive crank axles.)	Les renseignements recueillis étant très incomplets, cette question n'a pas été traitée. (As the information collected on this question was very incomplete, it was not dealt with.)	...	...
		En français (In French) :		
E	Renseignements techniques sur les foyers des locomotives. (Technical information on locomotive fire boxes.)	Rapport, par Mr. Hodeige. . . . . . . Traduction anglaise non encore publiée. (English translation not yet ready.)	1895, vol. IX, p. 2627.	34 brun (brown).
		En français (In French) :		
F	Renseignements techniques sur les chaudières des locomotives. (Technical information on locomotive boilers.)	Rapport, par Mr. Belleroche. . . . . . Traduction anglaise non encore publiée. (English translation not yet ready.)	1895, vol. IX, p. 3077.	35 brun (brown)
		En français (In French) :		
G	Renseignements techniques sur le graissage des véhicules. (Technical information on the lubrication of rolling stock.)	Rapport, par Mr. Hubert. . . . . . . Traduction anglaise non encore publiée. (English translation not yet ready.)	1895, vol. IX, p. 2793.	36 brun (brown).
		En français (In French) :		
H	Renseignements techniques sur les machines de manœuvres. (Technical information on shunting engines.)	Les renseignements recueillis étant très incomplets, cette question n'a pas été traitée. (As the information collected on this question was very incomplete, it was not dealt with.)	...	...
		En français (In French) :		
I	Renseignements techniques sur le mouvement du personnel dans les différents pays. (Technical information on the movement of the staff in different countries.)	Les renseignements recueillis étant très incomplets, cette question n'a pas été traitée. (As the information collected on this question was very incomplete, it was not dealt with.)	...	...

N. B. — Le numérotage des tirés à part français et celui des tirés à part anglais sont différents. (The numbering of the separate issues in French and English is not the same.)

QUESTIONS

SOUMISES AUX DISCUSSIONS DE LA 5e SESSION.

1re SECTION. — VOIES ET TRAVAUX.

I. — Renforcement des voies en vue de l'augmentation de la vitesse des trains.

Modèle de voie à adopter pour les lignes parcourues par des trains de grande vitesse. Renforcement graduel de la résistance des voies existantes, de manière à permettre l'augmentation de la vitesse des trains :

A. Profil du rail. Détermination des efforts dynamiques supportés. Résultats d'expériences.

B. Conditions de fabrication et nature du métal des rails. Comparaison de l'acier mou avec l'acier dur. Acier produit : par le procédé acide au convertisseur Bessemer ; par le procédé basique au convertisseur ; par l'un ou l'autre procédé au four Martin.

C. Liaisons des rails. Fatigue supportée par les éclissages. Construction du joint qui assure le mieux la résistance uniforme de la voie dans toutes ses parties : rails à coussinets et rails Vignoles.

D. Traverses : qualité, dimensions, écartement.

E. Ballast : nature, conditions d'établissement.

Rapporteurs, pour les pays de langue non anglaise, Mr. Ast (W.), conseiller de régence, directeur des voies et travaux du chemin de fer du Nord-Empereur Ferdinand d'Autriche, à Vienne, et

Pour les pays de langue anglaise, Mr. Hunt, ingénieur de la voie du Lancashire and Yorkshire Railway, à Manchester.

QUESTIONS

FOR DISCUSSION AT THE FIFTH SESSION.

Ist SECTION. — WAY AND WORKS.

I. — Strengthening of Permanent in View of the Increased Speed of Trains.

Type of permanent way suited for lines traversed by trains at high speed. Gradual strengthening of existing roads so as to permit of an increase in the speed of trains :

A. Section of rail. Calculation of the strains imposed by the rolling load. Results of experiments.

B. Mode of manufacture and nature of rail-metal. Comparison of soft with hard steel. Steel produced : (1) by the acid process in the Bessemer converter; (2) by the basic process in the converter; (3) by either process in the Martin furnace.

C. Rail connections. Fatigue of fish plates. Construction of joint best calculated to secure uniform strength of the road throughout. Rails laid in chairs, and Vignoles rails.

D. Sleepers, their quality, dimensions; and distance apart.

E. Ballast, the various descriptions and methods of laying.

Reporters, for non English speaking countries, Mr. Ast (W.), Chief Engineer, Kaiser Ferdinand's Nordbahn of Austria, Vienna,

For English speaking countries, Mr. Hunt, Chief Engineer, Lancashire and Yorkshire Railway, Manchester.

II. — Points spéciaux de la voie.

Moyens à employer pour supprimer le ralentissement des trains rapides et éviter les chocs au passage des points spéciaux de la voie (courbes de faible rayon, pentes de grande longueur, aiguilles abordées par la pointe, traversées, passages à niveau, ponts tournants, etc.).

Rapporteur : Mr. Sabouret, ingénieur des ponts et chaussées, ingénieur principal du service central de la voie au chemin de fer de Paris à Orléans, à Paris.

III. — Bifurcations.

Conditions les plus favorables de construction des bifurcations sur les voies des trains rapides en vue d'éviter absolument les ralentissements. Meilleures dispositions à adopter pour les aiguilles et les traversées. Moyens les plus efficaces de maintenir la vitesse des trains en supprimant la surélévation dans les courbes des bifurcations.

Rapporteur : Mr. Zanotta (A.), ingénieur, chef de section au service de l'entretien, surveillance et travaux du chemin de fer de la Méditerranée (Italie), à Milan.

IV. — Construction et épreuves des ponts métalliques.

A. Quelles sont les quantités de métal mises et à mettre en œuvre dans les ponts de chemins de fer en tenant compte des prescriptions en vigueur dans les différents pays?

B. Quelles sont la nature et la valeur des procédés des différentes Administrations de chemins de fer pour les épreuves initiales et pour les épreuves périodiques des ponts métalliques?

Quelle est l'importance réelle que l'on doit attribuer à ces épreuves, et peut-on les regarder comme un moyen expérimental pour établir les conditions effectives de solidité et le degré de sûreté des constructions susdites?

Rapporteur : Max Edler von Leber, inspecteur en chef du corps I. R. de la surveillance générale des chemins de fer de l'Autriche, au ministère du commerce, à Vienne.

II. — Places in Permanent Way requiring special attention.

Means to avoid the necessity of expresses slackening speed, and to prevent shocks in passing special points, such as sharp curves, long and sleep gradients, facing points, rail-crossings, road-crossings, swing bridges, &c.

Reporter, Mr. Sabouret, Principal Engineer, Orleans Railway, Paris.

III. — Junctions.

Best method of constructing junctions upon express lines so as absolutely to avoid slackening speed.

Best arrangements of points and crossings.

The most efficacious means of maintaining the speed of trains while abandoning super-elevation at junction-curves.

Reporter, Mr. Zanotta (A.), Divisional Engineer, Mediterranean Railway of Italy, Milan.

IV. — Construction and Tests of Metallic Bridges.

A. What are the quantities of metal used and required to be used in railway bridges, according to the regulations in force in different countries?

B. What are the nature and value of the methods adopted by the different railway administrations for the original and the subsequent periodical testing of metal bridges?

C. What is the real value of these tests, and can they be regarded as practical means of settling the actual state of repair and the margin of safety of the above-mentioned structures?

Reporter, Max Edler von Leber, Principal Inspector of the Railway Control Department of Austria, Ministry of Commerce, Vienna.

2e SECTION. TRACTION ET MATÉRIEL.

V. — Chaudières, foyers et tubes a fumée des locomotives.

A. Chaudières et foyers en acier. Efforts supportés en service et conditions de réception des tôles.

B. Tubes à fumée en fer. Moyens d'éviter les fuites aux plaques tubulaires.

C. Action nuisible exercée par les eaux d'alimentation sur les chaudières et les tubes. Systèmes d'épuration.

D. Programme d'essais relatifs à la production de la vapeur, savoir :

Résultats donnés par les tubes suivant leur diamètre, leur longueur, leur système, leur disposition dans la chaudière et le métal dont ils sont formés;

Essais sur l'influence du volume de la boîte à fumée et des différentes formes des cheminées et des pare-étincelles;

Essais sur les divers systèmes d'échappement;

Essais sur l'influence que peut avoir la vitesse sur la production de la vapeur.

Rapporteur : Mr. Sauvage, ingénieur en chef des mines, ingénieur en chef adjoint du matériel et de la traction des chemins de fer de l'Est français, à Paris.

VI. — Locomotives des trains a grande vitesse.

Type de moteur à vapeur le plus favorable aux grandes vitesses.

Emploi des hautes pressions et application du principe compound.

Distributions perfectionnées et tiroirs équilibrés.

Conditions de construction des locomotives en vue de diminuer la grandeur des efforts dynamiques exercés sur la voie. Influence, à ce dernier point de vue, de la disposition compound.

Rapporteur : Mr. Aspinall, ingénieur en chef de la traction du Lancashire and Yorkshire Railway, à Horwich, Lancashire.

2nd SECTION. — LOCOMOTIVES AND ROLLING STOCK.

V. — Boilers, Fire-Boxes and Tubes.

A. Steel boilers and fire-boxes. Strain to which they are subjected in use, and conditions on which the plates are accepted.

B. Iron tubes. Means of preventing leakage at the tube plates.

C. Injurious effect of the feed water on the boilers and tubes. Systems of purifying.

D. Synopsis of experiments as to the production of steam, viz. :—

Results obtained with tubes according to their diameter, length, system, arrangement in the boiler, and the metal of which they are made.

Experiments as to the influence of the capacity of the smoke-box, and the different forms of chimneys and spark-arresters.

Experiments with the various forms of blast-pipe.

Experiments as to the effects of speed on the production of steam.

Reporter, Mr. Sauvage, Assistant Locomotive Engineer, Eastern Railway of France, Paris.

VI — Express Locomotives.

Type of engine most suitable for high speeds.

The use of high pressure, and application of the compound principle.

Improvements in distribution and balanced slide-valves.

Engine-building regarded from the point of view of diminishing the strains of the permanent way. The effect from this latter point of view of the compound principle.

Reporter, Mr. Aspinall, Chief Mechanical Engineer, Lancashire and Yorkshire Railway, Horwich, Lancashire.

VII. — Voitures des trains à grande vitesse.

(2e et 3e sections réunies.)

Type de voitures pour les trains à grande vitesse et pour les trains à long parcours. Train flexible et continu. Perfectionnements apportés aux dispositions intérieures. Divers modes de chauffage et d'éclairage.

Rapporteur : Mr. Park, chef du service des voitures du London and North Western Railway, à Wolverton.

VIII. — Traction électrique.

Étude générale de la traction électrique.

Rapporteur : Mr. Auvert, ingénieur attaché au service central du matériel du chemin de fer de Paris-Lyon-Méditerranée, à Paris.

VII. — Rolling stock for Express Trains.

(2nd and 3rd Sections combined.)

Type of rolling stock for express trains, and long journeys. Vestibule trains. Improvements in internal arrangements. Various modes of heating and lighting.

Reporter, Mr. Park, Carriage Superintendent, London and North Western Railway, Wolverton.

VIII. — Electric Traction.

The general question of electric traction.

Reporter, Mr. Auvert, Engineer in the Rolling Stock Department of the Paris and Lyons Railway, Paris.

3e SECTION. — EXPLOITATION.

IX. — Accélération des transports de marchandises.

(2e et 3e sections réunies.)

Influence de la vitesse des transports sur les dépenses de traction et l'utilisation du matériel, d'une part, sur l'effectif du matériel et le développement des installations fixes, d'autre part.

Rapporteur : Mr. Lambert, directeur général du Great Western Railway, Paddington, Londres, W.

X. — Manoeuvres de gare.

A. Moyens d'accélérer les manœuvres de gare et les manutentions des marchandises. Dispositions des gares de formation.

Rapporteurs pour les pays de langue

3rd SECTION. — TRAFFIC.

IX. — Acceleration of Transport of merchandise.

(2nd and 3rd Sections combined.)

Influence of speed upon of the expenses of haulage, and the utilisation of rolling stock, on the one hand. and on the other hand, upon the number of vehicles and the amount of accommodation and plant required.

Reporter, Mr. Lambert, General Manager, Great Western Railway, Paddington, London, W.

X — Station Working.

A. Methods of accelerating the shunting of trucks and handling of merchandise. Arrangement of sorting sidings.

Reporters for non English speaking

non anglaise, Mr. Richter (J.), adjoint du directeur de la ligne de Saint-Pétersbourg à Varsovie des chemins de fer de l'État russe à Saint-Pétersbourg, et

Pour les pays de langue anglaise, Mr. Turner, directeur général du Midland Railway, à Derby.

B. Emploi des moyens mécaniques et électriques pour accélérer la manutention des marchandises et les manœuvres de gare.

Rapporteurs pour les pays de langue non anglaise, Mr. Sartiaux (Eug.), chef des services électriques du chemin de fer du Nord, à Paris, et Mr. von Boschan (A.), ingénieur au chemin de fer du Nord-Empereur Ferdinand d'Autriche, à Vienne;

Pour les pays de langue anglaise, Mr. Turner, directeur général du Midland Railway, à Derby.

XI. — Signaux.

Perfectionnements récents dans les appareils de block-system et d'interlocking-system, notamment au point de vue de l'économie des installations.

Signaux dans les tunnels.

Moyens à employer pour éviter les collisions aux points dangereux des lignes rapides en cas de franchissement des signaux à l'arrêt.

Remplacement du langage des couleurs par celui des formes géométriques en vue d'éviter les dangers provenant du daltonisme ou du défaut d'acuité visuelle.

Rapporteurs pour les pays de langue non anglaise, Mr. Motte (Lucien), ingénieur adjoint au chef de service des voies et travaux du chemin de fer de l'État belge, à Namur, et

Pour les pays de langue anglaise, Mr. Thompson, chef du service des signaux du London and North Western Railway, à Crewe.

countries, Mr. Richter (J.), Assistant Superintendent of the State Railway from St. Petersburg to Warsaw, St. Petersburg;

For English speaking countries, Mr. Turner, General Manager, Midland Railway, Derby.

B. Employment of mechanical and electrical appliances in shunting and marshalling.

Reporters for non English speaking countries, Mr. Eugène Sartiaux, Electrical Engineer of the Northern of France Railway, Paris, and Mr. von Boschan (A.), Engineer, Kaiser Ferdinand's Nordbahn, Vienna;

For English speaking countries, Mr Turner, General Manager, Midland Railway, Derby.

XI. — Signals.

Recent improvements in block and interlocking apparatus, chiefly from the point of view of economy in initial outlay.

Signals in tunnels.

Methods of preventing collisions at points of danger on express lines, in case of over-running stop signals.

Replacement of colour signals by geometric form signals, in order to avoid the dangers arising from colour-blindness or defective vision.

Reporters for non English speaking countries, Mr. Motte (Lucien), Engineer, Belgian State Railway, Namur;

For English speaking countries, Mr. Thompson, Signal Superintendent, London and North Western Railway, Crewe.

XII. — Factage et camionnage.

Organisation du service de factage et de camionnage pour la remise et la prise à domicile des marchandises à expédier par chemin de fer.

Rapporteur : Mr. Twelvetrees, directeur du service des marchandises du Great Northern Railway, King's Cross, Londres, N.

XII. — Cartage and Delivery.

Organisation for the collection and delivery of goods and parcels consigned by railway.

Reporter, Mr. Twelvetrees, Chief Goods Manager, Great Northern Railway, King's Cross, London, N.

4e SECTION. — ORDRE GÉNÉRAL.

XIII. — Organisation des services.

Organisation des services d'administration centrale et des services extérieurs sur les divers réseaux des différents pays.

Rapporteurs pour les pays de langue non anglaise, Mr. Duca, directeur général des chemins de fer de l'État roumain, professeur à l'école des ponts et chaussées, à Bucharest, et

Pour les pays de langue anglaise, Mr. Harrison, directeur général du London and North Western Railway, Euston, Londres, N. W.

XIV. — Règlement des litiges.

Règlement des litiges qui se produisent entre les Administrations des chemins de fer à l'occasion du transport des marchandises.

Rapporteur : Mr. de Perl, conseiller d'État, directeur gérant de l'Union russe pour les relations internationales des chemins de fer, à Saint-Pétersbourg.

XV. — Cadran de vingt-quatre heures.

(3e et 4e sections réunies.)

Introduction dans les horaires de la numération continue des heures de 1 à 24 et de la division de l'heure en 100 grades. État de la question. Applications partielles dans les différents pays.

4th SECTION. — GENERAL.

XIII. — Organisation.

Organisation of the central administration, and outdoor staff on the various systems of different countries.

Reporters for non English speaking countries, Mr. Duca, General Manager, Roumanian State Railways, professor at the École des ponts et chaussées, Bucharest;

For English speaking countries, Mr. Harrison, General Manager, London and North Western Railway, Euston, London, N. W.

XIV. — Settlement of Disputes.

Rules for settlement of differences arising between Railways with respect to goods traffic.

Reporter, Mr. de Perl, Privy Counsellor, Chief of the Foreign Traffic Department, Russian Railway Union, St. Petersburg.

XV. — The Twenty-four hours Day.

(3rd and 4th Sections combined.)

Introduction in the time-tables of continuous reckoning from 1 to 24 hours, and of the division of the hour into 100 parts. Present state of the question. Partial adoption in different countries.

Avantages pour le public et pour le service. La modification des cadrans des horloges serait-elle nécessaire, et dans l'affirmative comment devrait-elle se faire ?

Rapporteurs : Messrs. Scolari (Léon), docteur en droit, inspecteur principal de la direction générale des chemins de fer de la Méditerranée (Italie), et Rocca (Joseph), ingénieur, inspecteur de la direction générale du même chemin de fer, à Milan.

XVI. — Système décimal.

(1re et 4e sections réunies.)

Généralisation de l'adoption du système décimal dans les calculs relatifs aux constructions et à l'exploitation des chemins de fer.

Moyens de favoriser l'introduction du système métrique des poids et mesures dans les pays où il n'est pas en usage.

Rapporteur : Mr. Wilkinson, directeur du service des marchandises du Great Western Railway, Paddington, Londres, W.

5e SECTION. CHEMINS DE FER ÉCONOMIQUES.

XVII. — Affluents de transports et chemins de fer a faible trafic. *(4e et 5e sections réunies.)*

A. *Chemins de fer économiques affluents.* Moyens employés par les Administrations des grandes lignes pour faciliter l'établissement ou l'exploitation des chemins de fer économiques affluents.

Rapporteur : Mr. De Backer (H.), directeur général de la Société générale de chemins de fer économiques de Belgique, à Bruxelles.

B. *Facilités à accorder aux chemins de fer à faible trafic.* Facilités qui pourraient être

Advantages to the public, and to the railway service. Would the alteration of existing clocks be necessary, and if so, how could it best be accomplished?

Reporters, Messrs. Scolari (Léon), Chief Inspector of the Mediterranean Railway of Italy, and Rocca (Joseph), Engineer and Inspector of this Railway, Milan.

XVI. — Decimal System.

(1st and 4th Sections combined.)

General adoption of the decimal system in calculations relating to the construction and working of railways.

Method of facilitating the introduction of the metric system of weights and measures in those countries where it is not already in use.

Reporter, Mr. Wilkinson, Chief Goods Manager, Great Western Railway, Paddington, London, W.

5th SECTION. — LIGHT RAILWAYS.

XVII. — Contributive Traffic and relaxation of normal requirements for Light Railways. *(4th and 5th Sections combined.)*

A. *Light feeder lines.* Method adopted by the great Railways to encourage the building or working of light feeder lines.

Reporter, Mr. De Backer, General Manager of the Belgian General Economic Railway Society, Brussels.

B. *Relaxation of normal requirements for light railways.* In the case of light railways accordées par les autorités gouvernementales pour favoriser l'établissement et l'exploitation des chemins de fer à faible trafic, sans qu'il en résulte d'inconvénient au point de vue de la sécurité.

Rapporteurs : Messrs. A. C. Humphreys-Owen, membre du Parlement anglais, président du Conseil du comté de Montgomeryshire, administrateur des Cambrians Railways, et P. W. Meik, membre de l'Institut des ingénieurs civils, Londres.

what relaxation can be made by the Government in its normal requirements for construction and working without risking the public safety?

Reporters, Mr. Humphreys Owen, M. P., Chairman of the Montgomeryshire County Council, Director of the Cambrian Railways, and Mr. P. W. Meik, M. Inst C. E., London.

XVIII. — Affermage de l'exploitation des chemins de fer économiques.

Quels sont les pays où l'affermage a été appliqué? Quelles sont les conditions auxquelles il a été accordé, et quels sont les résultats utiles que l'on en a retirés?

Rapporteur : Mr. de Burlet, directeur général de la Société nationale belge des chemins de fer vicinaux, à Bruxelles

XVIII. — The Working of Light Railways by Leasing Companies.

In what countries has the system of leasing light railways been adopted? On what terms are such leases granted and with what practical results?

Reporter, Mr. de Burlet, General Manager of the Belgian National Light Railway Society, Brussels.

XIX — Dépôts des chemins de fer économiques.

Faut-il placer le dépôt principal au milieu ou à l'une des extrémités de la ligne?

Rapporteur : Mr. Terzi, directeur du chemin de fer de Suzzara-Ferrara, à Sermide (Italie).

XIX. — Light Railway Shops.

Should the principal shops be in the middle or at one end of the line?

Reporter, Mr. Terzi, Manager of the Railway from Suzzara-Ferrara to Sermide, Italy.

XX. — Freins des chemins de fer économiques.

(2e et 3e sections réunies)

Étude des divers systèmes de freins appliqués aux chemins de fer économiques. Conditions techniques et conditions de sécurité.

Rapporteur : Mr. Plocq, ingénieur, chef de l'exploitation de la Société générale des chemins de fer économiques, à Arras, France.

XX. — Brakes for Light Railways.

(2nd and 5th Sections combined.)

Account of the different kind of brakes in use on light railways. Their respective advantages both from the technical and from the public safety point of view.

Reporter, Mr. Plocq, Superintendent of the General Light Railway Society, Arras, France.

ANNEXE.

RENSEIGNEMENTS TECHNIQUES

à recueillir conformément aux formulaires adoptés par le Congrès sur :

A. Les bris des rails d'acier, par Mr. Bricka, ingénieur en chef de la voie et des bâtiments des chemins de fer de l'État français, professeur du cours de chemins de fer à l'école des ponts et chaussées, à Paris.

B. L'entretien courant des traverses métalliques comparé a celui des traverses en bois, par Mr. Kowalski, ingénieur en chef du service central de l'exploitation du chemin de fer de Bône-Guelma, à Paris.

C. La durée des traverses en bois des différentes essences non injectées ou injectées d'après les divers procédés, par Mr. V. Herzenstein, ingénieur des voies de communication de Russie, vice-président de la Commission pour l'étude de la conservation des bois, à Saint-Pétersbourg.

D. Les essieux coudés des locomotives (1), par Mr. Hodeige, ingénieur principal au chemin de fer de l'État belge, à Bruxelles.

E. Les foyers des locomotives, par Mr. Hodeige, précité.

F. Les chaudières des locomotives, par Mr. Belleroche, ingénieur chef de service au chemin de fer Grand Central Belge, à Bruxelles.

G. Le graissage des véhicules, par Mr. Hubert, ingénieur en chef, directeur d'administration au chemin de fer de l'État belge, à Bruxelles.

H. Les machines de manœuvres (1), par Mr. Hodeige, précité.

I. Le mouvement du personnel dans les différents pays (1), par Mr. G. de Laveleye, membre du conseil d'administration du chemin de fer du Congo, à Bruxelles.

(1) Les renseignements recueillis étant très incomplets, cette question n'a pas été traitée.

APPENDIX.

TECHNICAL INFORMATION

collected in conformity with the forms adopted by the Congress :

A. The breaking of steel rails, by Mr. Bricka, chief engineer of the French State Railways, professor of railway engineering at the École des ponts et chaussées, Paris.

B. The current cost of metallic compared with wooden sleepers, by Mr. Kowalski, chief engineer of the Bona Guelma railway, Paris.

C. The life of wooden sleepers of different kinds, not pickled or pickled according to various processes by Mr. V. Herzenstein, engineer of ways and communications, vice-president of the Commission for the study of the preservation of timber in Russia, St. Petersburg.

D. Locomotive crank axles (1), by Mr. Hodeige, chief engineer, Belgian State Railways, Brussels.

E. Locomotive fire-boxes, by Mr. Hodeige, aforesaid.

F. Locomotive boilers, by Mr. Belleroche, chief engineer, Grand Central Railway of Belgium, Brussels.

G. Lubrication of rolling stock, by Mr. Hubert, chief engineer, Belgian State Railways, Brussels.

H. Shunting engines (1), by Mr. Hodeige, aforesaid.

I. The movement of the staff in different countries (1), by Mr. G de Laveleye, director of the Congo Railway, Brussels.

(1) As the information collected on this question was very incomplete, it was not dealt with.

1st SECTION — WAY AND WORKS

PRELIMINARY MEETING

Held on June 26, 1895, at 4.30 p. m.

Mr. Ludvigh, *member of the International Commission,* took the chair provisionally and spoke as follows :—

Gentlemen, the International Commission of the railways Congress have appointed me to preside at the election of the officers for the 1st Section.

By the Commission's wish I propose that you choose as your president Mr. Jeitteles, aulic councillor and general manager of the Northern of Austria.

You are aware, gentlemen, that this great railway Company is one of the most prosperous and one of the best managed undertakings in Austro-Hungary. The selection of its illustrious general manager will be of real assistance to your discussions, especially because, in the investigations upon one of the most important questions in your programme, " the question of strengthening the permanent way in view of the increased speed of trains ", his Company has been of the greatest help in lightening the labours of its chief engineer, Mr. Ast, who will give you a summary of his striking report with his usual ability. (*Hear! Hear!*)

Mr. Jeitteles thereupon took the chair and said :—

Gentlemen, I feel highly flattered at the very kind way in which you have been good enough to approve the selection of myself. I can assure you I appreciate the compliment and you may count on my doing my very best.

I propose that the other officers of the section shall be the following :—

Principal secretaries. — Mr. Debray, ingénieur en chef des ponts et chaussées de France, professeur à l'École des ponts et chaussées, secrétaire général de la commission des méthodes d'essai des matériaux de construction.

Mr. Edmund Andrews, resident engineer, London and South Western Railway.

Secretary reporters. — Mr. Demoulin, engineer, Western of France Railway.

Mr. Leslie Robinson, Associate member of the Institution of Civil Engineers.

— This being adopted, the meeting adjourned.

1st SECTION. — WAY AND WORKS

QUESTION I

STRENGTHENING OF PERMANENT WAY

IN VIEW OF THE

INCREASED SPEED OF TRAINS

Type of permanent way suited for lines traversed by trains at high speed. Gradual strengthening of existing roads, so as to permit of an increase in the speed of trains.

A. *Section of rail. Calculation of the strains imposed by the rolling load. Results of experiments.*

B. *Mode of manufacture and nature of rail-metal. Comparison of soft with hard steel. Steel produced (1) by the acid process in the Bessemer converter; (2) by the basic process in the converter; (3) by either process in the Martin furnace.*

C. *Rail connections. Fatigue of fish plates. Construction of joint best calculated to secure uniform strength of the road throughout. Rails laid in chairs, and Vignoles rails.*

D. *Sleepers, their quality, dimensions, and distance apart.*

E. *Ballast, the various descriptions and methods of laying.*

Reporter for English speaking countries, MR. HUNT, Chief Engineer, Lancashire and Yorkshire Railway.

Reporter for non English speaking countries, MR. AST, Chief Engineer, Kaiser Ferdinand's Nordbahn.

QUESTION I

CONTENTS

2[ND] REPORT (FOR ENGLISH SPEAKING COUNTRIES)

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With a view of ascertaining the practices of British, Irish, American, Indian, African, and Australian Railways, the reporter prepared a list of questions in reference to the subject of this report.

This list of questions was issued by the Brussels Commission of the Congress to such Companies as are members of the Congress, and in addition, the reporter issued the same list to twelve Railway Companies in America with whose practices he considered it might be desirable for the Congress to become acquainted; of these twelve, six have replied.

It was requested in the list of questions that the replies to them might have reference only to lines on which there are services of express trains travelling at a minimum speed of 40 miles (64 kilomètres) per hour. Three of the Indian, two of the African, and one of the Australian lines replied that no advantage would have resulted from their answering the questions, inasmuch as there are no services of express trains travelling on their lines at the speed specified.

Three Railways in the United Kingdom have not replied to the questions at all, and two have stated that they do not propose to reply, their mileage being only small.

The replies which have been received are from : —

13 Railways in England and Wales, viz. :

Cambrian.
Furness.
Great Eastern.
Great Northern.
Great Western.
Lancashire and Yorkshire.
London Brighton and South Coast.
London and North Western.
London and South Western.
Manchester Sheffield and Lincolnshire.
Midland.
North Eastern.
South Eastern.

4 Railways in Scotland, viz. :

Caledonian.
Glasgow and South Western.
Highland.
North British.

2 Railways in Ireland, viz. :

Great Northern Railway of Ireland.
Great Southern and Western.

6 Railways in America, viz. :

Chesapeake and Ohio.
Chicago, Burlington, and Quincy.
Illinois Central.
Lake Shore and Michigan.
Pennsylvania.
New York Central and Hudson River.

1 Indian Railway, viz. :

East Indian.

1 Australian Railway, viz. :

New South Wales Government Railways.

In order that the practices of the different Companies and Administrations may be the more readily compared with each other, the reporter has compiled from the above answers 10 statements which form appendices to this report. In these appendices the actual wording of the replies as received has not been adhered to, but the substance of them is believed to be correctly recorded. The reason for not adhering strictly to the actual wording of the replies was to enable the practice of any Railway to be more easily compared with that of others.

In addition to these statements, this report is accompanied by 30 plates, illustrating the type of permanent way used by those Companies and Administrations, who have answered the questions addressed to them.

It should be noted that both statements and the plates show the latest standard of each Company so far as the United Kingdom is concerned. These latest standards are not in use at present over the whole of the several systems, but in their renewals the Companies are gradually introducing them.

The replies received from the American Railways give various weights of rails on their several lines, but do not state whether the Companies are going to raise everything up to the highest standard, or intend to continue the use of the lighter section of rails on branches of their lines.

It must be understood that the remarks in this report apply only to the 27 Companies and Administrations who have replied to the questions addressed to them.

Types of permanent way.

As regards the type of permanent way, it would appear from the replies received that the railways in the United Kingdom are almost universally adopting bull-headed steel rails, keyed into chairs fastened to transverse sleepers by means of treenails, spikes, or screws, or combinations of these fastenings. The type of permanent way adopted in America by the Companies who have answered the questions consists of flat-bottomed rails resting directly on transverse sleepers, and fastened to them principally by means of spikes.

The only engineers who have in their replies expressed any opinion as to the types of permanent way, are the engineer of the Great Northern Railway of Ireland, and the engineer of the New York Central and Hudson River Railroad. The former gentleman, who uses both types of permanent way, expresses himself as follows :—

« As the steel rail is immediately in contact with the sleepers, the result is a very smooth running road, at the same time there is no doubt that our steel bull-headed road with the chairs keyed inside, is far superior, stronger, more permanent, and better in every way than any flange railroad.»

and the latter gentleman, writing on the American type, says :—

« Rails supported in « chairs » have been out of date in this country for many years past, the Vignoles type, or « flange » rail, as it is termed in this country, having proved immeasurably superior in service and economy on American railroads.»

Strengthening of permanent way.

With regard to the strengthening of permanent way so as to permit of an increased speed of trains, the Railway Companies in the United Kingdom have, over a long series of years, been gradually increasing the weight of their rails, and the weight and bearing area on the sleepers of their chairs, but from the information which the reporter has received, most of the principal Companies do not contemplate any further strengthening of the roads, as their latest standards of permanent way are fully capable of taking the highest speeds that can be obtained with the present rolling stock. The Great Western Railway Company, however, state that greater strength of the permanent way could be obtained by increasing the weight of the rail, and the bearing area of the chair, which should be made with a wider jaw to provide for a larger key. The London and South Western Company strengthen their road on sharp curves and down steep inclines by introducing an additional sleeper under each pair of rails.

The American Railways have been and are evidently strengthening their rails with a view to suit high speeds, but none, except the New York Central and Hudson River Railroad Company, state that they intend to further strengthen their road with a view to still higher speeds.

Great Britain and Ireland.

A. — Rails, etc.

(See statement *A.*)

The section of rail usually adopted is the steel bull-headed rail, the bull-head being much larger than the bottom member, to allow for wear and tear, the bottom member being made sufficiently strong, after allowing for oxidation, to form with the top member when worn down a sufficiently strong girder to carry the rolling load.

In England the weight of the rails varies from 80 to 92 lbs. (39 1/2 et 45 1/2 kilogrammes par mètre), in Scotland from 77 to 90 lbs. (38 et 44 1/2 kilogrammes par mètre), and in Ireland from 74 to 85 lbs. per lineal yard (36 1/2 et 42 kilogrammes par mètre). (There are some rails weighing 100 lbs. to the yard (49 1/2 kilogrammes par mètre) but these are few in number.) With the exception of the Great Western, whose rails are 32 feet long (9^m74), and the London and North-Western Company, who are adopting a standard length of 60 feet (18^m29), the length of rail adopted by English Companies is 30 feet (9^m14). In Scotland and Ireland the standard length of the rails is also 30 feet (9^m14), with the exception of the Caledonian and Great Northern of Ireland, who use rails 32 feet and 26 feet long (9^m74 and 7^m92) respectively.

No absolute weight per yard appears to be adopted to which rails may be worn down before being renewed, the general condition of the whole of the materials forming the permanent way, and other vaying circumstances, being taken into consideration in determining when the road should be renewed. The renewals, when they take place, are usually in long lengths, and the material recovered, when not too far worn, is utilized for the repairs and sometimes renewals of branch lines, loop lines, and sidings.

As regards the calculations of the strains imposed on rails by the rolling load, as the various stresses cannot be ascertained sufficiently accurately to enable a rail to be designed on the same scientific principles as a girder would be, it is considered by English engineers that close and careful observations of the effects produced upon the road by the rolling loads which pass over it is the best means of determining the size and shape of the rail.

B. — Mode of manufacture and nature of rail metal.

(See statement *B.*)

From the replies received, it is clear that most of the Railway Administrations have their rails rolled from steel manufactured by the Bessemer acid process, although some of them return the Bessemer process without stating whether it is the acid proces or the basic process. The only Companies who, in their specification, permit the use of the basic process, are the Manchester Sheffield and Lincolnshire, and the North Eastern.

The London and North Western, the Manchester Sheffield and Lincolnshire, the Caledonian, and the North British Companies have a specification for the Siemens Martin acid process.

With reference to the testing of rails, all Companies, except the Cambrian, test their rails by blows produced by various weights falling from various heights on various lengths of rail supported on bearings from 3 feet to 3 feet 6 inches (0^m914 à 1^m067) apart. The amount of permanent deflection varies in each case in proportion to the weight used and the height from which that weight is dropped.

Some Railway Companies, in addition to this, test the rails as girders, suspending dead weights from the centre, and specifying the deflections which will be allowed under the test of certain weights.

The chemical tests do not appear generally to form part of the specification for rails, only four Companies giving a more or less detailed specification of the chemical analysis. The Great Northern Railway of Ireland state that they test their rails chemically, but do not give particulars of their requirements.

The breaking weight in tons per square inch (par centimètre carré) is only specified by five Companies. The extension per cent. is only specified by three Companies, and the contraction of area per cent. is only specified by one Company.

It appears, therefore, from these returns, that the Railway Companies mainly rely on the falling weight test to determine the quality of the rail manufactured for them.

As to the relative merits of hard and soft steel, only five Companies give any information, and of these five, four lean to the use of mild steel as being less liable to fracture and therefore ensuring a greater measure of safety.

C. — Rail connections.

(See appendix *C.*)

The form of joint universally adopted in the United Kingdom is a suspended one, the rails being connected by two fish plates bolted together through the rails by four fish bolts.

With the exception of the Great Western and London and North Western Railways, whose fish plates are 20 inches (508 millimètres) long, all the Companies adopt a fish plate 18 inches (457 millimètres) long. Much longer fish plates than these were in use some years ago, but there seems to be a general opinion that the fish plates should be as short as possible in order to bring the chairs and sleepers at the joints as near together as possible, and in reply to the question as to whether this form of joint gives satisfaction, 16 out of 19 Companies state that it does.

As to the shape of the fish plates in use, they may be divided into two classes, viz., plates whose depth is the distance between the top and bottom flange of the rail, and plates in which the depth is increased to the underside of the bottom flange, and even deeper, in some instances underlapping the rail. The sections of this class of fish plate are shown in the book of diagrams. 10 Companies use the former class, and 9 Companies use different sections of the second class. There are no suggestions as to how the joint could be improved.

All the Railways (so far as their bull-headed rails are concerned) support the rails in chairs fastened to transverse sleepers, using various kinds of fastenings. The Great Northern Railway of Ireland for their flat bottom rails, and the Great Southern and Western Railway of Ireland, fasten their flat-bottomed rails direct to the sleepers by means of fang bolts and spikes.

The weight of the chairs used by the different Companies varies considerably, the smallest weight being that of the South Eastern Railway, 37 lbs. (16.78 kilogrammes) the heaviest being that of the Lancashire and Yorkshire Railway which weighs 56 lbs. (25.40 kilogrammes).

The bearing area of the chair on the sleeper also varies considerably, the smallest area being that of the South Eastern Railway, viz. : — 70 square inches (451.2 centimètres carrés), the largest being that of the Manchester Sheffield and Lincolnshire Railway which has a bearing area of 117 square inches (754.8 centimètres carrés).

The only Companies who place felt between the chair and the sleeper throughout their systems are the Cambrian and the London and North Western Railways. The London Brighton and South Coast Railway use it in special tunnels where the noise is excessive. No other Company uses a packing of any kind between the chair and the sleeper.

The pattern of the chair on each side of the joint used by any Company is the same as that of the rest of the chairs in the road.

The number and kind of fastenings for attaching the chairs to the sleepers varies with almost every Company. The details are given in appendix *C*.

D. — Keys and sleepers.

(See statement *D.*)

Of the eighteen Companies who use the chair road, eleven of them use oak for their keys, two use teak and oak, one teak only, one fir, one pine, and one elm. Eight Companies compress their keys, and ten do not. All the Companies are keying on the outside of the rail except the Furness Railway, but they are now gradually adopting outside keying.

Baltic red wood is the timber most generally used for sleepers, although some Companies use Memel, Riga red wood, Scotch fir, red pine. Every Company creosotes its sleepers.

The lengths of sleepers are 8 feet 11 inches or 9 feet (2^m718 ou 2^m743), and the breadth 10 inches (254 millimètres) amd the thickness 5 inches (127 millimètres).

The distance apart of the sleepers on the several lines is shown in the accompanying plates.

Although metal sleepers have been put down in places, notably on the London and North Western Railway, they do not seem to have found favour with the Railway Companies of the United Kingdom. The London and North-Western Railway have not put any down since 1888; the Great Eastern and London and South Western Companies have experimented with a few, but are not continuing their use.

E. — BALLAST.

(See statement *E.*)

The ballast used by the various Companies, details of which are given in appendix *E*, varies according to the locality through which the lines pass. The bottom ballast generally consists, in districts where it can be obtained, of large hand-packed stones, but where this cannot be obtained, slag, burnt clay, and ashes are used. For top ballast various materials are used, viz. : — Broken stone, gravel, slag, chippings, ashes, and cinders screened and unscreened, and Thames gravel; the best material in each district consistently with economy being obtained, so as to get the best drainage possible.

The practice of laying ballast above the level of the top of the sleeper varies a good deal. Details are given in appendix *E.*

American, Indian, and Australian Railways.

A1. — SECTION OF RAIL.

(See statement *A1.*)

The section of rail usually adopted by the six Railway Companies in America, who have answered the questions, and by the East Indian Railway, and New South Wales Government Railways, is a flat bottom rail with bull head. The area of the bottom member is somewhat stronger than need be, considering the rail as a girder, being apparently so made to distribute the weight of the traffic over as large an area of the sleeper (or « tie » as it is called in America) as possible.

The weight of the rails varies from 60 lbs. to 85 lbs. per lineal yard (30 et 40 kilogrammes par mètre), but the New York Central Railway have laid down for trial a certain length of road with rails weighing 100 lbs. per lineal yard (49 1/2 kilogrammes par mètre). The result of this trial will guide them as to what weight of rail they will adopt in the future.

As to the length of rails used, the standard length is 30 feet (9^m14), but the Pennsylvania Railway have used 60 feet (18^m29) rails, though they do not say whether they intend to continue them or not. Rails of 60 feet (18^m29) length are also in use on a portion of the New York Central and Hudson River Railway, where their engineer writes, « This length promises well, with the prospect of a substantial economy in maintenance of way expenses ».

As with the English Railways, these Companies, as a rule, do not fix an absolute weight per yard to which the rails may be worn before being renewed, but the New-York Central Railway gives a minimum, a medium, and a maximum weight of rails at which they should be renewed, and the New South Wales Government gives the weights to which the rail are worn down.

B1. — Mode of manufacture and nature of rail metal.

(See appendix *B1.*)

Six Companies specify that the steel from which the rails are rolled shall be manufactured by the Bessemer process, two out of the six specifying the acid process. The Chicago, Burlington, and Quincy Railroad do not specify any particulars by which the steel from which the rails are rolled is to be manufactured. The East Indian Railway prefer the Siemens acid process.

As far as tests go, the six American Railways do not subject their rails to any bending test. The Chesapeake and Ohio and the Illinois Central Railroads test the steel, however, from which the rails are rolled, by hammering two test pieces into bars which, when cold, must bend to an angle of 90 degrees without breaking. The Chicago, Burlington, and Quincy Railroad purchase the rails under a five years guarantee.

The East Indian and New South Wales Government Railways adopt the falling weight tests, similar to those used by the English Railways. They also test the rails as girders with suspended weights.

The New York Central and Hudson River Railroad Company specify a chemical test.

The New York Central and Hudson River Railroad and the New South Wales Government have also a breaking weight in tons per square inch (par centimètre carré), that of the former being from 49 to 58 tons per square inch (7.à 27 9.13 tonnes par centimètre carré), and that of the latter being 44 tons per square inch (6.93 tonnes par centimètre carré). The elongation in the case of the New York Central and Hudson River Railroad is from 6 to 12 per cent., and the New South Wales Government Railroad 14 per cent.

It is clear from the returns that the American Railways prefer a hard steel to a mild one, as giving a longer wear.

C1. — RAIL CONNECTIONS.

(See statement *C1.*)

Three of the American Railways state that they use suspended joints, and the other three use supported joints. In two instances, viz., the Chicago, Burlington and Quincy Railway, and the New York Central and Hudson River Railway, the joint is supported by a transverse sleeper centrally underneath it.

The East Indian and the New South Wales Government Railways use suspended joints.

The fish plates on the American Railways vary from 20 inches to 38 inches long. (508 et 965 millimètres). Four of these Railways have long fish plates with six fish bolts. The other two use short fish plates 20 inches and 24 inches (508 et 610 millimètres) long with four fish bolts.

The East Indian Railway uses fish plates 22 inches (559 millimètres), and the New South Wales Government Railways use for their flat bottom rails, fish plates 18 inches (457 millimètres) long, and for their bull-headed rails, fish plates 20 inches (508 millimètres) long, each with four fish bolts.

On the Chicago, Burlington, and Quincy Railroad, and the New York Central and Hudson River Railroad the rails are laid with broken joints, that is, the joints in one rail being opposite the centre of the other rail in its road.

Six of the Companies consider their joints are satisfactory. The Lake Shore and Michigan Railroad do not consider the joint satisfactory, stating « a joint fastening which is as strong as the rail is required ». The Pennsylvania Railroad Company state that their joint is not universally satisfactory, and they suggest an improvement by shortening the fish plates. The New York Central and Hudson River Railroad throw out a suggestion that joints should be abandoned altogether, and some form of compound continuous rail substituted for them, but so far as the reporter can ascertain this has not been tried.

The American Railways fasten their rails to the sleepers in various ways, by spikes, clips, and screws, details of which are given in appendix *C 1*.

The bearing area of the rails on the sleeper varies from 36 to 50 square inches. (232.3 et 322.6 centimètres carrés).

The iron chairs used by the East Indian Railway are 30 lbs. (13.61 kilogrammes) weight, having a bearing area on the sleeper of 86 square inches (554.8 centimètres carrés); on the New South Wales Government Railway, where bull-headed rails are used, the weight of the chair is 45 lbs. (20.41 kilogrammes), and the bearing area on the sleeper 108 square inches (696 centimètres carrés).

On both these last mentioned lines the chairs on each side of the joint are of the same pattern as the rest.

D1. — Keys and sleepers.

(See statement *D1.*)

Keys are of course not used on the American Railways.

Keys of teak are used on the East Indian Railway, and teak and cedar on the New South Wales Government Railways. On the first-named line the keys are not compressed, but on the latter they are. Both Railways key on the outside of the rail.

The wood used for the sleepers, as will be seen by the appendix, varies with the locality. Neither of the Railways creosote their sleepers.

The length of the sleeper varies from 8 feet to 9 feet 6 inches (2^m438 et 2^m896), the breadth from 8 inches to 10 inches, and the thickness from 5 inches to 7 inches (127 et 178 millimètres).

E1. — Ballast.

(See statement *E1.*)

The American, Indian, and Australian Railways, like the English Railways, adopt for bottom ballast, broken stone, gravel, or sand according to the locality. The top ballast varies in thickness from 5 inches to 12 inches (127 et 305 millimètres), and consists principally of gravel, crushed stone, cinders, or slag.

STATEMENT *A*. — **Rails.**

Numbers.	QUESTIONS.	England		
		Cambrian (Pl 1.)	**Furness.** (Pl. 2.)	**Great Eastern** (Pl. 3.)
1	Weight of rail . . . { Per yard . / Par mètre.	80 lbs. / 39 1/2 kilog	80 1/2 lbs. / 40 kilog.	85 lbs. / 42 kilog.
2	Length	30 feet (9m14).	30 feet (9m14).	30 feet (9m14).
3	Holes for fish bolts :			
a	a) Number	Four.	Four.	Four.
b	b) Shape	Round.	Elongated.	Oval.
c	c) Distance apart from centre to centre of holes	4 1/2 inches (114 mill.).	4 1/2 inches (114 mill)	4 1/2 inches (114 mill.)
d	d) Distance from end of rail to centre of nearest hole. . .	2 1/8 inches (54 mill.)	2 1/8 inches (54 mill.).	2 5/8 inches (67 mill.)
4	Is the line relaid when the rails wear down to minimum weight per yard?	No attention is paid to this, but renewed when required	Relaying of line is ruled by the position, gradient, amount of traffic, etc.	Relaying is carried on year by year all over the system at various points wherever required. Judging by this it gives an average life of 14 to 24 years. On the suburban lines, and at or near the London termini, where the traffic is very heavy, rails have been taken out at a much shorter life than this.
5	If so, give weight			
6	Is line relaid when rails wear down to minimum thickness of top flange or minimum depth over all? . .			
7	If so, give thickness or depth. . .			
8	Have you made use of rails of unusual length, 60 feet (18m19) or upwards?	On viaducts only.	No.	No.
9	If so, state object and what result .		"	"

nd Wales.

Great Northern. (Pl. 4.)	Great Western. (Pl. 5.)	Lancashire and Yorkshire. (Pl. 6.)	London, Brighton and South Coast. (Pl. 7.)	London and North Western. (Pl. 8.)
85 lbs.	92 lbs.	86 lbs.	84 lbs.	80 lbs. and 90 lbs.
42 kilog.	45 1/2 kilog.	42 1/2 kilog.	41 1/2 kilog.	39 1/2 et 44 1/2 kilog.
30 feet ($9^{m}14$).	32 feet ($9^{m}74$).	30 feet ($9^{m}14$).	30 feet ($9^{m}14$).	30 feet and 60 feet ($9^{m}14$ et $18^{m}29$).
Four.	Four.	Four.	Four.	Four.
Oval.	Oval.	Oval.	Oval.	Circular.
1/2 inches (114 mill.).	5 inches (127 mill.).	4 1/8 inches (105 mill.).	4 1/2 inches (114 mill.).	4 1/2 inches (114 mill.).
3/16 inches (58 mill.).	2 7/16 inches (62 mill.).	2 7/8 inches (73 mill.).	2 1/2 inches (64 mill.).	2 3/8 inches (60 mill.).
Dependent on the mount of traffic, and life of rails.	As a rule it may be taken that with from 15 to 20 years of average traffic, a rail loses 15 to 20 per cent. of its weight, and is taken out and used in sidings or goods lines, the fittings and sleepers being removed at the same time, and likewise used again.	Approximate minimum weight 66 lbs. per lineal yard (32 1/2 kilog. par mètre), provided the other component parts of the permanent way are in sufficiently good order to allow of them being so worn down, if not the whole road is taken out and the unworn rails used for sidings.	Top flange. When 1/2 inch (12.7 mill.) has been worn off.	No weight is arbitrarily fixed. The nature of traffic, the condition of sleepers and chairs, and the demand for second-hand rails for repairs, are taken into consideration, as well as the deformation and weight of the rail.
No.	No.	No.	No.	60 feet ($18^{m}29$) is the standard length, shorter rails are also used.
•	•	•	•	Fewer joints.

*

STATEMENT *A*. — **Rails.** (*Continuation.*)

Numbers.	England and Wales. (*Continuation.*)				
	London and South Western. (Pl. 9.)	**Manchester Sheffield and Lincolnshire.** (Pl. 10.)	**Midland.** (Pl. 11.)	**North Eastern.** (Pl. 12.)	**South Eastern.** (Pl. 13.)
1	Per yard, 87 lbs. Per mètre, 43 kilog.	86 lbs. 42 1/2 kilog.	85 lbs. 42 kilog.	90 lbs. 44 1/2 kilog.	82 lbs. 40 1/2 kilog.
2	30 feet (9m14).	30 feet (9m14).	30 feet (9m14).	30 feet (9m14).	30 feet (9m14).
3					
a	Four.	Four.	Four.	Four.	Four.
b	Oval.	Oval.	Oval.	Oval.	Oval.
c	4 1/2 inches (114 mill.).	4 1/2 inches (114 mill.).	4 1/2 inches (114 mill.)	5 inches (127 mill.).	4 5/8 inches (117 mill.)
d	2 inches (51 mill.).	2 5/8 inches (67 mill.).	2 3/16 inches (58 mill.).	2 7/20 inches (60 mill.).	2 5/16 inches (59 mill.)
4	No such standard prevails. The necessity for relaying any section of the permanent way is determined by the general condition of all its component parts, coupled with the amount and class of traffic which passes over it.	Yes.	The length of time which our rails can remain in the road varies so largely that it is almost impossible to give any satisfactory information on the subject. The average life of steel rails in our main lines appears to be something like 20 to 21 years.	Yes.	Yes.
5		72 lbs. per yard. (36 1/2 k. par mètre).		70 lbs. par yard (34 1/2 k. par mètre).	Average, 70 lbs. per yard (34 1/2 kilog. par mètre).
6		Thin top flange.		»	Yes.
7		Top flange worn to thickness of bottom flange.		»	4 5/8 inches to 4 7/8 inches (117 à 124 mill.).
8	No	No.	No.	No.	No.
9	»	»	»	»	»

Scotland.				Ireland.	
Caledonian. (Pl. 14.)	Glasgow and South Western. (Pl. 15.)	Highland. (Pl. 16.)	North British. (Pl. 17.)	Great Northern of Ireland. (Pl. 18 et 19.)	Great Southern and Western. (Pl. 20.)
90 lbs. 44 1/2 kilog.	90 lbs. (44 1/2 kilog.). — Only one section is now used, but there are still different sections in use, which are being replaced by the standard section when worn out.	76 1/2 lbs. (38 kil.) Double-headed. 77 and 80 lbs. (38 et 39 1/2 kilog.). Bull-headed.	84 lbs. (41 1/2 kilog.).	Steel Bull-headed, 85 lbs. (42 kilog.). Steel flat-bottomed, 79 lbs. (39 k.).	74 lbs. (36 1/2 kilog.).
32 feet (9m74).	30 feet (9m14).	30 feet (9m14).	30 feet (9m14)	26 feet (7m92).	30 feet (9m14).
Four.	Four.	Four.	Four.	Four.	Four.
Oval.	Oval	Round.	Oval.	Elongated.	Oval.
4 10/16 inches (117 mill.).	4 5/8 inches (117 mill.).	4 5/8 inches (117 mill.).	4 inches (102 mill.).	4 inches (102 mill.).	4 inches (102 mill.).
2 5/16 inches (59 mill.).	2 3/8 inches (60 mill.)	2 7/32 inches (56 mill.).	2 7/16 inches (68 mill.)	2 15/16 inches (75 mill.).	2 5/16 inches (59 mill.).
No weight is arbitrarily fixed, but generally wear down to 70 lbs. per lineal yard (34 1/2 kilog. par mètre) If, however, state of ballast and sleepers require renewal, the rails would be taken out whether they are worn down to 70 lbs. (34 1/2 kil. par mètre) or not.	The line is relaid when the rails are worn so that they are considered too weak to carry the traffic. The rails which come out of the main line when relaying weigh from 68 lbs. (32 1/2 kilog.) to 72 lbs. per yard (36 1/2 kilog. par mètre), and we consider that they should not be used any lighter than this.	Steel rails substituted for iron.	There is no fixed minimum weight per yard when line must be relaid. There is no fixed minimum thickness when line must be relaid.	All old iron rails taken up when much laminated, worn, and cracked, and relaying with new steel rails carried out in long continuous lengths.	We have no fixed rule as to when this should be done.
No.	No.	No.	No.	No.	No.
»	»	»	»	»	»

STATEMENT *B.* — **Manufacture and testing of rails.**

Numbers.	QUESTIONS.	England			
		Cambrian. (Pl. 1.)	**Furness.** (Pl. 2.)	**Great Eastern.** (Pl. 3.)	**Great Northern.** (Pl. 4.)
1	By what process in the steel for rails manufactured?				
a	*a*) Bessemer acid	Bessemer acid.	Bessemer acid.	Bessemer.	Bessemer acid.
b	*b*) Siemens Martin acid . .	»	»	»	»
c	*c*) Basic in Siemens Martin hearths	»	»	»	»
2	To what tests are rails subjected before acceptance?				
a	*a*) Bending	No specification.	3 feet 6 inches ($1^{m}067$) length to be cut from rails, and placed on supports 3 feet (914 mill.) apart, and shall then receive a blow from a weight of 1 ton (1,016 kilog.), falling from a height of 20 feet ($6^{m}09$) without breaking, and without a permanent deflection of more than 3 inches (76 mill.).	A rail to be placed, bull-head uppermost, on bearings 3 f. 6 inch. ($1^{m}067$) apart. Weight of 18 tons (18.289 tonnes) to be suspended from centre, deflection not to exceed 3/8 of an inch (9.5 mill.) after weight has been on half-an-hour, permanent set after removal not to exceed 1/8 of an inch (3.2 mill.) The same rail placed bull-head uppermost on bearings 3 f. 6 in. ($1^{m}067$) apart must bear two blows from ball weighing 1,800 lbs. (816 kilog.) from a height of 8 feet ($2^{m}438$) without breaking, and without deflecting more than 1 inch (25 mill.).	5 feet ($1^{m}524$) lengt placed on solid iro supports, having soli foundations 3 f. 6 in ($1^{m}067$) clear apart, an shall then receive suc cessive blows from weight of 1,120 lbs (508 kilog.) falling height of 10 f. ($3^{m}048$ Rails not to break be fore or under the thir blow, nor take a perman ent set after the firs blow exceeding 1 3/ inch (35 mill.).
b	*b*) Chemical	No specification.			
c	*c*) Tension :		None specified.	None specified.	None specified.
	Breaking weight in tons per unit of area.	100 tons (101.5 tonnes) placed half-way between bearings of 3 feet 6 inches ($1^{m}067$).			
	Extension per cent				
	Contraction of area, per cent .				
3	Particulars as to the relative merits of Hard and Soft steel.	»	»	»	»

and Wales.

Great Western. (Pl. 5)	Lancashire and Yorkshire. (Pl. 6.)	London, Brighton and South Coast. (Pl. 7.)	London and North Western. (Pl. 8.)
ngots from which rails are made to be cast of best steel for the purpose, made from English or Spanish hœmatite ore and charcoal spiegeleisen.	Bessemer acid. " "	Bessemer acid. " "	Bessemer acid. Siemens Martin acid.
feet length (1m524) to be cut off one rail from each cast. This to be placed bull head upwards on two iron supports having solid foundations, with centres 3 feet 6 inches (1m067) apart, then subjected to blows from a falling iron weight of 1 ton 1,016 kilog.) without fracture or deflection beyond the following: — First blow 7 feet 2m134) initial deflection 7/8 inch to 1 1/4 inch (22 à 32 mil.), second blow 20 feet 6m096), total deflection 3 inches to 4 1/4 inches (76 à 108 mill.). If the rail after the second blow has not deflected 3 inches 76 mill.) it is to be subjected to a third blow with the same weight from a fall of 12 feet (3m658), the deflection after the third blow to be not less than 4 1/4 inches (108 mill.).	5 feet length (1m524) placed bull-head uppermost on perfectly firm bearers 3 feet 6 inches (1m067) apart must bear one blow from a weight of one ton (1,016 kilog.), falling a height of 20 feet (6m096), without fracture, the permanent set not to be less than 2 1/2 in. (48 mill.) nor to exceed four inches (89 mill.).	A rail to be placed head uppermost on iron bearings 3 feet 6 inches (1m067) apart to receive two blows from a weight of 1 ton (1.016 kil.) falling a height of 20 feet (6m096), without causing greater permanent deflection at first blow than 1 7/8 inches (48 mill.), or than 3 1/2 inches (89 millim.) at second blow.	Rails placed on bearings, centres 3 feet (914 mill) apart, and shall then receive a blow from a weight of one ton (1,016 kilog.), falling a height of 20 feet (6m096), when the permanent deflection shall not be less than 3 inches (76 mill.).
arbon . . . from ·40 to ·50 per cent. ilicon . . . — ·10 to ·06 — anganese . . — ·95 to ·85 — ulphur as low as possible, not to exceed ·08 per cent. hosphorus as low as possible, not to exceed ·08 per cent.	None specified.	None specified.	Bessemer acid steel. Per cent. / Siemens Martin acid steel. Per cent. Carbon. . ·20 to ·40 / ·25 to ·50 Silicon. ·Trace to ·10 / ·01 to ·25 Sulphur . ·01 to ·10 / ·05 to ·10 Phosphorus ·01 to 10 / ·05 to ·15 Manganese ·25 to 1·25 / ·25 to 1·25 Iron. . .99·53 to 98·05 / 99·39 to 97·75 100·00 100·00 / 100·00 100·00
Not less than 40 nor more than 48 tons per square inch f not less than 6.3 tonnes nor more than 7.56 tonnes per centimètre carré.			30 to 35 tons per square inch, (4.72 to 5.51 tonnes per square centim.)
ot less than 20 per cent. in 2 in. (51 mill.). Not given.			About 15 per cent. on lengths of 10 inches. About 22 per cent.
"	"	"	A rather soft steel is used to insure a greater measure of safety.

STATEMENT *B*. — **Manufacture and testing of rails.** (*Continuation.*)

Numbers.	**England and Wales.** (*Continuation.*)				
	London and South Western. (Pl. 9.)	**Manchester, Sheffield and Lincolnshire.** (Pl. 10.)	**Midland.** (Pl. 11.)	**North Eastern.** (Pl. 12.)	**South Eastern.** (Pl. 13.)
1 a	Bessemer acid.	By all processes.	Bessemer acid.	Bessemer acid with hœmatite iron.	Bessemer acid.
b	"		"	Bessemer basic process with Cleveland iron.	"
c	"		"		"
2 a	12 feet (3m658) length placed on bearings 3 feet (914 mill.) apart must bear a blow from a weight of 1 ton (1,016 kilog.) falling from a height of 20 f. (6m096). Permanent set not to be less than 1 5/8 inch (41 mill.) or more than 1 7/8 in. (48 mill.)	5 feet (1m524) length placed on solid iron bearings 3 feet 6 inches (1m067) clear apart, and shall then receive blows from a weight of 10 cwts. (508 kilog.) falling a height of 10 feet (3m048). Rails not to break before or under the third blow, nor take a permanent set after the first blow exceeding 1 3/8 inch (35 mill.).	Rail placed on bearings 3 feet 6 inches (1m067) apart, must not deflect more than a quarter of an inch (64 mill.) with a weight of 20 tons (20,320 tonnes) suspended from the centre. Rail placed on bearings 3 feet 6 inches (1m067) apart to receive two blows from a weight of one ton (1.016 kilog.) falling 12 feet (3m658) without breaking or deflecting more than 3 inches (76 mill.).	Rails to be placed on bearings 3 feet (914 mill.) apart, and shall then receive two blows from a ball weighing one ton (1,016 kilog.), falling a height of 5 feet (1m524). Not to show any signs of fracture, and permanent deflection not to exceed one inch (25 mill.).	A short length of rail placed on bearings 3 feet (914 mill.) apart must on first blow from a weight of 1 ton (1,016 kilog.) falling 14 f. (4m267) not have a greater permanent set than 2 1/8 inches (54 mill.) or more than 3 1/2 inches (89 mill.) at the second blow. Each test rail must bear reversing and straightening under the 1 ton (1,016 kilog.) weight falling 14 f. (4m267) at each blow.
b		Per cent. Carbon to be from . ·3 to ·45 Silicon not to be more than 06 Phosphorus — ·06 Sulphur — ·06 The only metals shall be iron and manganese.		Rail not to contain less than 0·45 per cent. of carbon.	
c	None specified.	"	None specified.	None specified.	None specified.
		"			
		"			
3	We endeavour to secure rails which, while being hard (to resist wear), are not brittle.	Mild steel less liable to fracture	"	"	No data.

Scotland.				Ireland.	
Caledonian. (Pl. 14.)	**Glasgow and South Western.** (Pl. 15.)	**Highland.** (Pl. 16.)	**North British.** (Pl. 17.)	**Great Northern of Ireland.** (Pl. 18 et 19.)	**Great Southern and Western.** (Pl. 20.)
	Bessemer acid.	Bessemer.	Bessemer acid.	Bessemer acid.	Bessemer acid.
Bessemer, Siemens, or other equally approved process.	»	»	Siemens acid.	»	»
	»	»	»	»	»
Each rail placed on bearings 3 feet (914 mill.) apart, shall bear a weight of 40 tons (40.640 tonnes) suspended midway between those bearings without a greater deflection than 3/8 inch (9.5 mill.), and without any permanent deflection after the load has been on for one hour. Also two blows from a weight of 1 ton (1,016 kilog.) falling a height of 12 feet (3m658) without breaking, or more deflection than 1 inch (25 mill.) for each blow.	Not less than 15 feet (4m572) length of rail, placed on bearings 3 f. (914 mill.) apart, shall bear weight of 40 tons (40.640 tonnes) suspended midway between these bearings without greater deflection than 3/8 inch (9.5 mill.), and without any permanent deflection after the load has been on for one hour. Also two blows from a weight of 1 ton (1,016 kilog.) falling a height of 12 feet (3m658) without breaking, or more deflection than 1 1/4 inch (32 mill.) for each blow.	A rail to be placed bull-head uppermost on bearings 3 feet 6 inch. (1m067) apart, must bear a weight of 20 tons (20.320 tonnes) midway between the bearings without permanent deflection, and 36 tons (36.580 tonnes) without fracture. A rail placed on two supports, 3 feet (914 mill.) apart, must stand two blows from an iron ball weighing 1 ton (1,016 kilog.), falling upon it from a height of 20 f (6m096) without breaking, and without a greater permanent set than 3 1/2 inches (89 mill.).	A rail placed on bearings 3 f. 8 in. (1m118) apart, must bear one blow from a weight of 1 ton (1,016 kil.) falling a height of 15 feet (4m572) without deflecting more than 2 1/2 inches (64 mill.), and without showing any imperfections.	A rail placed on bearings 3 feet (914 mill.) apart must bear a weight midway between the bearings of 23 tons (23.370 tonnes) without permanent set, and 35 tons (35.560 tonnes) without breaking. A rail placed on bearings 3 feet (914 mill.) apart, must bear three blows from a ball weighing 18 cwt. (914 kilog.), falling from a height of 9 feet (2m743), without deflecting more than 3 inches (76 mil.).	A rail placed on bearings 3 f. (914 mil.) apart must bear a weight of 23 t. 23.37 t.) without permanent set, and a weight of 35 tons (35.360 t.) without breaking. A rail placed on bearings 3 feet (914 mill.) apart must bear three blows from a ball weighing 1 ton (1,016 kilog.) falling a height of 9 feet (2m743) without deflecting more than 3 inches (76 mill.).
	»	»		Detail not given.	
None specified.		30 tons per square inch (4.72 tonnes per square centimètre) of sectional area.	None specified.	32 to 39 tons per square inch. (5·04 to 6·14 t. per square cent.)	None specified.
	»				
	»	»		16 to 23.	
	»	»		Not taken.	
»	We prefer steel for rails to be of the hard side.	»	»	Soft steel rails less liable to fracture in the line.	»

STATEMENT *C.* — **Rail connections.**

NUMBERS.	QUESTIONS.	Cambrian. (Pl. 1.)	Furness. (Pl. 2.)	Great Eastern. (Pl. 3.)
1	Is the rail suspended or supported in a joint chair or on sleepers?	Suspended.	Suspended.	Suspended.
2	Fish plate :			
a	Length	18 inches (457 mill.).	18 inches (457 mill.).	18 inches (457 mill.).
b	Depth	4 7/8 inches (124 mill.).	4 15/16 inches (125 mill.).	4 7/8 inches (124 mill.)
c	Thickness	13/16 inch. (21 mill.).	3/4 inch (19 mill.).	13/16 inch. (21 mill.).
d	Weight of each.	20 1/2 lbs. (9.30 kilog.).	20 lbs. (9.07 kilog.).	21 1/2 lbs. (9.30 kilog.)
3	Fish bolts :			
a	Number.	Four.	Four.	Four.
b	Size	4 inches (102 mill.) by 29/32 inch. (23 mill.).	4 inches (102 mill.) by 7/8 inches (22 mill.).	4 inches (102 mill.) by 7/8 inch (22 mill.).
c	Weight including nut and washer (where used).	1 lb. 9 1/4 oz. (0.716 kilog.)	1 3/8 lbs. (0.624 kilog.).	1 1/2 lb. (0.68 kilog.).
4	Description of fish bolt.	Cup headed, with square shoulder at head end.	Eureka patent cup headed, with square shoulder at head end.	Cup headed with squar shoulder at the head en
5	Description of nut (and washer if any) .	Ordinary square nut with differential thread, no washer.	Ordinary square nut and round washer.	Ordinary square nuts a no washers.
6	Are holes in fish plates square or circular, punched or drilled?	Square—punched.	Square in one plate, and circular in the other. Punched.	Square.—Punched.
7	Does the form of joint used give satisfaction?	Yes.	Yes.	Yes.
8	If not, in what respect is improvement required with a view to securing uniform strength of road throughout?. .	-	-	-
9	How are rails secured to sleepers?			
a	With chairs on wood sleepers. . .	Yes.	Yes.	Yes.
10	Weight of chair?	42 lbs. (19.05 kilog.).	45 lbs. (20.41 kilog.).	43 lbs. (19.50 kilog.).
11	Base of chair area in { square inches . . / centimètres carrés.	101 1/2 square inches (654.8 cent. carrés).	116 square inches (748.4 cent. carrés).	98 square inches (632.3 cent. carrés).
12	Is felt or other material placed between chair and sleeper?	Felt.	No.	No.
13	Are the chairs on each side of the joint of the same pattern as the rest? If not, give particulars	Yes.	Yes.	Yes.
14	Full particulars of mode of attachment of each chair to sleeper	2 fang bolts and 1 spike.	Two 7/8 inch (22 mill.) cup headed spikes and two compressed oak treenails.	Two iron spikes 5 1/2 i ches (140 mill.) by 7 inch (22 mill.), and tw solid treenails.
15	Full particulars of mode of attachment of flat-bottomed rail to sleeper. . . .	-	-	-

England and Wales.

Great Northern. (Pl. 4.)	Great Western. (Pl. 5.)	Lancashire and Yorkshire. (Pl. 6.)	London, Brighton and South Coast. (Pl. 7.)	London and North Western. (Pl. 8.)
Suspended.	Suspended.	Suspended.	Suspended.	Suspended.
18 inches (457 mill.).	20 inches (508 mill.).	18 inches (457 mill.).	18 inches (457 mill.).	20 inches (508 mill.).
3 1/4 inches (83 mill.).	3 1/4 inches (83 mill.).	3 3/8 inches (86 mill.).	6 7/8 inches (175 mill.).	5 1/4 inches (133 mill.).
1 inch (25 mill.).	13/16 inch (21 mill.).	7/8 inch (22 mill.).	29/32 inch (23 mill.).	7/8 inch (22 mill.).
13 1/2 lbs. (6.12 kilog.).	14 lbs. (6.35 kilog.).	14 lbs. (6.35 kilog.).	29 lbs. (13.15 kilog.).	27 1/4 lbs. (12.36 kilog.).
Four.	Four.	Four.	Four.	Four.
4 1/2 inches (114 mill.) by 7/8 inch. (22 mill.).	4 1/8 inches (105 mill.) by 15/16 inch. (24 mill.).	4 1/4 inches (108 mill.) by 7/8 inch (22 mill.).	4 1/2 inches (114 mill.) by 7/8 inch (22 mill.).	4 inches (102 mill.) by 7/8 inch (22 mill.).
2 lbs. (0.91 kilog.)	1·87 lb. (0.85 kilog.).	1 7/8 lb. (0.85 kilog.).	1 1/2 lb. (0.68 kilog.).	1 1/2 lb. (0.68 kilog.).
Steel—both cup and square headed, with square shoulders at the head end.	Steel—square heads, with pear-shaped shoulder at head end.	Cup head, with square shoulders at head end.	Square head fitting into square recesses in one of the fish plates.	Square head. Shape of fish plate prevents head turning while bolt is being screwed.
Lock nuts are used. Those patented by Messrs. Ibbotson and the Patent Nut and Bolt Co, respectively, are equally preferred.	Lock nuts, with differential threads.	Ibbotson's patent nut. Flat circular washer.	Hexagonal nut with Grover's patent washer.	Steel nut. No washer used.
Square—punched.	Pear-shaped--punched.	Square in one plate, circular in the other—punched.	Circular—punched.	Circular—punched.
Yes.	Yes.	Yes.	Yes.	No—but we know no better one.
"	"	"	"	"
Yes.	Yes.	Yes.	Yes.	Yes.
46 lbs. (20.87 kilog.).	46 lbs. (20.87 kilog.).	56 lbs. (25.40 kilog.).	44 lbs. (19.96 kilog.).	45 lbs. (20.41 kilog.).
103·6 square inches (668.4 cent. carrés).	107·5 square inches (693.5 cent. carrés).	116 square inches (748.4 cent. carrés).	112 square inches (732.6 cent. carrés).	107 square inches (690.3 cent. carrés).
No.	No.	No.	Only in special tunnels where noise is excessive.	Yes—tarred felt.
Yes.	Yes.	Yes.	Yes.	Yes.
2 wrought iron spikes, and 2 oak treenails.	Two 7 1/2 inches (190 mill.) by 13/16 inch. (21 mill.) fang bolts.	2 iron spikes, and 2 wood treenails.	Three hollow treenails with spikes 6 inches (152 mill.) long, 23/32 inch (18 mill.) diameter at head, tapering to 5/8 inch (16 mill.) diameter at the end, which is specially formed to give it a hold in the sleeper.	Two iron spikes 6 inches (152 mill.) long and 13/16 inch (21 mill.) diameter and two galvanized steel screws 6 1/2 inches (165 mill.) long by 13/16 inch (21 mill.) diameter.
"	"	"	"	"

STATEMENT *C.* — **Rail connections.** (*Continuation.*)

Numbers.	England and Wales. (*Continuation.*)				
	London and South Western. (Pl. 9.)	**Manchester, Sheffield & Lincolnshire.** (Pl. 10.)	**Midland.** (Pl. 11.)	**North Eastern.** (Pl. 12.)	**South Eastern.** (Pl. 13.)
1	Suspended.	Suspended.	Suspended.	Suspended.	Suspended.
2					
a	18 inches (457 mill.).	18 inches (457 mill.).	18 inches (457 mill.).	18 inches (457 mill.).	18 inches (457 mill).
b	4 11/16 inches (119 mill.).	3 3/8 inches (86 mill.).	3 1/2 inches (89 mill.).	3 1/4 inches (89 mill.)	3 3/8 inches (86 mill.).
c	3/4 inch (19 mill.).	1 inch (25 mill.).	1 inch (25 mill.).	1 inch (25 mill.).	7/8 inch (22 mill.).
d	20 lbs. (9.07 kilog.).	14 lbs. (6.35 kilog.).	16 lbs. (7.26 kilog.).	13 1/2 lbs. (6.12 kilog.).	13 lbs. (5.90 kilog.).
3					
a	Four.	Four.	Four.	Four.	Four.
b	4 1/8 inches (105 mill.) by 13/16 inch (21 mill.).	4 3/8 inches (111 mill.) by 7/8 inch (22 mill).	4 3/4 inches (121 mill.) by 7/8 inch (22 mill.).	4 1/4 inches (108 mill.) by 7/8 inch (22 mill.)	4 inches (102 mill.) by 3/4 inch (19 mill.).
c	1 1/4 lb. (0.57 kilog.).	1 7/8 lb. (0.850 kilog.)	1 1/2 lb. (0.68 kilog.).	1 1/2 lb. (0.68 kilog)	1 1/4 lb. (0.57 kilog.).
4	Wrought-iron cup headed with square shoulder at head end	Steel. Cup headed with square shoulder at head end.	Steel. Cup headed, with pearshaped shoulder.	Cup headed with square shoulder at head end.	Square head. Shape of fish plate prevents head turning while bolt is being screwed.
5	Ordinary square iron nut and plain washer.	Ibbotson's patent lock nut and ordinary washer.	Ibbotson's lock nut.	Ordinary square iron nut. Washer used in special cases only.	Ordinary square nut and washer.
6	Square in one plate and circular in the other—punched.	Square with rounded corners, punched.	Pear-shaped—drilled.	Square in one plate, and circular in the other. Punched.	Circular—punched.
7	If fish plates could be strengthened cheaply and efficiently, « Occasional » breakages of plates might be reduced still further.	Yes.	Yes.	Yes.	Yes.
8		»	»	»	»
9					
a	Yes.	Yes.	Yes.	Yes.	Yes.
10	46 lbs. (20.87 kilog.).	51 lbs. (23.13 kilog.).	50 lbs. (22.68 kilog.).	40 lbs. (18.40 kilog.).	37 lbs. (16.78 kilog.).
11	97 square inches (625.8 cent. carrés).	117 square inches (754.8 cent. carrés).	102 square inches (658.1 cent. carrés).	108 square inches (696 cent. carrés).	70 square inches (451.2 cent. carrés).
12	No.	No.	No.	No.	No.
13	Yes.	Yes.	Yes.	Yes.	Yes.
14	Three hollow treenails 6 inches (152 mill) by 1 1/8 inch (29 mill.) with wrought-iron spikes 6 1/8 inches (156 mill.) by 5/8 inch (16 mill.).	2 spikes and 2 oak treenails.	2 cup-headed wrought iron spikes, 6 5/8 inches (168 mill.) long by 7/8 inch (22 mill.) diameter. 2 oak treenails, 6 1/2 inches (165 mill.) long by 1 1/4 inch (32 mill.) diameter, the top 2 inches (51 mill.) length, tapering out to 1 1/2 inch (38 mill.) diameter.	Two twisted spikes in opposite corners. 1 inside and 1 outside.	Two wrought iron spikes within two hollow oak treenails.
15	»	»	»	»	»

Scotland.				Ireland.	
Caledonian. (Pl 14.)	**Glasgow and South Western.** (Pl. 15.)	**Highland.** (Pl. 16)	**North British.** (Pl. 17.)	**Great Northern of Ireland.** (Pl. 18 et 19.)	**Great Southern and Western.** (Pl. 20.)
Suspended.	Suspended.	Suspended.	Suspended.	Suspended.	Suspended.
18 inches (457 mill.).	18 inches (457 mill.).	18 inches (457 mill.).	18 inches (457 mill.).	18 inches (457 mill.).	18 inches (457 mill.).
4 7/8 inches (124 mill.).	3 1/2 inches (89 mill.).	2 15/16 inches (75 mill.).	3 inches (76 mill.).	Bullhead rail, 4 3/16 inches (106 mill). Flat-bottomed rail, 4 1/2 inches (114 mill.).	4 3/8 inches (111 mill.).
13/16 inch (21 mill.).	7/8 inch (22 mill.).	3/4 inch (19 mill.).	3/4 inch (19 mill.).	3/4 inch (19 mill.).	3/4 inch (19 mill.).
22 lbs. (9.98 kilog.).	12 1/4 lbs. (5.55 kilog.).	10 lbs. (4.54 kilog.)	11 lbs. (4.99 kilog.).	For bull-headed rails 17 1/2 lbs. (7.94 kilog.). For flat-bottomed rails, 19 1/2 lbs. (8.85 kilog).	15 lbs. 1 oz. (6.80 kilog.).
Four.	Four.	Four.	Four.	Four.	Four.
4 1/4 inches (108 mill.) by 7/8 inch (22 mill.).	4 1/8 inches (105 mill.) by 7/8 inch (22 mill.).	4 inches (102 mill.) by 7/8 inch (22 mill.).	4 inches (102 mill.) by 7/8 inch (22 mill.).	4 1/8 inches (105 mill.) by 7/8 inch (22 mill.).	3 1/2 inches (89 mill.) by 7/8 inch (22 mill.).
1 1/2 lb. (0.68 kilog.).	1 lb. 7 oz. (0.65 kilog.).	1 3/4 lb. (0.79 kilog.).	1 lb. 3 oz. (0.54 kilog.).	1 lb. 5 oz. (0 60 kilog.).	1 lb. 1 1/2 oz. (0.458 kilog.).
Steel cup headed with shoulders at head end.	Soft steel cup headed, oval shoulder at head end.	Cup headed, pear-shaped shoulders.	Cup headed with square shoulders at head end.	Cup headed, pear-shaped shoulder at head end.	Cup headed with square shoulder at head end.
Ordinary square nut.	Ordinary square nut.	Ibbotson's patent nut and washer.	Ordinary square nut.	Hexagonal nut. No washer used.	Ordinary nut. No washer used.
Pear shaped in one plate and circular in the other.	Oval in one plate and circular in the other. Punched.	Pear-shaped punched.	Square in one plate and circular in the other. Punched.	Pear-shaped—punched.	Square—punched.
Yes.	Yes.	Yes.	Yes.	Yes.	»
»	»	»	»	»	»
Yes.	Yes.	Yes.	Yes.	Yes, for Bull-headed rails.	No chairs.
46 lbs. (20.87 kilog).	44 lbs. (19.96 kilog.).	40 lbs. (18.14 kilog.)	40 lbs. (18.14 kilog.).	39 lbs. (16.78 kilog.)	»
105 inches (677.4 cent. carrés)	103 square inches (664.5 cent. carrés)	71·773 squ. inch. (463.1 cent.carr.).	98 square inches (632.3 cent.carrés)	87 square inches (561.3 cent. carrés).	»
No.	No.	No.	No.	No.	»
Yes.	Yes.	Yes.	Yes.	Yes.	»
Spikes 5 3/4 inches (146 mill) by 7/8 inch (22 mill.).	Four spikes each 6 inches (152 mill.) by 7/8 inch (22 mill.).	On curves, 3 spikes in each chair. Straights, 2 spikes in each chair.	Two malleable iron spikes 6 inches (152 mill.) by 15/16 inches (24 mill.) diameter with cup heads.	3 cup-headed spikes, with square shoulders at cup end, 6 inch (152 mill.) by 7/8 inch (22 mill.) diameter at head, tapering to 3/4 inch (19 mill.) at end.	»
»	»	»	»	For flat-bottomed rails, rails fastened to sleepers in the centre of the rails by 2 fang bolts and clips, at each end of the rail by 1 fang bolt, at one end of the rail by a fang bolt inside, and at the other end by a fang bolt inside the road. The remaining 14 fastenings being spikes.	Rails fastened to sleepers with 9 fang bolts (6 outside rail and 3 inside), and 13 spikes (5 outside the rail and 8 inside)

STATEMENT *D.* — **Keys and sleepers.**

Numbers.	QUESTIONS.	England		
		Cambrian. (Pl. 1.)	**Furness.** (Pl. 2.)	**Great Eastern.** (Pl. 3.)
	Keys.			
1	What wood is used?	Oak.	Teak.	Oak.
2	Is it compressed?	Yes.	No.	No.
3	Particulars of metal keys, if used. .	"	"	"
4	Are rails keyed on inside or outside?.	Outside.	Inside-but outside keying is now being adopted.	Outside.
	Sleepers-wood.			
5	What kind of wood is used? . . .	Baltic redwood.	Baltic redwood.	Baltic redwood.
6	Are sleepers creosoted, or treated with other antiseptic?	Creosoted.	Creosoted.	Creosoted.
7	Dimensions :			
a	*a*) Length	9 feet (2^m743).	8 feet 11 inches (2^m718).	8 feet 11 inches (2^m718).
b	*b*) Breadth	10 inches (254 mill.).	10 inches (254 mill.).	10 inches (254 mill.).
c	*c*) Thickness	5 inches (127 mill.).	5 inches (127 mill.).	5 inches (127 mill.).
8	Are they placed in the road heart side or waney side upwards? . .	Waney side upwards.	Waney side upwards.	"

and Wales.

Great Northern. (Pl. 4.)	Great Western. (Pl. 5.)	Lancashire and Yorkshire. (Pl. 6.)	London, Brighton and South Coast. (Pl. 7.)	London and North-Western (Pl. 8.)
Fir.	Oak.	Pine.	Oak.	Oak.
Yes.	Yes.	Yes.	Yes.	Yes.
»	»	»	»	»
Outside.	Outside.	Outside.	Outside.	Outside.
Baltic redwood fir.	Memel.	Baltic.	Baltic redwood.	Red pine or « Pinus sylvestris »
Creosoted.	Creosoted.	Creosoted.	Creosoted.	Creosoted.
8 feet 11 inches (2m718).	9 feet (2m743).	9 feet (2m743).	9 feet (2m743).	9 feet (2m743).
10 inches (254 mill.).	10 inches (254 mill.).	10 inches (254 mill.).	10 inches (254 mill.).	10 inches (254 mill.).
5 inches (127 mill.).	5 inches (127 mill.).	5 inches (127 mill.).	5 inches (127 mill.)	5 inches (127 mill.).
Heart side upwards.	Majority-waney side upwards.	Heart side upwards.	Waney side upwards.	Waney side upwards.

STATEMENT *D.* — **Keys and sleepers.** (*Continuation.*)

Numbers.	England and Wales. (*Continuation.*)				
	London and South Western. (Pl. 9.)	**Manchester Sheffield and Lincolnshire.** (Pl. 10.)	**Midland.** (Pl. 11.)	**North Eastern.** (Pl. 12.)	**South Eastern.** (Pl. 13.)
1	English oak.	Elm.	Oak.	Oak.	Heart of oak.
2	Yes.	Yes.	No.	No.	No.
3	"	"	"	"	"
4	Outside.	Outside.	Outside.	Outside.	Outside.
5	Baltic redwood fir.	Baltic redwood.	Memel.	Riga redwood and Scotch fir.	Baltic redwood.
6	Creosoted.	Creosoted.	Creosoted.	Creosoted.	Creosoted.
7					
a	9 feet (2^m743).	9 feet (2^m743).	9 feet (2^m743).	9 feet (2^m743).	9 feet (2^m743).
b	10 inches (254 mill.).	10 inches (254 mill.).	10 inches (254 mill.).	10 inches (254 mill.).	10 inches (254 mill.)
c	5 inches (127 mill.).	5 inches (127 mill.).	5 inches (127 mill.).	5 inches (127 mill).	5 inches (127 mill.).
8	Waney side upwards.	Heart side upwards.	Heart side upwards.	Heart side upwards.	Waney side upwards.

Scotland.				Ireland.	
Caledonian. (Pl. 14.)	**Glasgow and South Western.** (Pl. 15.)	**Highland.** (Pl. 16.)	**North British.** (Pl. 17.)	**Great Northern of Ireland.** (Pl. 18 and 19.)	**Great Southern and Western.** (Pl. 20.)
Oak.	Teak and oak.	Teak.	Oak and Teak.	Oak.	No keys used on this line as there are no chairs.
No.	No.	No.	No.	No.	
"	"	"	"	"	
Outside.	Outside.	Outside.	Outside.	Inside.	
Baltic redwood.	Baltic redwood.	Scotch fir and larch.	Red pine and Scotch fir.	Baltic fir.	Baltic redwood.
Creosoted.	Creosoted.	Creosoted.	Creosoted.	Creosoted.	Creosoted.
8 feet 11 inches (2^m718).	8 feet 11 inches (2^m718).	9 feet (2^m743).	9 feet (2^m743).	8 feet 11 inches (2^m718).	9 feet (2^m743.).
10 inches (254 mill.).	10 inches (254 mill.).	10 inches (254 mill.).	10 inches (254 mill.).	10 inches (254 mill.).	10 inches (254 mill.).
5 inches (127 mill.).	5 inches (127 mill.).	5 inches (127 mill.).	5 inches (127 mill.).	5 inches (127 mill.).	5 inches (127 mill.).
Waney side upwards.	Waney side upwards.	Waney side upwards.	Waney side upwards.	Waney side upwards.	Waney side upwards.

STATEMENT *E.* — Ballast.

NUMBERS.	QUESTIONS.	England		
		Cambrian. (Pl. 1)	**Furness.** (Pl. 2.)	**Great Eastern.** (Pl. 3.)
1	Material adopted for bottom ballast.	Pitched stone.	Stone or slag.	Burnt ballast, topped with good rough gravel.
2	If stone, what mesh?	"	2 1/2 inches (63 mill.).	"
3	Depth of bottom ballast	12 inches (305 mill.).	12 inches (305 mill.).	12 inches (305 mill.).
4	If cinders, whether screened or not.	Not screened.	"	"
5	Materials used for top ballast.	Gravel or refuse from lead mines.	Cinders generally.	Good rough gravel to pass through a 2 inch (51 mill.) ring.
6	Thickness of top ballast	12 inches (305 mill.).	7 inches (178 mill.).	"
7	Is the top ballast laid above the top of the sleeper, and if so, to what extent?	Top of sleeper in middle. Top of rail on outside.	Yes. 1 inch (25 mill.)	Finished height to be level with top of rails.
8	What advantages are found to result from the use of the material selected for ballast?	Gravel good. Ashes better. Refuse of lead mines best in preserving sleepers.	Firmness, dryness, and absence of dust.	"

and Wales.

Great Northern. (Pl. 4.)	Great Western. (Pl. 5.)	Lancashire and Yorkshire. (Pl. 6.)	London, Brighton and South Coast. (Pl. 7.)	London and North Western. (Pl. 8.)
Broken stone in stone districts. Burnt clay elsewhere.	Stone and slag, according to locality.	Hand-packed stones, 9 inches (229 mill.) deep, capped with 3 inches (76 mill.) of ashes wherever the stones can be obtained, and where these cannot be obtained, hard clinkers capped with ashes.	Chalk or broken stone.	Broken stone, slag, cinders, gravel, as may be most readily and economically obtained.
2 inches (51 mill.).	Smallest, 3 inches (49 mill.) cube; largest, 6 inches (98 mill.) cube.	»	»	Any size up to the depth of the bottom ballast.
12 inches (305 mill.).	12 inches (305 mill.).	12 inches (305 mill.).	12 inches (305 mill.).	From 6 inch. (152 mill.) to 9 inches (229 mill).
Not screened.	Screened.	Not screened.	»	Generally screened.
Clean gravel or hard well burnt ashes.	Stone, and slag, and gravel, according to locality.	Ashes.	Gravel.	Broken stone, slag, cinders, gravel, as may be most readily and economically obtained.
9 inches (229 mill.).	6 inches (152 mill.).	9 inches (229 mill.).	12 inches (305 mill.).	9 inches (229 mill).
Yes. 2 inches (51 mill).	Sometimes about 4 inches (102 mill.) on outside, and 1 1/2 inch (38 mill.) on inside.	No.	About 3 inches (76 mill.) above.	No.
Better drainage.	»	Ease of running.	»	»

STATEMENT *E.* — **Ballast.** (*Continuation.*)

Numbers.	England and Wales. (*Continuation.*)				
	London and South Western. (Pl. 9.)	**Manchester, Sheffield and Lincolnshire.** (Pl. 10.)	**Midland.** (Pl. 11.)	**North Eastern.** (Pl. 12.)	**South Eastern.** (Pl. 13.)
1	Dry lump chalk, roughly broken stone, or coursed stony ballast.	Stone pitching 9 inches (229 mill.) thick.	Slag or stone.	Ashes, stone, or gravel.	Ballast (unscreened), rough ballast or other available material.
2	"	Hand pitched.	Hand-packed, 8 inches (203 mill.) deep.	2 inches (51 mill.).	"
3	9 inches (229 mill.).	9 inches (229 mill.).	11 inches (279 mill.).	12 inches (305 mill.).	6 inches to 12 inches (152 à 305 mill.).
4	"	Selected engine ashes.	"	Not screened.	Loco cinders, unscreened.
5	Gravel or Thames river ballast and in West of England stone ballast, broken to pass through 2 inch (51 mill.) ring.	Ditto.	Clean sharp gravel, ashes, slag chippings, or granite chippings.	Coke ballast from furnaces, cinders.	Sea beach and Thames river gravel.
6	9 inches (229 mill.).	6 inches (152 mill.).	6 inches (152 mill.).	6 inches (152 mill.).	6 inches to 12 inches (152 à 305 mill.).
7	Not much above sleeper.	Yes. 3 inches (76 mill.).	No.	Level with the top of the sleeper.	About 5 inches (127 mill.) above the sleepers.
8	Stone bottom more suitable than gravel where obtainable, as it facilitates drainage.	Very good drainage and preservation of materials.	Good drainage. Absence of dust (with slag).	Cinder ballast gives an easy running road, is economical, drains easily, is packed easily, and does not set.	Better preservation of the sleepers and keys, and additional steadiness of the permanent way.

Scotland.				Ireland.	
Caledonian. (Pl. 14.)	Glasgow and South Western. (Pl. 15.)	Highland. (Pl. 16.)	North British. (Pl. 17.)	Great Northern of Ireland. (Pl. 18 et 19.)	Great Southern and Western. (Pl. 20.)
Slag, bottom of ballast, 21 inches (533 mill.) below rails.	Iron slag	Clean hard gravel or broken stone.		Stone pitching.	Stone.
»	2 1/4 inch (57 mill.) ring.	Not exceeding 4 inch. (102 mill.).		»	2 inch (51 mill.) ring.
»	10 inches (254 mill.).	12 inches (305 mill.).		6 inches (152 mill.).	10 inches (254 mill.).
»	»	»	All kinds.	Screened.	»
Slag.	Iron slag.	Clean gravel or broken metal not exceeding 2 inches (51 mill.) mesh.		Gravel, broken stone and cinders.	Gravel.
»	5 inches (127 mill.).	6 inches (152 mill).		1 foot 3 inches (381 mill.) to 1 foot 6 inches (457 mill.).	10 inches (254 mill.).
No.	Level with top of sleeper.	No.	»	Ballast laid to underside head of rail and channelled in centre of sleeper.	No.
Found to be suitable, and best to be got.	The road is kept dry and easily packed up with iron slag ballast, and the ballast lasts a very long time.	Good drainage and firmness of road.	»	Good drainage of permanent way.	»

STATEMENT *A1*. — **Rails.**

QUESTIONS.	Ame[rican]			
	Chesapeake and Ohio. (Pl. 21.)	**Chicago, Burlington & Quincy.** (Pl. 22.)	**Illinois central.** (Pl. 23.)	**Lake shore & Michigan Southern.** (Pl. 24.)
Weight of rail. Par mètre.	31 kilog.	37 kilog.	34 1/2 à 37 kilog.	35 kilog.
Weight of rail. Per yard.	75 lbs.	75 lbs.	Drawings datd 1894 show 70 lbs. and 75 lbs. per lineal yard. Previous dates show lighter sectns.	71 lbs.
Length	30 feet (9m14).	30 feet (9m14).	30 feet (9m14).	30 feet (9m14).
Holes for fish bolts :				
a) Number	Six.	Six.	Four.	Four.
b) Shape	Circular.	Circular.	Circular.	Circular.
c) Distance apart from centre to centre of holes. . .	5 inches (127 mill.)	5 inches (127 mill.).	4 1/2 inches (114 mill.).	6 inches (152 mill.)
d) Distance from end of rail to nearest hole . . .	1 15/16 inches (49 mill.).	2 3/8 inches (60 mill.)	2 13/64 inches (56 mill.).	2 15/16 inches (74 mill.).
Is line relaid when rails wear down to a minimum weight per yard ?	"	No minimum weight.	No minimum weight.	"
If so, give weight.	"	"	"	"
Is line relaid when rails wear down to minimum thickness of top flange or minimum depth over all ?	Rails are renewed when necessary, in judgment of engineer.	No minimum thickness or depth.	No minimum thickness or depth.	We relay when rails become too rough or too badly worn to make smooth track.
If so, give thickness and depth.	"	"	"	"
Have you made use of rails of unusual length, 60 feet (18m19) or upwards ?	No.	No.	No.	No.
If so, state object and with what result	"	"	"	"

rica.		India.	Australia.
New York Central and Hudson River. (Pl. 25-26 and 27.)	Pennsylvania. (Pl. 28.)	East Indian. (Pl. 29.)	New South Wales Government Railways. (Pl. 30 and 31.)
32, 34 1/2, 37, 39 1/2 and 49 1/2 kilog.	1875 Standard, 30 kil. 1887 Standard, 42 kil. 1889 Standard, 34 1/2 k.	42 kilog.	Bull-headed rails, 39 1/2 kilog. Flat-bottomed, 39 1/2, 35 1/2 and 30 kilog.
65, 70, 75, 80 and 100 lbs.	1875 Standard, 60 lbs. 1887 Standard, 85 lbs. 1889 Standard, 70 lbs	85 lbs.	Bull-headed rails, 80 lbs. Flat-bottomed, 80, 71 1/2, and 60 lbs.
30 feet (9m14).	30 feet (9m14).	30 feet (9m14).	30 feet (9m14).
Six. Circular.	Six. Circular.	Four. Oval.	Four. Circular.
5 6/10 inches (142 mill.). 2 7/10 inches (69 mill.).	First to second 5 in. (127 mill.), second to third 6 in. (152 m.). 1 15/16 inch (49 mill.)	6 inches (152 mill.). 2 7/8 inches (73 mill.).	4 1/2 inches (114 mill.). 2 3/8 inches (60 mill.).
No. It has not been found practicable with us to wear rails down to the so-called residual section. We renew rails whenever the surface becomes rough from uneven wear, and the section not stiff enough for the traffic loading.	Yes.	»	Yes.
»	Varies.	»	80 lbs. (39 1/2 kilog.). Bull-headed. No information. 80 lbs. (39 1/2 kilog.). Flat-bottomed rails to 70 lbs. (34 1/2 kilog.). 71 1/2 lbs. (35 1/2 kilog.). Flat-bottomed rails to 65 lbs. (32 kilog.). 60 lbs. (30 kilog.) Flat-bottomed rails to 56 lbs. (28 kilog.).
Three rates of wear are noted, « minimum », « medium » and « maximum ». Minimum wear is upon level, straight line, and with rails of 65 lbs., 70 lbs. and 75 lbs. (32, 34 1/2 et 37 kilog. par mètre). Sections become rough when the loss of metal reaches 6 to 8 per cent. per yard. Medium wear is upon gradient, straight lines, the rails becoming rough, and are renewed when the loss of metal reaches 6 to 10 per cent. per yard. Maximum wear is upon gradients combined with curvature, and the rails are renewed when the outer rail of the curve has from 3/8 to 1/2 inch (10 à 13 mill.) side wear while the vertical wear reaches hardly one-half as much.	Governed by wear of top of rail.	With the old rails the ends go. No new rails worn out yet. So far, therefore, we have not fixed any minimum weight.	General condition of rails taken into consideration.
From 1/4 inch to 3/8 inch (6 à 10 mill.) on the head, and from 1/32 inch to 1/16 inch (0mm8 à 1mm6) on the base.	»	»	»
Not as yet. The use of greater lengths than 30 feet (9m14) is only in the experimental stage, and is under trial and consideration. 60 feet (18m29) lengths seem to promise well, with prospect of substantial economy in maintainence of way expenses.	Yes. We have used 60 feet (18m29) rails.	No.	No.
»	To save joint material, but found them heavy to handle; if, however, difficulty of handling can be got over and improved service in the road can be proved, think 60 feet (18m29) none too long.	»	»

STATEMENT *B 1.* — **Manufacture and testing of rails.**

QUESTIONS.	**Ame[rica]**			
	Chesapeake & Ohio. (Pl. 21.)	**Chicago, Burlington & Quincy.** (Pl. 22.)	**Illinois central.** (Pl. 23.)	**Lake Shore & Michigan Southern.** (Pl. 24.)
By what process is the steel for rails manufactured?				
a) Bessemer acid	Bessemer.	No particular process specified.	Bessemer acid.	Bessemer.
b) Siemens Martin acid . .	»		»	»
c) Basic in Siemens Martin hearths	»		»	»
To what tests are rails subjected to before acceptance?				
a) Bending		»	»	»
b) Chemical.	Rails themselves not tested, but the steel from which they are made is tested as follows: Two test pieces 4 inches (102 mill.) long, 3 inches by 3 inches (76 mill. by 76 mill.) from the first and last ingots run. Each of these are drawn out at one heat by hammering to bars 1/2 inch (3.23 cent. carrés) square. When cold, this bar must bend to an angle of 90 degrees without breaking.	Rails not subjected to any physical test, but they are purchased under a five years' guarantee, and all rails that fail, or become unduly worn or battered within the five years, are replaced by the manufacturers, who also have to bear the cost of replacing the rails, and the expense of delivering them along the line.	Rails themselves not tested, but the steel from which they are made is tested as follows: Two test pieces 4 inches (102 mill.) long, 3 inches by 3 inches (76 mill. by 76 mill.) from the first and last ingots run. Each of these are drawn out at one heat by hammering to bars 1/2 inch square (3.23 cent. carrés). When cold, this bar must bend to an angle of 90 degrees without breaking.	Usual mill tests only.
c) Tension . . . . Breaking weight in tons, per . . { squ. inch. / cent. car. Extension, per cent . . . Contraction of area, per cent.				
Particulars as to the relative merits of hard and soft steel .	Carbon, as high as possible, on heavy sections, not to exceed .50 per cent.	»	Much prefer hard steel.	Use as hard a rail as can be got without being brittle.

rica.		India.	Australia.
New York Central & Hudson River. (Pl. 25-26 and 27.)	Pennsylvania. (Pl. 28.)	East Indian. (Pl. 29.)	New South Wales Government Railways. (Pl. 30 and 31.)
Bessemer acid.	Bessemer.	"	Bessemer.
"	"	Prefer Siemens Martin.	"
"	"	"	"
No bending test.	No bending test	Rail to be placed on iron bearings, 3ft. 6in. (1m067) clear apart. Deflection not to exceed 3/8 of an inch (10 mill.), after a weight of 28 tons (28.450 tonnes) has been suspended from the centre for half an hour. No permanent set after removal of weight. Same rail supported as before, to receive two blows from a weight of a ton (1,016 kilog.) falling a height of 25 feet (7m62). Permanent set from first blow not to exceed 2 1/2 inches (63 mill.) total deflection, after both blows not to exceed 5 inches (127 mill.). The rail must then be broken by further blows, when it must have a perfectly sound and homogeneous fracture.	Portions of the rails 4 feet 6 inches (1m371) long on same bearings, to carry a suspended load of 25 tons (25.4 tonnes) with a permanent set not exceeding 1/4 of an inch (6 mill.). Piece of rail 4 feet 6 inches (1m372) long, placed on iron bearings 3 feet 6 inches (1m067) clear apart, to receive three blows from the weight of a ton (1,016 kilog.) falling 6 feet (1m829); the deflection from these three blows to be not less than 3 1/2 inches (89 mill.) and not more than four inches (103 mill.). It is then to receive two more blows from a height of 12 feet (3m66), the deflection from these last two blows to be not less than 8 1/2 inches (216 mill.), nor more than 10 inches (254 mill.).
« Carbon » determination for every « heat, » and at least two complete analyses per day. 80 lbs. (39 1/2 k.) / 100 lbs. (49 1/2 k.). Carbon . . . . . ·55 to ·60 / ·65 to ·75 Silicon . . . . . ·10 to ·15 / ·10 to ·15 Manganese . . . ·80 to 1·00 / ·80 to 1·00 Sulphur not to exceed . . . ·069 / ·069 Phosphorus not tot exceed . . ·060 / ·060 Rails having carbon below will be rejected . . ·55 / ·60 Rails having carbon above will be rejected . . ·65 / ·75	Rails tested chemically, but details not given.		No chemical test specified.
49 to 58 tons per square inch. 7.72 à 9.13 tonnes per cent. carré. 6 to 12 per cent. 9 to 25 per cent.	" " " "	Not specified.	44 tons per square inch. (6.93 tonnes per cent. carré.) 14 per cent. 38 per cent.
Hard tough steel now required to sustain prevailing traffic « wheel loading » with a high « elastic limit » to prevent taking « permanent set ». At the present time our high carbon rails are carrying relatively much heavier traffic loads than formerly low carbon rails did.			Although, as stated above, the drop test is relied upon, the figures here given show the average quality of steel supplied for rails for this colony, and they are found to wear satisfactorily, while the number of fractures is moderate.

STATEMENT *C1.* — **Rail connections.**

Numbers.	Questions.	Chesapeake and Ohio. (Pl. 21.)
1	Is the joint suspended or supported in a joint chair or on sleepers?	Suspended.
2	Fish plate:	
a	a) Length	34 inches (864 mill.).
b	b) Depth	3 1/4 inches (83 mill.).
c	c) Thickness	3/4 inch (19 mill.).
d	d) Weight.	29 lbs. (13.15 kilog.).
3	Fish bolts:	
a	a) Number	Six.
b	b) Size.	3 7/8 inches (98 mill.) by 3/4 inch (19 mill.).
c	c) Weight.	1·30 lbs. (0.59 kilog.).
4	Description of fish bolt	Cup headed, with oval shoulder at head end.
5	Description of nut (and washer if any)	Hexagonal nut with washer.
6	Are holes in fish plates square or circular, punched or drilled?	Inside plate, round. Outside plate, oval. Punched.
7	Does the form of joint used give satisfaction?	Yes.
8	If not, in what respect is improvement required with a view to securing uniform strength of road throughout?	"
9	How are rails secured to sleepers?	
a	a) Wood sleepers with chairs	"
b	b) Wood ditto without chairs	Yes.
10	Weight of chair	No chairs used.
11	Base of chair area, in { square inches / centimètres carrés.	
12	Is felt or other material placed between chair and sleeper?	
13	Are the chairs on each side of the joint of the same pattern as the rest? If not, give particulars	
14	Full particulars of mode of attachment of chair to sleeper	
15	Full particulars of attachment of each flat-bottomed rail to sleeper	By two spikes, 5 1/2 inches (140 mill.) by 9/16 inch (14 mill.).
16	Bearing area of flat-bottomed rail on sleeper in { square inches	41 5/8 inches.
	centimètres carrés.	268.6 centimètres carrés.

America.	
Chicago, Burlington and Quincy. (Pl. 22.)	**Illinois Central.** (Pl. 23.)
Supported on sleepers. The rails are laid with broken joints, *i. e.* joints on one line of rails are opposite the centre of the rail of the other line. A splice bar five inches long (of same section as fish plates) is bolted to the centre of each rail opposite the joint on the other line of rail. These splices are bolted to the rail with one 7/8 inch (22 mill.) bolt and spiked to the tie with one spike on each side.	Supported.
38 inches (965 mill.).	20 inches (508 mill.).
3 1/2 inches (89 mill.).	3 19/32 inches (91 mill.).
5/8 inch (16 mill.).	7/8 inch (22 mill.).
32·3 lbs. (14.65 kilog.).	19 lbs. (8.62 kilog.).
Six.	Four.
4 inches (102 mill.) by 7/8 inch (22 mill.).	4 inches (102 mill.) by 3/4 inch (19 mill.).
1 1/2 lb. (0.68 kilog.).	1 lb. each (0.453 kilog.).
Square head, shape of fish plates, prevents head turning when bolt is being screwed.	Cup headed, with oval shoulder at head end.
Hexagonal nut.	Square nut, « Verona » lock nut.
Round.	Circular in one plate and oval in the other. Punched.
Yes.	Yes.
"	"
-	-
Yes.	Yes.
No chairs used.	No chairs used.
By two spikes, 5 1/2 inches (140 mill.) by 9/16 inch (14 mill.).	By two spikes, 5 1/2 inches (140 mill.) by 9/16 inch (14 mill.).
38 1/2 inches.	75 lbs. rail, 38 1/2 inches. 70 lbs. rail 37 inches.
248.4 centimètres carrés.	37 kilog. rail, 248.3 cent. carré. 34 1/2 kilog. rails, 238.7 cent. carrés.

STATEMENT *C1.* — **Rail connections.** (*Continuation.*)

Numbers.	**America.** (*Continuation.*)		
	Lake Shore and Michigan Southern. (Pl. 24.)	**New York Central and Hudson River.** (Pl. 25-26 and 27.)	**Pennsylvania.** (Pl. 28.)
1	Supported.	Supported on three sleepers, the centre one centrally under the joint. The rails are laid with broken joints, *i.e.*, joints on one line of rails are opposite the centre of the rail of the other line.	Suspended.
2			
a	24 inches (610 mill.).	36 inches (914 mill.).	34 inches (864 mill.).
b	3 1/2 inches (89 mill.).	3 3/4 inches (95 mill.) to 4 3/4 inches (121 mill.)	3 1/8 inches (79 mill.).
c	3/4 inch (19 mill.).	9/16 inch (14 mill.) steel, 5/8 inch (16 mill.) iron.	Varies from 3/4 inch to 1 1/16 inch. (19 mill. et 27 mill.).
d	20 1/2 lbs. (9.30 kilog.).	Rails . . . . . 65 — 70 — 75 — 80 — 100 lbs. per yard or . . . . 32 1/2 — 34 1/2 — 37 — 39 1/2 — 49 1/2 kilog. per metre Fishplates . . 54 — 58 — 64 1/2 — 64 1/2 — 80 lbs. per pair or . . . . 24 1/2 — 26 1/4 — 29 1/4 — 29 1/4 — 36 1/4 kilog. per pair	28 4/10 lbs. in steel (12.88 kilog.)
3			
a	Four.	Six.	Six.
b	3 3/4 inches (95 mill.) by 3/4 inch (19 mill.).	4 1/8 inches (103 mill.) by 3/4 inch (19 mill.) diameter.	4 1/4 inch (108 mill.) by 3/4 inch (19 mill.).
c	·82 lbs. (0.37 kilog.).	1 lb. 1 3/4 oz. (0.503 kilog.).	96/100 of a lb. (0.435 kilog.).
4	Cup headed with oval shoulder at head end.	Cup headed with square shoulder at the head end.	Cup headed with oval shoulder at head end.
5	No washer used. Differential Thread on bolt.	Square nut, no washer used.	Square nut and washer, 1/4 inch (6 mill.) section split ring.
6	Inside plate oval; outside plate circular.	Square in one and round in the other. Punched.	Oval. Punched.
7	Not in all respects.	Gives great satisfaction.	Not universally.
8	A joint fastening which is as strong as the rail is required.	Only by discarding all so-called joints altogether and adopting some form of compound continuous rail.	Shorten the splices.
9			
a	"	"	"
b	Yes.	Yes.	Yes.
10			
11			
12	No chairs used.	No chairs used.	No chairs used.
13			
14			
15	By two spikes, 5 1/2 inches (140 mill.) by 9/16 inch (14 mill.).	Four clips and screws to the sleeper on each side of joint. Intermediate fastenings, two 5 inches (125 mill.) by 5/8 inch (16 mill.) screws.	By two spikes 5 1/2 inch (140 mill.) by 9/16 inch (14 mill.).
	245.2 millimètres carrés.	Rails . . . . 65 — 70 — 75 — 80 — 100 lbs. per yard. or . . . . . . 32 1/2 — 34 1/2 — 37 — 39 — 49 1/2 kilog. per metre	232.3 centimètres carrés.
16	38 inches.	Area . . . . 40 1/2 — 41 5/8 — 42 3/4 — 45 — 49 1/2 square inches. or . . . . . . 261.3 — 268.5 — 275.8 — 290 — 319.4 centim. carrés	36 inches.

India.	Australia.	
East Indian. (Pl. 29.)	New South Wales Government Railways. (Pl. 30 and 31.)	
Suspended	Suspended.	
	For 80 lbs. (39 1/2 kilog. par mètre) flat bottomed rails.	For 80 lbs. (39 1/2 kilog. par mètre) bullheaded rails.
22 inches (559 mill.).	18 inches (457 mill.).	20 inches (508 mill.).
4 1/4 inches (108 mill.).	3 inches (76 mill.).	3 3/8 inches (86 mill.).
31/32 inch (24 1/2 mill.).	13/16 inch (21 mill.).	15/16 inch (24 mill.).
28 1/2 lbs. (12.9 kilog.).	10 1/2 lbs. (4.76 kilog.).	16 1/4 lbs. (7.37 kilog.).
Four.	Four.	Four.
4 3/4 inches (121 mill.) by 7/8 inch (22 mill.).	4 1/8 inches (105 mill.). by 7/8 inch (22 mill.).	4 7/8 inches (124 mill.) by 7/8 inch (22 mill.).
1·58 lb. (0.72 kilog.)	1·28 lb. (0.581 kilog.).	1·47 lb. (0.667 kilog.).
Square headed, shape of fish plate prevents head turning when bolt is being screwed.	Cup headed, with oval shaped shoulder at head end.	Square headed, shape of fish plates prevents head turning when bolt is screwed up.
Hexagonal head with washer 1/8 inch (3.2 mill.).	Hexagonal nut.	Square nut.
	Washers not used till fastenings are worn, when Grover's washers are used.	
Circular.	Oval. Punched.	Circular. Punched.
As good as any other.	Yes.	Yes.
"	"	"
Yes.	"	Yes.
"	Yes.	"
30 lbs (13.61 kilog.).	"	45 lbs. (20.41 kilog.).
86 square inches.	"	107·89 square inches.
554.8 centimètres carrés.	"	696.1 centimètres carrés.
No.	"	No.
Yes.	"	Yes.
Two spikes, 6 7/8 inches (175 mill.) by 3/4 inch (19 mill.).	"	Four holes are provided in each chair, but only two spikes are used, and these are placed diagonally.
"	By two 7/8 inch (22 mill.) spikes.	"
322.6 centimètres carrés.	"	"
50 inches.	"	"

STATEMENT *D1.* — **Keys and sleepers.**

QUESTIONS.	Ame[rica]		
	Chesapeake and Ohio. (Pl. 21.)	**Chicago, Burlington and Quincy.** (Pl. 22.)	**Illinois central.** (Pl. 23.)
Keys.			
What wood is used?	None used.	None used.	None used.
Is it compressed?			
Particulars of metal keys, if used.			
Are rails keyed on inside or outside?			
Sleepers-wood.			
What kind of wood is used?	White oak generally, also chestnut, oak, locust, walnut.	Oak.	White oak and cypress.
Are sleepers creosoted, or treated with other antiseptic?	No.	No.	No.
Dimensions :			
Length	8 feet 6 inches (2m59).	8 feet (2m438).	8 feet and 9 feet (2m438 et 2m743).
Breadth	9 inches (228 mill.).	8 inches (203 mill.).	8 inches (203 mill.) and upwards.
Thickness	7 inches (178 mill.).	6 inches (152 mill.).	6 inches and 7 inches (152 and 178 mill.)
Are they placed in the road heart side or waney side upwards?	Waney side upwards.	Waney side upwards.	Waney side upwards.

rica.			India.	Australia.
Lake Shore and Michigan Southern. (Pl. 24.)	New-York Central and Hudson River. (Pl. 25-26 and 27.)	Pennsylvania. (Pl. 28.)	East Indian. (Pl. 29.)	New South Wales Government Rys. (Pl. 30 and 31.)
None used.	None used.	None used.	Teak.	Teak and cedar.
			No.	Yes.
			»	»
			Outside.	Outside.
White and burr oak.	Oaks, yellow pine, chestnut, yellow cedar, hemlock and tamarack.	White oak.	Sâl and Deodar.	Iron bark.
No.	No.	No.	No.	No.
8 feet 6 inches ($2^{m}59$).	8 feet ($2^{m}438$).	8 feet 6 inches ($2^{m}59$).	9 feet 6 inches ($2^{m}896$).	9 feet ($2^{m}743$).
8 inches (203 mill.).	9 inches (229 mill.) average.	7 inches (178 mill.) and upwards.	10 inches (254 mill.).	10 inches (254 mill.).
7 inches (178 mill.).	6 inches (152 mill.).	7 inches (178 mill.).	5 inches (127 mill.).	5 inches (127 mill.).
Our ties are hewn on two sides only.	Heart side upwards.	»	Waney side upwards. If laid heart side upwards they split more, and water gets in and rots them.	Waney side upwards.

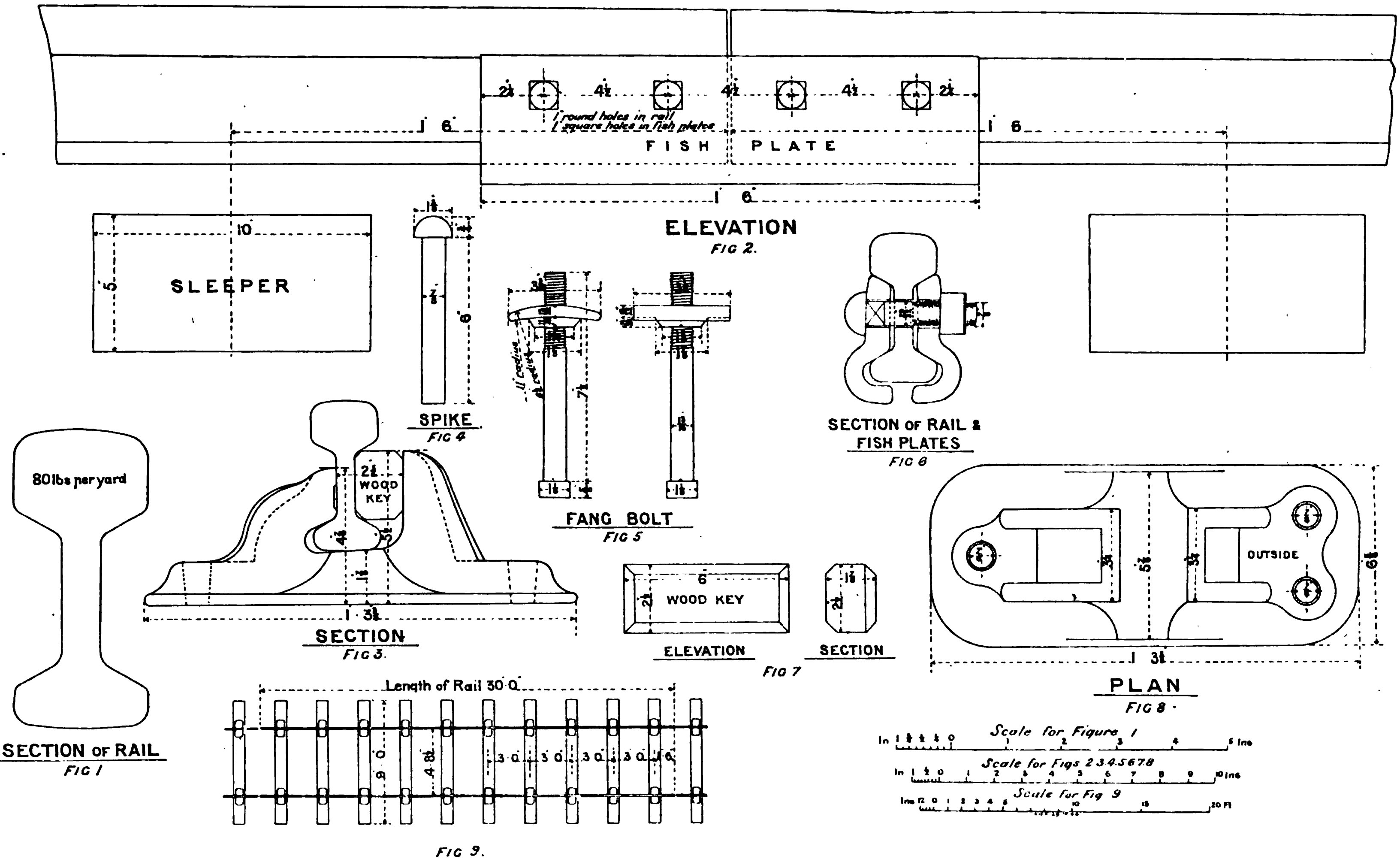
STATEMENT *E 1*. — Ballast.

QUESTIONS.	Ame		
	Chesapeake and Ohio. (Pl. 21.)	**Chicago, Burlington and Quincy.** (Pl. 22.)	**Illinois Central.** (Pl. 23.)
Material adopted for bottom ballast . . .	Broken stone and gravel.	Stone or gravel.	Stone or gravel.
If stone, what mesh?	"	"	2 1/2 inches (63 mill.)
Depth of bottom ballast	10 inches (254 mill.) at centre of road, increasing in thickness towards side.	9 inches (229 mill.) at centre of road, increasing to 14 inches (356 mill.) at sides.	10 inches (254 mill.).
If cinders, whether screened or not? . . .	"	"	"
Material used for top ballast	Gravel.	Stone and gravel.	Stone or gravel.
Thickness of top ballast	No answer, but according to diagram about 6 inches (152 mill.).	6 inches (152 mill.)	8 inches (203 mill.).
Is the top ballast laid above the top of sleeper, and if so, to what extent?	No answer, but shown on diagram to be level with top of sleeper.	Shown on diagram to be slightly above top of sleeper.	Yes, 3 to 4 inches (76 à 102 mill.) at centre.
What advantages are found to result from the use of the material selected for ballast? .	"	"	"

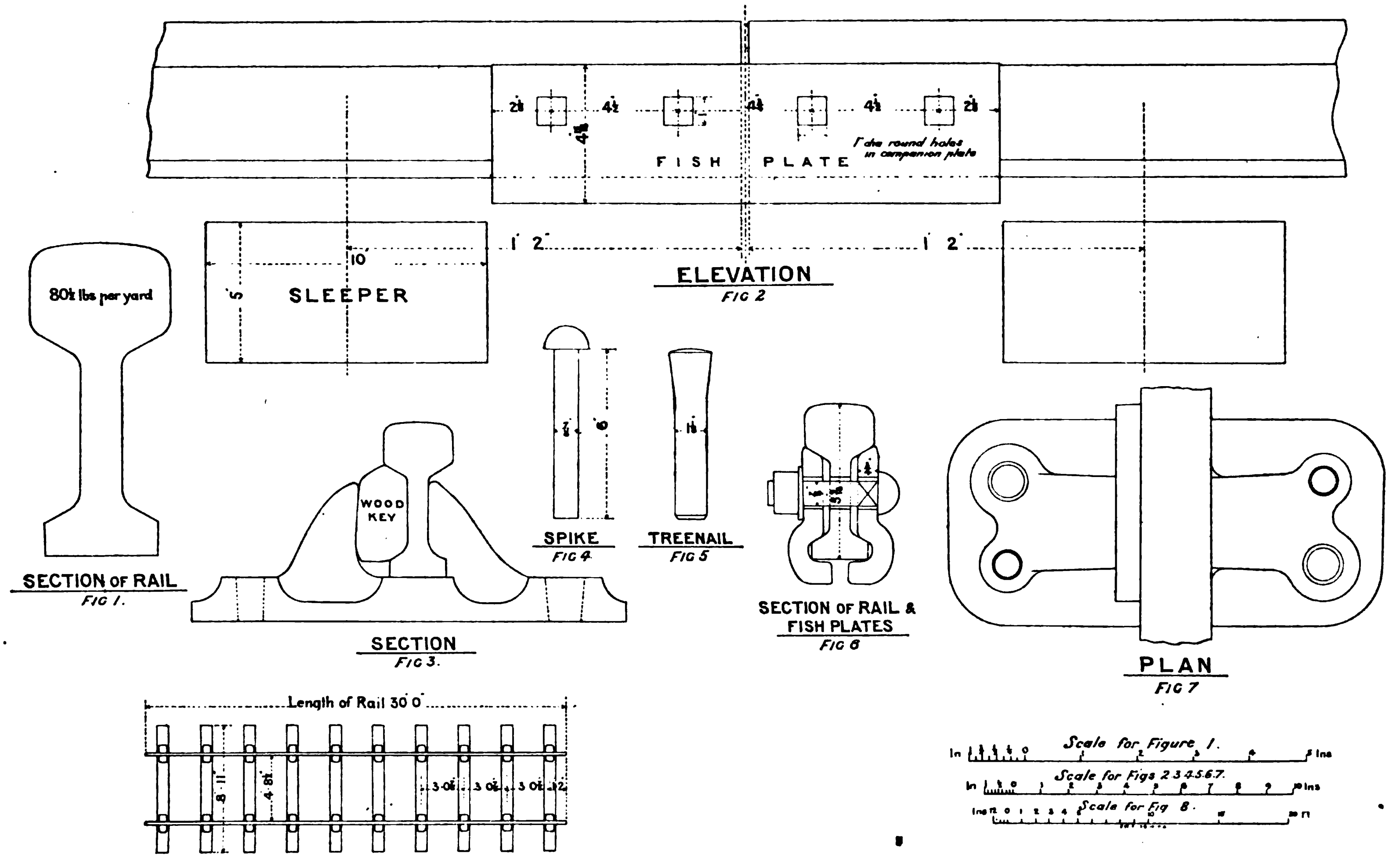
rica.			India.	Australia.
Lake shore and Michigan Southern. (Pl. 24.)	New-York Central and Hudson River. (Pl. 25-26 and 27.)	Pennsylvania. (Pl. 28.)	East Indian. (Pl. 29.)	New South Wales Government Rys. (Pl. 30 and 31)
Clay or sand.	Stone.	Large stones.	Stone.	Stone.
"	4 inches to 6 inches (102 à 152 mill.) Spawls.	5 to 8 inches (127 à 203 mill.) in diameter.	1 3/4 inch cubes (26.81 cent. cubes).	4 inches (102 mill.).
"	6 inches (152 mill.)	8 inches (203 mill.)		9 inches (229 mill.).
"	Not screened.	"		Only a small quantity has been used, and these have been screened.
Gravel.	Crushed stone gravel, Cinders, or slag.	Stone that will pass through a 2 1/2 inch (63 mill.) ring.	No distinction between bottom and top ballast.	Principally Hardstone broken to a 2 1/2 inch (63 mill.) gauge.
Not given.	12 inches (305 mill.).	About 5 inches (127 mill.).		12 inches (305 mill.).
Shown on diagram to be level with top of sleeper at centre of road, and 5 inches (127 mill). below top of sleeper at each end.	Level with top of sleeper.	Top of sleepers at centre, bottom of sleepers at ends.	Varies from the underside of the head of the rail to the underside of the chair.	2 1/2 inches (63 mill.).
An elastic roadway, economically maintained.	Crushed stone ballast affords better drainage, decreases wet rot of sleepers, and obviates frost « heaving » of track in winter, and affords firmer bearing to the sleepers.	Gives a solid road bed and affording good drainage preserves the ties.	Better life of sleepers and running than either brick or kunkur, the only alternatives.	It provides efficient drainage, does not pulverize under the beater, preserves the alignment of the road and gives a firm and elastic bed, and consequently minimises cost of maintenance.

PLATES

CAMBRIAN RAILWAY



FURNESS RAILWAY



ELEVATION
FIG 2

SECTION OF RAIL
FIG 1.

SECTION
FIG 3.

SPIKE
FIG 4

TREENAIL
FIG 5

SECTION OF RAIL & FISH PLATES
FIG 6

PLAN
FIG 7

FIG 8

Plate 3.

GREAT EASTERN RAILWAY

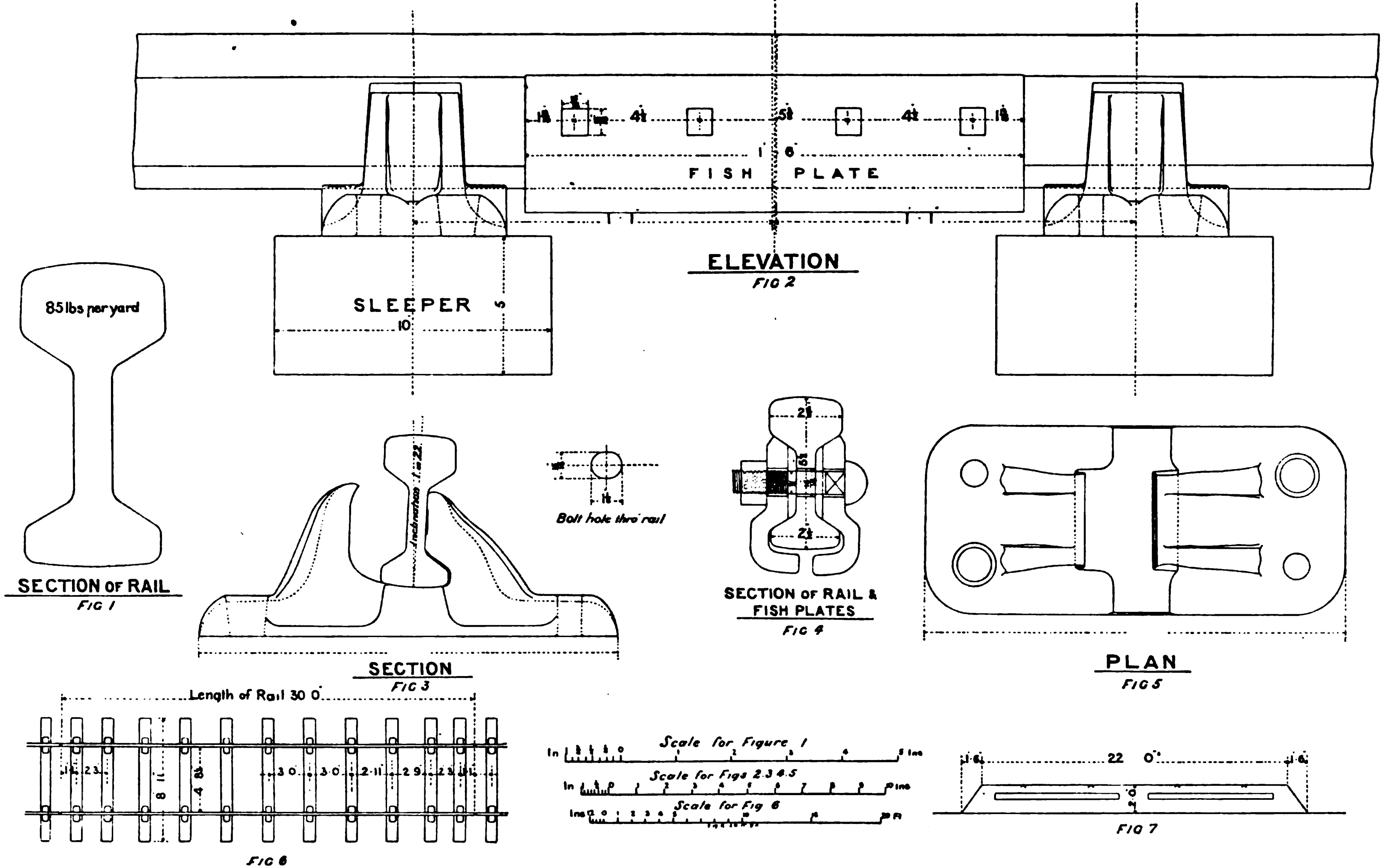
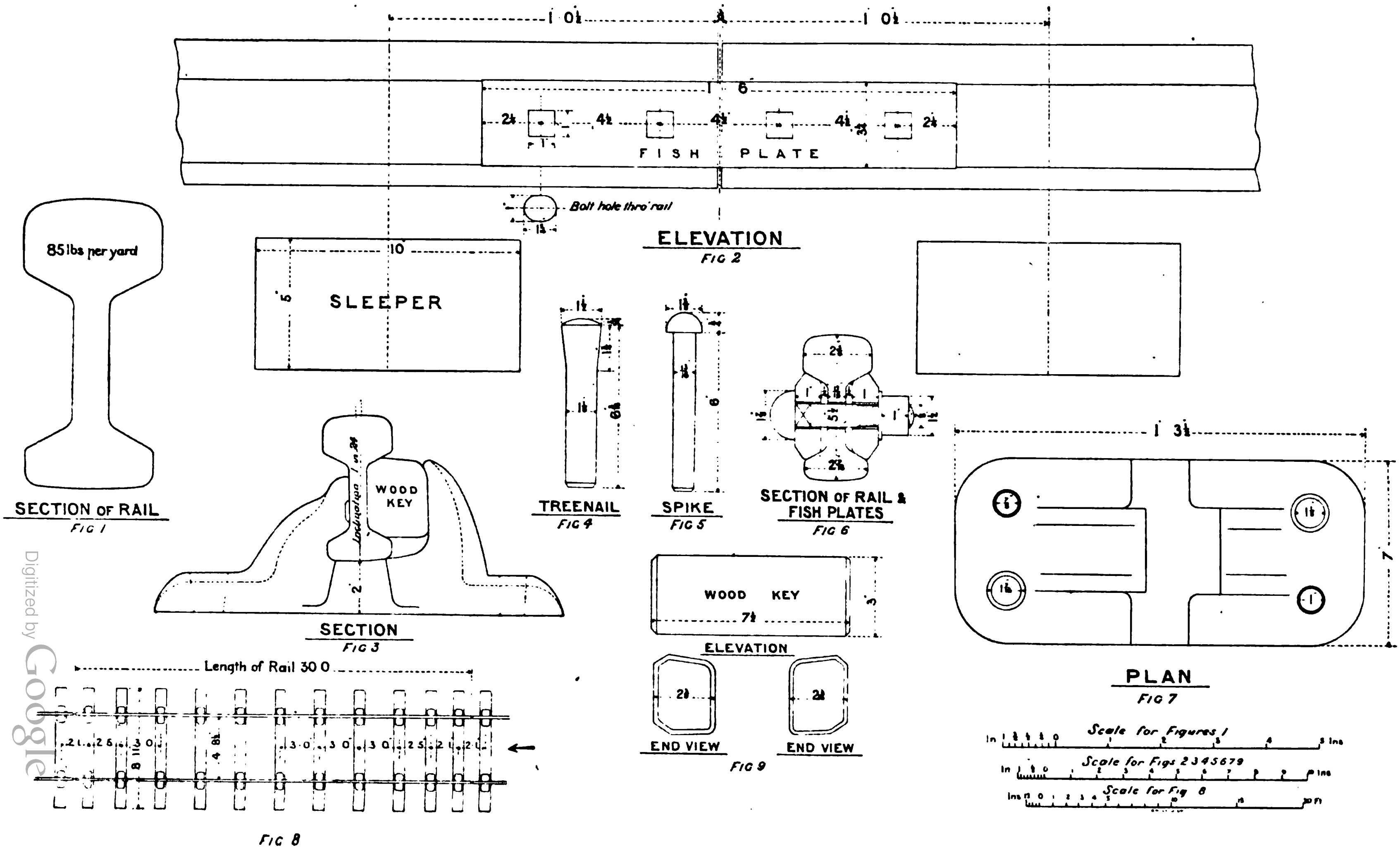
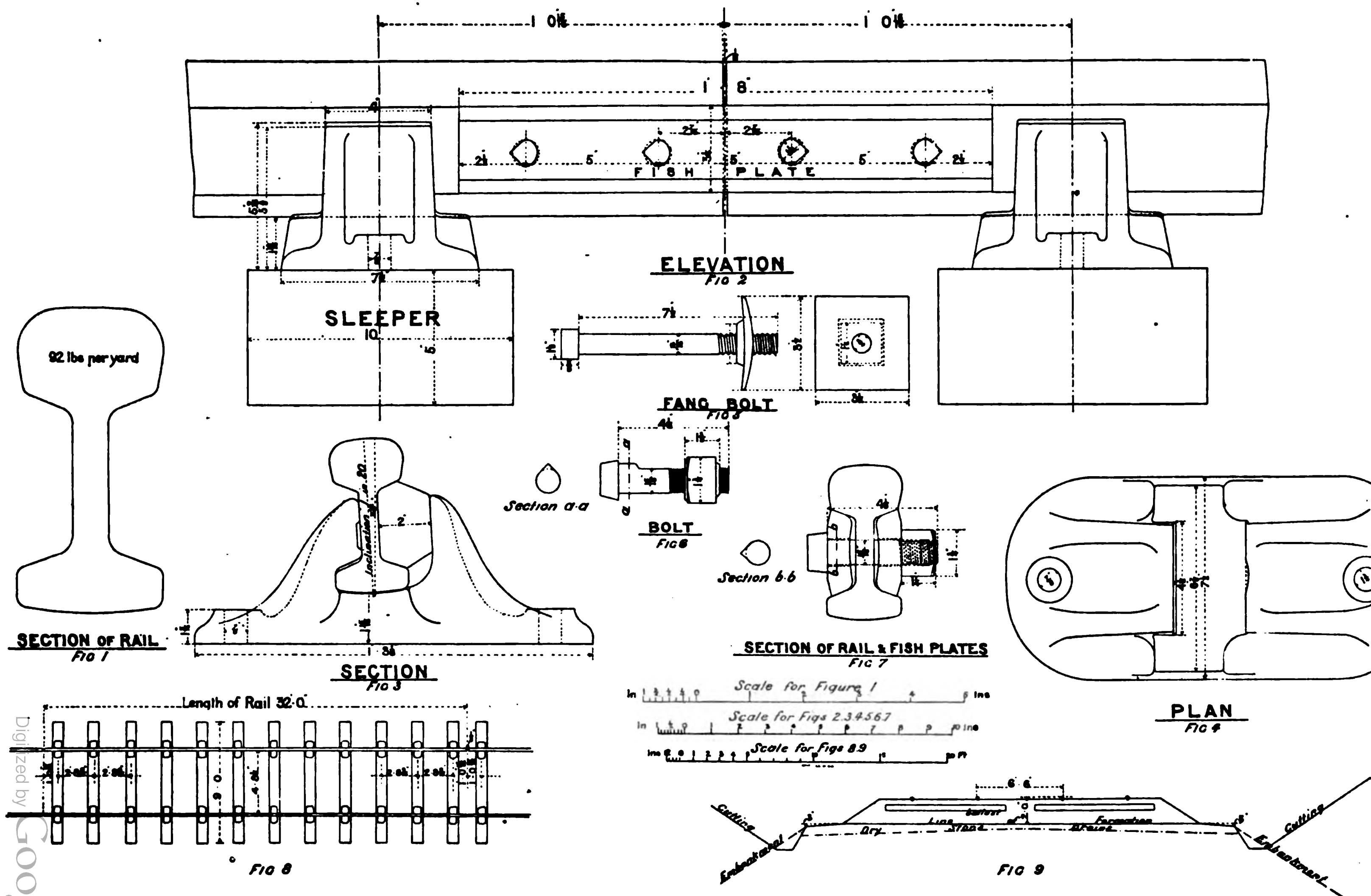


Plate 4.

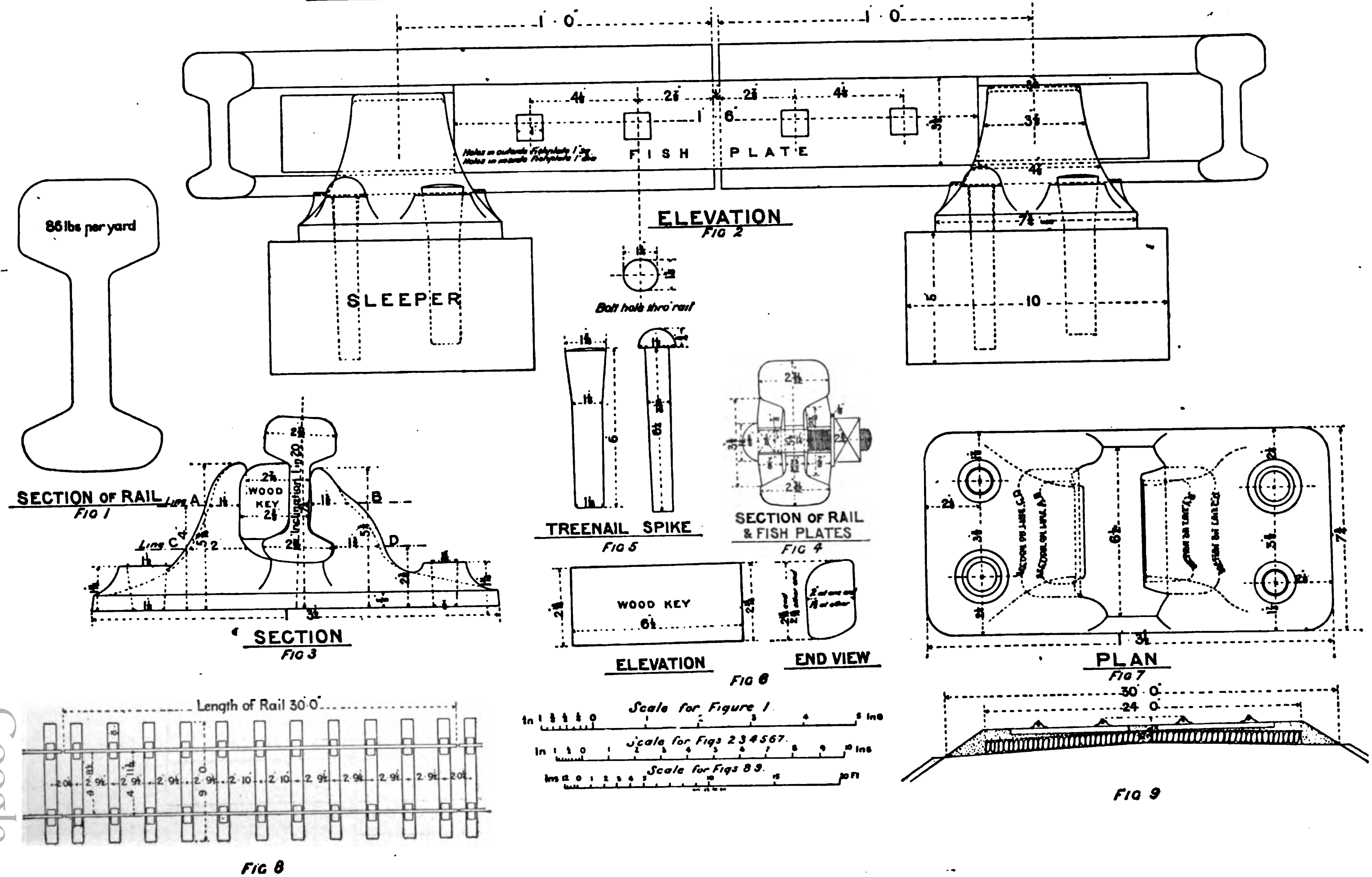
GREAT NORTHERN RAILWAY



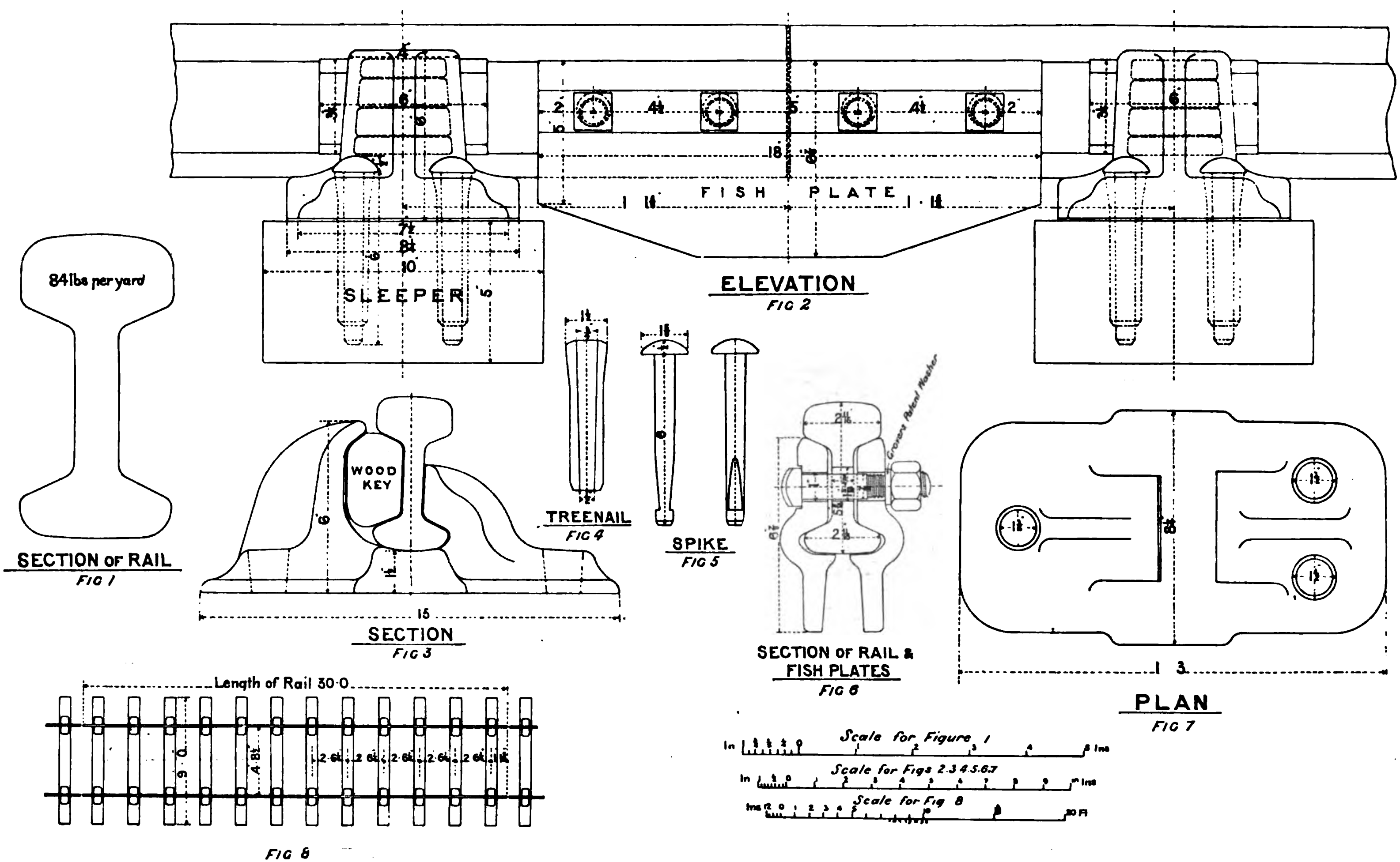
GREAT WESTERN RAILWAY



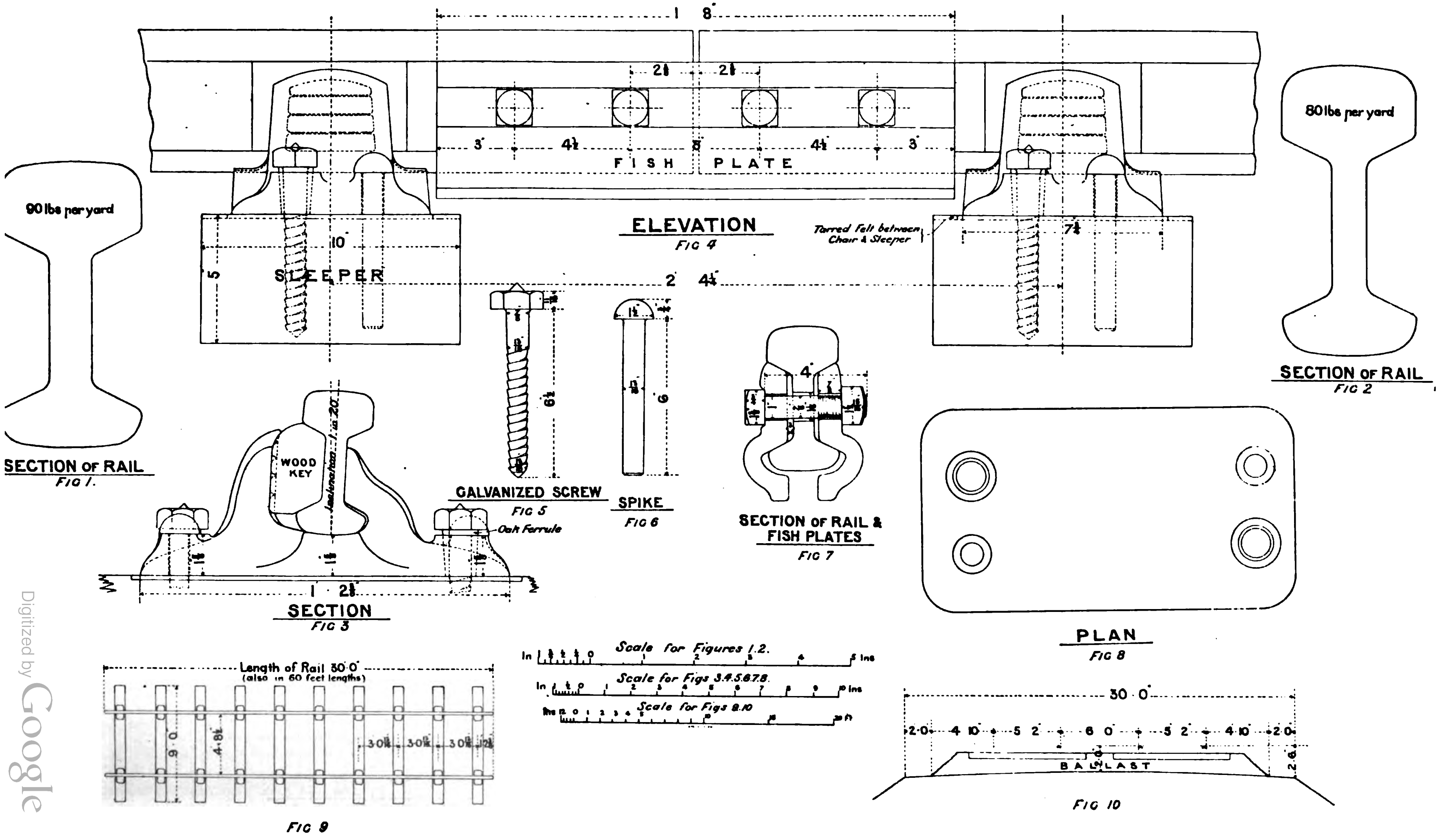
LANCASHIRE & YORKSHIRE RAILWAY



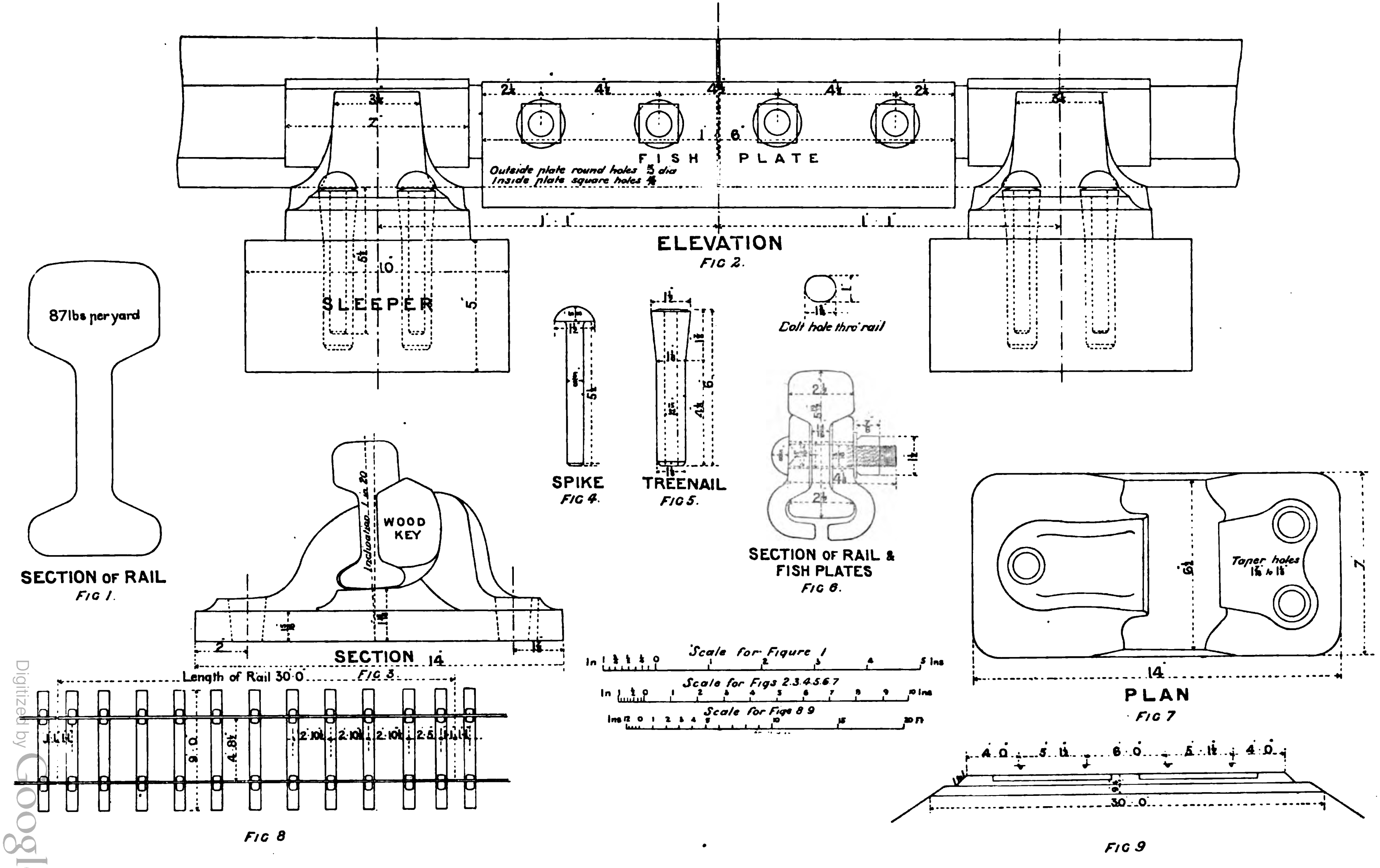
LONDON BRIGHTON & SOUTH COAST RAILWAY



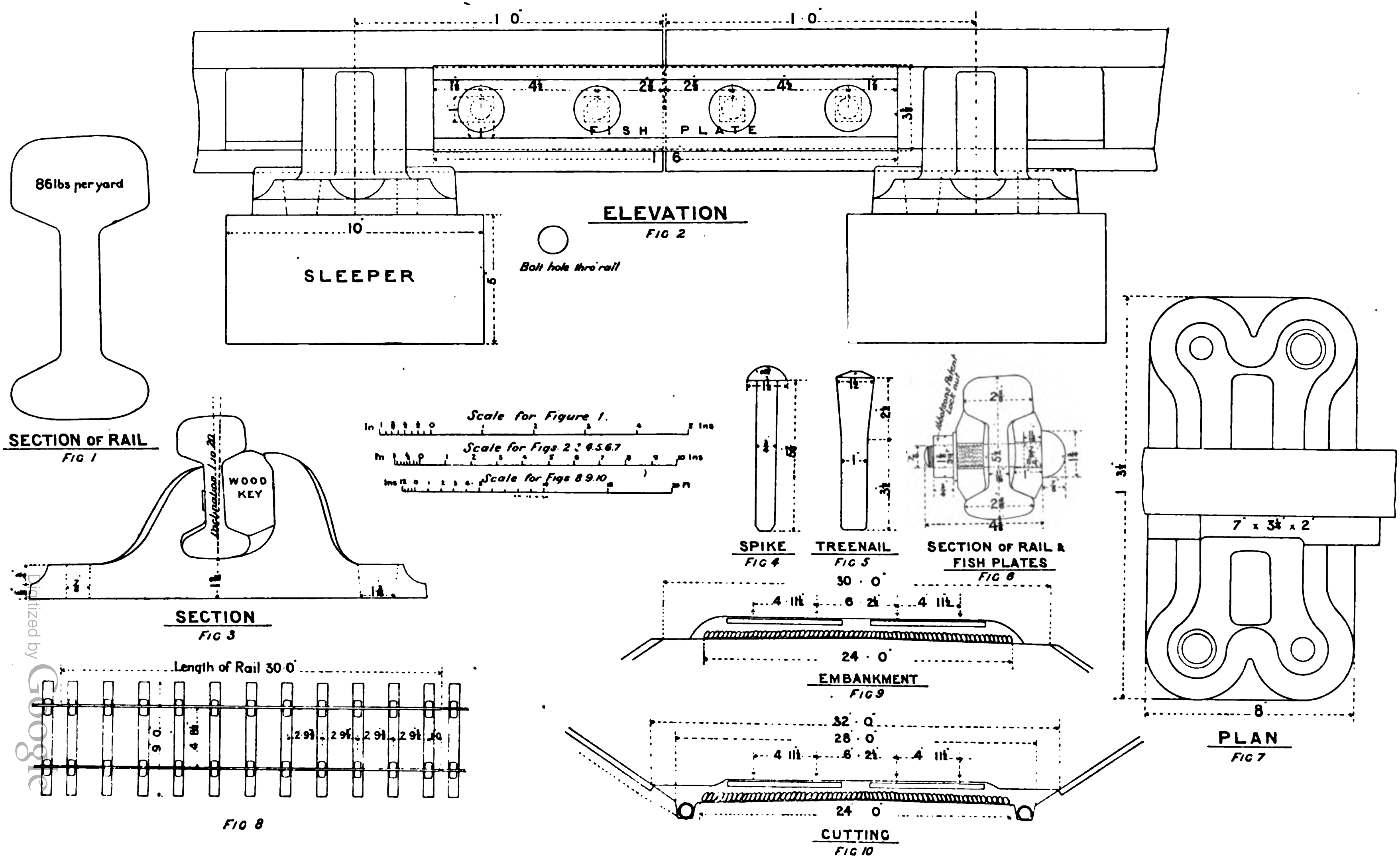
LONDON & NORTH WESTERN RAILWAY



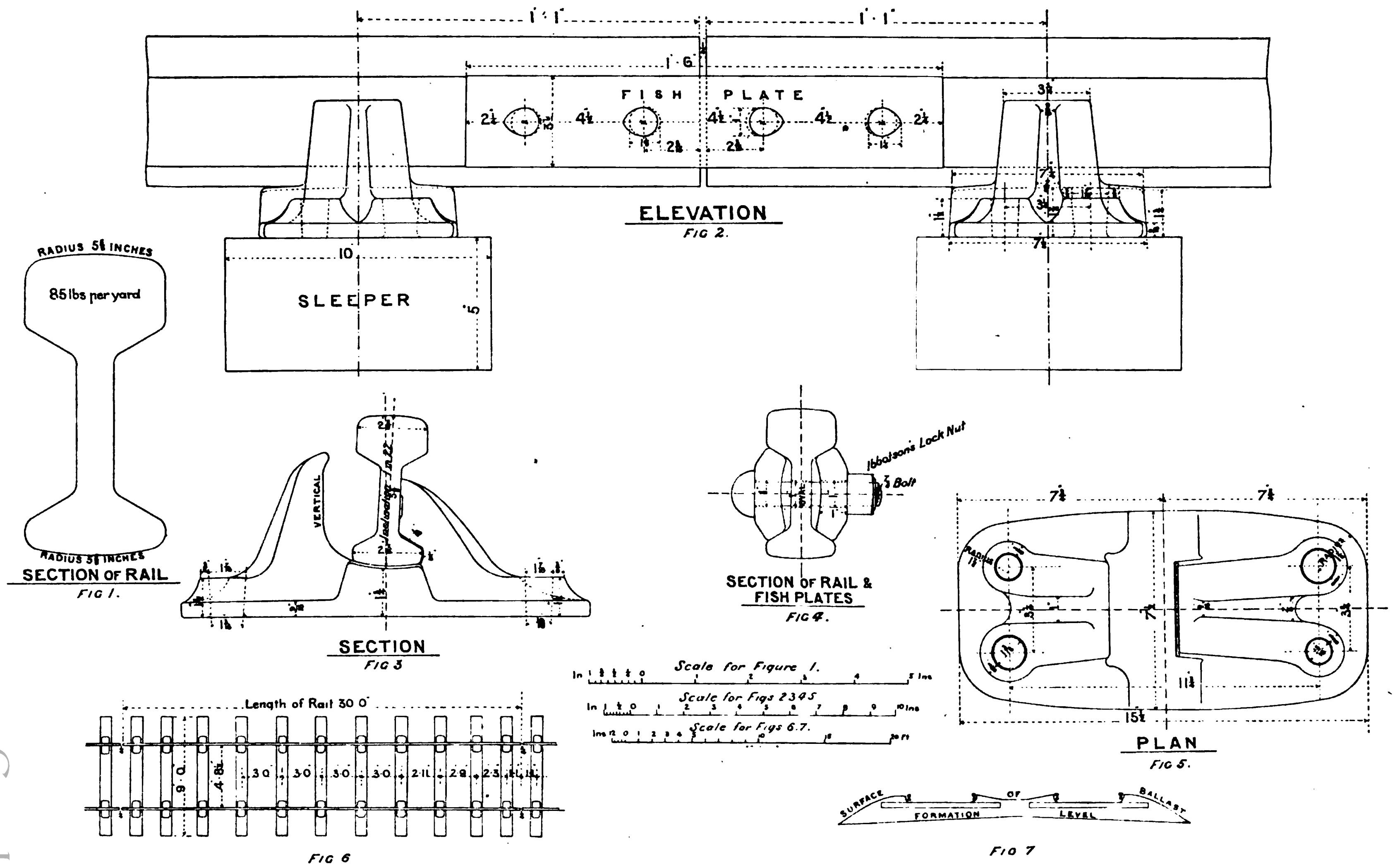
LONDON & SOUTH WESTERN RAILWAY



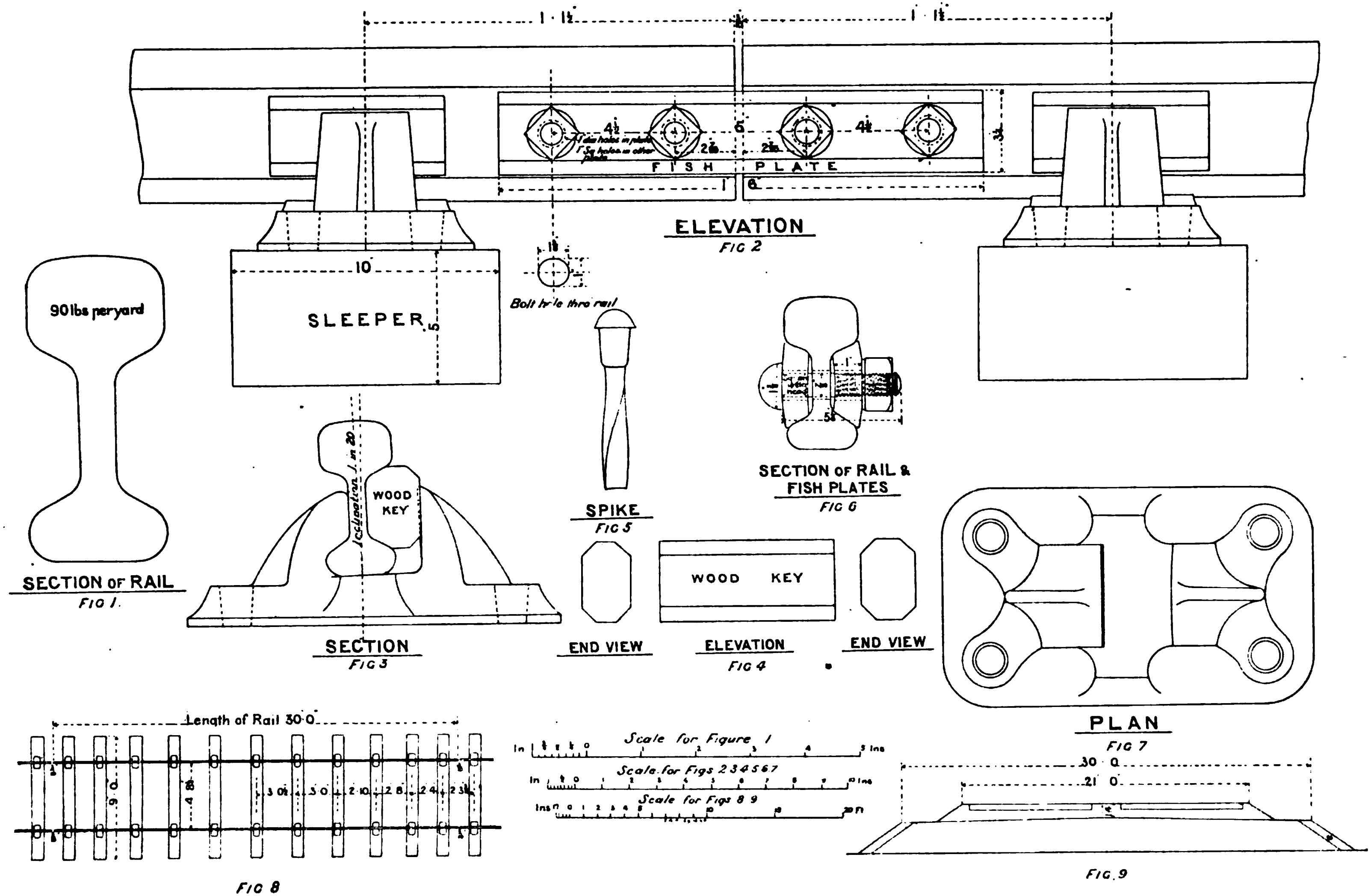
MANCHESTER SHEFFIELD & LINCOLNSHIRE RAILWAY



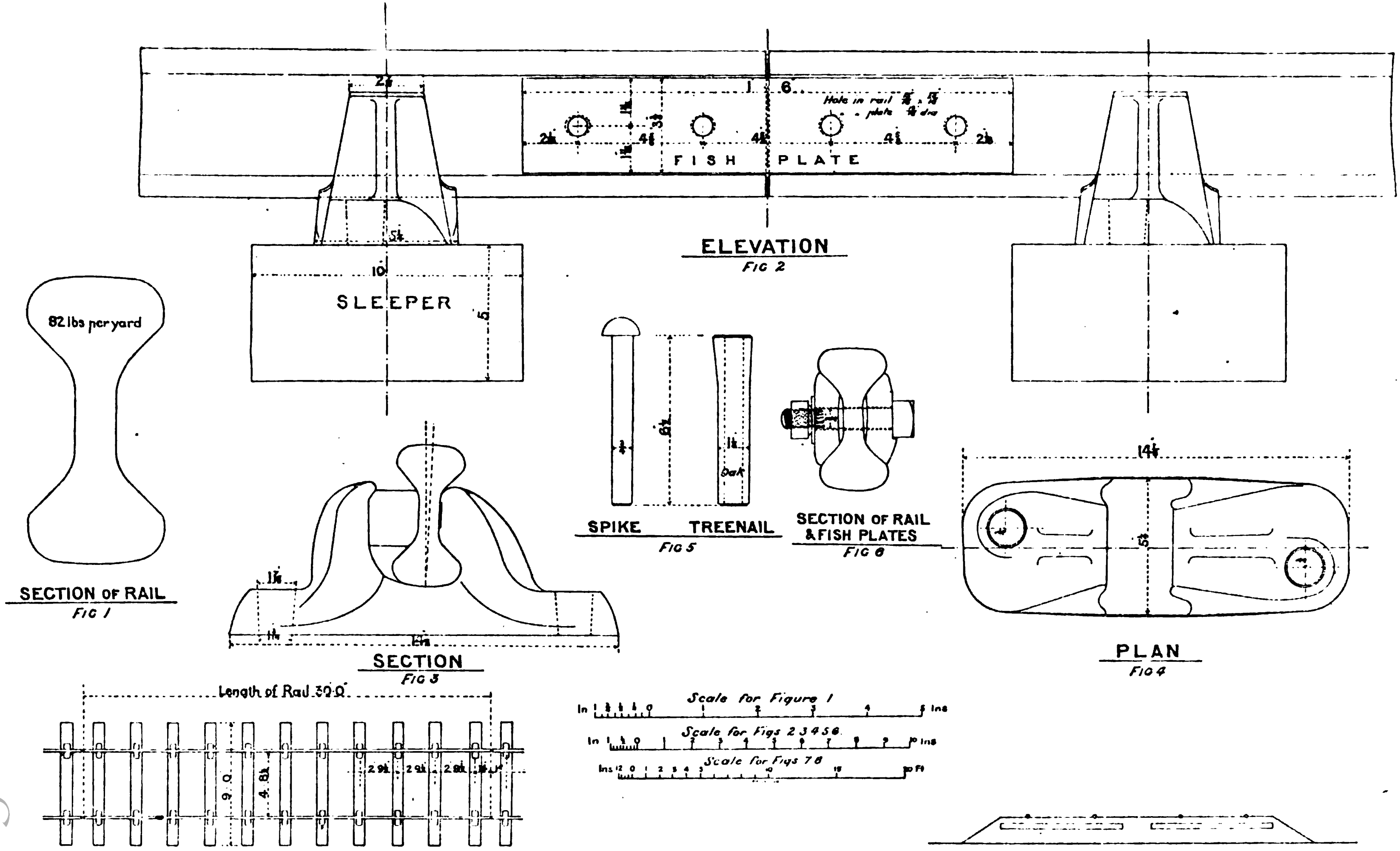
MIDLAND RAILWAY



NORTH EASTERN RAILWAY



SOUTH EASTERN RAILWAY



ELEVATION
FIG 2

SECTION OF RAIL
FIG 1

SECTION
FIG 3

SPIKE TREENAIL
FIG 5

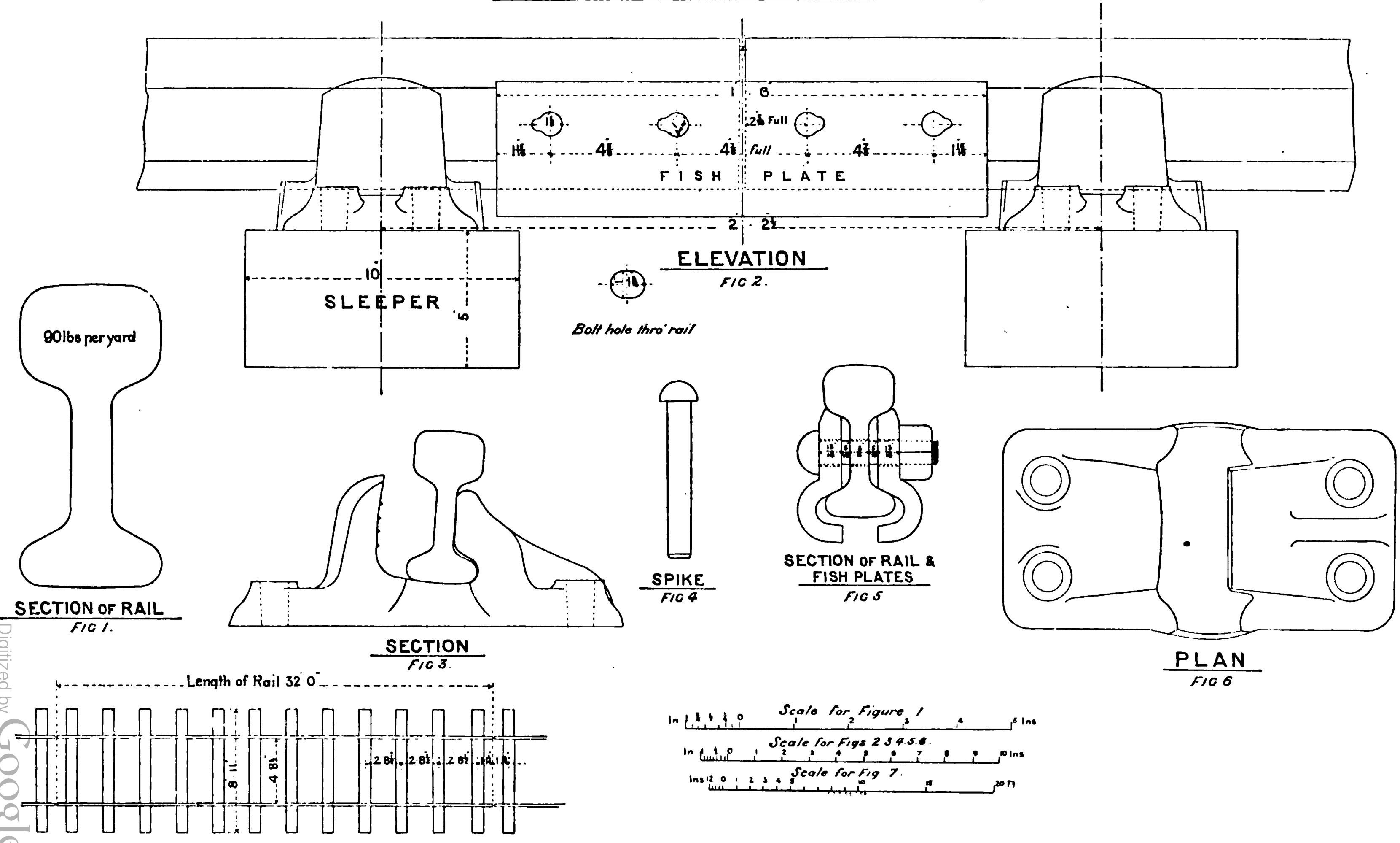
SECTION OF RAIL & FISH PLATES
FIG 6

PLAN
FIG 4

FIG 7

FIG 8

CALEDONIAN RAILWAY



ELEVATION
FIG 2.

SECTION OF RAIL
FIG 1.

SECTION
FIG 3.

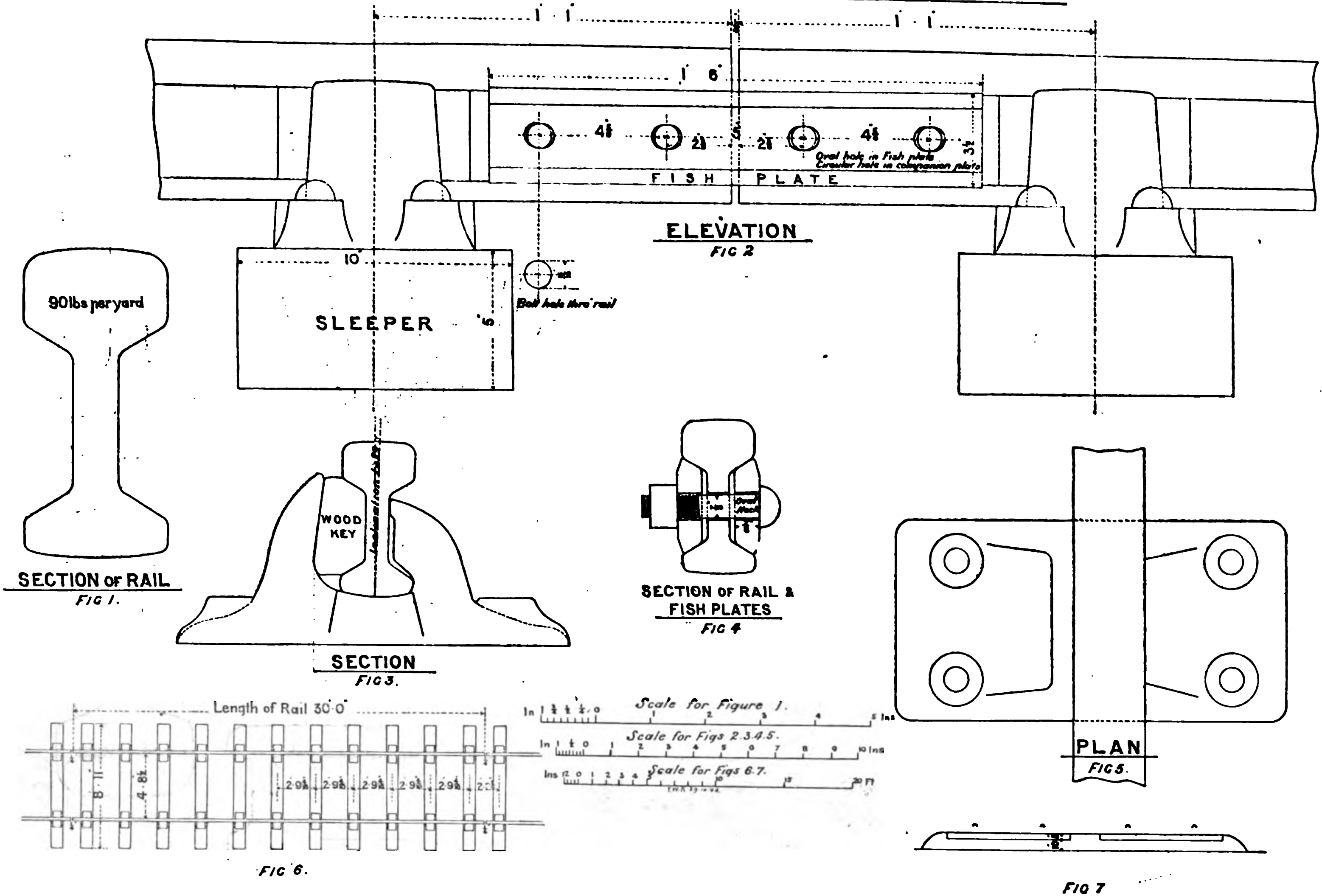
SPIKE
FIG 4

SECTION OF RAIL & FISH PLATES
FIG 5

PLAN
FIG 6

FIG 7.

GLASGOW & SOUTH WESTERN RAILWAY



HIGHLAND RAILWAY

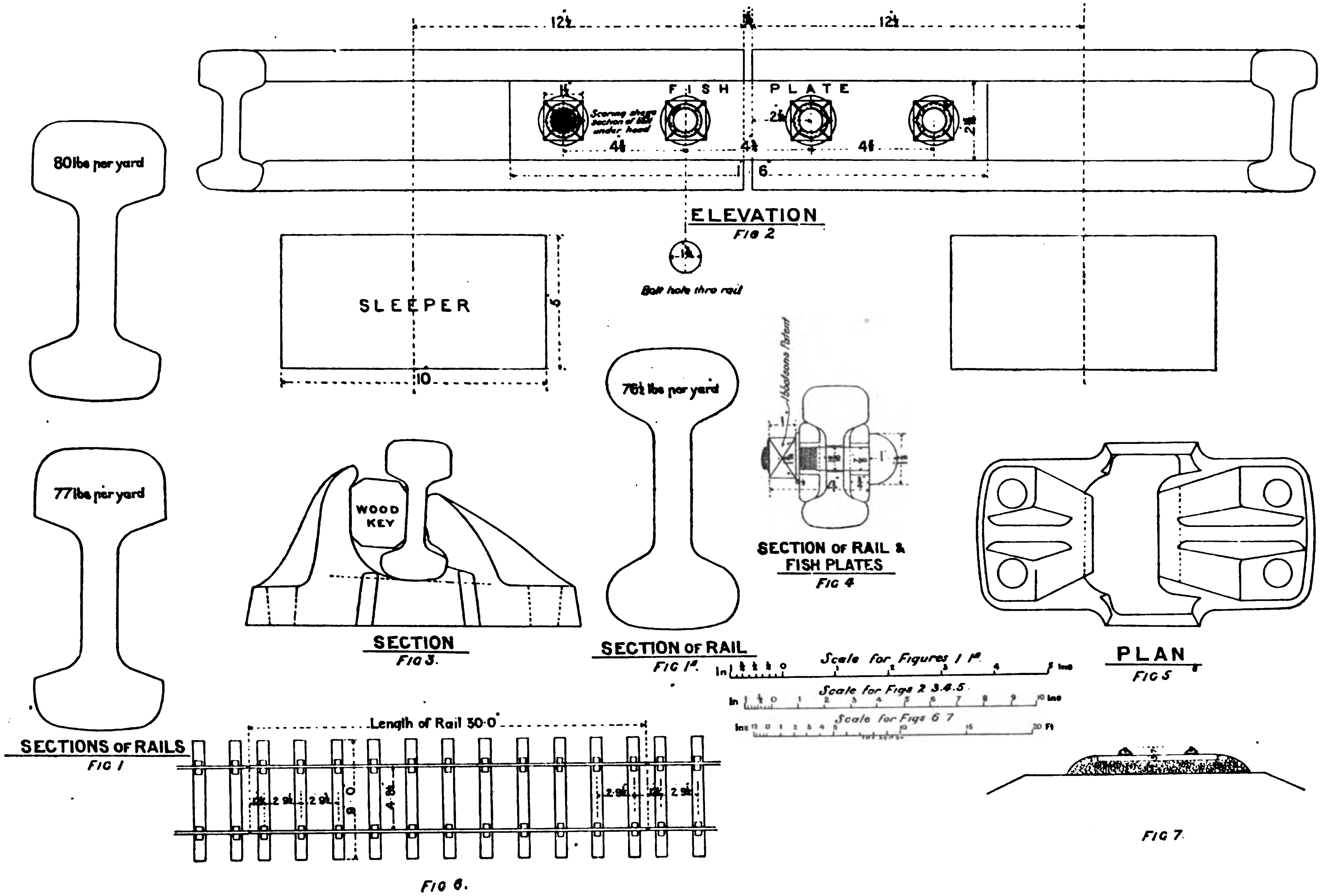
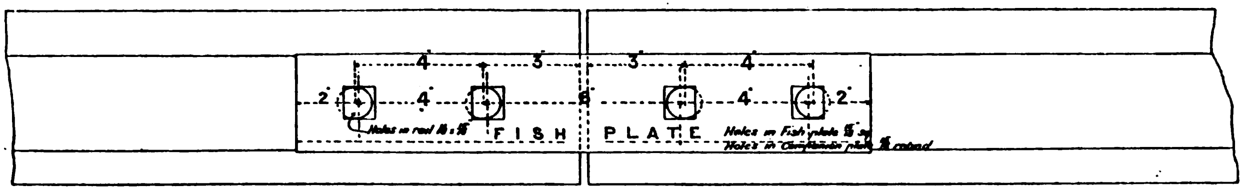


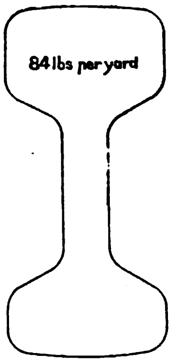
Plate 17.

NORTH BRITISH RAILWAY



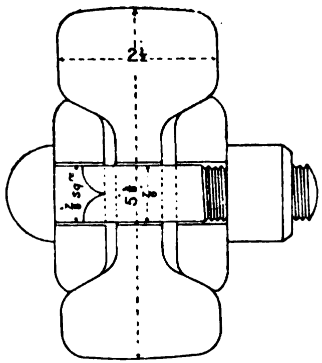
ELEVATION

FIG 3



SECTION OF RAIL

FIG 1



SECTION OF RAIL & FISH PLATES

FIG 2.

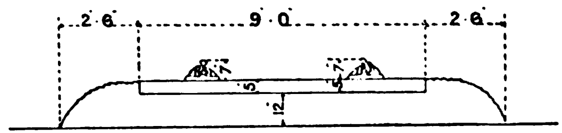
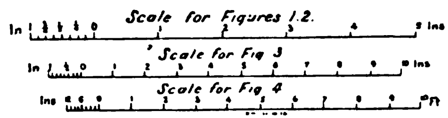
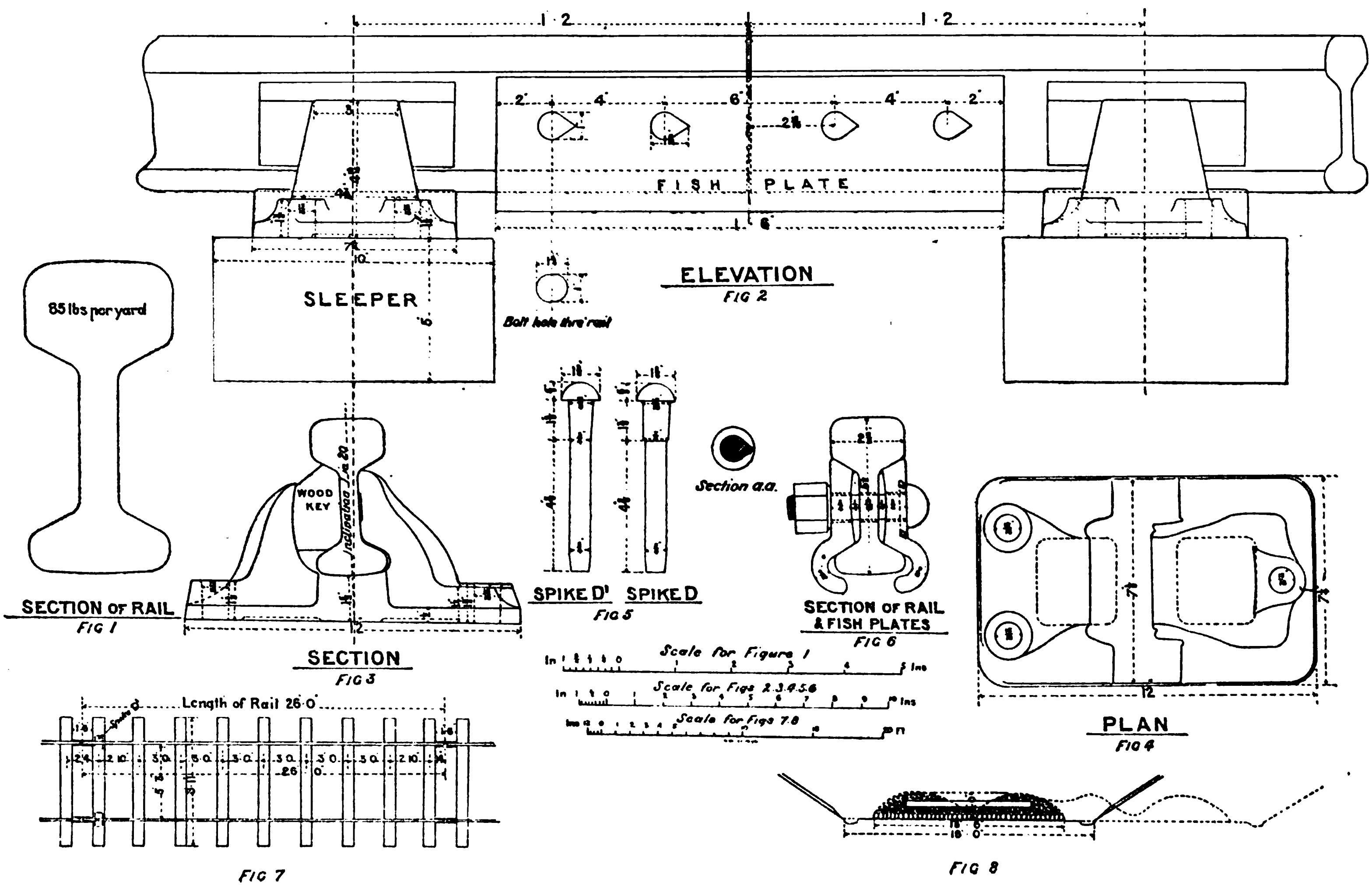


FIG 4.



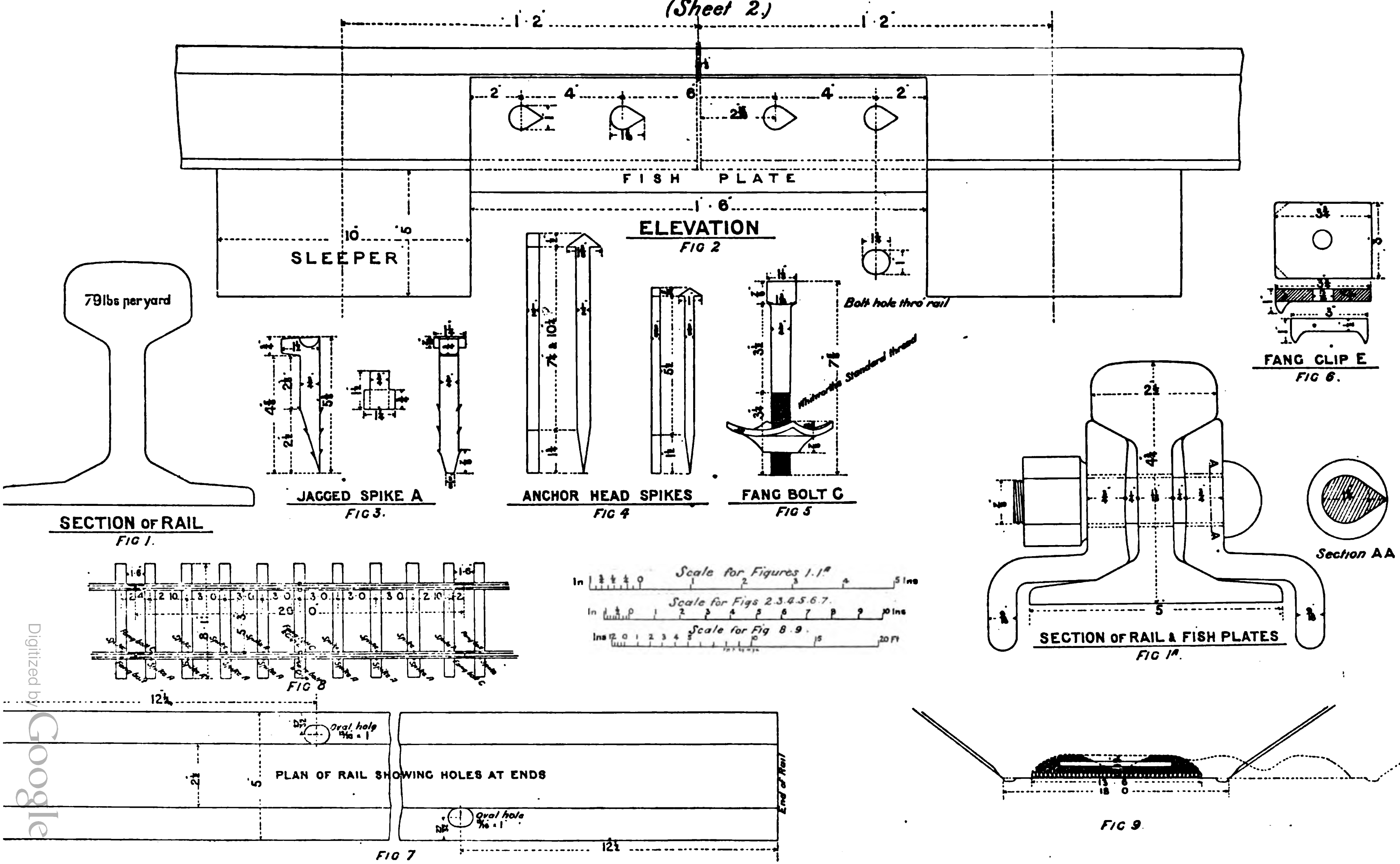
GREAT NORTHERN RAILWAY IRELAND

(Sheet 1.)

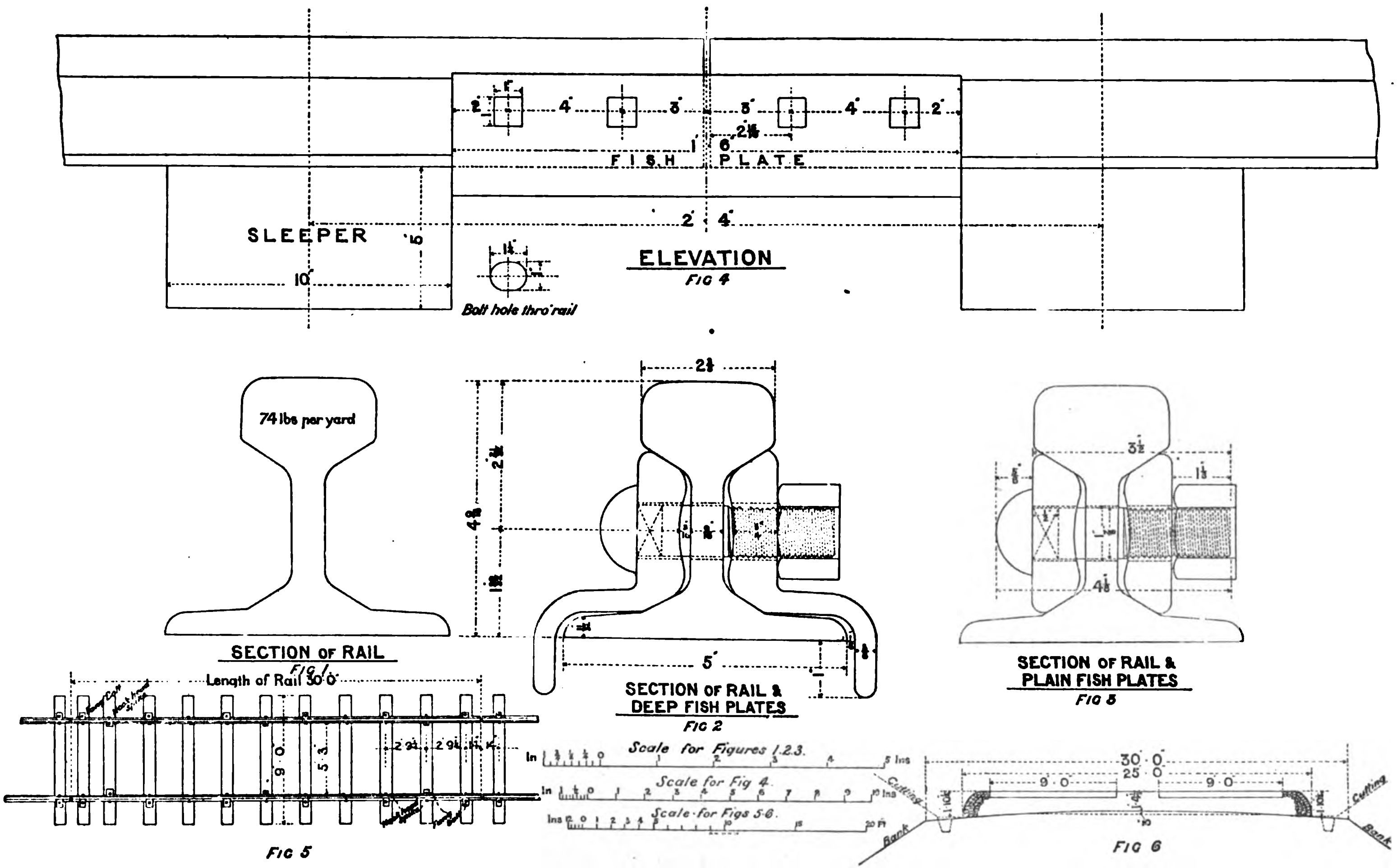


GREAT NORTHERN RAILWAY IRELAND

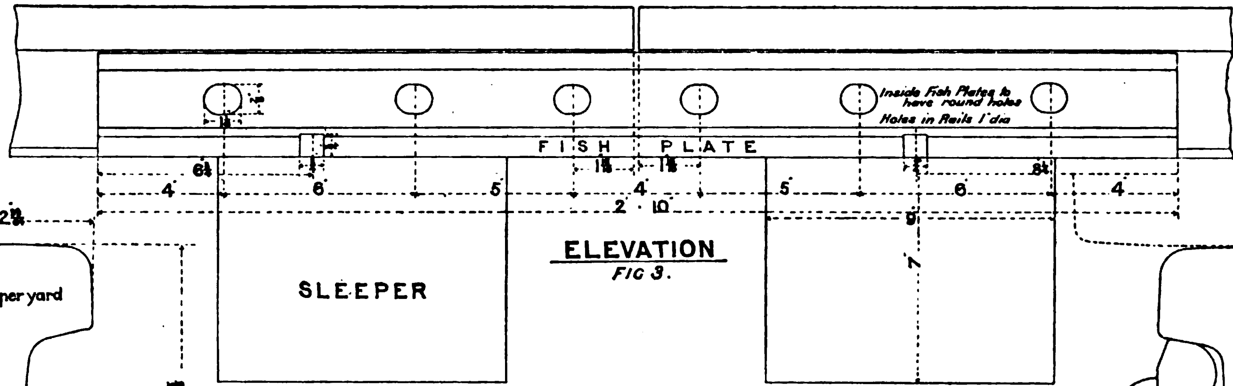
(Sheet 2.)



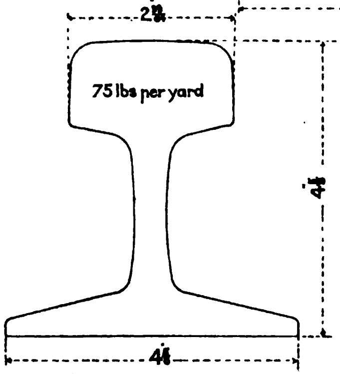
GREAT SOUTHERN & WESTERN RAILWAY



CHESAPEAKE & OHIO RAILWAY



ELEVATION
FIG 3.



SECTION OF RAIL
FIG 1.

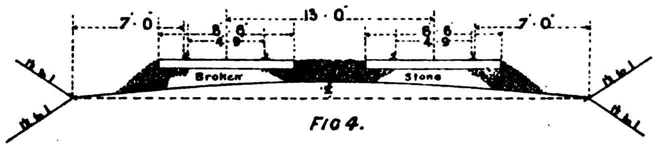
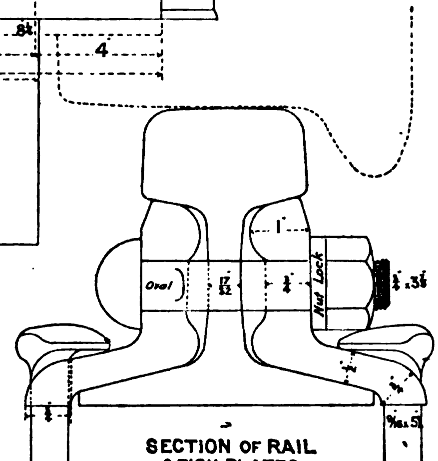


FIG 4.



SECTION OF RAIL
& FISH PLATES
FIG 2.

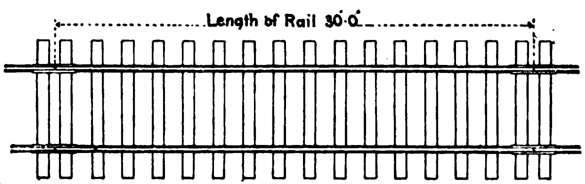
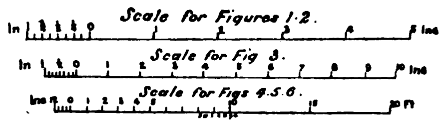


FIG 5



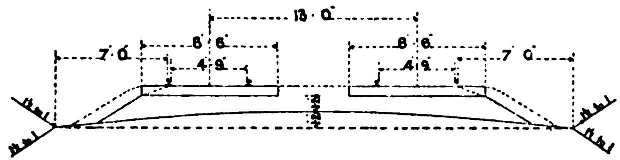
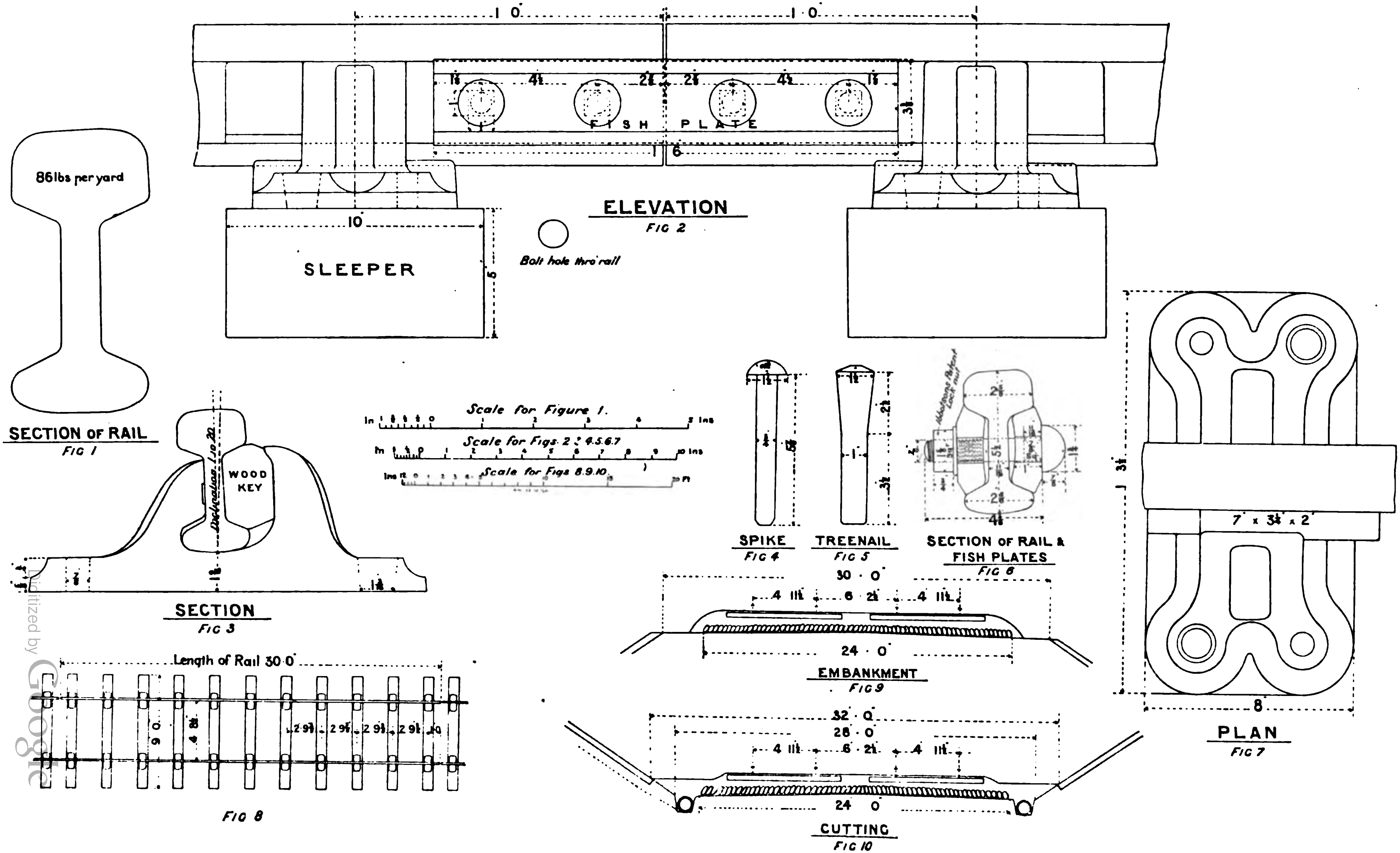
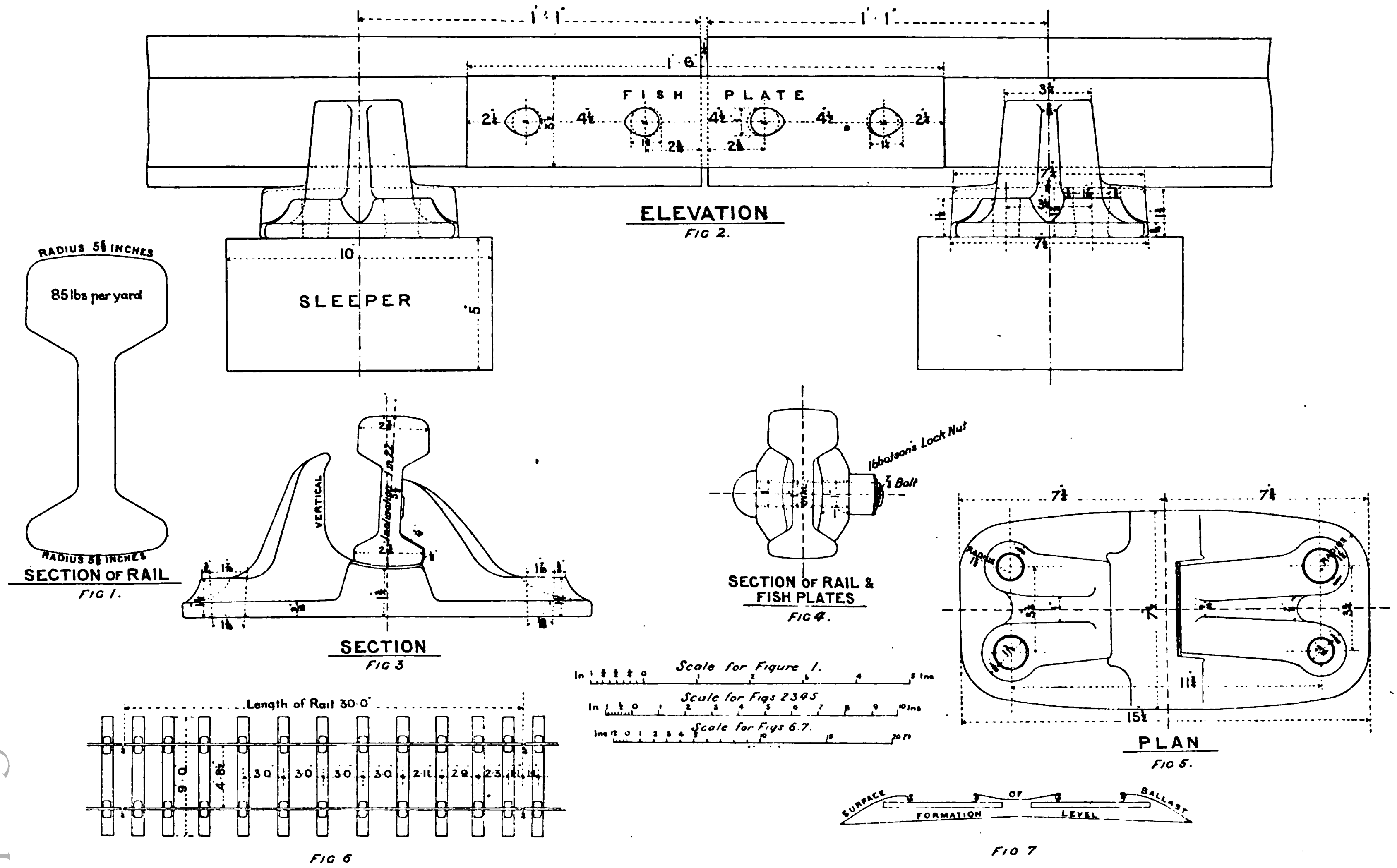


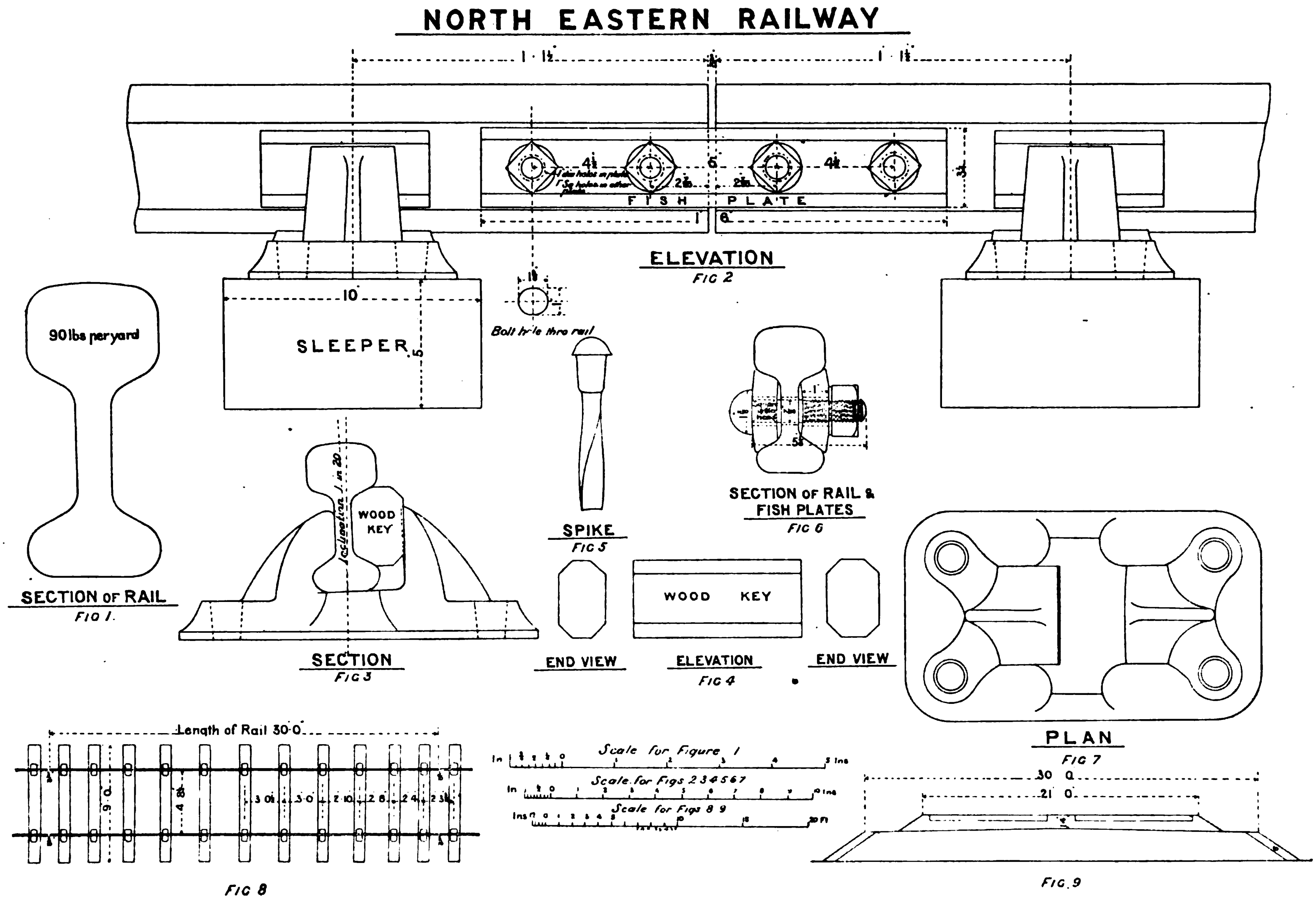
FIG 6.

MANCHESTER SHEFFIELD & LINCOLNSHIRE RAILWAY



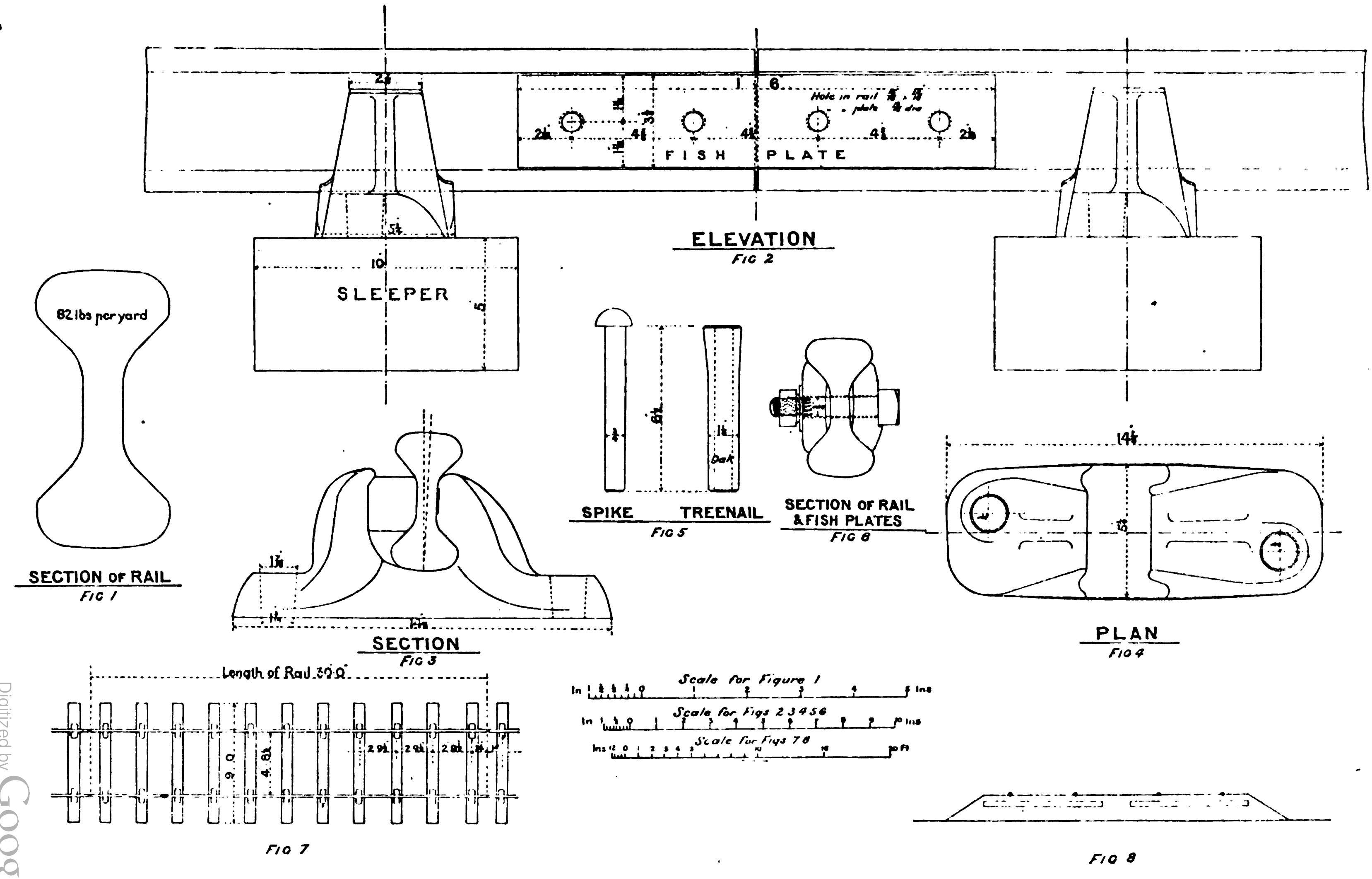
MIDLAND RAILWAY



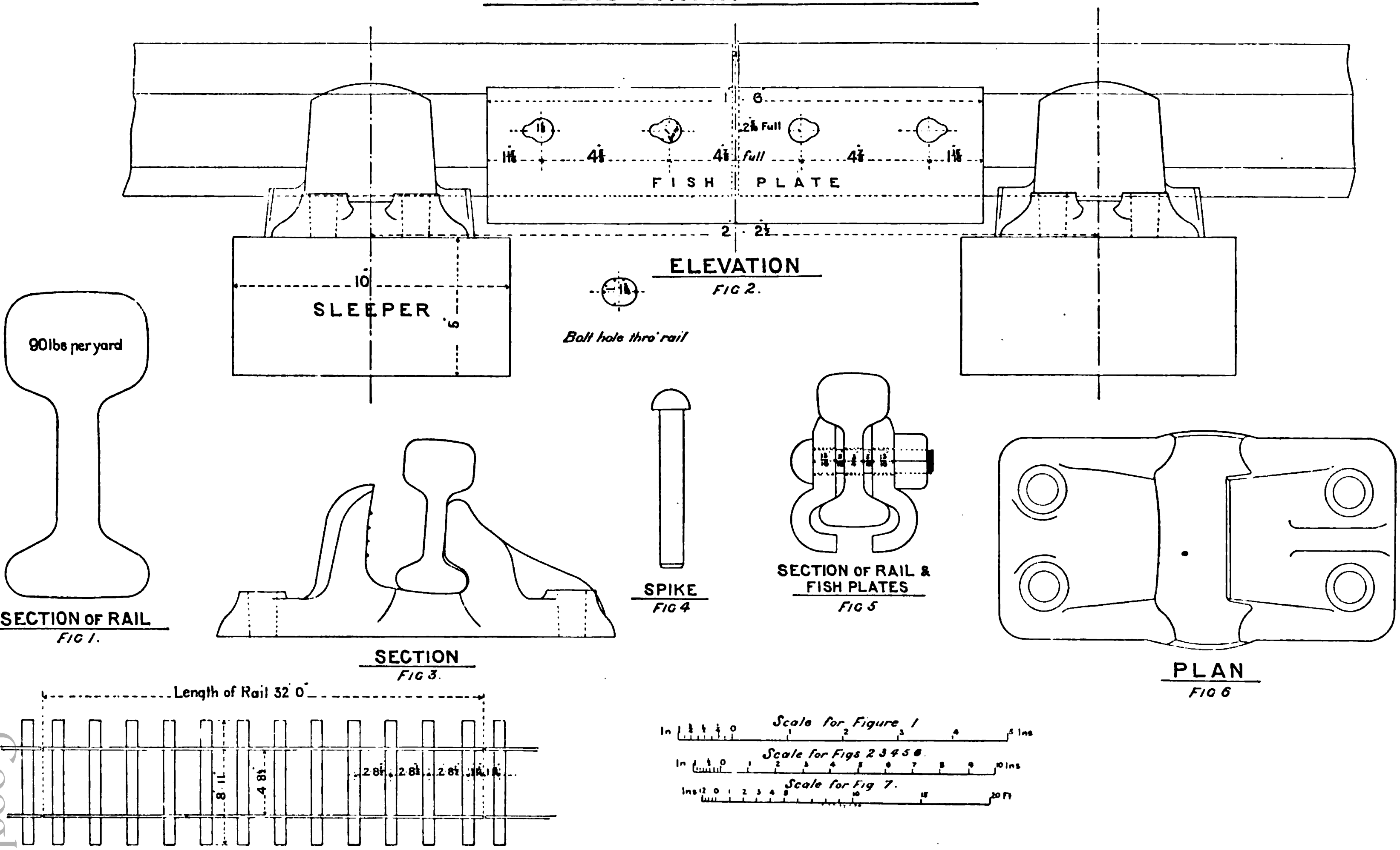


NORTH EASTERN RAILWAY
1 · 1½
FISH PLATE
ELEVATION
FIG 2
SLEEPER
10
90 lbs per yard
SECTION OF RAIL
FIG 1.
Bolt hole thro rail
SPIKE
FIG 5
SECTION OF RAIL & FISH PLATES
FIG 6
WOOD KEY
Inclination 1 in 20
SECTION
FIG 3
END VIEW
ELEVATION
FIG 4
END VIEW
PLAN
FIG 7
Length of Rail 30·0
FIG 8
Scale for Figure 1
Scale for Figs 2 3 4 5 6 7
Scale for Figs 8 9
FIG. 9

SOUTH EASTERN RAILWAY



CALEDONIAN RAILWAY



ELEVATION
FIG 2.

SECTION OF RAIL
FIG 1.

SECTION
FIG 3.

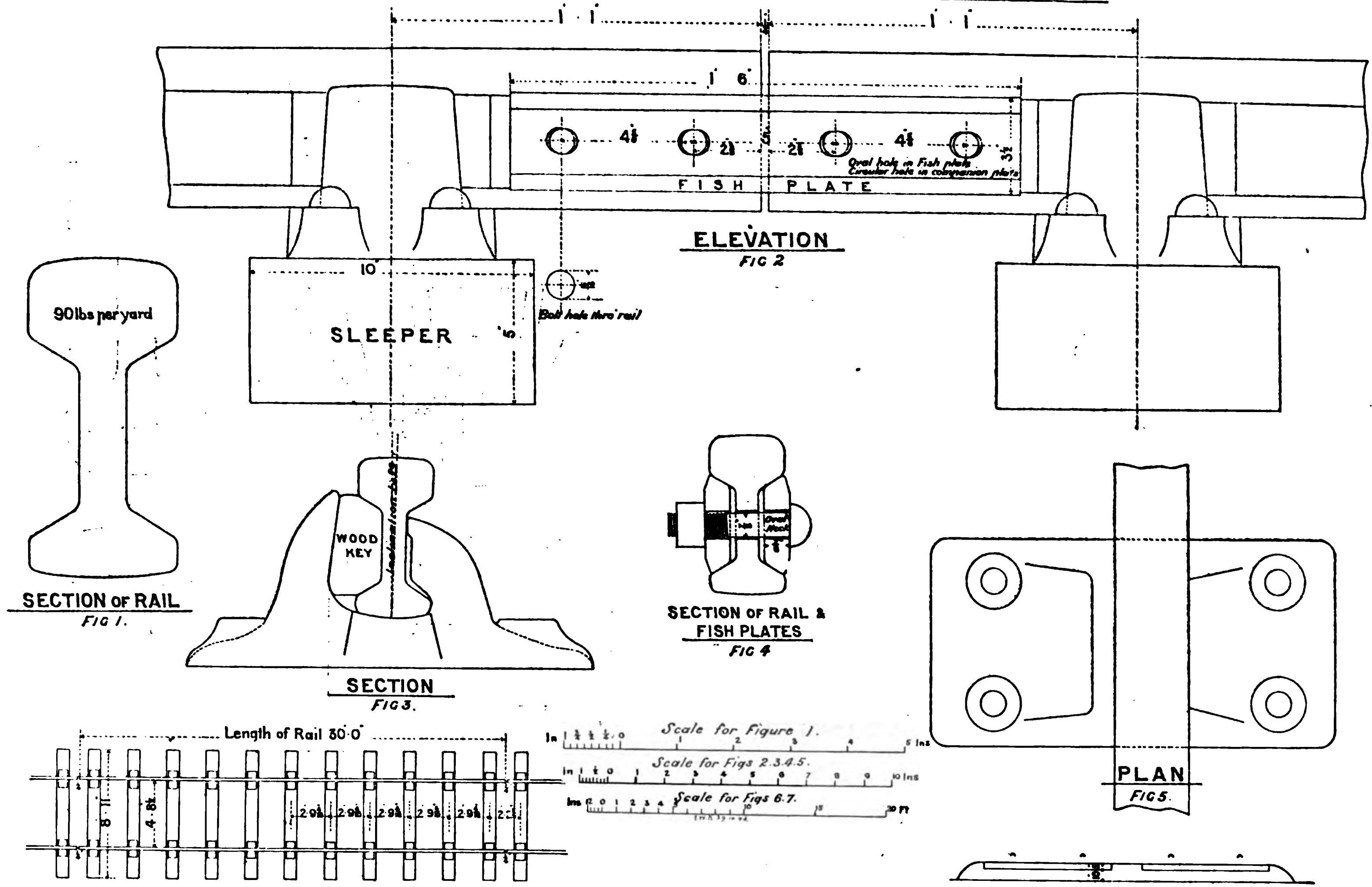
SPIKE
FIG 4

SECTION OF RAIL & FISH PLATES
FIG 5

PLAN
FIG 6

FIG 7.

GLASGOW & SOUTH WESTERN RAILWAY



ELEVATION
FIG 2

SECTION OF RAIL
FIG 1.

SECTION
FIG 3.

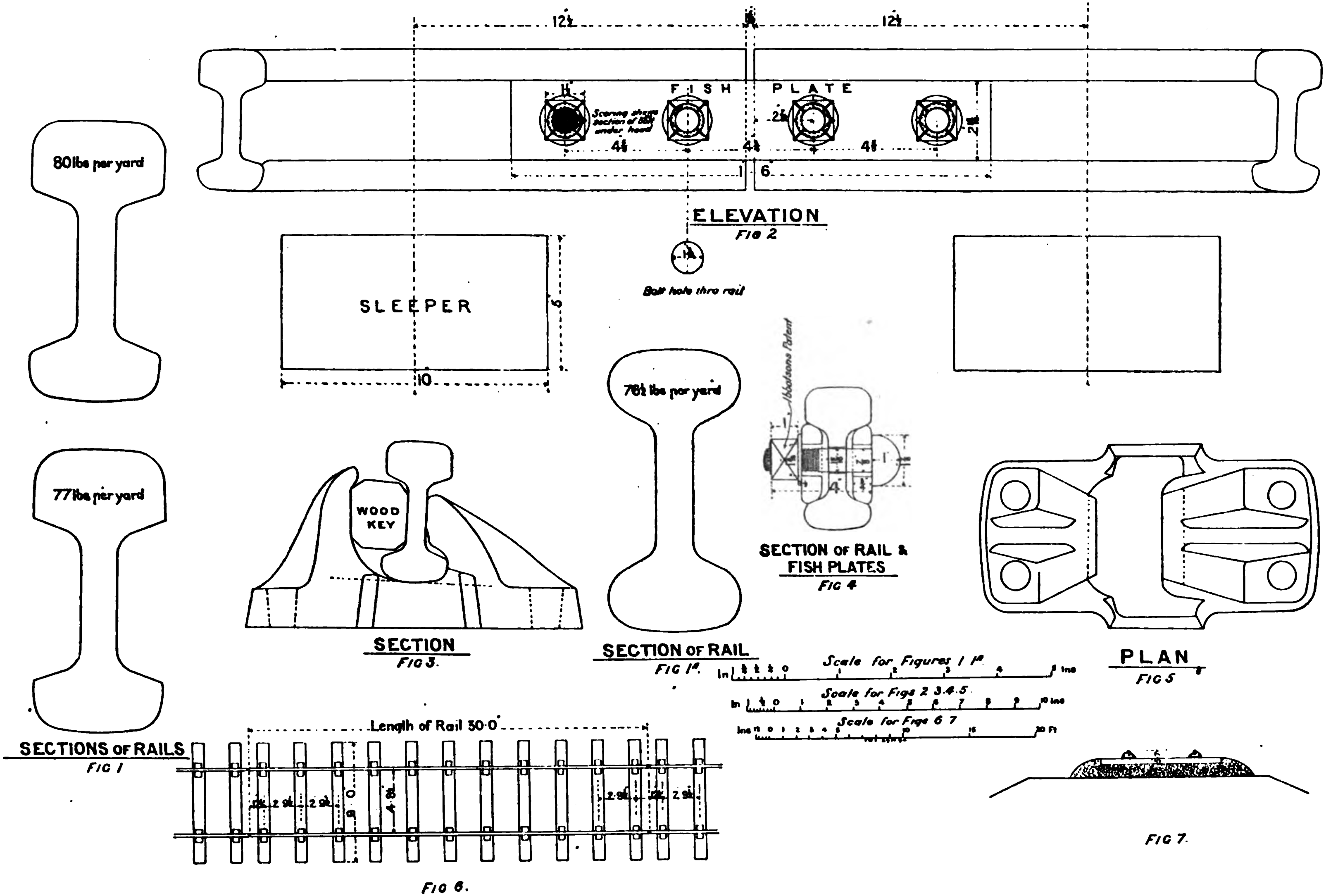
SECTION OF RAIL & FISH PLATES
FIG 4

PLAN
FIG 5.

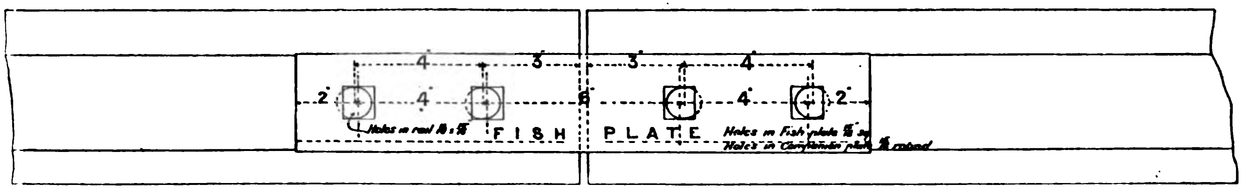
FIG 6.

FIG 7

HIGHLAND RAILWAY

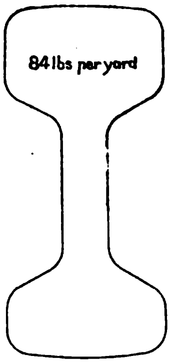


NORTH BRITISH RAILWAY



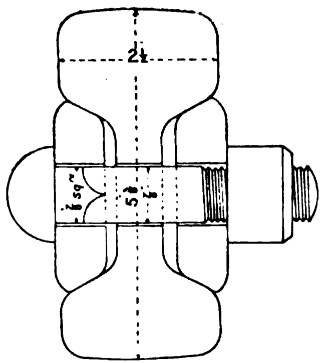
ELEVATION

FIG 3



SECTION OF RAIL

FIG 1



SECTION OF RAIL & FISH PLATES

FIG 2.

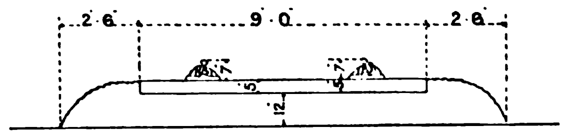
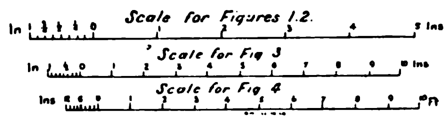
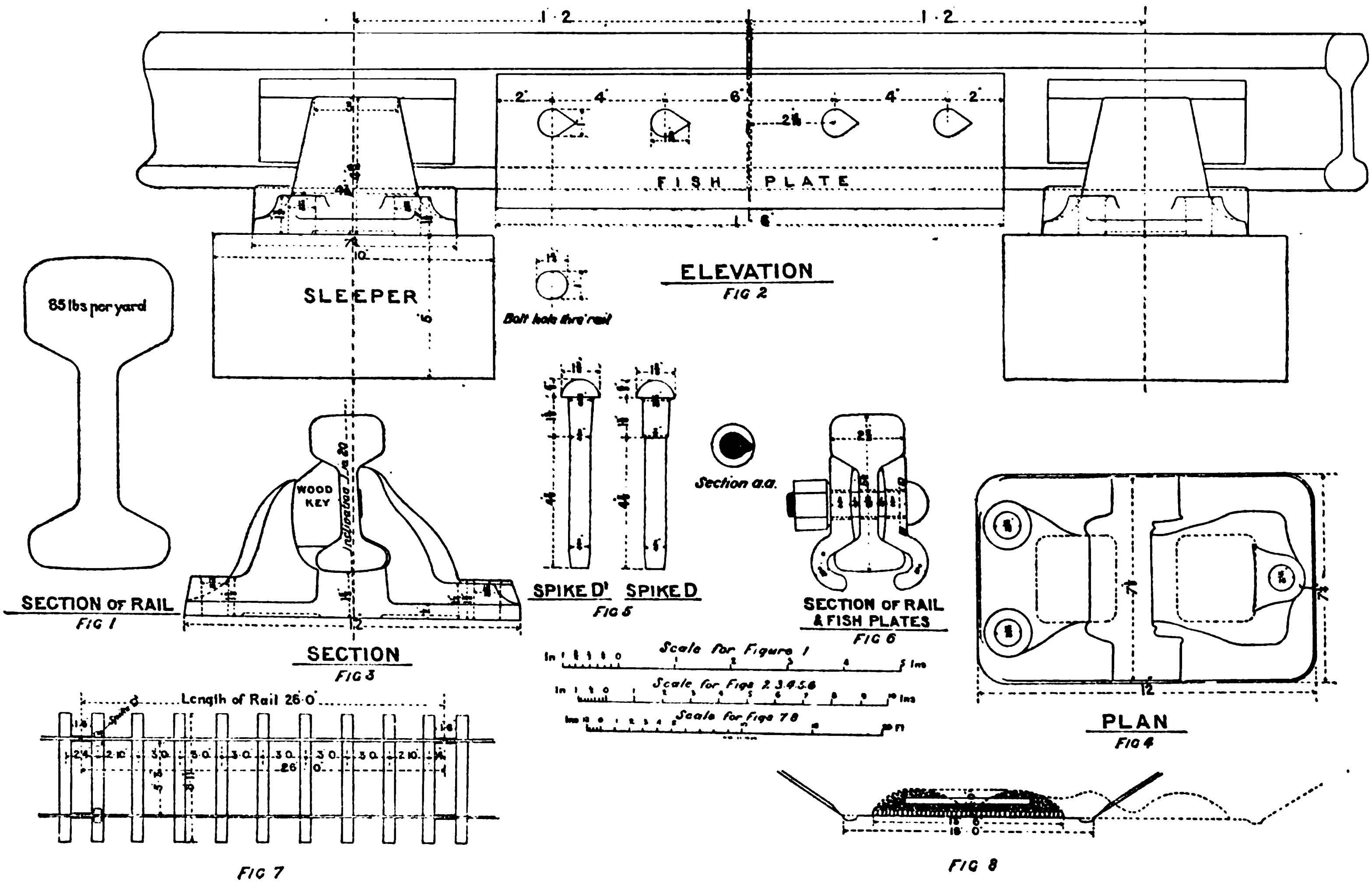


FIG 4.



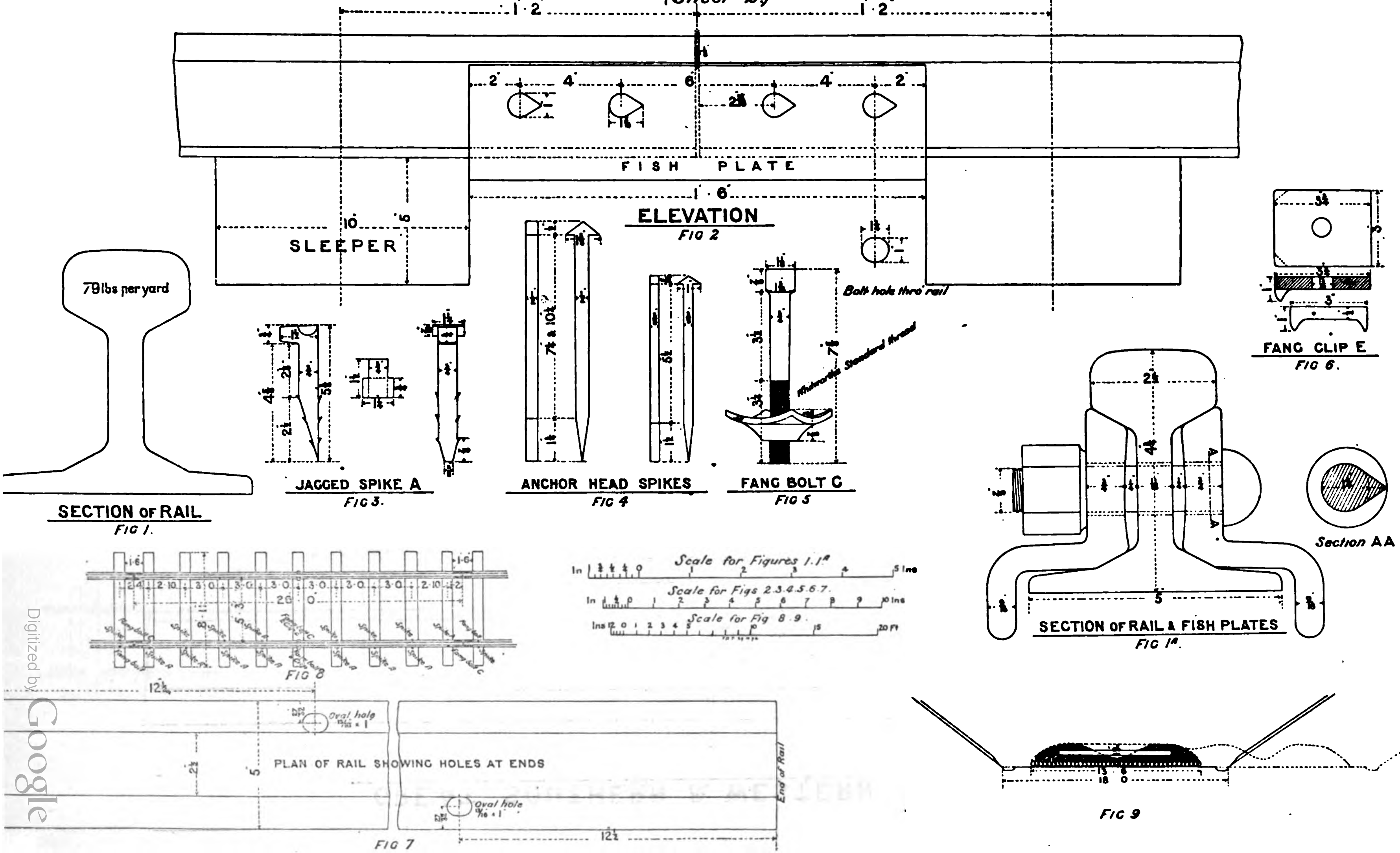
GREAT NORTHERN RAILWAY IRELAND

(Sheet 1.)

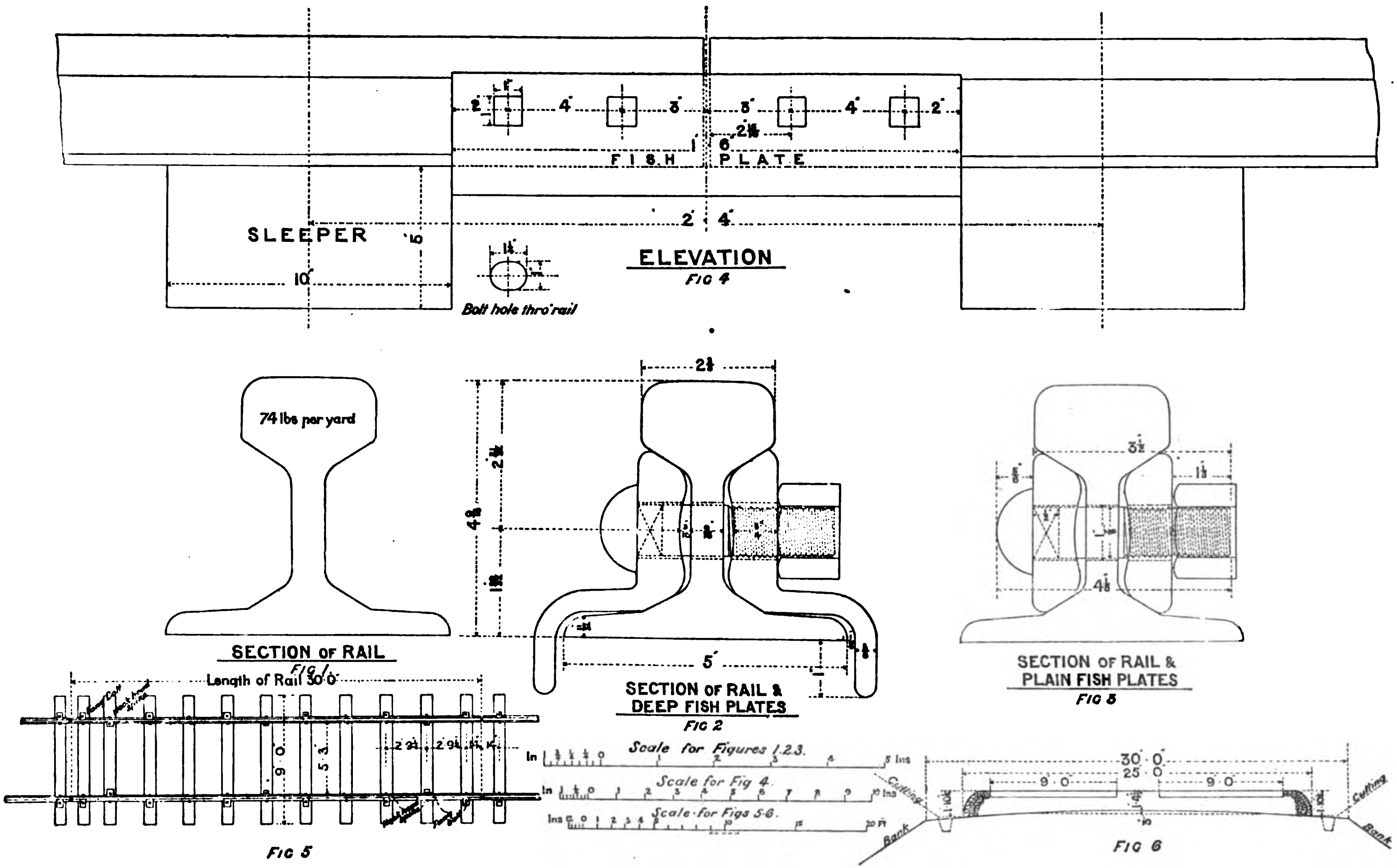


GREAT NORTHERN RAILWAY IRELAND

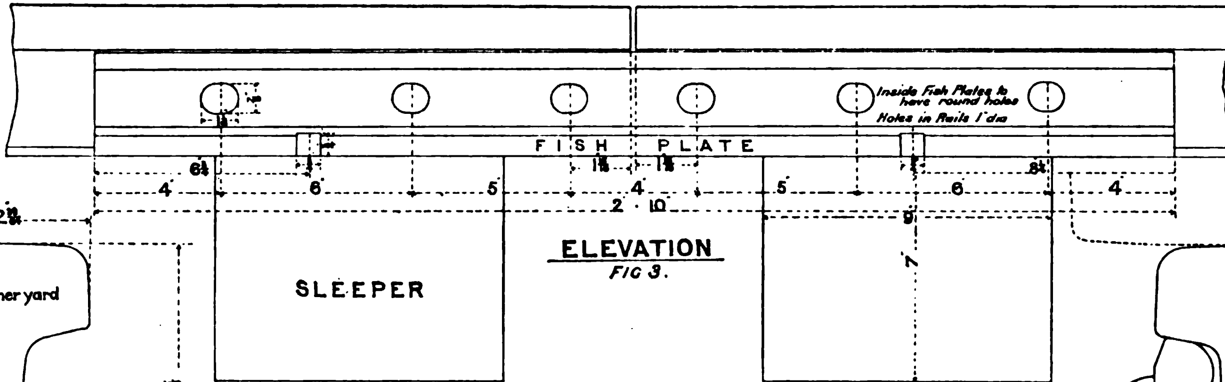
(Sheet 2.)



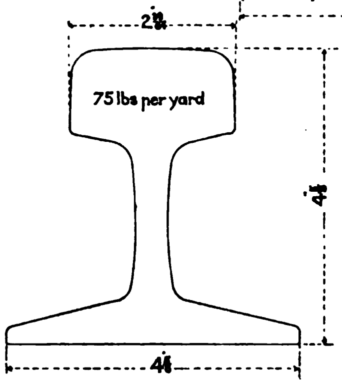
GREAT SOUTHERN & WESTERN RAILWAY



CHESAPEAKE & OHIO RAILWAY



ELEVATION
FIG 3.



SECTION OF RAIL
FIG 1.

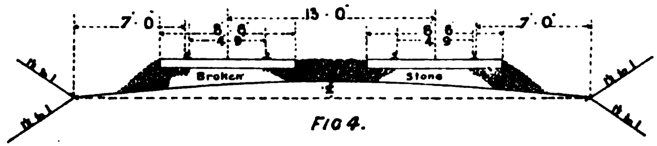
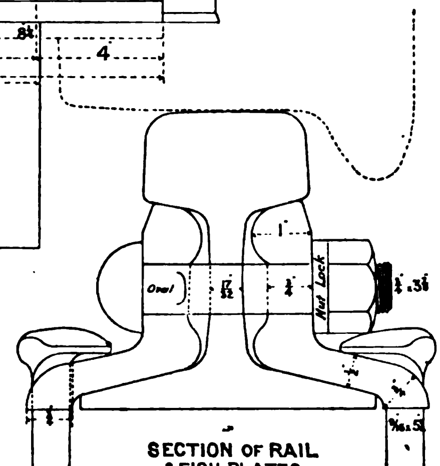


FIG 4.



SECTION OF RAIL & FISH PLATES
FIG 2.

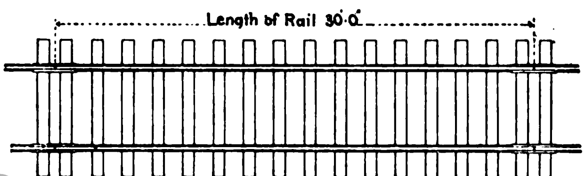
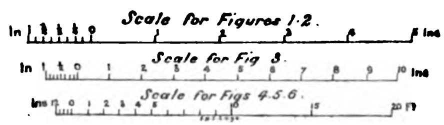


FIG 5



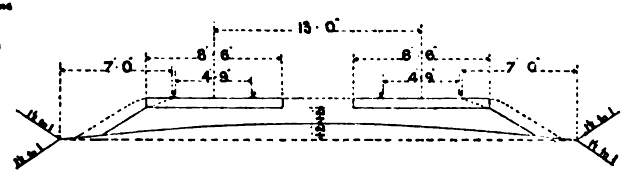
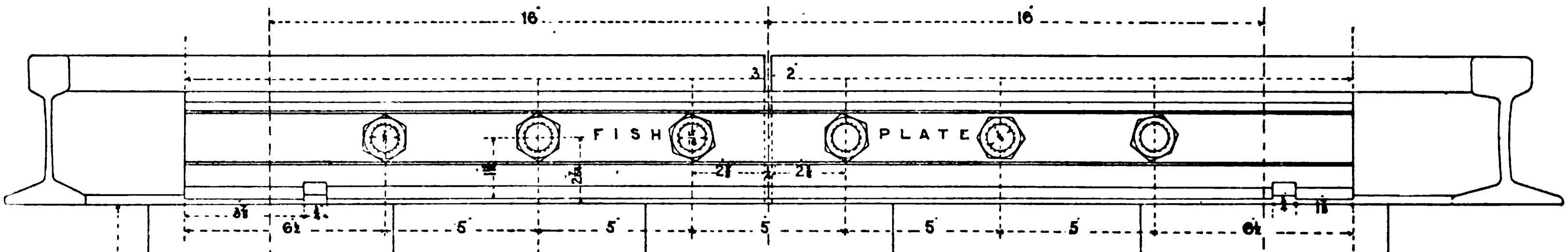
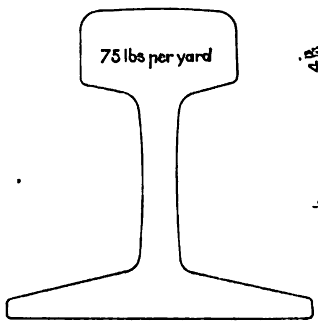


FIG 6.

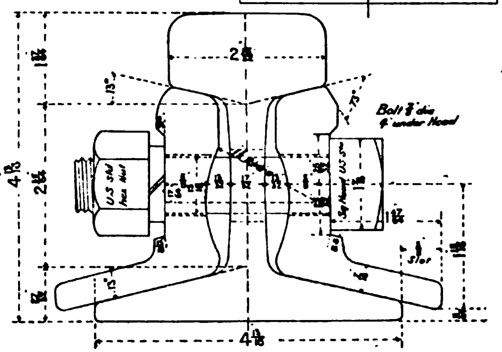
CHICAGO BURLINGTON & QUINCY RAILROAD



ELEVATION
FIG 3.



SECTION OF RAIL
FIG 1



SECTION OF RAIL & FISH PLATES
FIG 2.

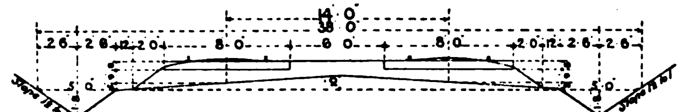


FIG 4.

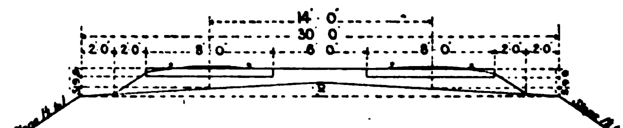


FIG 5.

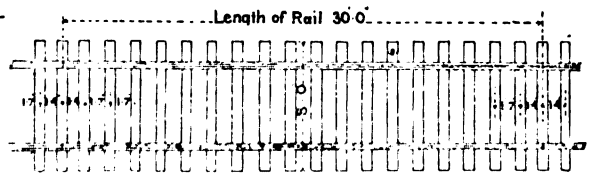
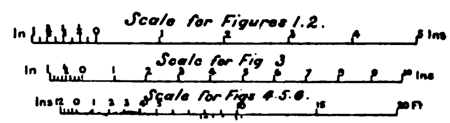
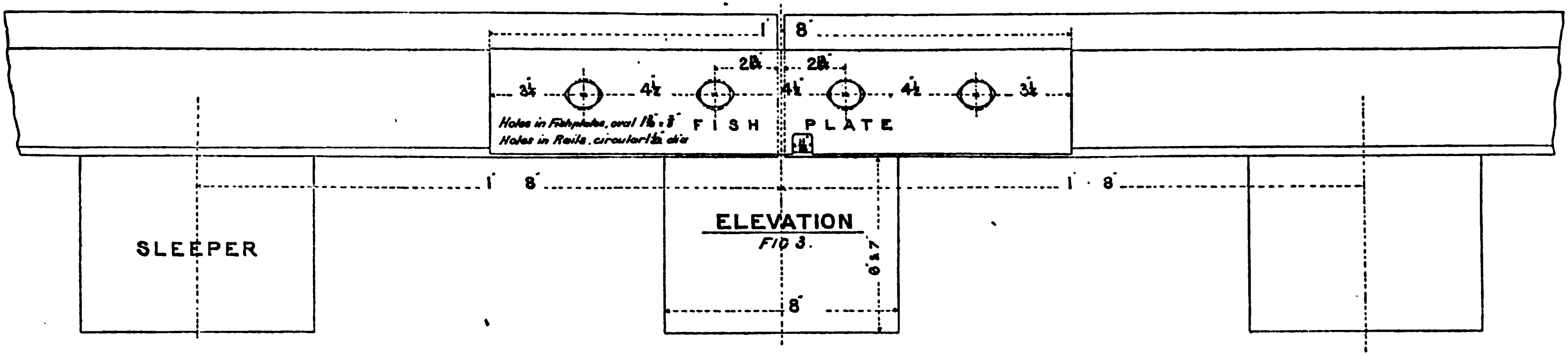
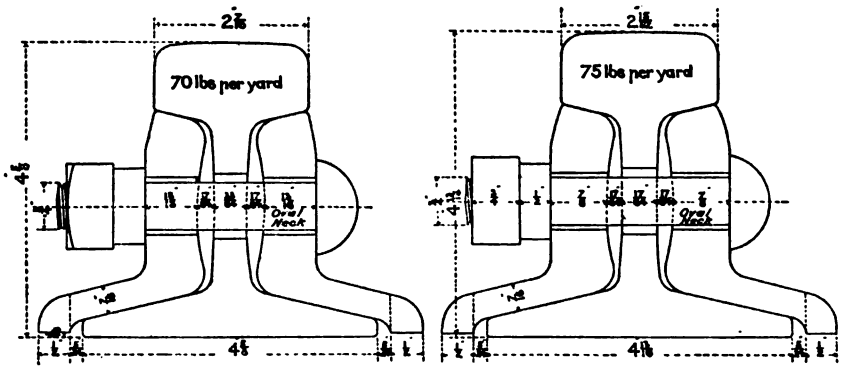


FIG 6



ILLINOIS CENTRAL RAILROAD





SECTION OF RAIL & FISH PLATES

FIG 1.

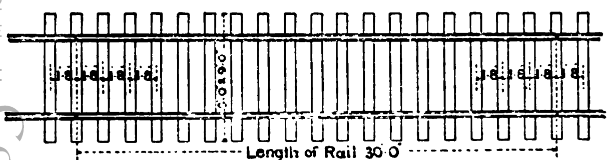
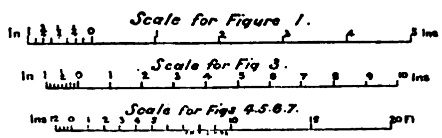


FIG 7.



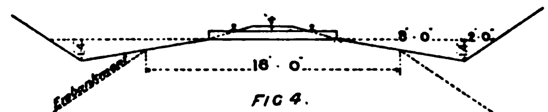


FIG 4.
Section of Earth Track

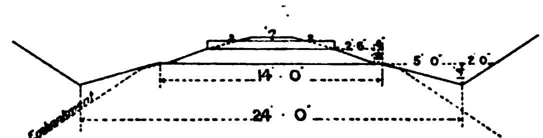


FIG 5.
Section of fine Gravel Ballast & for Cementing Gravel

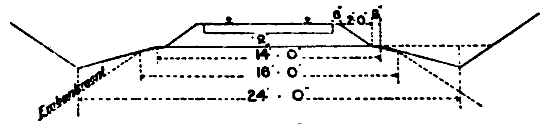
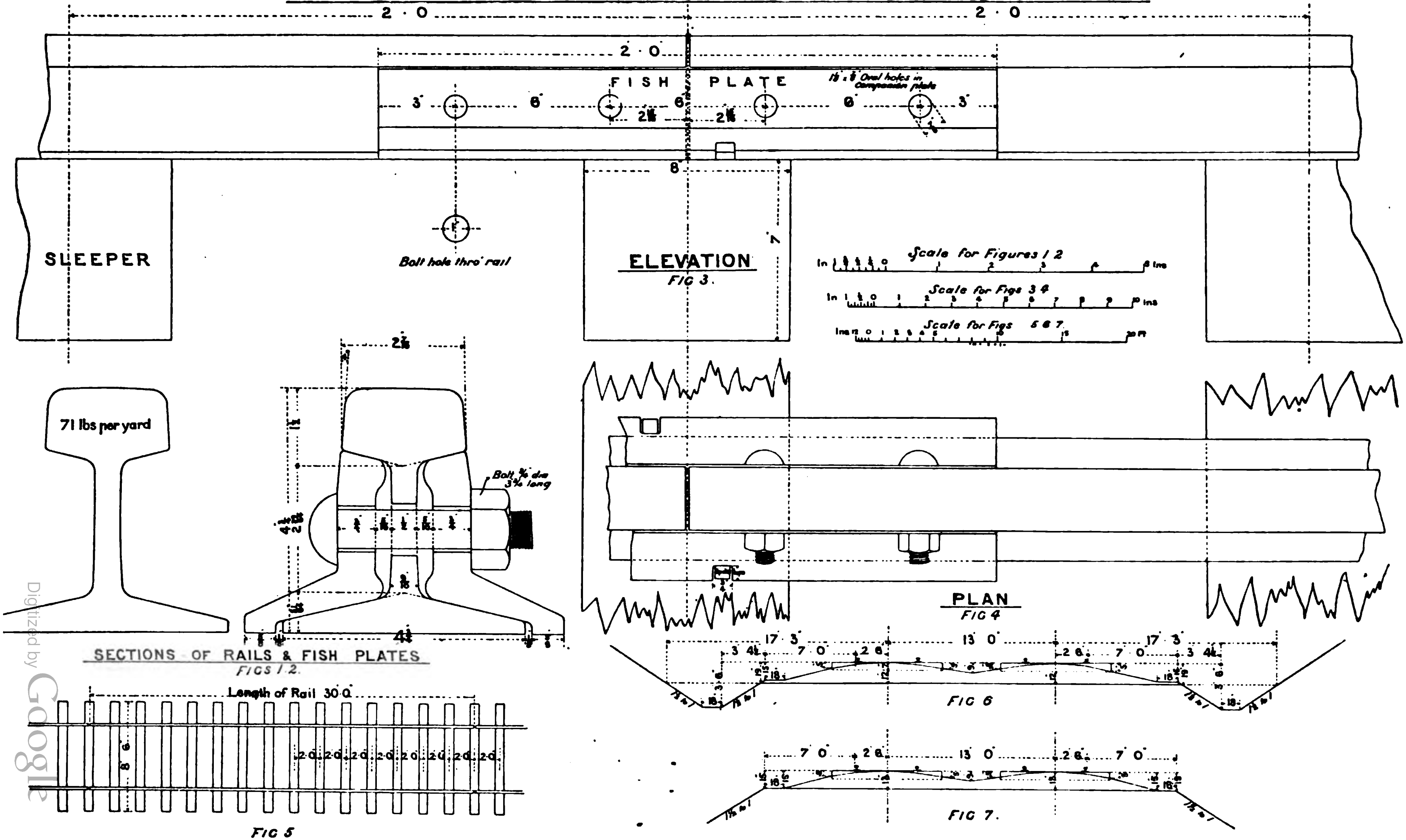


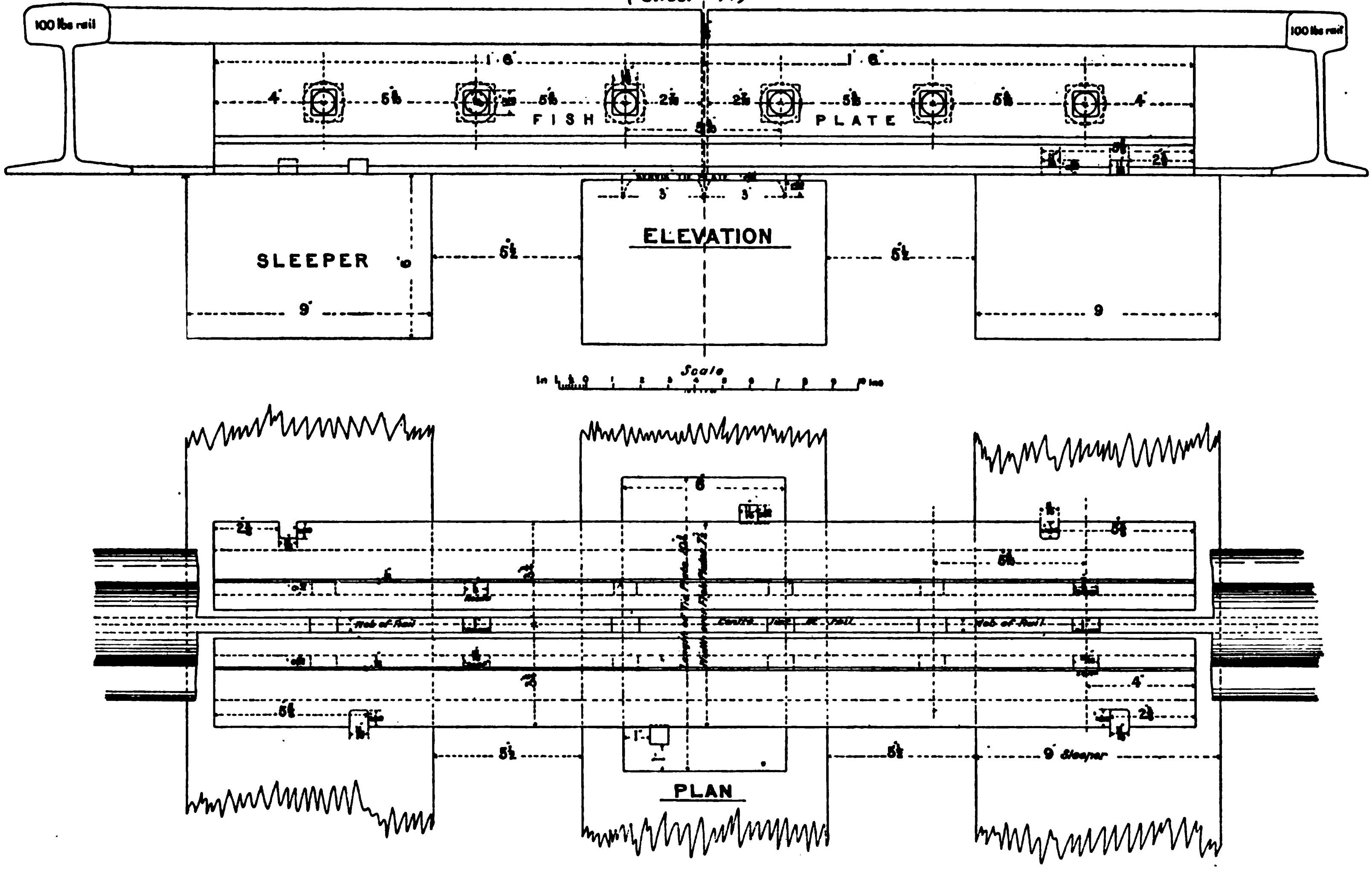
FIG 6.
Section of Stone or coarse & loose non-cementing Gravel Ballast

LAKE SHORE & MICHIGAN SOUTHERN RAILROAD



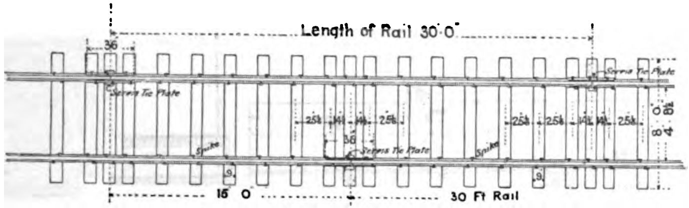
NEW YORK CENTRAL & HUDSON RIVER RAILROAD

(Sheet 1.)



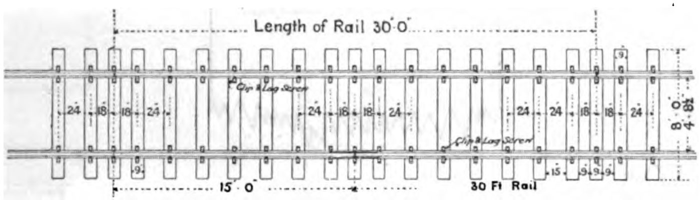
NEW YORK CENTRAL & HUDSON RIVER RAILROAD

(Sheet 2)



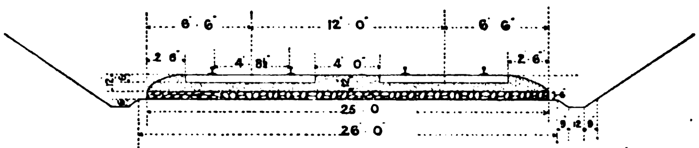
Plan shewing method of laying Track with Common Spikes

FIG 3.



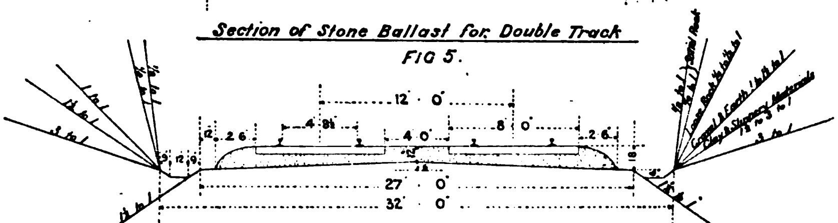
Plan shewing method of laying Track with Clips and Lag-Screw Fastenings

FIG 4.



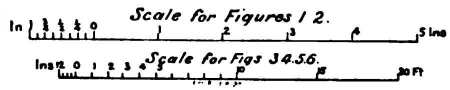
Section of Stone Ballast for Double Track

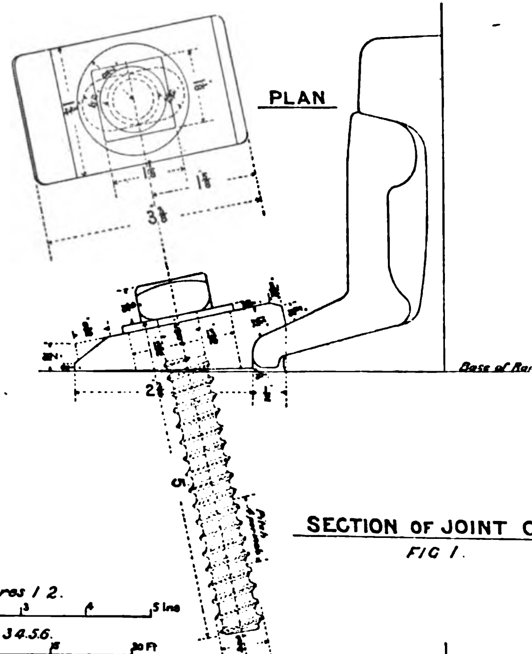
FIG 5.



Section of Gravel Ballast for Double Track

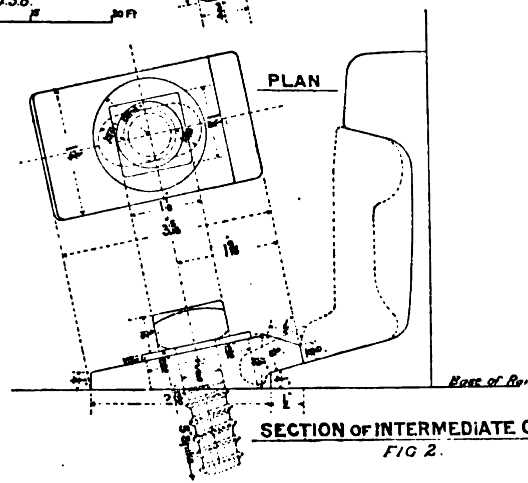
FIG 6.





SECTION OF JOINT CLIP

FIG 1.

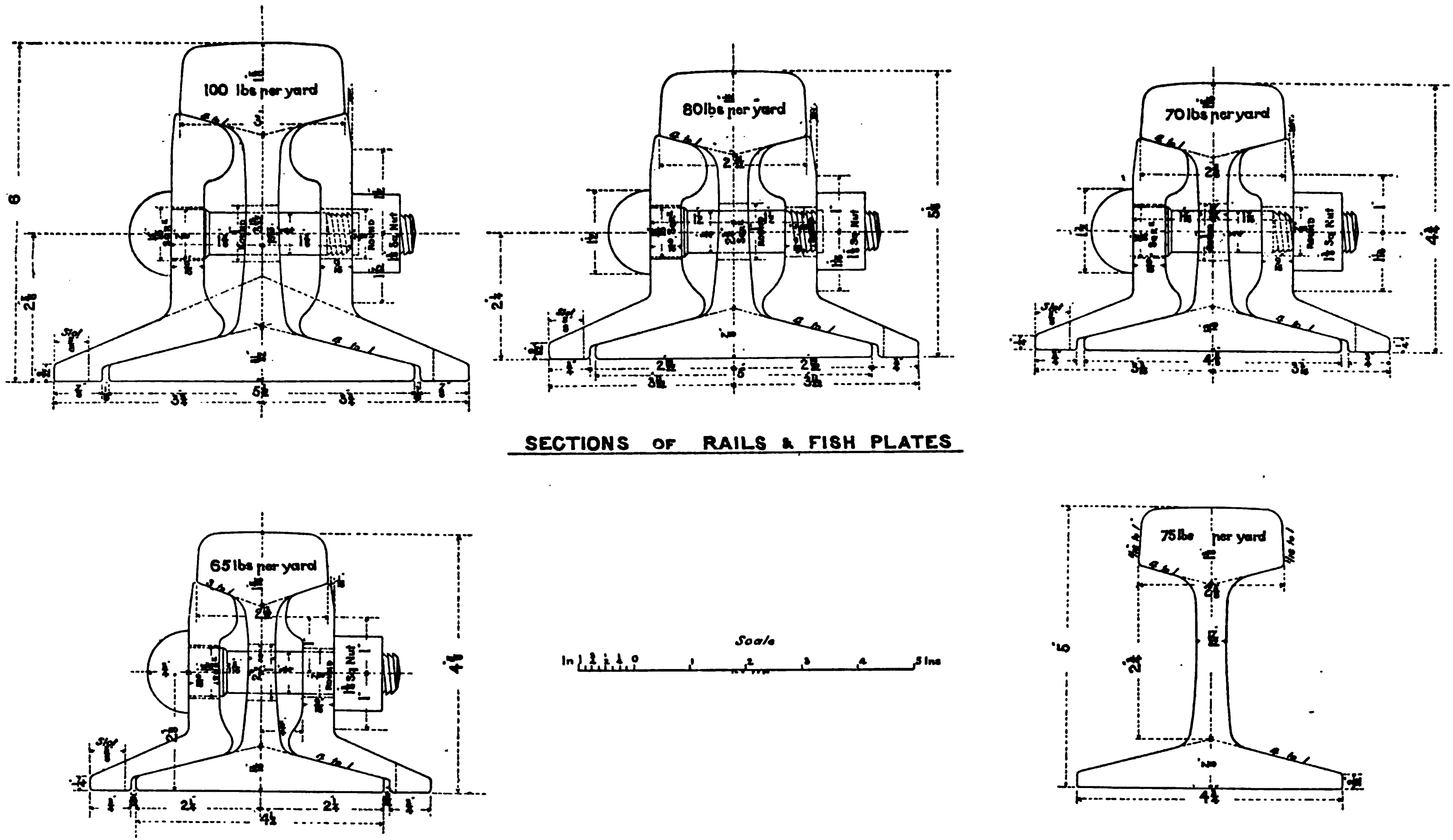


SECTION OF INTERMEDIATE CLIP

FIG 2.

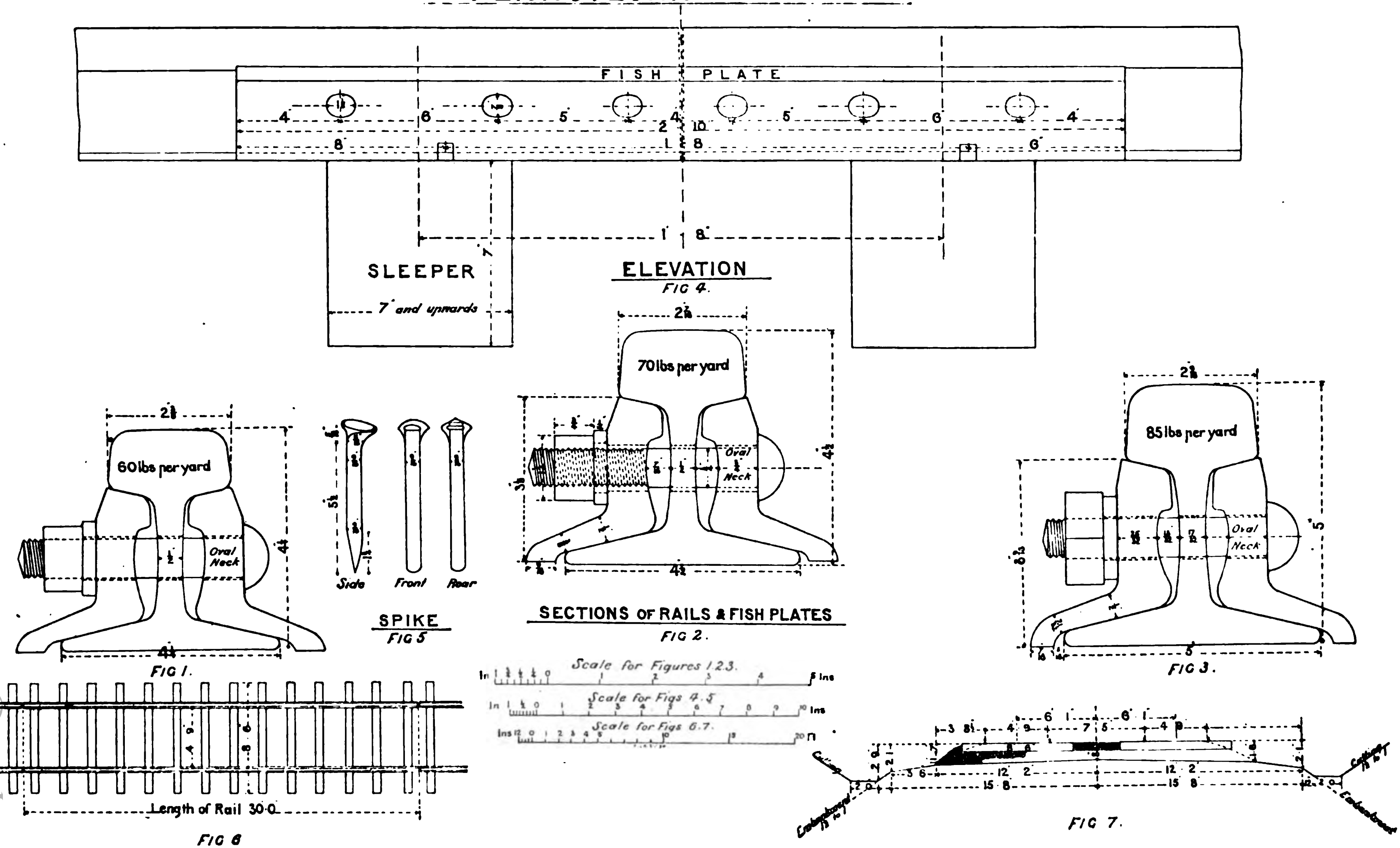
NEW YORK CENTRAL & HUDSON RIVER RAILROAD

Sheet 3.



SECTIONS OF RAILS & FISH PLATES

PENNSYLVANIA RAILROAD



ELEVATION
FIG 4.

FIG 1.

SPIKE
FIG 5

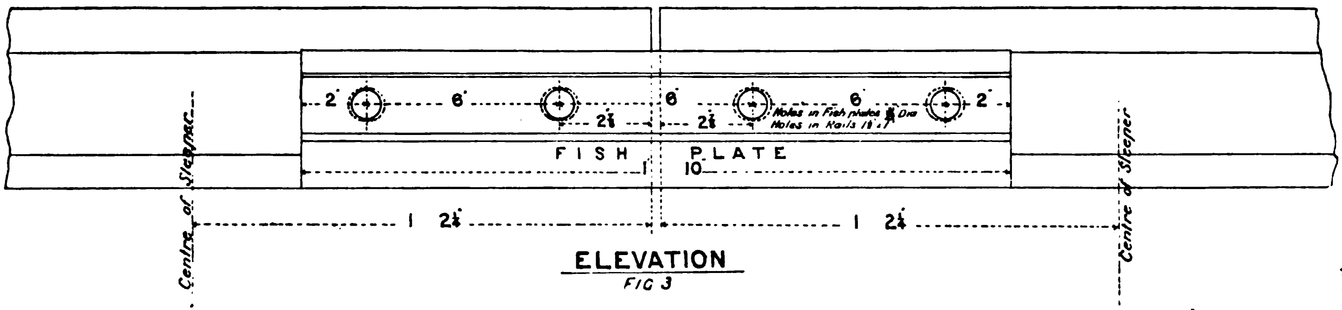
SECTIONS OF RAILS & FISH PLATES
FIG 2.

FIG 3.

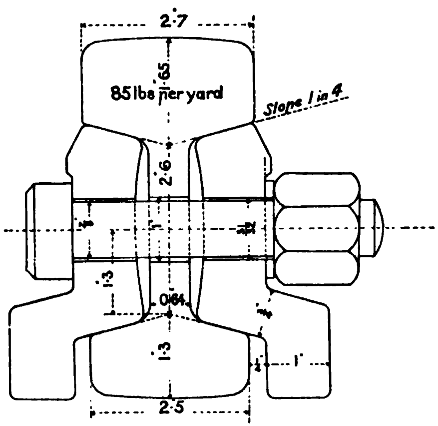
FIG 6

FIG 7.

EAST INDIAN RAILWAY



ELEVATION
FIG 3



SECTION OF RAIL & FISH PLATES
FIG 1

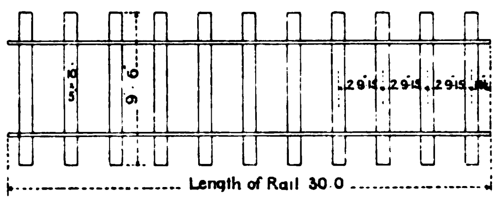
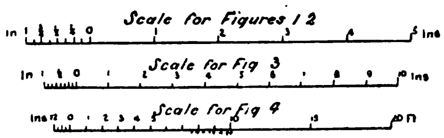
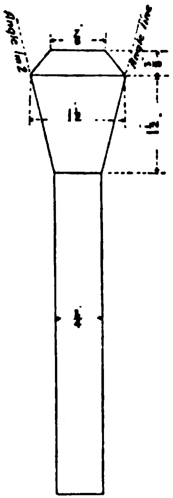


FIG 4

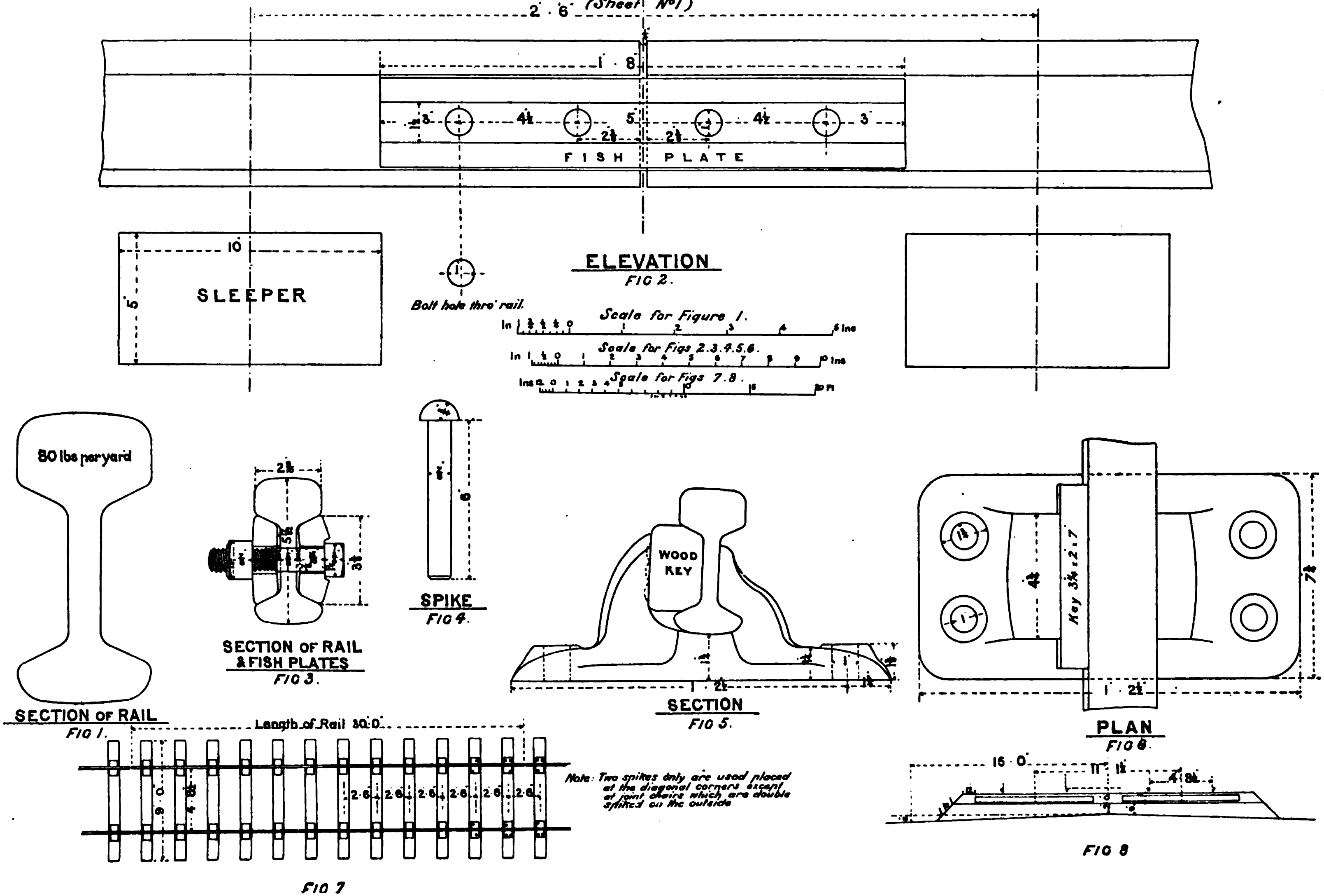




SPIKE
FIG 2

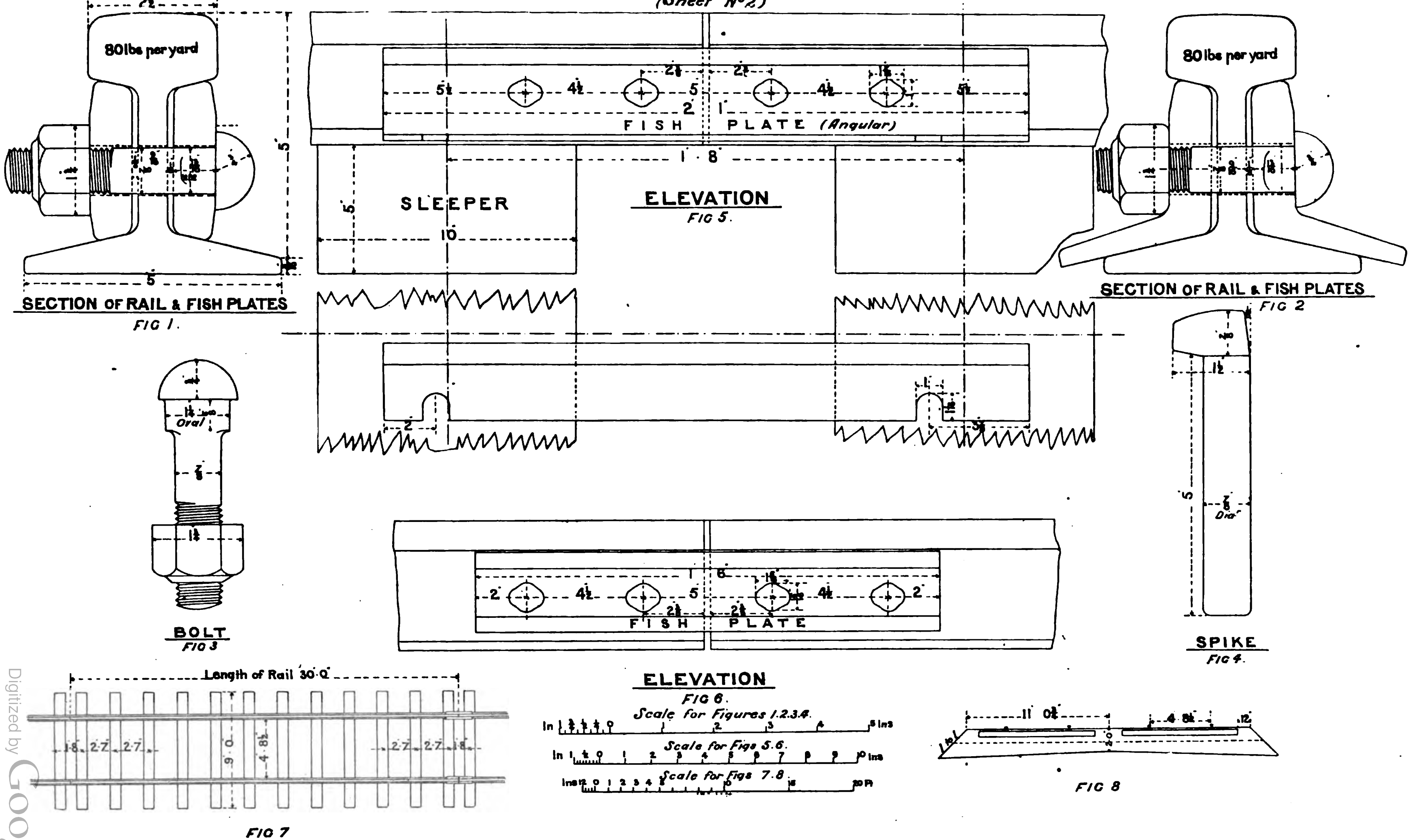
NEW SOUTH WALES GOVERNMENT RAILWAYS

(Sheet No 1)



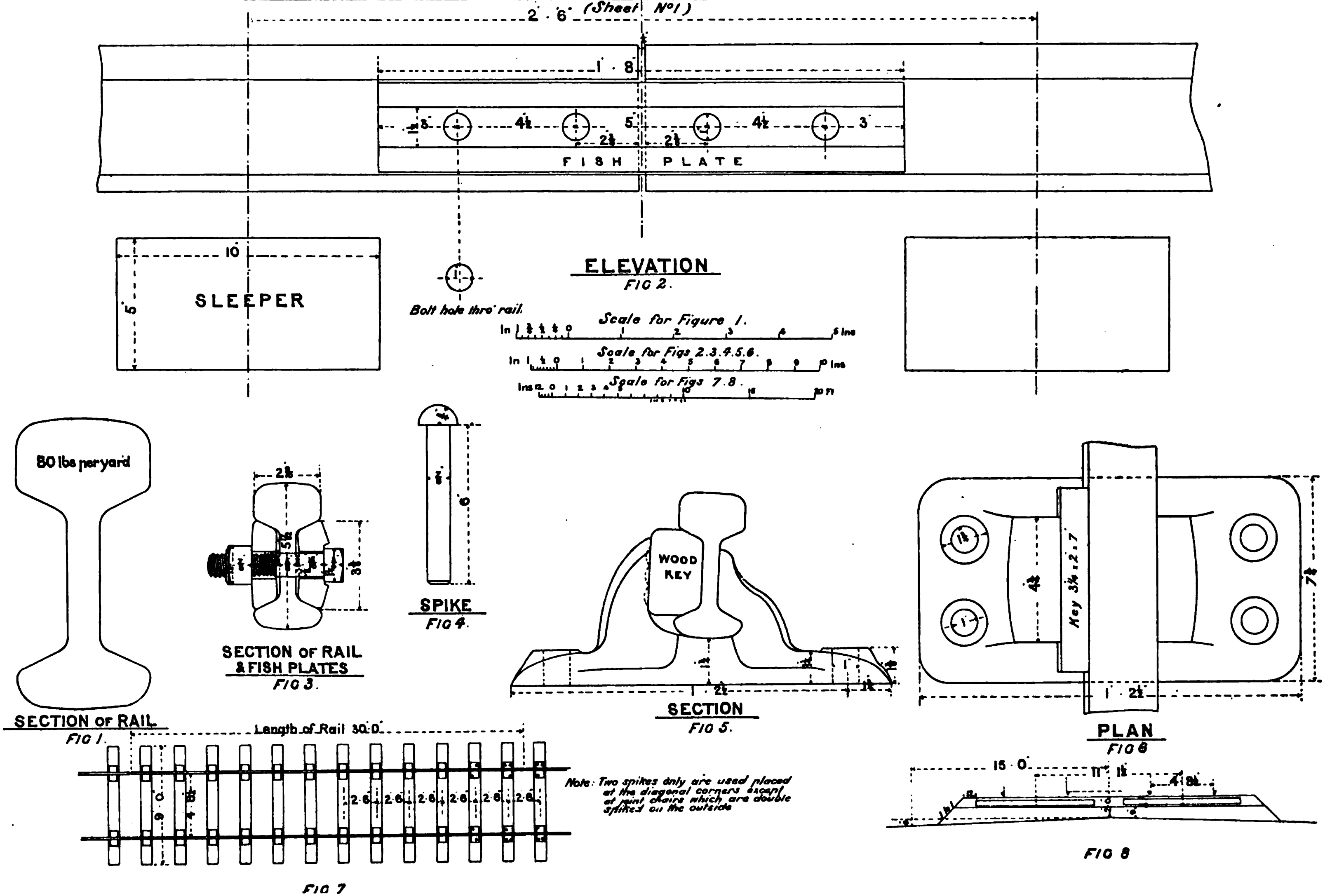
NEW SOUTH WALES GOVERNMENT RAILWAYS

(Sheet No. 2)



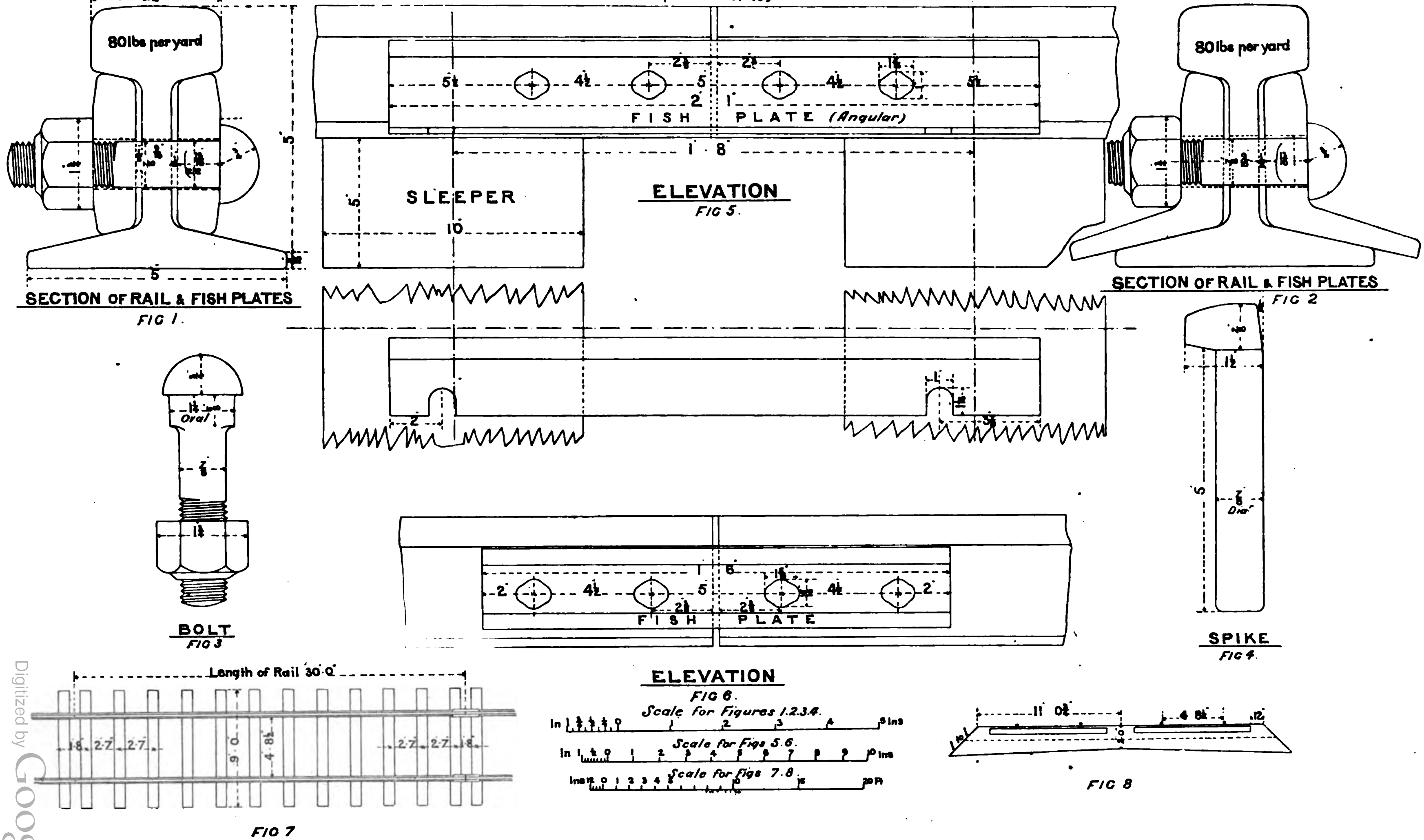
NEW SOUTH WALES GOVERNMENT RAILWAYS

(Sheet No 1)



NEW SOUTH WALES GOVERNMENT RAILWAYS

(Sheet No. 2)



ADDENDA

TO THE 2nd REPORT (FOR ENGLISH SPEAKING COUNTRIES) ON THE QUESTION OF STRENGTHENING OF PERMANENT WAY IN VIEW OF INCREASED SPEED OF TRAINS (SUBJECT I OF THE LIST OF QUESTIONS FOR DISCUSSION AT THE FIFTH SESSION OF THE CONGRESS)

By WILLIAM HUNT
CHIEF ENGINEER OF THE LANCASHIRE AND YORKSHIRE RAILWAY

*

APPENDIX *A.* — **Rails.**

QUESTIONS.	**England.** London Tilbury and Southend Railway. (Pl. 32.)	**America.** Atchison Topeka and Santa Fe. (Pl. 33 and 34.)	**Australia.** South Australian Railways. (Pl. 35.)
Weight of rail . . Per yard .	72 lbs.	52, 56, 66, 67 and 71 lbs.	80 lbs.
Weight of rail . . Per metre.	(35 1/2 kilog.)	(26, 28, 32 1/2, 33 et 35 kilog.)	(39 1/2 kilog.)
Length	24 feet ($7^{m}31$).	30 feet ($9^{m}14$).	30 feet ($9^{m}14$).
Holes for fish bolts :			
a) Number	Four.	Some four some six.	Four.
b) Shape	Slotted.	Oval.	Oval.
c) Distance apart from centre to centre of holes. . .	4 1/2 inches (114 mill.).	5 inches (127 mill.).	5 1/2 inches (140 mill.).
d) Distance from end of rail to centre of nearest hole.	2 1/4 inches (57 mill.).	2 3/8 inches (60 mill.).	2 5/8 inches (67 mill.).
Is the line relaid when the rails wear down to minimum weight per yard ?	No.	No special rules for renewal. — They are made as required by circumstances. — Traffic and load being considered.	No definite rule.
If so, give weight	"		
Is line relaid when rails wear down to minimum thickness of top flange or minimum depth over all ?	Minimum depth over all.		
If so, give thickness or depth . .	From 5 3/16 to 4 11/16 inches (132 to 119 mill.)		
Have you made use of rails of unusual length, 60 feet or upwards ?	No.	No.	No.
If so, state object and what result.	"	"	"

APPENDIX *B.* — **Manufacture and testing of rails.**

QUESTIONS.	England. London Tilbury and Southend Railway. (Pl. 32.)	America. Atchison Topeka and Santa Fe. (Pl. 33 and 34.)	Australia. South Australian Railways. (Pl. 35.)
By what process is the steel for rails manufactured?			
a) Bessemer acid	Bessemer.	Bessemer acid.	Bessemer acid.
b) Siemens Martin acid. . .	"	"	"
c) Basic in Siemens Martin hearths	"	"	"
To what tests are rails subjected to before acceptance?			
a) Bending	5 feet (1^m524) length placed on solid iron bearings 3 feet 6 inches (1^m067) apart shall then receive successive blows from a weight of 1,800 lbs (816 kilog.) falling a height of 6 feet (1^m83). Rails not to break before or under third blow nor take a permanent set after first blow exceeding 1 5/8 inches (41 mill).	No special tests. Rely or reputation of manufacturer.	Rail placed on supports 3 feet (0^m918) apart and to receive from blows from a weight of 13 cwt (660 kilog.) falling from a height of 10 to 16 feet (3^m05 à 4^m88) without fracture. Also to bear a weight of 15 tons (15,250 kil.) for 10 minutes without permanent deflection.
b) Chemical	"	"	"
c) Tension :			
Breaking weight in tons, per square inch.	"	"	"
Extension per cent. . . .	"	"	"
Contraction of area, per cent.	"	"	"
Particulars as to the relative merits of hard and soft steel. .	"	No experience with hard steel.	"

APPENDIX C. — **Rail connections.**

QUESTIONS.	**England.** London Tilbury and Southend Railway. (Pl. 32.)	**America.** Atchison Topeka and Santa Fe. (Pl. 33 and 34.)	**Australia.** South Australian Railways. (Pl 35.)
Is the rail suspended or supported in a joint chair or on sleepers? .	Suspended.	Mainly supported	Suspended.
Fish plate :			
Length	18 inches (457 mill.).	4 hole plates 23 inches (584 mill). 6 hole plates 38 inches (965 mill.).	21 1/2 inches (546 mill.).
Depth	4 1/2 inches (114 mill.).	3 1/8 inches (79 mill.).	6 3/4 inches (172 mill.).
Thickness	7/8 inch (22 mill.).	3/4 of an inch (19 mill.).	7/8 inches (22 mill.).
Weight of each.	18 lbs (8.16 kilog.).	38 inches (965 mill.) plates 34 3/4 lbs (15.75 kilog.). 23 inches (584 mill.) plates. 21 lbs (9.53 kil.)	24.87 (11.28).
Fish bolts :			
Number.	Four.	Four and six.	Four.
Size	4 inches × 7/8 inch. (102 × 22 millimetres).	4 inches × 3/4 inch. (102 × 19 millimetres).	4 1/4 inches × 7/8 inches. (108 × 22 millimetres)
Weight including nut and washer (where used) . .	1 1/2 lb. (0.68 kilog.).	1 lb (0.45 kilog.).	1 1/2 lb (0.68 kilog.).
Description of fish bolt. . . .	Cup headed with square shoulder.	Cup headed with rounded shoulder.	Cup headed with square shoulder.
Description of nut (and washer if any)	Ordinary square nut. No washers.	Ordinary hexagonal nut next fish plate with square nut outside.	Ordinary hexagon nut and Grovers washer.
Are holes in fish plates square or circular, punched or drilled? .	Square in one plate circulare in the other.	Square in one plate and elliptical in the other.	Oblong, punched.

QUESTIONS.	England. London Tilbury and Southend Railway. (Pl. 32.)	America. Atchison Topeka and Santa Fe. (Pl. 33 and 34.)	Australia. South Australian Railways. (Pl 35)
Does the form of joint used give satisfaction ?	Yes.	Partial.	Yes. The special form of deep flange to fish plates insures the necessary strength to the plates while allowing the adjoining sleepers to be brought near enough together to give the required support.
If not, in what respect is improvement required with a view to securing uniform strength of road throughout ?	»	This problem has not yet been solved.	»
How are rails secured to sleepers ?			
With chairs on wood sleepers . .	Yes.		
Weight of chair ?	43 lbs (19.5 kilog.).		
Base of chair area in { square inches . .	98 square inches		
Base of chair area in { centimetres square.	(632.3 square cent.).		
Is felt or other material placed between chair and sleeper ? . .	No.	None used.	None used.
Are the chairs on each side of the joint of the same pattern as the rest? If not, give particulars .	Yes.		
Full particulars of mode of attachment of each chair to sleeper .	3. Wrot iron spikes 5 1/8 inches (130 mill.) long under the head 3/4 inch (19 mill.) diameter.		
Full particulars of mode of attachment of flat-bottomed rail to sleeper.	»	By spikes detail not given.	By 12 fang bolts and 12 spikes on the outsides of the rails and by 24 spikes on the inside of the rails.

APPENDIX *D.* — **Keys and sleepers.**

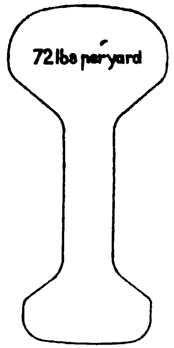
QUESTIONS.	**England.** London Tilbury and Southend Railway. (Pl. 32.)	**America.** Atchison Topeka and Santa Fe. (Pl. 33 and 34)	**Australia.** South Australian Railways. (Pl. 35)
Keys.			
What wood is used?	Oak.		
Is it compressed?	Yes.		
Particulars of metal keys, if used .	»	None used.	None used.
Are rails keyed on inside or outside?	Outside.		
Sleepers-wood.			
What kind of wood is used? . .	Baltic redwood.	Oak. Pine and cedar.	Red gum, sugar gum, Jarrah and Karri hardwoods.
Are sleepers creosoted, or treated with other antiseptic? . . .	Some.	Pine is treated with chloride of zinc, tannin and glue. Others not treated.	No.
Dimensions :			
Length	9 feet (2^m743).	8 feet (2^m438).	8 feet 6 inches (2^m591).
Breadth	10 inches (254 mill.).	8 inches (203 mill.).	10 inches (254 mill.).
Thickness	5 inches (127 mill.).	7 inches (178 mill.).	5 inches (127 mill.).
Are they placed in the road heart side or waney side upwards? .	Creosoted sleepers waney side upwards. Un creosoted sleepers some one side and some the other.	No special care in this respect.	No distinction made. It is not necessary with Australian hardwoods.

APPENDIX *E.* — **Ballast.**

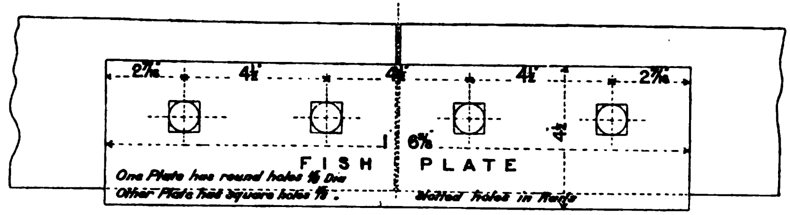
QUESTIONS.	England. London Tilbury and Southend Railway. (Pl. 32)	America. Atchison Topeka and Santa Fe. (Pl. 33 and 34.)	Australia. South Australian Railways. (Pl. 35.)
Material adopted for bottom ballast.	Burnt clay chalk, brick and stone rubble.	Stone.	Broken limestone or quarry stone generally, river gravel occasionally.
If stone, what mesh?	No restriction.	2 inches ring (51 mill).	2 1/2 inches (63 mill.) ring.
Depth of bottom ballast	9 inches (229 mill.).	10 inches (254 mill.).	6 inches (152 mill.) in level districts, 9 inches (229 mill.) hilly districts.
If cinders, whether screened or not?	"	"	"
Material used for top ballast . .	Pit gravel-chalk always covered with gravel or clinkers.	Cinders, gravel slag burned clay and stone.	Same as for bottom ballast.
Thickness of top ballast	Average 21 inches (534 mill.).	6 inches (152 mill.).	7 inches to 8 1/2 inches (178 to 216 mill.).
Is the top ballast laid above the top of the sleeper, and if so, to what extent?	Yes. 4 inches (102 mill.).	No.	Yes. 3 inches (76 mill.).
What advantages are found to result from the use of the material selected for ballast? . . .	The materials adopted for bottom ballast both acts as drain and keeps clay from getting soft and squeezing up into top gravel rendering it dirty and wet. Clinkers are most efficient at ends of sleepers to let water escape freely from sides of top ballast, chalk for top ballast is used principaly at outside ends of sleepers.	Cinders and burned clay give easiest riding track. Slag and rock more durable.	Good drainage and a good elastic bed.

PLATES

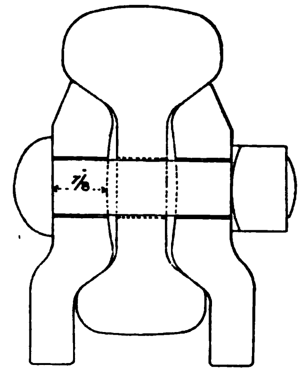
LONDON TILBURY & SOUTHEND RAILWAY



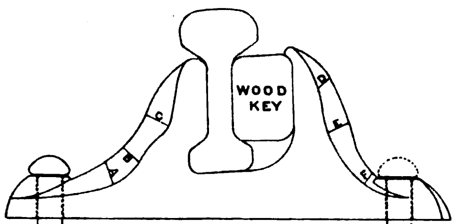
SECTION OF RAIL
FIG 1



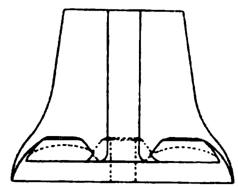
ELEVATION
FIG 3



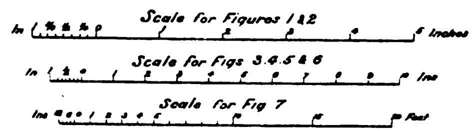
SECTION OF RAIL & FISH PLATES
FIG 2

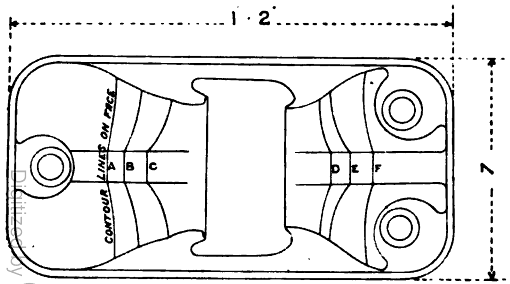


SECTION
FIG 4



END ELEVATION
FIG 5





PLAN
FIG 6

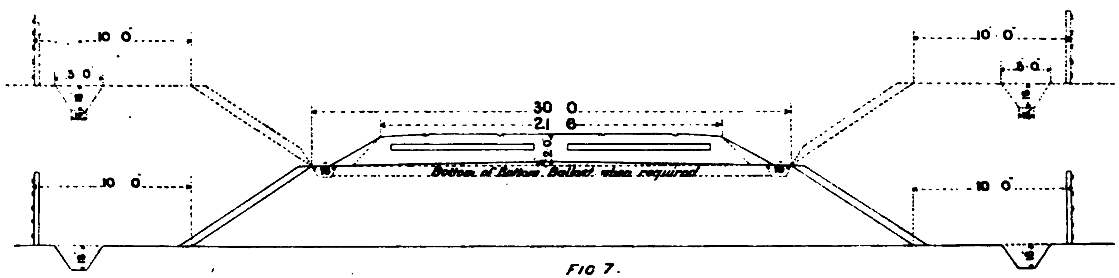
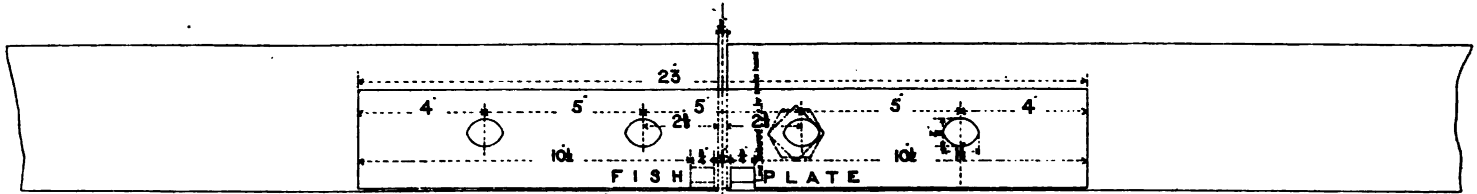


FIG 7.

Plate 33.

ATCHISON TOPEKA & SANTA FÉ RAILWAY

(Sheet No. 1.)



ELEVATION

FIG 1

HOLE THRO RAIL

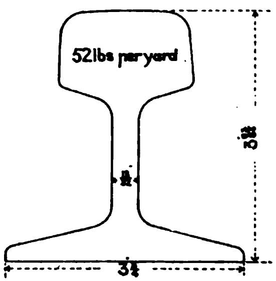


FIG 2

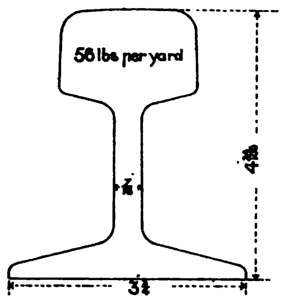


FIG 3

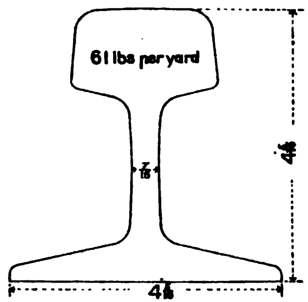


FIG 4

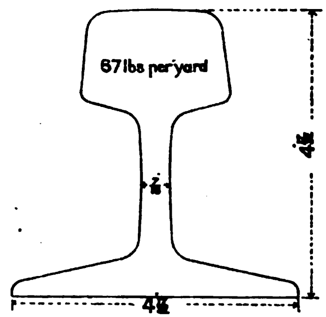


FIG 5

SECTIONS OF RAILS

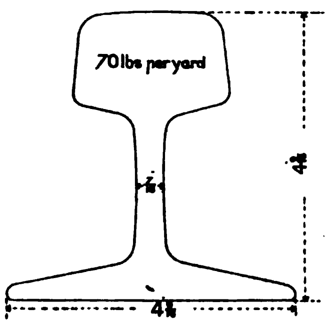
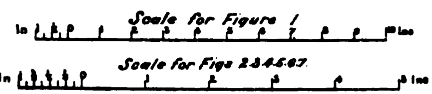
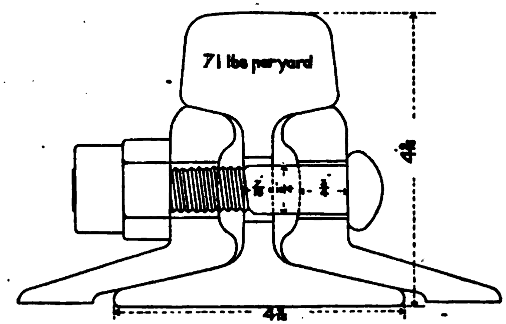


FIG 6



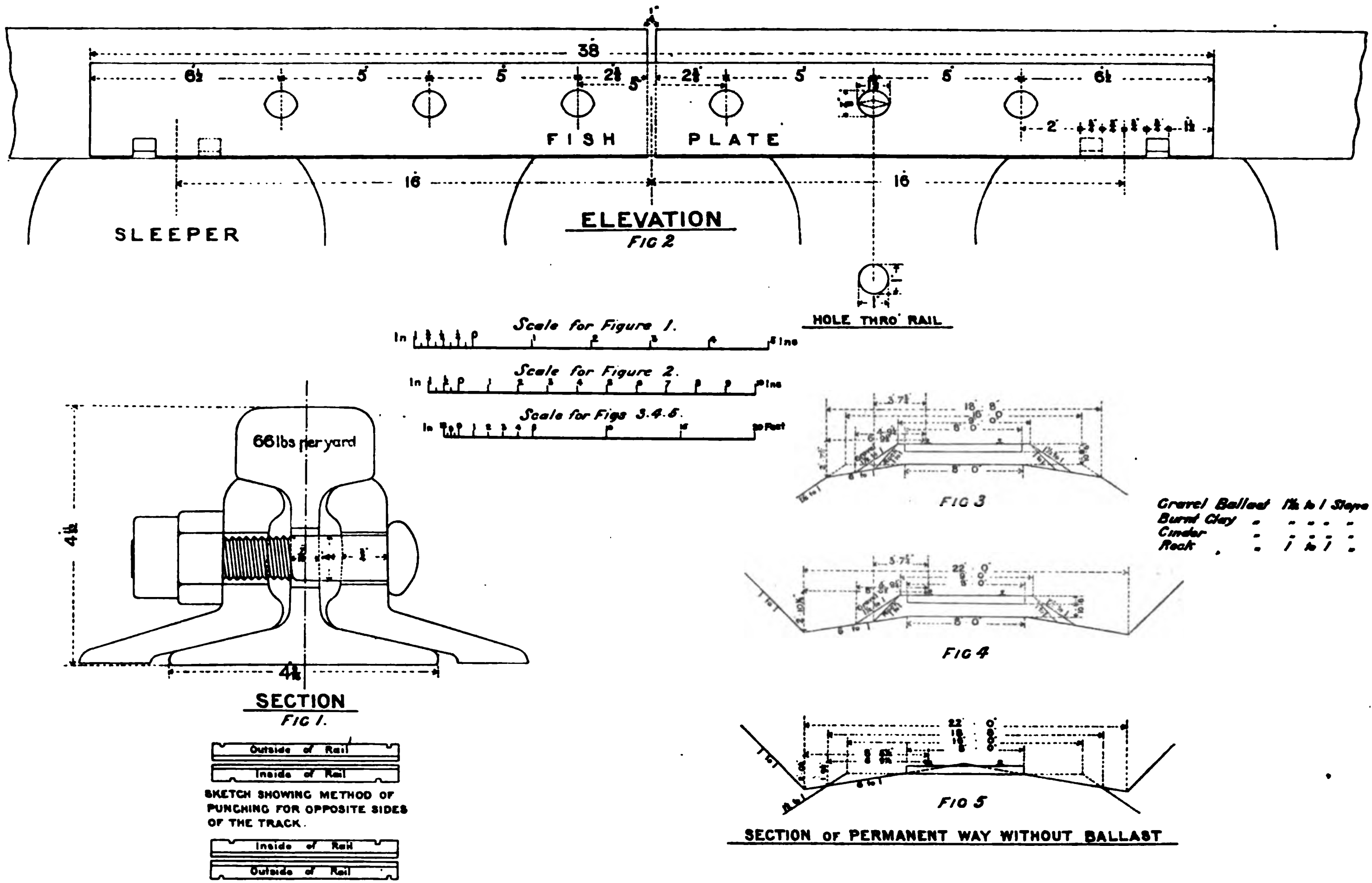


SECTION OF RAIL & FISH PLATES

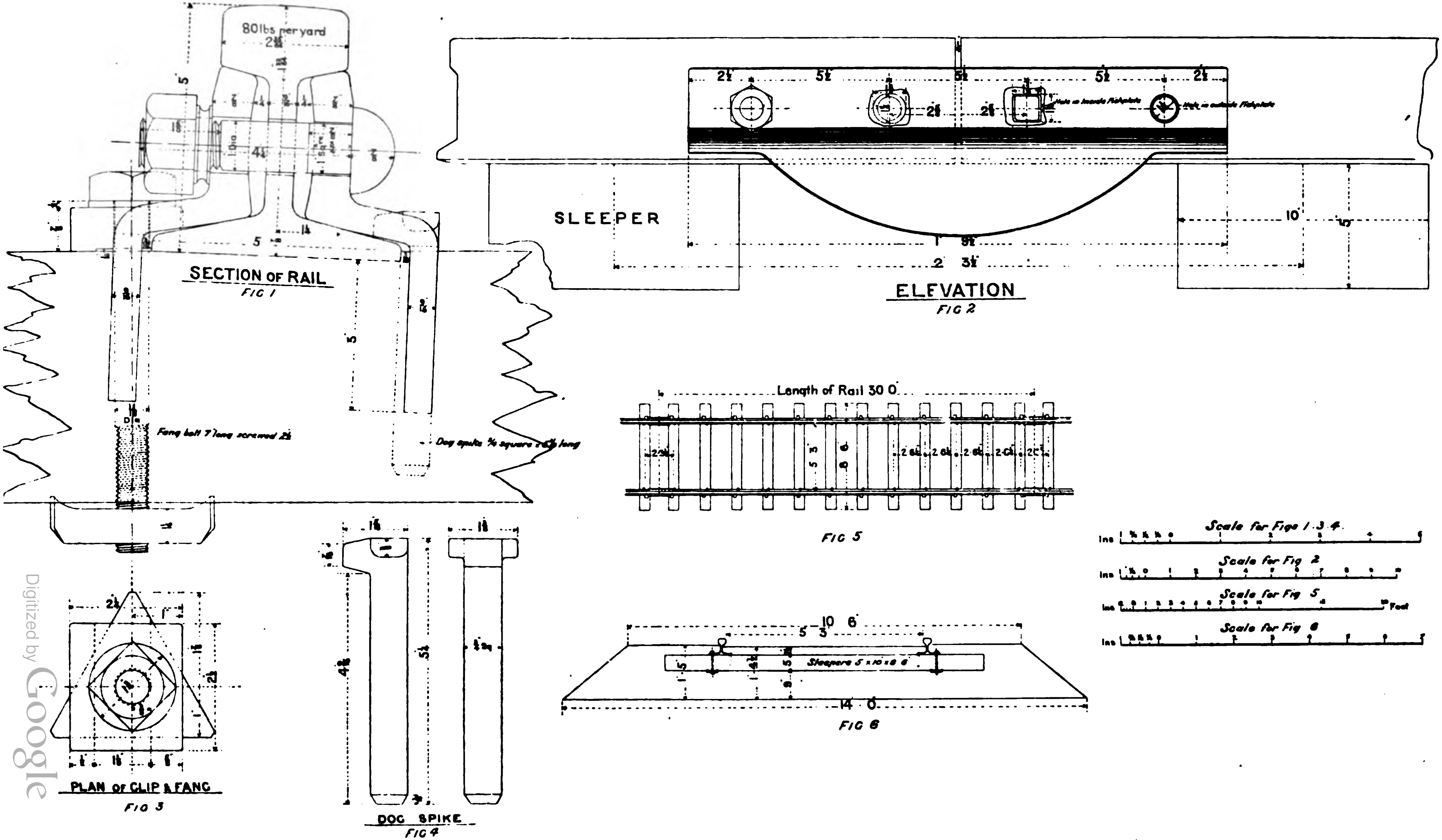
FIG 7

ATCHISON TOPEKA & SANTA FE RAILWAY

(Sheet No. 2.)



SOUTH AUSTRALIAN RAILWAYS



1RST REPORT (FOR ENGLISH SPEAKING COUNTRIES)

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INTRODUCTION.

The enormous development of railway travelling during the last decade has produced growing requirements on the part of the public with regard to the speed and convenience of travelling. The following table shows the highest speeds attained by express trains in different countries :

COUNTRY.	SECTION OF LINE.	Length of Section.		MEAN SPEED.				Maximum speed authorised or recorded.	
				Speed according to time table-stoppages excluded.		Approximate speed after deducting time lost in starting and stopping.			
		Kilom.	Miles.	Per kilom.	Hour miles.	Per kilom.	Hour miles.	Per kilom.	Hour miles.
Austria	Vienna-Lundenburg.	83	51·50	67·2	42·0	70	43·6	90 (*)	55·9
Italy	Piacenza-Modena. .	110	68·0	68	42·3	72	45·0	80	49 7
Germany. . . .	Berlin-Wittenberg .	159·4	99·0	82·5	51·3	84	52 2	90 (*)	55·9
Holland	Amsterdam-Hague .	61	37·9	72	44·7	79·5	49·4	90	55·9
Belgium	Brussels-Ostend . .	120·9	75·1	72·5	45·0	81·5	50·6	100	62·1
France	Paris-Amiens . . .	131	81 41	81·9	50·9	83·4	51·8	120	74 6
England	London-Grantham .	169	105·0	83·3	51·8	84·6	52·6	120	74·6

(*) Maximum allowed by law.

The actual speeds are thus shown to be high, yet one hears everywhere the opinion discussed (without saying however on what it is based) that they do not meet the requirements of the traffic and it is announced that an English railway is preparing a locomotive capable of drawing trains at the speed of 160 kilometres (99 miles) per hour. Academic discussion has even taken place, as to the possibility of obtaining speeds of 200 kilometres (124 miles) per hour or more. On the other hand the shortening of the duration of the journeys obtained by means of these high speeds has not prevented the public from being more and more exacting with respect to the comfort of the carriages. Considering that our trains are composed partly of sleeping, of dining, and of drawing-room cars, we ought not to be surprised that, the dead weight per passenger is now two or even three times the amount that it was in former years. On the other hand whilst the accommodation of the carriages has been improved and the speed of the trains increased, fares have been put into operation which have facilitated travelling, as a result of which we have a considerable increase in the number of express trains and a very extraordinary increase in the gross tonnage.

Under these circumstances the management of the railways has everywhere been obliged to modify the construction of the permanent way, and the working of the line, so as to enable them to procure quicker, cheaper, and more comfortable travelling for the public than in earlier years, and that with the same safety and the same economy.

To do this it is first necessary to consider the permanent way and its construction, the wheel loads, and the relation between the permanent way and the rolling stock.

The International Railway Congress, recognising the importance of these questions, has, from the first, made them the object of its careful consideration. (See appendix VIII.)

The construction of the permanent way has especially been the subject of reports and discussions having for object the study of its different materials, and considering them not only singly and together, but also in the relation which the permanent way and live load bear to each other.

The present paper is one which answers a question put by the Congress. It is a new link in the chain of evidence resulting from research on the state of affairs set forth above.

The following question bearing on the complex study of the relations between the permanent way and the rolling stock, which is one of the subjects under investigation can be thus stated :

How far does the usual practice of laying permanent way answer the actual requirements, and further, how can the present method of construction be adapted to satisfy the increasing demands on its strength?

The Commission of the International Railway Congress has put this important question in the programme of the meeting which will b held in London in 1895, and has stated it as follows :

« Type of permanent way suited for lines traversed by trains at high speed.

« Gradual strengthening of existing roads so as to permit of an increase in the speed of trains.

« *A*. Section of rail. Calculation of the strains imposed by the rolling load. Results of experiments.

« *B*. Mode of manufacture and nature of rail-metal. Comparison of soft with hard steel. Steel produced : (1) By the acid process in the Bessemer converter; (2) by the basic process in the converter; (3) by either process in the Martin furnace.

« *C*. Rail connections. Fatigue of fishplates. Construction of joint best calculated to secure uniform strength of the road throughout. Rails laid in chairs, and Vignoles rails.

« *D*. Sleepers, their quality, dimensions, and distance apart.

« *E*. Ballast, the various descriptions and methods of laying. »

The International Commission has entrusted the author with the task of studying this vast question and rendering an account to the fifth session, embodying communications and results of observations received from the managements of the Continental railways who have joined the Congress.

In the earlier and preliminary studies of this question the conviction has been forced upon us that, in its present state, no exact solution can be found.

The difficulty arises from the impossibility of separating the road from the locomotive. The equilibrium between the stress and the resistance of the permanent way can be determined within the limits of the latter. But the stresses can be increased not only intentionally but also accidentally and unexpectedly beyond such limits.

The fact that, in a locomotive, the moving parts cause vibration, due to the want of uniform rigidity throughout the road, renders still more complex the relation which exists between the stress due to the moving load and the resistance of the line.

Hence, in considering this question, it is necessary to take into account not only the facts relating to the permanent way and its different parts, but also those relating to the description and make of the vehicles, especially the locomotives, and further those which concern the number and weight of the trains, and their speed.

Moreover it is first necessary to consider how the permanent way offers a resistance to the loads it has to carry. As a criterion of the facts concerning this last point, we can, on the principle that the best constructed lines are those that are least expensive to repair, state that the first things to be taken into account are the frequency of repairs, the amount of time devoted to those repairs, and the cost of the labour.

It is necessary to recognise at the same time that the cost of labour, skilled or unskilled, varies in different countries, for it is impossible to have workmen of the same intelligence wherever we go, so that information concerning the rate of wages, or the standard of salaries, does not by itself suffice for the object in view.

Finally we must not forget that on certain lines we meet with improvements in the permanent way that are but little known elsewhere, and also that some railway managements are acquainted with results of experiments and observations, which might be of the greatest use for our purpose, and about which it is desirable to possess full information.

To obtain the requisite information about the matters referred to above, we have been obliged to enquire on many points from different railway authorities; but to avoid fruitless work, we have specified that replies should only be sent about such lines as are used for express trains.

These considerations have induced us to put the questions which are printed as an appendix, to the different railway managements in Europe asking them to be good enough to reply to them fully.

SECTION I.

Examination of the replies forwarded by the various railway managements.

Sixteen important railway Companies, representing roughly 12,500 miles (20,000 kilometres) worked by express trains, send us information on the following points :

(1). The amount of wear and stress produced by traffic.

(2). The construction and arrangement of locomotives and rolling stock.

(3). The construction of the permanent way.

(4). The cost of maintenance, and frequency of repairs.

(5). Experiments concerning the behaviour under different conditions of the permanent way, and of its parts.

(6). Arrangements for strengthening the permanent way.

As we are not able to fully reproduce the information sent to us by the different railways, we have in some cases made extracts from their books of rules and regulations, and we have been obliged to replace some of the figures by their mean value in drawing up our tables.

To facilitate comparison we have compiled a table of those facts which appear to us the most important.

When several types of permanent way were described by one Company, we always took as their standard the most recent one, even when it had only been applied to short lengths of the line.

An examination of the information sent us shows that on the lines to which it refers, the speed of the express trains varies from 25 (40 kilometres) to 50 miles (80 kilometres) per hour and that the annual number of trains run, of every description, varies from 4,000 to 31,000, and of express trains from 900 to 3,600.

The wear and tear on these lines consequently varies between very wide limits, which render simple comparison between the types of construction chosen, and the measures adopted, almost impossible.

In considering the different systems of constructing the permanent way, it is necessary also to take into account the construction and arrangement of the locomotives and of the rolling stock.

The facts about these different points are shown systematically in appendix IX, where they are condensed into a table which permits us to take in at a glance the information we have received from the different managements respecting the facts and figures for rolling stock and trains used on their lines.

This table shows us that the load on the crank-axle of the most heavily weighted of the different locomotives, which actually take the express trains on the lines mentioned, is between 12.3 tons (12.5 tonnes) French State, and 15.55 tons (15.8 tonnes) Gothard railway; the total weight of these locomotives is between 34.4 and 65 tons (35 and 65 tonnes); they have 6 to 10 wheels, and the maximum distance apart of the coupled wheels is 9 feet 10 inches (3 metres).

The majority of these engines have four wheels coupled, and a four-wheeled leading bogie.

In some 8 wheeled locomotives the leading and trailing wheels are simply carriers, the four coupled wheels being placed in the middle.

The Belgian State railways are almost the only lines which work a road with heavy gradients by means of 6 wheel coupled engines, having leading wheels with radial axle-boxes.

These engines, like the new locomotives of the Northern Railway of France, have inside cylinders, whilst all the other engines described have outside cylinders.

The weight of the locomotive and tender varies from 54.1 to 83.3 tons (55 to 84.6 tonnes).

There are from 30 to 76 carriage-wheels on the express trains that these engines draw, with a gross weight of 98.4 to 196.8 tons (100 to 200 tonnes).

The coaches have 4, 6 or 8 wheels. Those with 8 wheels are bogie-carriages.

The greatest distance between centres of the wheels in the 4-wheeled coaches is 19 feet 4 1/4 inches (5.9 metres), and the greatest weight per pair of wheels is 7.87 tons (8 tonnes).

On comparing together the data given relating to the types of locomotive and the speed attained it appears that the railways which have a standard maximum weight of from 13.78 to 15.55 tons (14 to 15.8 tonnes) per pair of wheels, are those which have expresses running at a mean speed of more than 37.3 miles (60 kilometres) per hour on a road with unfavourable gradients.

Rails and sleepers. — We will next consider whether these higher speeds cannot be obtained except by constructing locomotives with a greater weight per pair of wheels, and we will compare the statements regarding the construction of the permanent way with a view to its wear and strain.

In the tables in appendix I and II the size of the principal parts (rails, sleepers, joints) of the lines of the different railways that have sent in a report are given; and we have divided them into two groups according to whether the weight per pair of wheels of the engines which draw the expresses is above or below 13.78 tons (14 tons).

The figures shown in the table as the denominator under the headings « height », « moment of inertia » and « moment of resistance » are those which correspond to the condition of the material when worn down to the point at which it is condemned.

The table shows us that on some lines where they have a weight on the wheels of from 6.15 tons (6.25 tonnes) to 6.89 tons (7.00 tonnes) they use rails the weight of which is between 66.5 lbs per yard (33 kilograms per metre) and 85.7 lbs per yard (42.5 kilograms per metre), with a moment of inertia between 20.73 and 30.27 square inches per square inch (863 and 1,260 square centimetres per square centimetre) and a moment of resistance between 8.24 and 12.19 cubic inches (135 and 200 cubic centimetres).

Lines which have a load on the wheels of more than 6.89 tons (7 tonnes) use rails, the weight of which is between 72.6 and 104.8 lbs per yard (36 and 52 kilograms per metre), with a moment of inertia between 23.94 and 42.50 square inches per square inch (997 and 1,769 square centimetres per square centimetre) and a moment of resistance between 9.08 and 14.65 cubic inches (148.3 and 240 cubic centimetres).

This shows a general tendency to increase the weight of rails beyond 80.6 lbs per yard (40 kilograms per metre).

As a rule the rails are of cast steel made either by the Bessemer or by the Martin process.

In the Vignoles rails the tensile strength is not less than 34.9 tons per square inch (5,500 kilograms per square centimetre) and sometimes attains 42.5 tons per square inch (6,700 kilograms per square centimetre).

The elongation varies from 20 to 14 per cent.

The steel of the rails used on the Egyptian railways has a tensile strength of from 42.5 tons per square inches (6,700 kilograms per square centimetre) to 45.7 tons per square inch (7,200 kilograms per square centimetre) with an elongation of 11 per cent.

The steel of the double-headed rails is usually harder than that of the Vignoles rails, and the managements employing this section of rails state that their tensile strength is between 44.4 tons per square inch (7,000 kilograms per square centimetre) and 57.1 tons per square inch (9,000 kilograms per square centimetre) with an elongation of from 4 to 11 per cent.

There is a tendency to use hard steel with a very high limit of elasticity.

The majority of the railways use wooden sleepers. Two only make use of sleepers made of soft steel, with a tensile strength of from 28.6 tons per square inch (4,500 kilograms per square centimetre) to 30.5 tons per square inch (4,800 kilograms per square centimetre).

The bell-shaped supports of the rails of the Egyptian railways are being replaced by sleepers.

The sizes of the sleepers used vary considerably.

Their length varies from 7 feet 10.5 inches (2.40 metres) to 8 feet 11 inches (2.72 metres), averaging 8 feet 6.4 inches (2.60 metres).

The width varies between 7.9 and 11.8 inches (20 and 30 centimetres), the average being 9.8 inches (25 centimetres).

The characteristic of the cross-section $\frac{E'I'}{10}$ 8 varies between 0.97 and 2.63 lbs per square inch (2.85 and 7.7 kilograms per square centimetre).

The statements made by the managements show a marked tendency to increase the length of the sleepers.

The standard English sleepers are the longest, with a length of 8 feet 11 inches (2.72 metres); and the Egyptian railways are putting down sleepers of the same length as an experiment.

We find no particular tendency to increase the width of the sleepers; but, on the contrary, we do find that in some cases there is a tendency to use narrower sleepers and more of them.

SPACE BETWEEN SLEEPERS. — The number of sleepers used depends on their distance apart, which is an important factor in the construction of the line.

In laying down new lines intended for express trains the space varies from 2 feet 4.5 inches (72.3 centimetres) to 3 feet 27 inches (98.4 centimetres); the average distance being 2 feet 8.7 inches (83 centimetres). There is a distinct tendency to decrease this distance, this being recognised as the best way for obtaining greater strength and stiffness in the rails and joints and their attachment to the sleepers.

SECURING RAILS TO SLEEPERS. — In the greater number of cases the rails are fastened directly to the sleepers. There are only four cases where the rails are not directly secured to the sleeper. The securing of the rails to the sleepers is always done by either straight spikes or dog-spikes or more generally by screwspikes (*tire-fond*); the last method is finding increasing favour.

In the case of iron sleepers the rails are secured with plates and cheese head bolts.

Most of the managements using Vignoles rails interpose a foundation-plate between the rail and the sleeper. This plate has generally parallel faces when used for wooden sleepers, but when iron sleepers are used it is always wedge shaped to give the rail its proper inclination.

One management states that it uses slabs of tarred felt to protect the surface of the sleeper supporting the rail.

In this case special importance is attached to the use of three screw-spikes.

Two managements have given up the use of foundation-plates; one nails its Vignoles rails directly on to the wooden sleeper, the other fixes the rails directly to the steel sleeper, which has been previously bent to suit the inclination of the rail.

The managements who do not fix the rails directly to the sleepers use cast-iron chairs with wooden or iron keys, and use double headed rails only.

The Kaiser Ferdinands Nordbahn and some other railways belonging to the German Railway Union, with the intention of keeping separate the attachment of the Vignoles rails, are using experimentally tension-plates and cramp-plates (*plaques à mâchoires*) together with flat plates and cheese head bolts or screw-spikes (*tire-fond*) (fig. 1).

One Italian Railways informs us (*Revue générale*, Sept. 1894) that, on a line used for heavy traffic, they are adopting a fastening for the Vignoles rails consisting of cast-iron chairs and wooden keys.

Cramp-plates used by the Kaiser Ferdinand Nordbahn for Vignoles rails.

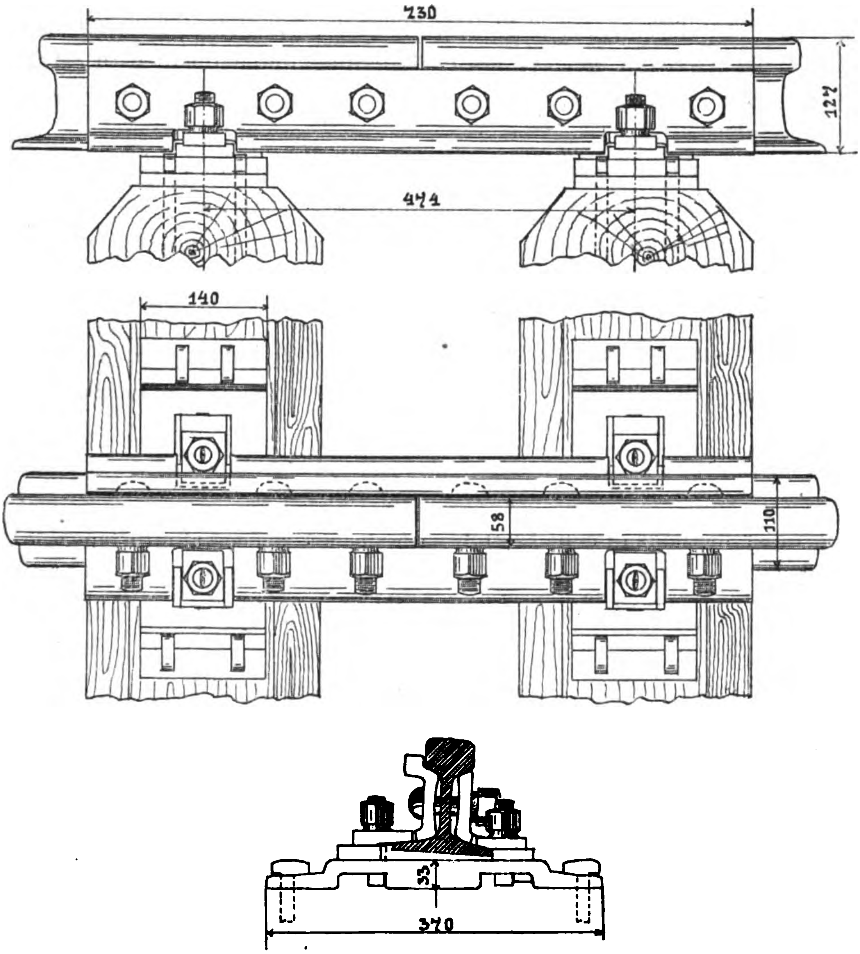


Fig. 1.

There is no doubt, and it has been frequently proved, that when the speeds are very high, the direct attachment of the rails to the sleepers with or without foundation plates is not sufficient.

We can see, on reading the information supplied to us, that the managements attempt to counteract this disadvantage of direct attachment by increasing the number of points of attachment.

If we compare an old-fashioned system of laying the rails in which they were fixed with two dog-spikes or screw-spikes 3 feet 2·6 inches apart (98 centimetres) with a more recent system in which the rails are fixed by means of four screw-spikes on sleepers 2 feet 4.3 inches (72 centimetres) apart, we notice that for each ·621 mile (1 kilometre, there are in the first case 1,091 points of attachment with 2,182 dog-spikes or screw-spikes and in the second case 1,500 points of attachment with 6,000 screw-spikes.

If we consider that this increase in the number of points of support has resulted in a reduction of the span of the clear part of the rail, we come to the conclusion that this latter method has consequently reduced the stress sustained by the separate points of attachment, in a manner which is similar to the former but more complete.

As regards the system of fixing by means of cast-iron chairs, there is a tendency to increase the weight of these chairs, and to diminish the space between the sleepers.

The principle is the same as that of increasing the number of screw-spikes or dog-spikes.

In the older methods of construction with sleepers spaced at a distance of 3 feet 2·6 inches (98 centimetres) apart, the high stresses caused by the passing of express trains were accompanied by great pressure of the rail on its supports which the old fashioned light chairs where unable to bear.

The authorities have attempted to meet these increased stresses resulting from pressure on the rail by increasing the strength of the chairs, and, at the same time, by bringing the sleepers closer together, to give the rails more support, and to reduce the intensity of the pressure on the ballast.

Special methods of fixing the rails. — The railway managements have sent some information on some special methods of fixing the rail with the purpose of maintaining the exact gauge during the passing of expresses on curves of less than 547 yards (500 metres) radius.

We find in these statements the following methods given :

The « Seidle » cross tie, the use of which has given good results on the Austro-Hungarian State Railways, and which constitutes a means of making a connection between the two sets of rails.

The use of wooden cleats bussing up against the head of the rail and spiked to the sleeper on the outerside of the curve to prevent canting.

The use of an increased number of sleepers and screw-spikes at the curve itself.

The use (in the case of Vignoles rails) of chairs or foundation plates on some or all of the sleepers.

In order to prevent the displacement of the track on gradients and on curves, pieces of wood forming a longitudinal connection between the sleepers, or also wooden posts driven in at the outer ends of the sleepers at the curves are used on the Pistoïa-Bologna section in Italy.

In curves of small radius with the rails laid in chairs it is preferable to replace the ordinary wooden keys with iron keys and also with keys like those of Barbarot's system.

The managements are unanimous in the opinion that in curves of more than 547 yards (500 metres) radius special measures for fixing the rails are unnecessary.

Fish-joints. — In appendix III is a table showing the information we have received from the different managements in reference to the pattern of their fish-joints when laying down new sections of line.

The ends of the rails are in every case joined together with fish-plates, at a point between two sleepers.

Most of these are made of angle or channel section. Only two managements still use on the inside of the rails flat fish plates.

Most managements use fish-plates of the same shape both inside and outside the rails.

With the Vignoles rails the fish-plates generally overlap the two sleepers, and their length is from 1 feet 6·1 inches (460 millimetres) to 2 feet 7·1 inches (800 millimetres).

There is a marked tendency to increase the length of these fish-plates. The weights given are between 9·5 lbs (4·3 kilograms) and 48·5 lbs (22 kilograms). They are generally made of very mild or medium mild steel having a tensile strength of from 28·5 to 34·8 tons per square inch (4,500 to 5,500 kilograms per square centimetre) and an elongation of 15 to 20 per cent.

The fish plates are fixed by bolts, usually 4 in number; some managements use 5 and one even uses 6.

The diameter of the bolts varies from 0·748 into 1·004 inch (19 to 25·5 millimetres).

The majority of managements use bolts of 0·984 inch (25 millimetres) diameter.

This method of uniting rails by means of fish-plates and bolts is generally recognised as unsatisfactory; and consequently attempts are made in all directions to improve on this method.

The defects of this method are first shown by the sleepers on each side of the joint sinking more into the ballast; for this reason it has been proposed to make these sleepers wider, in order to reduce the space between them to 13 inches (33 centimetres), and to use at these places sand as ballast.

It has been observed that when a vehicle passes over a joint the rail which is being left is subjected to a greater amount of torsional stress than the other.

Experience having shown that a better joint results when rails are fixed according to the « Heindl » method, one management has experimentally fixed tension plates to the sleepers between which the joint is situated; thus, in this case, adopting Heindl's method.

The frequent breakage of the fish-plates has caused managements to increase the section of the fish plates and to substitute for fish-plates of flat section some of angular section.

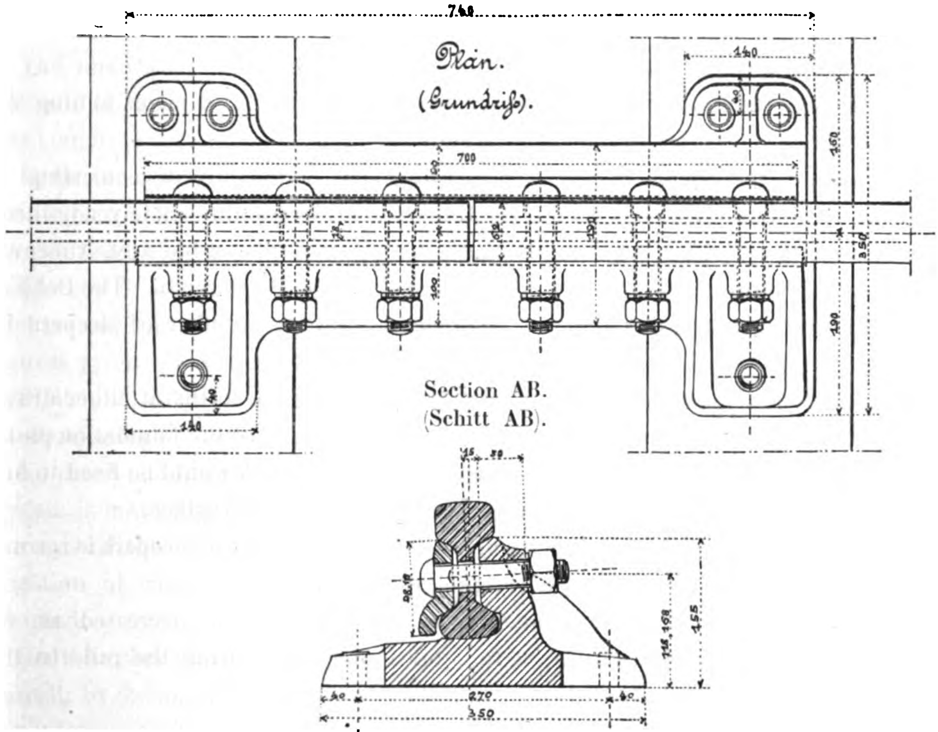
They have attempted to counteract the wear on the fish-plates by the use of harder metal, and by increasing the bearing surface by enlarging the head of the rail, and the bearing surfaces of the fish-plates, and by lengthening the latter.

Here we must specially mention the strong form of fishjoint used on the Belgian State Railway in which the lower surface of the fish-plate coincides with the under surface of the rail, in such a way that it is supported on the sleepers, and gives a great width of bearing surface to the joint. The fixing of the fish-plates on to the sleepers is made by means of screw-spikes passing through holes drilled in the angle thereof. In this way the fish-plates act as a sort of bridge supporting the rails.

The Western Railway of France are now trying experimentally a system of supported joints.

In this method a long chair is used, bridging the space between the two sleepers at the rail joint. The rail ends are secured to each other and to the chair by a fish-plate and six bolts (fig. 2).

Fish-plates on the Western of France.



Elevation.

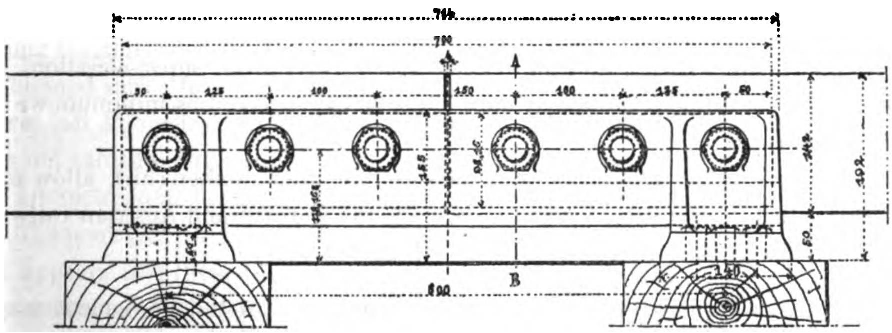


Fig. 2.

SPECIAL CONSTRUCTIONS AT THE FISH-JOINTS. — Several plans have been submitted for counteracting the creeping of the rails. Most of them are intended to make the two sleepers more rigid by a junction piece, and some even by the use of intermediary sleepers tied together.

We include among these plans :

(1). That of the Italian Mediterranean Company in which two plates joining the two sleepers are used with satisfactory results.

(2). That of the Society of the Austro-Hungarian State Railways consisting of uniting the longitudinal sleepers to the transverse sleepers immediately adjoining them, either by means of an iron plate and an angle iron placed like a St. Andrew's Cross, or by means of several iron plates placed parallel to the line. The Belgian State Railway recommends a similar method of joining a number of sleepers by iron rods.

Another method is to bend the angled part of the fishplate so that it either draws up tight against the side of the chairs, or of the sleepers, or of the foundation plate.

It has been proposed to rivet angle-irons to the rails which would be fixed to one or two intermediary sleepers by means of dog-spikes or screw spikes.

It should be mentioned that the use of an increased number of sleepers is recommended as a means of lessening the creeping of the rail.

We may conclude that the tendency to creeping will be decreased as we improve the method of making the rail joints and of securing the rails to the sleepers.

SUPER-ELEVATION OF THE RAILS AND WIDENING OF THE TRACK AT CURVES. — In considering the advantages of the above arrangements we have also to consider the arrangements for super-elevation and increase of gauge.

The different managements however vary so greatly in their practice that no satisfactory general conclusion can be arrived at.

We find that 6.3 inches (160 millimetres) is the maximum super-elevation, and 1.1 inch (28 millimetres) the maximum increase of gauge and as minimum we find nil in both cases.

It is to be noted that the railways which use the latter method (nil), allow more clearance than is the case, for example, with the German and Austrian railways. (Vide 3rd Congress, Report on questions VIII and IX/7.)

MAINTENANCE OF PERMANENT WAY. — The maintenance of the permanent way is carried out by two methods, either by repairing when reported necessary, or by examination at stated intervals. Neither method is sufficient by itself, each requiring to be supplemented by the other.

In both cases strict attention is given to keeping the rails in their correct relative position.

The reports referring to the frequency of repairs show a dependence on the amount of the traffic, and on the age of the line. The general inspection of the road ought to take place at intervals of from one to two years.

In the method of repairing when the line is noticed to require it, each section of the line ought to be adjusted at intervals of from five to eight months. Most railways do this twice a year.

The cost of adjusting the track and the amount of labour required for this purpose vary, according to the statements we have received, within large limits. The figures given show that the annual outlay for each yard of the line varies from 1.76 d. to 3.52 d. per yard (0.20 to 0.40 franc per metre) and the labour from .15 to .40 of a day.

No direct comparison is, however, possible. It can be stated that the regular system is more costly than the reporting system; also that the cost increases with the age of the rails and with increase of traffic, but also depends on the general question of curves and gradients and largely on the method of construction adopted.

On the other hand the expenses are affected to an appreciable extent by the ballast, by the amount of bearing surface of sleeper per unit length of rail, and by the intensity of the pressure on the ballast due to the weight of the traffic.

In the table appendix II we have made calculations respecting the lines that have supplied us with information regarding the total number of sleepers per mile of road. We have assumed the sleepers to be bedded over a portion of their length only; i. e. for a length on the inside of each rail equal to the length projecting beyond the rail.

The total varies from 5.91 to 10.63 square feet per yard (600 and 1,080 square metres per kilometre): the average for the lines where the weight on the wheel does not exceed 6.89 tons (7 tonnes) is 6.89 square feet per yard (700 square metres per kilometre) and for those where the weight is more than (7 tonnes) the average is 7.32 square feet per yard (744 square metres per kilometre).

It appears that those lines which have the least amount of sleepers buried per mile are those which have the heaviest costs for repairs.

However is it impossible to establish any definite direct relation between these two items, because there are as already mentioned, so many other important circumstances which affect the cost of repairs.

INFORMATION ABOUT THE CONSTRUCTION OF LINES BELONGING TO THE GERMAN RAILWAY UNION. — To complete the consideration of the present state and future tendencies of the practice of permanent way construction, we have to refer to the transactions of the fourteenth meeting of the Engineers of the German Railway Union; the conclusions then arrived at have also been published in the *Bulletin* of the Railway Congress, volume VIII, n° 5. May 1894, p. 347-348.

The general conclusion arrived at was that the following arrangements were adequate for loads not exceeding 13.78 tons (14 tonnes) per pair of wheels and for speeds not exceeding 56 miles (90 kilometres) per hour :

Rails weighing 66.5 lbs. per yard (33 kilograms per metre).

With sleepers 31.5 inches (80 centimetres appart).

Rails weighing 70.5 lbs per yard (35 kilograms per metre).

With sleepers 35.4 inches (90 centimetres) apart, such sleepers to be 7 feet 10.5 inches to 8 feet 10.3 inches (240 to 270 centimetres) long and 5.90 per 0.98 inch (15 × 25 centimetres) in section with foundation plates, or else iron sleepers weighing from 121.2 to 143.2 lbs (55 to 65 kilograms). But although such arrangements suffice, for business reasons it is considered advisable to use stronger forms even at present.

And since then the authorities of the Prussian State Railways have decided to use, on their main lines, rails weighing 82.6 lbs. per yard (41 kilograms per metre) the transverse section of which has a moment of resistance of 11.77 cubic inches (193 cubic centimetres) and sleepers measuring 8 feet 10.3 inches per 10.2 inches per 6.3 inches (270 centimetres × 26 × 16) spaced 33.1 inches (84 centimetres) apart.

The State Railways of Saxony use rails weighing 92.1 lbs per yard (45.7 kilograms per metre) with a moment of resistance of 14.8 cubic inches (242 cubic centimetres) placed on sleepers 8 feet 2.4 inches (2.5 metres) long and 2 feet 8.5 inches (82.5 centimetres) apart.

The Wurtemberg State Railway has recently used experimentally rails weighing 87.7 lbs per yard (43.5 kilograms per metre) laid on metal sleepers (Heindl system) whic h are 8 feet 10·3 inches (2.7 metres) long and 2 feet 5.5 inches and 2 feet 7.5 inches (75 and 80 centimetres) apart respectively.

STRENGTH OF PERMANENT WAY. — All the managements who have furnished us with information on the question we are now considering, inform us that their new system of laying the road, already partly carried out, and which they intend to use in the future for renewals, will satisfy the requirements of considerable traffic for many years to come.

It is only on lines with heavy gradients and sharp curves where increase of the load on the wheels is contemplated that not only the fish-joints will have to be strengthened, but also some of the other portions on certain sections of the road.

In order to determine a good type of road for express traffic it is necessary to compare the different types of permanent way and their various parts.

The expert who has to decide between such different methods which answer all requirements, will be guided by the principle that the best construction of line is that which costs the least for maintenance.

Elsewhere a proof is given that it is impossible to make a comparison based on this principle from the materials at our disposal.

Another method which allows us to compare different systems of construction reduced to a common basis is by way of theory.

Although a thêoretical examination does not give us an absolute measure of the capabilities of a line, we may still use it to compare different methods of construction, and we may admit, other things being equal, such as the ballast, and the depth the sleepers are buried, that the amount of the strains imposed on the rails and sleepers, and the compression of the ballast is approximately that which can be deduced from formulae.

We will now consider to what extent the present status of theoretical analysis, and observations made on rails, allow us to determine whether the methods adopted by the Administrations in strengthening their road are satisfactory, and how such methods may be improved in the future. In doing this we must refer to question V-A of the fourth session of the International Congress. There are given methods of calculation which permit us to allow for modifications of shape in the principal parts of the construction of a railway.

We have since then applied this method of calculation to the comparison of the different lines laid on cross sleepers, and we refer the members of the Congress to our paper (*Bulletin*, p. 3, 1895, vol. IX) entitled « The sleeper and its bearing on the ballast ».

In that paper we attempt by a detailed calculation to establish the part played by the sleeper and its bearing on the ballast in the strength of the line, and also to determine a standard sleeper. We also show the limiting conditions between which the engineer has to keep.

*

We shall follow the lines of the above mentioned papers in an attempt to determine (with the material at our disposal) the effect of the shape and arrangement of the different most essential parts of the track; and we shall also take into consideration the fact that the demands on the strength of the permanent way are not merely dependent on the wheel load by itself but also on the distribution of this load and the arrangement of the sleepers.

THEORETICAL INVESTIGATION OF THE INFORMATION SUPPLIED BY THE ADMINISTRATIONS. — With the information before us we have examined the construction of the lines and we have compiled some figures which *serve to exemplify the amount of resistance that the line can offer to the stresses produced by the dead weight of the locomotives used on that particular line.*

The difference between the figure representing the resistance calculated in this way, and that which corresponds to a strain on the different parts equal to the limit of elasticity constitutes a margin of safety intended in the first place to ensure the necessary resistance to the live loads and to the increased stresses due to increase of speed.

In the second place this margin of safety has to allow for the gradual decrease of strength that the road suffers through the continual wear and tear of the materials, particularly the rails and ballast, under the action of the trains. This may become very considerable.

In comparing the different ways of constructing the line, one ought not only to consider it when its material is new, but also when continual wear has brought it to the extreme limit at which it may be safely used.

When laying down a new line it will always be possible to have ballast such that the resistance of the line may be indicated by a coefficient of ballast $K = 180.6$ ($C = 5$). For this the foundations may be of inferior quality but must be properly drained. Higher coefficients of ballast may possibly be attained if the sub-soil be either rocky or very firm, or by recourse to the interposition of stonework. Such coefficients can only be considered admissible on special sections of the road.

During the working of the line the elasticity and firmness of the ballast diminishes continually by reason of the deterioration undergone by its particles.

This deterioration is brought about just as much by the effect of the traffic (and work required) on the line as by atmospheric agencies. We shall take into account in our calculations this reduction in the resistance of the ballast by giving its coefficient its least value, viz : $K = 108.4$ ($C = 3$).

When considering the shape of section of the rail we must not lose sight of the fact that the head suffers a continual loss of material owing to wear.

This loss, which may be as much as from 0·354 to 0·472 inch (9 to 12 millimetres), sensibly reduces the section of the rail, and has a marked effect on the strength of the rail and other essentials of the whole road.

In making our calculations we have taken note of this fact. The figures are given both for new rails and for those that have arrived at the limit of their wear in the table; the respective figures being separated by a division line.

The resistance of the different parts of the permanent way depends largely on the quality of their material.

In making the calculations we have assumed the materials to be of average quality, and accordingly we have taken as the value of the modulus of elasticity of the metal of the rails and metal sleepers E = 24,170,000 and for wooden sleepers B′ = 1,422,000 (= 1,700,000 and 100,000 respectively). We have also assumed the sleepers to be only partially embedded between the rails and completely embedded outside.

It follows that more favourable conditions should give higher figures for the resistance of the line.

The results thus calculated for the dead load due to the heaviest express locomotive are given in the table showing the strains in each component part of the road.

Pressure on the rails. — In order to determine the figures which influence the rigidity of the line and of its fastenings, the stress on the rail is of special importance.

I have shown above to what extent this stress depends not only on the load but also on its distribution and on the spacing of the sleepers. In the calculations made I have considered each case individually from its different aspects and thus have obtained the maximum on the rail.

If we compare the different values of this pressure P on the rail shown in the table Appendix IV, we find that with worn rails P is between 3·235 tons (3·287 tonnes) and 3·850 tons (3·912 tonnes) on lines where the weight on the wheel does not exceed 6·89 tons (7 tonnes) and that P is between 3·105 and 4·691 tons (3·155 and 4·766 tonnes) on lines where the weight of the wheel is more than 6.89 tons (7 tonnes).

A point to be specially noticed is the fact that the lower limit of the pressure P can in the case of the greater wheel loads become equal or even inferior to that on lines with wheel loads of 6·89 tons (7 tonnes) or less, and this fact shows clearly the influence of the method of construction of the road and the distribution of the wheel loads.

The minimum pressure on the rail is found on those lines where the ratio of the distance between wheel centres to the space between the sleepers is 4·1 or even 3·1.

In those cases in which the smallest pressures have resulted the factor $\gamma = \frac{B}{D}$ is of importance and the increase of this ratio results in reduced pressure.

In general we may conclude that on a line with heavy rails and the sleepers closely spaced (that is where the value of B is great) it is advantageous, so far as the road is concerned, to use locomotives having a considerable distance between wheel centres.

Strain in the rails. — On lines where the weight on the wheel does not exceed 6·89 tons (7 tonnes) the strain in the rails when new is between 6·350 and 8·254 tons per square inch (1,000 and 1,300 kilograms per square centimetre) and in the rails when worn between 7·156 and 9·334 tons per square inch (1,127 and 1,470 kilograms per square centimetre).

On lines on which the wheels are more heavily loaded, the strain when the rails are new is between 5·828 and 8.585 tons per square inch (918 and 1,352 kilograms per square centimetre) and between 6·666 and 10·09 tons per square inch (1,050 and 1,589 kilograms per square centimetre) when the rails are worn. As an average we may take 7·320 and 8·203 tons per square inch (1·153 and 1·292 kilograms per square centimetre).

This strain represents about one-third of the limit of elasticity of the material.

In the majority of the lines regarding which we have received information, the sleepers have such a great resisting moment that the strain only averages 825 lbs per square inch (58 kilograms per square centimetre) that is one-fourth of the limit of elasticity of the material.

We have thus a large margin of safety which is however necessary on account of the rapidity of deterioration of the wood.

For iron sleepers the strain on the material when the rails are worn is between 7·435 and 7 817 tons per square inch (1,171 and 1,231 kilograms per square centimetre).

In the case of worn rails the sleepers sink to a depth of between 0 154 to 0.256 inch (·39 and ·65 centimetres). But if we leave out of consideration the St-Gothard Railway which has sleepers of varying section and to which consequently the above reasoning cannot readily be applied, the sleepers sink from 0·154 inch to

0 224 inch (·39 to ·57 centimetres) with a mean of 0 189 inch (·48 centimetres); that is between narrow limits.

The corresponding pressure on the ballast (again not considering the case of the St-Gothard Railway) is between 16·5 and 24·46 lbs per square inch (1.16 and 1·72 hilograms per square centimetre), averaging 20·48 lbs per square inch (1·44 kilogram per square centimetre); this is 72 p. c. of the 28·44 lbs per square inch (2 kilograms per square centimetre), taken as the limit.

The theoretical examination of the existing methods of construction that we have just made enables us to give the following results :

(1). On lines where the weight on a pair of wheels is less than 13·78 tons (14 tonnes) rails with a large base and a maximum weight of 70·5 lbs per yard (35 kilogrammes per metre) can be used for a heavy traffic with high speeds, provided that the sleepers are of sufficient size and not laid too far apart.

(2). On lines where the weight on a pair of wheels exceeds 13·78 tons (14 tonnes) and increase in the weight of the rail beyond 70.5 lbs per yard (35 kilograms per metre) seems necessary with a resisting moment of the rail of 9·16 inch (150 centimetres), and these heavier rails should be used in conjunction with substantial sleepers closely spaced.

(3). On lines where the rails are heavy and the sleepers closely spaced, the use of locomotives with the axles well apart and the leading and trailing wheels not very heavily loaded appears advantageous in relation to the wear of the line.

Strains in the fish-plates. — In table appendix V we have set out, for the lines devoted to express traffic that we have received information on, the strains in the fish-plates calculated according to the theory of Dr Zimmermann, which is laid down in the report on question V-A of the International session of Congress held at Saint-Petersburg.

But as this theory is based on the hypothesis that the length of the fish-plates does not exceed the distance between the sleepers at the fish-joint, a state of affairs which we only find on the lines mentioned under the nos 4, 5 and 7 in the table, we shall nevertheless apply this to the other types of permanent way where longer fish-plates are used, in order to obtain an idea, if only an approximate one, of the stress upon them.

The fish-plates that we have taken for our calculation have together a resisting moment of between 21 and 60 p. c. of the resisting moment of the rails they are used to unite; it follows from this that, on the lines we have considered, the fish-plates work at a tensile strain of between 8·071 and 21·23 tons per square inch (1,271 and 3,343 kilograms per square centimetre) even under a dead load of 6·8 to 7·7 tons (6,900 to 7,800 kilograms).

The lines on which the fish-plates have the least strain are those shown under the n^{os} 1 and 2/*b*, which only have a maximum weight on the wheel of 6·8 tons (6,900 kilograms).

With regard to the fish-plates n° 2/*b*, it must be noticed in their favour that the sleeper is of very strong section, I = 184·3 square inches × square inch (I = 7,672 square centimetres × square centimetre); that the space between sleepers at the fish-joint is small, 18·7 inches (47·4 centimetres); and that the fish-plate is long 28·7 inches (73 centimetres). The ratio of the moment of resistance of the two fish-plates to that of the rail is comparatively high (48 p. c.).

The system of fish-plate which according to our calculations shows the worst results is that given under n° 7 which carries a maximum wheel load of 7·38 tons (7,500 kilograms). In this case the sleepers are very weak, I = 107·5 square inches × square inch (4,475 square centimetres × square centimetre); the space between the sleepers at the fish joint is large, 23·62 inches (60 centimètres); the fish-plates are short, 17·72 and 21·26 inches (45 and 54 centimètres) respectively; and the resisting moment of the two fish-plates is only 21 p. c. of that of the rail. The Company in question is already adopting stronger fish-plates.

Here we again find (and this has already been stated in the report on question V-A of the International Congress at Saint-Petersburg) that the strength of the fish-plate does not only depend on the construction of the fish-plate itself (that is on its absolute resisting moment and its length) but also on the other members used in the construction of the line, such as the size and spacing of the sleepers, and a suitable ratio between their resisting moment and that of the rails.

Mode of manuufacture and nature of rail metal. — We do not find in the replies sent us by the Administrations sufficient information to enable us to definitely give the best mode of manufacture and the most suitable class of material.

In our reply to question V-A of the Saint-Petersburg session of the Congress we have mentioned those points which seem to us of importance in this relation, in particular we have drawn attention to the fact that no one class of the tests usually applied can of itself give us complete information on all the properties affecting the safety and durability of the rail.

In order to obtain a well founded opinion on the quality and reliability of the rail it is necessary to compare the results of the different mechanical tests with those obtained by chemical analyses.

The way the rail behaves depends not only on its mechanical properties thus ascertained but also on the greater or less degree of homogeneity of the metal.

We have also said that in determining the proper hardness for the rails, we must not lose sight of the reciprocal action between the wheel and the rail, and consequently it would be better to use rails of steel of the same hardness as that which has been found best for the tyres.

The replies of the managements show us that material of very different breaking strength is used.

The Austrian, Italian, Gothard, Belgian State, and Dutch railways use rails with a breaking strength of 34·92 to 42·54 tons per square inch (55 to 67 kilograms per square millimetre) with an elongation of from 15 to 20 p. c. On the other hand, the French railways and Egyptian Railways use rails having a breaking strength of 44·45 tons per square inch (70 kilograms per square millimetre) to 50·80 tons per square inch (80 kilograms per square millimetre) and even 62·23 tons per square inch (98 kilograms per square millimetre) with an elongation of from 10 to 15 p. c., and some even with an elongation of 1 to 4 p. c.

We will simply state that there is a tendency *to give the preference to hard steels of high tensile strength.* It is important that when such rails are used the material should not be brittle.

The excellent results to be obtained with such rails seem to be substantiated by observations made on the Paris-Lyons-Mediterranean, Orléans, and Egyptian Railways.

We can here add that at the last meeting of the engineers of the German Railway Union held at Strasburg in 1893, it was said from the information received from the different lines belonging to the Union, that hard steel rails offered a greater resistance to the wear and tear, but are more liable to fracture, particularly if their elongation is small and if the material they are composed of is not sufficiently pure and not enough work has been put on it.

We shall be in a position to give a more precise answer to this question when we have obtained some results of the inquiry set on foot by the German Union, especially with regard to the quality of the materials.

The information supplied us by the managements with regard to steel rails does not permit us to draw any definite conclusion as to the merits of either Bessemer or Martin steel made by either the basic or acid processes.

It is worthy of notice that the large majority of the managements use rails made by the Martin process or by the acid Bessemer process.

Only two managements also use rails of Thomas steel obtained in the converter by basic process.

This is due to the fear that it is more difficult to obtain hard rails of uniform quality by the basic process than by the acid one.

This point, which already has been alluded to by M. Bricka in his report on fracture of rails road at the Paris session of the International Congress of 1889 VII-B is again raised in a communication that has been sent us by the Paris-Lyons and Mediterranean Railway Company.

The report of the Strasburg meeting of 1893 to which we have already alluded seems to put the facts thus : « Such information as we have at present leads us to think that the Bessemer or Martin steel rails are more satisfactory than those of Thomas steel ; but at the same time the present state of knowledge does not enable us to decide how far this may be due to difference in the nature of the steel, or to the amount of work put on it, or to the care exercised in the manufacture of the rails. »

In our opinion the managements should next devote their attention to the elucidation of this question by giving us careful and trustworthy statistics.

EXPERIMENTS TO DETERMINE STRESSES DUE TO ROLLING LOADS. — The International Railway Congress has repeatedly urged the necessity of recording observations, and of making special experiments to determine the nature and extent of the stresses due to rolling loads on the rails.

At the meeting held at Milan, the Belgian State Railway communicated the results of some experiments made for this object. The Paris, Lyons and Mediterranean Railway published the results of comprehensive experiments in the *Revue des chemins de fer* of 1887-1889; these were considered of sufficient importance to be quoted in the reply to questions IV and V-A at the fourth session held at Saint-Petersburg.

The statements of the managements show that since then they have not made, or at all events have not published, any further observations on this subject.

The management of the Kaiser Ferdinand's Nordbahn has considered the methods and appliances to be used to observe the phenomena attending high speeds and resultant heavy stresses and they have come to the conclusion that there is no method as good as, let alone better than the photographic one.

Up to the present the work in this direction has only been carried as far as the design and construction of a recording apparatus for making these experiments.

It would be beyond the scope of this paper to give a detailed description of this apparatus and the results that have been obtained from it; we only draw attention to it in the hope that we may induce managements to make similar experiments by the method indicated.

We cannot, however, omit giving several of the actual diagrams which show the movement of the rail-ends at the fishjoint (appendix VII, plates 1-6).

This we do in order to show how extremely sensitive and accurate the instrument is; but without analysing the result obtained.

The greatest difficulty to overcome was to arrange our apparatus in such a way that it was unaffected by vibrations.

Two ways of doing this were tried, each proving equally satisfactory.

One way consisted of making a completely isolated platform on a foundation 29 feet 6 inches (9 metres) deep, and built with layers of felt between the bricks.

The other method consisted in making a solid wooden frame supported on four piles. To protect these piles as much as possible from the effects of the vibrations the foundations were laid in deep pits.

This erection served as a stand for the camera.

Highly polished metal edges were fixed to the points of which we wished to observe the movement; by this means we obtained a sharp image on the sensitised plate. A millimetre scale is fixed by the point to be observed, which being photographed gives the necessary scale on the plate.

The plate is only exposed through a narrow vertical slit.

This plate receives a uniform motion behind this slit by means of a clock-work movement thus continually exposing a fresh ray on the plate.

A record in the form of a continuous line is thus obtained.

In this way we obtained a diagram completely analogous to those hitherto obtained by the lever apparatus, the only difference being that in this the lever is replaced by a ray of light, and the roll of paper by a sensitised plate.

The apparatus had to be made of fairly large size in order to admit of the record of the movements being made to a magnified scale.

The plates measured 5·12 × 14·17 inches (13 × 36 centimetres).

The figures (3) and (4) show the arrangement of the mechanism used to move the plates.

The front elevation figure 3 clearly shows the narrow slit through which the rays of light pass, and also the movable frame which carries the sensitised plate.

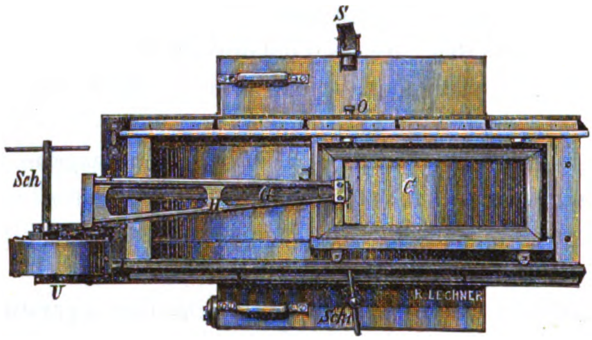


Fig. 3.

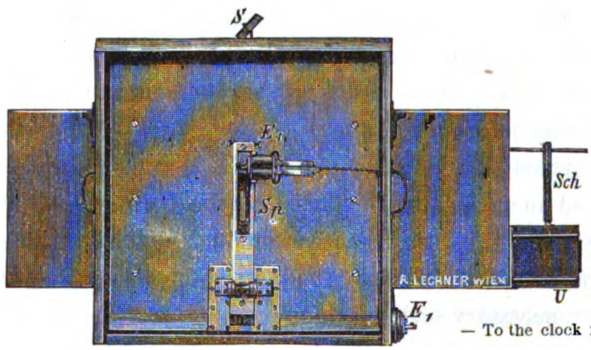


Fig. 4.

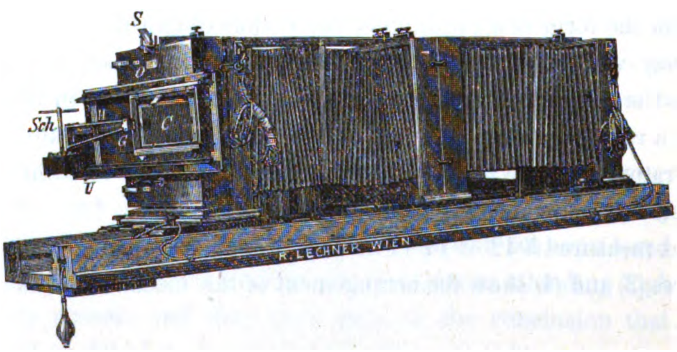


Fig. 5.

Photographical apparatus for recording the deflections of the road.

The back view figure 4 shows the way the clock-work mechanism is attached to the camera.

The electro-magnetic mechanism is also shown which is governed by an independant clock movement and which alternately covers and uncovers part of the slit. By this means the seconds are marked and the speed thus recorded.

SECTION II.

Type of line to be adopted for trains running at very high speed.

A. — General considerations.

When we consider the question: « What are the principles which determine the construction of permanent way which is to offer sufficient resistance to the stresses set up by trains running at high speed, we come to the conclusion that at present we can give no definite answer.

Actual practice shows that some modes of construction of the line on different systems allow of high speeds; nevertheless it is scarcely possible to decide that the construction of existing lines answers this purpose either taken as a whole, or considered in detail. To decide how far we may copy these to obtain a satisfactory method of construction can only be determined when the results obtained in actual practice are further confirmed by the analytical method of examination.

But when we attempt to apply such a method of analysis and to combine the results of experiment and theory, we are met by the difficulty that these results and more particularly those which are obtained from mathematical formulae do not allow us to definitively obtain the influence of the velocity of movement on the stress on the rail and do not enable us to calculate directly the dimensions relating to the permanent way.

Existing formulae. — The only formulae in which the speed enters as a factor are those which take into account the centrifugal force set up when the train is running round a curve.

Horizontal centrifugal force. — Only when the road is curved does a horizontal centrifugal force come into play. It has been attempted to counteract this by giving superelevation to the outer rail. This as is well known produces a number of disadvantages. Hence the question of superelevation cannot yet be considered definitely settled. We can even show theoretically, and several cases have confirmed this view in practice, that in many cases in which superelevation is at present applied it is quite unnecessary.

VERTICAL CENTRIFUGAL FORCE. — Formulae have previously been given which take into account a vertical centrifugal force on straight and curved lines. This force is due to the bending of the rails between consecutive sleepers as the vehicle passes over them. They consequently have to travel over an elastic curve which they cause by their own movement. These formulae take into account the increase of the stress on the rail due to the speed, and this is important, because having regard to the preponderating influence of the vertical load on the rail when making our calculations, they contain at least one factor which depends on the speed.

Only these formulae are useless because the wheels of the vehicle do not follow exactly the elastic curve of the rail. They take a different path which would be parallel to the surface of the rail if it were not for the fact that other factors which cause the wheel load to vary intervene.

FORMULAE FOR DEAD LOADS AND LIVE LOADS. — Nevertheless the formulae which are used in the case of dead loads may also be employed in the case of live loads if we substitute for the wheel pressure on the rail due to the dead load the value of this figure in the case of the moving load.

In making these calculations the momentary value of the wheel pressure due to live loads is taken as a static load. The value of this pressure varies during the movement of the wheel and we must base our calculations on its maximum value. The question thus reverts to the determination of this maximum and in this case we are considering to what extent it depends on the speed.

INFLUENCE OF THE SPEED. — The changes in the load on the wheel are due to the oscillations and other disturbing movements of the engine and carriages.

The speed has to be considered in this connection because the higher it is, the more rapid are the variations of the load.

A large increase in the load can even take place; as for example when the blows follow each other so quickly that the oscillation caused by one blow is not completed before the next blow is given and the directions of the successive blows coincide.

Theoretical research does not appear to have touched on this point; at least no published research on this subject is generally known. We have thus here an existing instance of the influence of speed that should be taken into account in our calculations for the permanent way, but which till now has not been considered in the formulae.

The determination of this maximum pressure of the wheel is rendered still more uncertain by the effect which these variations produce in the reaction of the rail due to the momentary pressure; for these are mutually interdependent.

Reactions of the permanent way. — The permanent way offers, as we know an elastic support to the vehicles moving over it. It yields under the load to an extent which, as can be seen approximately in practice, is proportional to the load if this latter be kept within certain limits. A special calculation shows also that although with a given load the total amount of this yielding varies with the rigidity of the construction of the permanent way and with the elasticity of the ballast, it remains nearly the same for an individual road, both when the load is directly over a sleeper or supported on the rail between two consecutive sleepers.

If the load were always constant in magnitude while in motion the sinking of the road would be the same at each point consecutively covered. The path that the load would then actually nove in, would be in a line below the normal surface of the rail, but always parallel to it, and that without regard to the variations in level of the original road. This is the case which we have cited as an example above.

But as the amount of the pressure is variable, the sinking of the line will at each point be proportional to this amount and hence will vary just as much as the amount of the pressure does.

There will not be as in the preceding case uniform sinking under each wheel of the vehicle, but it will vary and be above and below the average. The actual path of the wheel will no longer be in a line parallel to the surface of the rail, but will be in an undulating line and the vehicle will rise and fall while moving in exact accordance with the alterations of level now obtained.

This rising and falling of the vehicle produces oscillations in its suspended part, which again react and affect the pressure of the rails. This reciprocat increase of the sinking of the road and of the variations of the load does not continue indefinitely, but as in all similar cases there is a definite limit. The effect of the speed should here be considered just as we have considered its effect in the case of the wheel pressure of the locomotive, but in this case it is greater, since here the action on the road must be taken into account.

Determination of the effect of speed on the maximum load. — The great influence which the speed has on the maximum load obtained during movement (or the so-called dynamic action of the live load) has herewith been clearly described as to its nature but, unfortunately, not as to its quantity. But this is the very factor we require in order to be able to construct a road, which shall not only satisfy the requirements on it but also shall be of rational construction.

The dynamic action of the vehicles and the amount of the sinking of the track and the variations in this amount are considered in detail in the report V. A. of the Saint-Petersburg session of the International Railway Congress, but without definite consideration of the effect of the speed. On that occasion we gave estimated values for the amount of the dynamic action, and we gave certain formulae enabling the calculation for the permanent way required to be made, due consideration being given to the elasticity of the ballast which would allow us to establish a method of constructing a line as soon as the amount of the maximum load is known.

We have shown that the maximum load depends on how much the permanent way yields, on the method of construction of the rolling stock, especially of the locomotives, and on the speed. The amount of yielding of the road is confined within fairly narrow limits, and its quantitative determination can be made in each individual case with sufficient accuracy. This, by itself, does not enable us to determine the amount of the maximum load.

Thus when we wish to establish a suitable method of construction of road with consideration to the speeds of the live load we are always confronted by a problem not yet solved.

The only way of overcoming this difficulty consists in estimating the highest value of the possible or probable maximum load; and consequently one is obliged to construct a line which in most cases is stronger than is really necessary.

Relation between the expenditure on rolling stock and on permanent way. — Here we should remark that the rolling stock and the permanent way taken together form a single means of transport.

In order to obtain the best construction of the latter it is necessary that the relation which the cost of the rolling stock and its maintenance and the cost of the permanent way and its maintenance together bear to the capacity of the whole should be a minimum. Rolling stock which is built and kept in repair at the lowest possible cost nearly always necessitates a permanent way more costly both in construction and maintenance. On account of the great length of the road its expenses may become so considerable that it is worth while to determine in each individual case whether the total expenses as set forth above are actually a minimum.

The work a permanent way has to do constantly increases. Speeds are increased, more express trains are run and their weight is increased. Locomotives, unfortunately, are very often constructed so that their cost for given conditions as to power is as small as possible. Further it is necessary to make the permanent way stronger than is absolutely necessary because, the maximum load being only estimated, a large margin of safety must be allowed. We thus arrive at the fact that great demands are made on the strength of the road; the question then arises how far such demands may be extended.

HIGHEST ATTAINABLE LIMIT OF THE STRENGTH OF THE PERMANENT WAY. — When this question is considered the following conclusion is arrived at : the strength which can be given to the road has a highest possible limit; roads of strong build at present are not much below this limit.

There are two factors which chiefly necessitate this result : first the necessity of using such materials as we have to hand for the ballast and foundations so far as these are unworked, and second the width of the gauge of the line, which is absolutely unalterable.

The results of experiments made for the purpose show that neither the ballast not the foundation should where loaded take a higher pressure than 28·44 to 42·66 lbs per square inch (2 to 3 kilograms per square centimetre). If the lower value $p = 28{\cdot}44$ lbs per square inch (2 kilograms per square centimetre) the ballast will last for a comparatively long time; and the cost of maintenance of the road, which has a better life, is not too heavy.

The extent of the surface which transmits the pressure to the ballast depends on the area of the lower faces of the sleepers, which transmit the pressure from the rails to the ballast.

The maximum pressure of the rail depends on the maximum momentary wheel pressure due to the train, and on the stiffness of the rail.

The stiffness of the rail must be taken into consideration because the load is transmitted to other sleepers than those which directly support the load on the rail.

Calculations on this point show us however that when the stiffness is uniformly increased the increase of its utility for this purpose becomes rapidly smaller and smaller. In a rail of about 90·7 lbs per yard (45 kilograms per metre) the limit is reached; any further increase in the stiffness of the rail has practically no effect in distributing the load over more sleepers.

When the maximum pressure is attained we can find no means of distributing it over a larger number of sleepers unless indeed we are willing to use rails of monstrous construction; to give them the form of a girder, or use that construction in which the rails are fixed to girders resting on the sleepers. These can scarcely be considered rational methods of construction consisting as they do of very stiff continuous girders resting on elastic supports. These far fetched ideas which are the result of an imagination that has been allowed to run riot, are prohibited by reason of their expense.

A better means of distributing the load on the greatest possible number of sleepers, and also on the greatest possible surface of the ballast, is to reduce the space between the sleepers, and to increase the area of the supporting surfaces.

These two measures have however their limits; the first, because sufficient space must be left in order that the sleepers may be packed; the second, because the width of the sleepers cannot exceed a certain amount in order to make good packing possible and also because the suitable length of the sleepers depends on the gauge of the track. If the length of the sleepers exceed a certain limit the pressure of the rail will cause the extremities of the sleepers to rise, and consequently excessive length does not add to the carrying power. By a provisional calculation we can determine the resisting capacity of the strongest line capable of being constructed on an earthen foundation, using the possible values given below. The resistance of the bed of the sleeper is measured by the coefficient of ballast K (C) which is the pressure per unit of area producing compression of the ballast to the extent of 1 inch (1 centimetre). The experiments have shown that K (C) is between 108·4 and 288·9 lbs per square inch (3 and 8 kilograms per square centimetre). We can conclude that in by far the greatest number of cases the highest value of K (C) attained will be 180·6 lbs per square inch (5 kilograms per square centimetre); for higher values of K (C) are only met with in cases of exceptionally firm or rocky foundation On the other hand with a comparatively inferior sub-soil we may take $K = 180{\cdot}6$ lbs per square inch ($C = 5$ kilograms per square centimetre) provided that this sub-soil has been well drained, and that we have a sufficiently thick layer of ballast.

The sleepers are assumed to be 11·81 inches $= b$ (30 centimetres) wide and 8 feet 10·3 inches $= 2\,l$ long (270 centimetres). The product of the moment of inertia and the modulus of elasticity will be approximately $E'I' = 10^8 \cdot 2{\cdot}73$ lbs $\times$ square inch ($E'I' = 8 \times 10^8$ kilograms $\times$ square centimetre) assuming the sleepers to be spaced at a distance of 23·62 inches (60 centimetres).

The rails will have a moment of inertia of about $I = 43{\cdot}24$ square inches $\times$ square inch (I = 1,800 square centimetres × square centimetre). This corresponds to the section of the heaviest rail that can be used with economy.

If we designate the wheel pressure by W (G) the pressure P in tons (in *tonnes*) of the rail on the sleeper which is directly under the load is approximately = 0·5 W (0·5 G) in the case of a vehicle having its axles near together. In the case of a vehicle having its axles far apart we may take P = 0·4 W (0·4 G).

The grestest pressure p_r on the ballast per unit of area is calculated from the formulae or tables that we find in the Paper on « The Sleeper and its bearing on the ballast ». We find there that when b = 11·81 inches (b = 30 centimetres) l = 4 feet 5.2 inches (l = 135 centimetres) and $\frac{E' I'}{10^8}$ = 2·73 lbs × square inch (8 kilograms × square centimetre) and P = 1 ton (1 *tonne*) p_r in lbs per square inch (kilogram per square centimetre) has the following values :

For sleepers partially packed :

K = 108·4 (C = 3). . . . . p_r = 4·305 P. (p_r = 0·298 P.)
K = 288·9 (C = 8). . . . . p_r = 4·696 P. (p_r = 0·325 P.)
K = 180·6 (C = 5). . . . . p_r = 4·478 P. (p_r = 0·31 P.)

On substituting for P the values given above

$$p_r = 4{\cdot}478 \times \left\{ {0{\cdot}4 \atop 0{\cdot}5} \right\} W \quad \left(p_r = 0{\cdot}31 \times \left\{ {0{\cdot}4 \atop 0{\cdot}5} \right\} G\right)$$

that is to say p_r = 1·791 W (0·12 G) when the axles are wide apart and p_r = 2·239 W (0·16 G) when the axles are close together.

If p_r is not to exceed 28·44 lbs per square inch (2 kilograms per square centimetre) we get accordingly

$$\text{W maximum} = \frac{28{\cdot}44}{1{\cdot}791} = 15{\cdot}88 \text{ tons} \quad \left(\text{G max.} = \frac{2}{0{\cdot}12} = 16{\cdot}7 \text{ tonnes}\right)$$
$$\text{and W maximum} = \frac{28{\cdot}44}{2{\cdot}239} = 12{\cdot}70 \text{ tons} \quad \left(\text{G max.} = \frac{2}{0{\cdot}16} = 12{\cdot}5 \text{ tonnes}\right)$$

For sleepers partially packed the pressure of the wheel may thus attain 12·70 or 15·88 tons (12·5 or or 16·7 *tonnes*) according to the distance the axles are apart.

If the weight on the wheel in a state of rest is 6·89 tons (7 *tonnes*) it is possible that when in a state of motion it may increase to 1·8 or 2·4 times this amount.

The effect of the speed is intensified as the movement becomes more jerky and irregular.

A permanent way constructed as solidly as the one we are considering will allow the weight of traffic and more particularly the speed to be considerably increased if locomotives are used which do not produce great variations of wheel pressure. On

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the other hand if unsuitable locomotives are used at high speeds the limit of resistance of the permanent way is very soon reached. This is shown in the case of several existing railways of strong construction where the cost of maintenance is great in places.

How far we can increase the demands made on the permanent way more particularly when we consider the subject of increased speed of a line constructed according to the systems in use at present cannot be exactly determined for the reasons previously given. But it is clear that the limit of this increase is not much beyond the existing demands.

The necessity of keeping to the usual systems followed in the construction of the lines, at least for some time to come, requires us to determine with care the most suitable dimensions in full detail.

A considerable increase of traffic and of speed will only be attainable if the locomotive are so constructed that the permanent way does not have by itself to provide for this increase.

Of course we do not assume that the value calculated above for the maximum pressure due to the live load will actually represent the real numerical value. The values assumed for the coefficient of ballast, and the greatest pressure that can be allowed on the ballast, are of themselves too indefinite to allow us to obtain such precision.

As a matter of fact roads of weaker construction than the one we have based our calculations on, are used with heavy trains, locomotives with several coupled wheels, and at high speeds. And this is continued as long as the state of repair will allow it. But a railway can certainly not be considered properly constructed when the traffic on it can only be worked with excessive repairs; and it is from this point of view that we must consider the value we have found above by calculation as the highest limit of the serviceable capacity of a line.

Adjusment of the track. — So far we have not taken into consideration the adjustment of the line; this is however of great importance when we wish to introduce higher speeds.

Lines with heavy gradients necessitate the use of locomotives of great adhesion; such can be obtained by several coupled wheels placed close together.

The bad effects of such locomotives on the line have already been considered, and it has been pointed out that they increase notably with high speeds. If we cannot avoid heavy gradients on certain sections, the only thing to be done is to travel over these heavy gradients and the adjoining easier sections at a slower speed; and to change the locomotive as soon as possible.

It is quite as important to avoid sharp curves.

These necessitate much super-elevation which of itself is bad for the road because it results in an unequal distribution of the loads on the two wheels on each side of the vehicle. The length of the curve of transition and consequently the gradient presented by the outer rail, cannot in practice exceed certain limits; particularly not when reverse curves are close together.

For instance with a speed of only 37·3 miles (60 kilometres) per hour a transition curve of 76·6 yards (70 metres) long is passed over in about 4 seconds; the full amount the vehicles is tilted on account of the superelevation is thus attained in this exceedingly short time, in fact almost with a jerk. The suspended part of the vehicle thus receives a violent transverse movement which results in the inside rails having to bear a greater load than that directly due to the difference in the elevation of the rails. If the curve is not very long, the reaction produced by the return of the outer rail to its proper level takes place while the oscillations of the vehicle due to the first jerk have not yet ceased. If it happens that the fresh oscillations due to the return movement are produced at such time as to be in the same direction as the former ones, it follows that they have an increased effect.

The alternations in pressure first on one rail and then on the other will become yet larger when reversed curves are too close together.

The intensity of the oscillation of the vehicles, and the variation of the pressure on the wheels, consequently depend of the distance between the transition curves and on their respective lengths.

When the speeds are increased these two lengths are, so to speak, relatively reduced; they ought therefore to have their length proportioned to the increase of speed, if the harmful effects are to be redeced to an absolute minimum. Besides the effects that we have just described, the curves produce injurious movements in the vehicles by reason of the change of their direction; here also the influence of the speed is exerted in a manner analogous to that described above.

It is probable that in general the super-elevation of the rail is too great.

This is shown not only by theory and experiments, but also by practical experience obtained in some particular instances. It appears that we may accept as a fact that curves of more than 437 yards radius (400 metres), and without any superelevation may be passed with safety at speeds of about 62.1 miles (100 kilometres) an hour.

B. — Special propositions.

Special statements for the type of line to be traversed by trains at high speed.

From the preceding considerations we can deduce the following points with regard to the method of constructing a line, to satisfy the requirements of heavy traffic and high speeds.

Ballast and foundation. — The engineer is limited in his choice of ballast and foundation; both of them should be as good as local conditions will allow.

By draining the foundations, and using a sufficiently thick layer of ballast, a coefficient of ballast of at least K = 180·6 (C = 5) can be obtained.

The ballast must consist of material free from earth, and must resist disintegration through pressure as much as possible. In most cases a ballast can be obtained having a resistance of about 28·44 lbs per square inch (2 kilogrammes per square centimetre).

It is advisable to use a thickness of ballast not less than 11·8 inches (30 centimetres) under the lower surface of the sleepers. Of this at least 5·9 inches (15 centimetres) should be of material capable of being well packed.

The thickness ought to be increased when the formation is soft and if the sleepers are more than 2 feet 7·5 inches (80 centimetres) apart.

When the formation can not be sufficiently protected from moisture, and in consequence also becomes soft under the ballast, it is necessary to have the depth of the ballast under the sleeper equal to the clear space between the sleepers; in this way the local driving of ballast into the formation, which is so injurious, is prevented. But it is advisable to choose, for the construction of the road, one for which the coefficient K amounts to 108·4 (C = 3).

It is to be remembered that, whatever the method of construction of the road may be, the amount it can stand becomes seriously reduced when the live load of the vehicles produces a pressure on the ballast amounting to more than 28·44 lbs per square inch (2 kilogrammes per square centimetre). In this the maintenance becomes considerably more costly, because such pressures produce a partial destruction of the ballast which first becomes noticeable at the sleepers next to the joint.

Sleepers. — Roads intended for express traffic require the use of long sleepers of corresponding width.

I have described elsewhere in detail the advantages of the longer sleepers, and have drawn attention to the fact that they make a better support for the rail and give it the largest possible bearing surface on the ballast. These advantages result in the fact that lines laid with such sleepers give easier running, and the best results from the point of view of maintenance.

It is in England especially that experience of this has been chiefly gained, for the sleepers there are as a rule of standard dimensions : length 8 feet 11 inches (2·72 metres), width 10 inches (0·254 metre), thickness 5 inches (0·127 metre); the section is rectangular. As a result of this experience, wooden sleepers for lines intended for an express service of trains are recommended to have the following dimensions : length 8 feet 10·3 inches (2·70 metres), width 10·24 inches (0·26 metre), thickness 5·51 inches (0·14 metre); the latter dimension being thus increased to allow for the length of the dog-spikes or screw-spikes for Vignoles rails. Iron sleepers should have the same length and width as wooden ones. The cross section to be adopted should be such that the product of its moment of inertia by the modulus of elasticity divided by 10^8 should not be less than 1·71 (that is to say, $(\frac{E'I'}{10^8} \overline{\overline{>}}\ 5)$.

To prolong the life of the sleepers they should be treated with some suitable substance, preferably creosote, and steps should be taken to avoid cutting away the surface of the sleeper where the rail is supported.

Resistance D. — The resistance D which the sleeper opposes to being forced into the ballast is a quantity proportional to the product of the area of the lower surface of the sleeper by the coefficient of ballast.

The amount of this resistance, which affects the rigidity of the road, will in the case of the sleeper proposed above = 21.5 tons ins (D = 8,600) if the coefficient of ballast K = 108·4 (C = 3).

Space between the sleepers. — The space between the sleepers is an important factor in the construction of the line. On the one hand it influences the carrying capacity of the rail, and on the other hand, in conjunction with the spacing of the wheels of the vehicles, it modifies the pressure on the rail and consequently the pressure on the ballast. The spacing of the sleepers also determines the number of surfaces bearing on the ballast, and the number of points at which the rails are secured to the sleepers.

The diminution of the space between the sleepers is limited by the necessity of preserving sufficient room between the sleepers to allow them to be properly packed.

If, in accordance with the requirements of practice, we adopt 19·68 inches (50 centimetres) as the minimum clear space, and if moreover we consider it desirable to have sleepers 10·24 or 11·81 inches (26 to 30 centimetres) wide for lines on which the traffic is heavy it follows that the distance from centre to centre of the sleepers should be about 2 feet 7 1/2 inches (80 centimetres) except at the joints.

At a joint this distance should be reduced to 19·68 inches (50 centimetres) [1].

Rails. — In our choice of rails the principal things to consider are : the size and shape of the cross section, the strength of the material, and finally the length of the rail. Lines for express trafic should be made either of bullheaded or of Vignoles rails.

Symmetrical double headed rails cannot be recommended.

Section of rail. — (*a*). The cross-section of the rail should have a sufficient moment of resistance, to ensure adequate carrying power, and a sufficiently great moment of inertia to give adequate stiffness.

(*b*) The cross-section of the rail should be large enough to allow the necessary carrying power to the rail when in its most worn condition. It follows that we should allow as much additional material in the head of the new rail as will be worn away during its expected life by the expected traffic. This results in an increase of about 10 to 12 p. c. in the weight of the rail, of about 17 to 23 p. c. of its moment of inertia, and of about 10 to 20 p. c. of its moment of resistance.

(*c*) If the maximum stress on the rail due to all factors affecting it (such as the dead load, the construction of the rolling stock, the speed attained, etc.) we should not allow the maximum strain in the outer fibre to exceed the utmost limit of elasticity as determined by bending tests.

But when we only know the dead load due to the heaviest motors we cannot allow the maximum tension of the outer fibre produced by this dead load to exceed one-third of this utmost limit of elasticity.

This latter case is the more usual one. Dead loads producing a maximum strain of 7·00 to 8·25 tons per square inch (1,100 to 1,300 kilograms per square centi-

(1) See answer to question V-A of the session in Saint-Petersbourg, p. 163.

metre) in the outer fibre of the cross section are thus permissible as the utmost limit of elasticity of the material usually employed for rails is between 21·59 and 24·76 tons per square inch (3,400 and 3,900 kilograms per square centimetre). In the case of double headed rails which are generally made of stronger material the permissible strain is proportionately higher.

(*d*) The Administrations of the lines on which, under favourable conditions of working, the load on the wheel is equal to or less than 6·89 tons (7 tonnes) and on which the speed does not much exceed 49·7 miles (80 kilometres) per hour, have informed us that some lines constructed with rails of less than 80·64 lbs per yard (40 kilograms per metre) have given good results, although, in some cases, the cost of maintenance has been greater.

The cross-sections of these rails have a moment of inertia of 20·73 to 22·85 square inches × square inches (863 to 951 square centimetres × square centimetres) and a moment of resistance of 8·24 to 8·97 cubic inches (135 to 147 cubic centimetres). The cross-section of such rails if worn down about 0·4 inches (10 millimetres) has then a moment of inertia of 16·82 to 18·38 square inches × square inches (700 to 765 square centimetres × square centimetres) and a moment of resistance of 6·90 to 7·57 cubic inches (113 to 124 cubic centimetres); the maximum stress of the outer fibre will then be 8 25 to 9·33 tons per square inch (1,300 to 1,470 kilograms per square centimetre).

We can conclude from these facts that the use of motors having greater wheel pressures on roads so constructed would cause a considerable increase of the cost of maintenance.

For wheel pressures of 7·38 tons (7,500 kilograms) and upwards we therefore should adopt a construction of road having rails weighing more than 80·64 lbs per yard (40 kilograms per metre).

(*e*) If we are obliged, by reason of an increase in the weight on the wheel, or in the speed, to strengthen the section of the rail, we should consider whether there is not a possibility of still further increase of wheel pressure or of speed during the life of the proposed new rail. In this case it is advisable to adopt a rail of such cross-section that a simple measure, such as an increase in the number of sleepers, will be sufficient to enable it to satisfy these higher demands.

From this point of view the new cross-sections of the French and Belgian Railways which correspond to a weight of 88·70 to 100·8 lbs per yard (44 to 50 kilograms per metre) seem justified. This is shown in the subsequent table.

The increased wheel load being:					
In tons	W =	7·382	7·874	8·366	8·858
In *kg*	G =	7,500	8,000	8,500	9,000
The distance between centres of sleepers can be reduced to:					
In inches	a =	31·50	29·53	27·56	25·98
In *cm*.	a =	80	75	70	66
When a normal sleeper is used, and K is taken as 108·4:					
In tons per inch	D =	21·50	21·50	21·50	21·50
C being = 3, in *kg*. per *cm*.	D =	8,600	8,600	8,600	8,600
The superstructure getting more stiffness there is an increase in.	γ =	3	3·5	4	4.5
Hence, as $B = D\gamma$:					
In tons per inch	=	64·50	75·25	86·00	96·75
In *kg* per *cm*	B =	25,800	30,100	34,400	38,700
The bending moment:					
$M = \frac{\gamma + 0{\cdot}875}{2\gamma + 5} \times W \times a$.	M =	$0{\cdot}352 \times W \times a$	$0{\cdot}364 \times W \times a$	$0{\cdot}375 \times W \times a$	$0{\cdot}384 \times W \times a$
$M = \frac{\gamma + 0{\cdot}875}{2\gamma + 5} \times G \times a$. .	M =	$0.352 \times G \times a$	$0{\cdot}364 \times G \times a$	$0{\cdot}375 \times G \times a$	$0{\cdot}384 \times G \times a$
And as:					
In tons × inches. . . .	$W \times a$ =	232·5	232·5	230·6	230·1
In *kg* × *cm*	$G \times a$ =	600,000	600,000	595,000	594,000
M:					
In tons × inches. . . .	M =	81·84	82·62	86·45	88·35
In *kg* × *cm*	M =	211,200	218,400	223,100	228,100
The limit of tensile strength allowed being:					
In tons per square inch . .	σ =	8·25	8·25	8·25	8·25
In *kg* per square *cm* . . .	σ =	1,300	1,300	1,300	1,300
The moment of resistance required of the cross section must be:					
In cubic inches	Z =	9·92	10·26	10·48	10·71
In cubic *cm*	W =	162	168	171	175
Allowing 16 per cent for wear:					
In cubic inches	16 % =	1·59	1·64	1·68	1·71
In cubic *cm*	16 % =	26	27	27	28
The moment of resistance of the cross section of the new rail is:					
In cubic in.	Z_1 =	11.51	11·90	12·16	12·42
In cubic *cm*	W_1 =	188	195	198	203
So that the mean is. . .	. .	Z_1 = 12 cubic in.; W_1 = 196 cubic *cm*.			

Consequently a rail which is to carry a greater load than 7·38 tons (7·5 tonnes) and, which after an increase in the number of sleepers is to carry a load of 8·86 tons (9 tonnes) should have a moment of resistance of 11·96 cubic inches (195 cubic centimetres) and its weight should be 84·7 to 92·7 lbs per yard (42 to 46 kilograms per metre) for sections similar to those in our table.

These rails will satisfy the requirements of the traffic that we have supposed, assuming that the dynamic actions due to motion and speed will not produce a wheel pressure of more than three times that due to the dead weight.

In fixing on the section of the rail we ought to take into account whether the line is principally for light passenger trains drawn by engines with their axles fairly far apart, and with leading and trailing wheels not coupled, and possibly with inside cylinders, or whether the line has a heavy goods traffic necessitating the use of heavy engines with a large number of wheels close together. Thus in each case it is better to select a section of rail suited to the individual case than to attempt to generalise.

As in the case of double headed rails there is a higher value for the strength at the elastic limit, the resisting moment of the cross-section of the rail (hence the weight of unit length of rail) may be reduced in proportion.

Form of cross-section of the rails. — The form of the cross section of the rail was considered in the discussion of question V-A at the session of the International Railway Congress at Saint-Petersburg. We refer to this for the conclusions arrived at.

Length of rails. — The most suitable length of rail has been found to be about 39·27 feet (12 metres). In order to reduce the number of joints the length of the rail should certainly not be less than 29·45 feet (9 metres). Nor should it exceed 49·09 feet (15 metres) or else the spaces necessary for expansion become too large; and the handling necessary in laying rails or changing them becomes excessive.

Material of the rails. — Rails should be made of hard steel in order to prevent too rapid wear. The degree of hardness that can be allowed is governed by the condition that the material should be as homogeneous as possible; also by the degree of perfection to which the processes of rolling have been brought particularly in respect to the form of cross-section; we also must avoid using steel which is too brittle.

The tensile strength and elongation bear relation to the hardness.

Let σ lbs per square inch (kilograms per square centimetre) be the tensile strength at the limit of elasticity of the metal and let E be the corresponding modulus of elasticity. The extension of the metal is dependant on the value of the expression $(\frac{1}{E})$. If δ per cent represents the extension, δ will be proportional to the number $(\frac{1}{E})$. If we are given the section, the distance between the supports, and the manner of loading the rail, we can determine the safe load; that is to say the capacity of the rail for carrying dead load will be proportional to σ, the deflection or flexibility will be proportional to $\sigma\delta$, and the permissible dynamic strain (that is its capacity for work) proportional to $\sigma^2\delta$.

A relation exists between the increase of tensile strength and the diminution of the elongation, the numerical ratio of which we do not know, but we can in each case that occurs determine the two values.

If a ratio existed here, the strength of the rail would increase in proportion to the tensile strength of the material, the flexibility would remain constant; and the amount of work the rail was capable of would increase proportionately.

But as the relation between increase of tensile strength and decrease of elongation is not a constant ratio, if the tensile strength of the rail is increased the capacity for carrying dead load, the flexibility, and the capacity for work will vary in another way. These are to be determined in each given case according to the values for σ, $\sigma\delta$, and $\sigma^2\delta$.

Analogous relations between tensile strength and elongation exist at the point of fracture, although not so simple as the preceding ones; in particular we do not have the proportions mentioned between the capacity for carrying dead load, the flexibility, and the capacity for work, and σ, $\sigma\delta$, and $\sigma^3\delta$ respectively. If in these expressions σ and δ respectively represent the tensile strength and the elongation at the breaking point we have now in place of those simple ratios more complex relations which have not yet been sufficiently studied.

It is none the less true however that the capacity for carrying dead load, the flexibility, and the capacity for work increase with σ, $\sigma\delta$, and $\sigma^2\delta$ but not in a constant ratio.

We find in actual practice cases where σ is between 31·75 and 60·95 tons per square inch (5,000 and 9,600 kilograms per square centimetre), and δ is between 20 and 10 per cent; in most cases $\sigma\delta$ is between 508 and 762 tons per square inch (80,000 and 120,000 kilograms per square centimetre) and $\sigma^2\delta$ between 18,140 and 30,230 tons per square inch × tons per square inch (45 × 107 and 75 × 75 × 107 kilograms per square centimetre × kilograms per square centimetre).

The Swiss railways in their specifications for rails make a condition that $\sigma\delta$ = 571·5 tons per square inch (90,000 kilograms per square centimetre). On this assumption the following scales are obtained for permissible elongations for various hard metals of good tensile strength : —

I. $\sigma\delta$ = 571·5 tons per square inch (90,000 kilograms per square centimetre).

If σ in tons per square inch (in tonnes per square centimetre) =

31·75	34·92	38·10	41·27	44·45	47·62	50·80	53·97
(5·0)	(5·5)	(6·0)	(6·5)	(7·0)	(7·5)	(8·0)	(8·5)

Then δ (in percentages) =

18·0	16·4	15·0	13·9	12·9	12·0	11·2	10·6

Whence we get for the product $\sigma^2\delta$ tons per square inch × tons per square inch (tonnes per square centimetre × tonnes per square centimetre).

18,140	19,950	21,770	23,580	25,400	27,210	29,020	30,840
(450)	(495)	(540)	(585)	(630)	(675)	(720)	(765)

If we assume the rigidity to remain constant (in as much as it depends entirely on the material) increase of tensile strength will be attended by increased capacity for work and hence there will be greater security against deformation and breakage.

If we now take the lowest value of this latter measure of security, that is that given by a material of a tensile strength of 31·75 tons per square inch (5,000 kilograms or 5 tonnes per square centimetre) with an elongation of 18 per cent we can keep $\sigma^2\delta$ = 18,140 tons per square inch × tons per square inch (450 tonnes per square centimetre × tonnes per square centimetre); and we then get the following table of results :

II. $\sigma^2\delta$ = 18,140 tons per square inch × tons per square inch (450 tonnes per square centimetre × tonnes per square centimetre).

If σ in tons per square inch (in tonnes per square centimetre) =

31·75	34·92	38·10	41·27	44·45	47·62	50·80	53·97
(5·0)	(5·5)	(6.0)	(6·5)	(7·0)	(7·5)	(8·0)	(8·5)

Then δ (in percentages) =

18·0	14·9	12·5	10·6	9·2	8·0	7·0	6·2

Hence we get $\sigma\delta$ in tons per square inch (tonnes per square centimetre).

571·5	520·6	476·2	438·1	409·0	381·0	355·5	334·6
(90·0	82·0	75·0	69·0	64·4	60·0	56·0	52·7)

When the capacity for the work is constant and σ is increased the deflection diminishes and the rigidity increases.

A rail which is not very rigid will bend rather than break when it is accidentally submitted to an excessive load.

The contrary will happen when it has great rigidity. Hence it is recommended that a harder metal being chosen (with greater tensile strength) it should have an elongation between the values for δ given in the tables, or in other words the permissible limits of this elongation are found in the two tables; for instance a steel rail with a tensile strength of 38·10 tons per square inch (6,000 kilograms per square centimetre) should have an elongation of 12·5 to 15 per cent.

Similar tables can be drawn up for every value of $\sigma\delta$.

We must take into account the capabilities of the works on which we depend for our supply of rails, and must adopt in consequence a greater or less value of the product of the tensile strength and the elongation $\sigma\delta$. We can deduce from this product tables giving the values of σ and δ corresponding to each other for the same capacity for work for different hardnesses of material; these values of δ corresponding to the resistances σ that these steels have at the limit of elasticity.

The higher values of the actual strain in the rail, such as 8·21 to 10.09 tons per square inch (1,293 to 1,589 kilograms per square centimetre) are for double headed rails, which have a smaller moment of resistance for their cross-section, but are made of material of better quality.

Under these conditions we can take a strain under the dead load not exceeding one-third of the limit of elasticity as permissible.

For wooden sleepers the strain is taken between the sufficiently wide limits of $\sigma = 644$ and 1,268 lbs per square inch (45·3 and 89·2 kilograms per square centimetres) it being assumed that the rails have been weakened by the wear.

THE MEANS OF FASTENING THE RAIL. — When the speed is increased the lateral pressure which is exercised by the moving vehicles on the road increases to a very considerable extent. It becomes necessary in this case to increase, in the same proportion, the resistance produced by the fastenings. It has been recognised that it is necessary, in order to increase this resistance to increase the number of fastening points or to strengthen or improve the method of fastening. This is especially the case with Vignoles rails.

THE FASTENINGS OF VIGNOLES RAILS. — An increase in the number of fastening points is already obtained by the fact that on lines intended for express traffic we must have an increased number of sleepers.

Moreover if, instead of two dog-spikes or screw-spikes for each half sleeper (which was formerly the general practice) three or four are used, the necessary increase in the resistance of the rail to canting or lateral displacement is obtained. A further means of strengthening this resistance is to interpose a bed — or foundation — plate between the rail and the sleeper. This method results in distributing the pressure of the rail over a larger supporting surface, and also tends to unite the three or four means of attachment into one whole.

Another means of strengthening the method of fastening is to replace the dog-spikes by screw spikes, especially when these are made on the system laid down by Michel (*Revue générale*, June 1893, page 337).

The lateral pressures produced by high speeds are particularly felt on curves. To prevent the canting of the rail angle irons supporting the head of the rail are placed on some of the sleepers, holding down plates with bolts and packing plates are used, or even cast-iron chairs in which the rails are fixed by means of wooden keys. The two latter methods of fastening, in which the rails are not fixed directly to the sleeper, and in which the holding down plates or the chairs are secured to the sleepers by means of dog-spikes or better still screw spikes seem to be the best way of overcoming the horizontal pressures caused by the live loads.

The attachment of double headed rails. — When double headed rails are used it has always been customary to secure them with wooden or iron keys to cast iron chairs.

The increase of speed of the trains, and the consequent increase of pressure on the rail and also of the lateral pressure has made it necessary to strengthen the chairs. In England a minimum weight of 40 lbs (18 kilograms) for each chair has actually been fixed officially. Here again we obtain additional strength in the attachment by diminishing the space between the sleepers; in other words, by increasing their number.

Fish-joints. — No system of fish-joints, however applied, can effect the complete union of the successive lengths of rail. As it must be possible for the rail to alter its length in accordance with variations of temperature it is impossible to have a system of fish-joints capable of transmitting the horizontal components of the tensions in the rails.

The fish-joints are only capable of transmitting vertical pressures; this results in causing the two adjacent rail-ends to fall and to rise as simultaneously and as nearly equally as possible.

Every serviceable fish-joint should do this to the greatest possible extent.

From the information forwarded us by the Administrations with regard to fish-joints we make the following summary :

(1). The suspended joint is preferable to the supported one.

It is better if the line passing through the joints of the two rails is at right angles to the direction of the road, than oblique to it; i. e. broken joints are inferior.

(2). If possible, wider sleepers are to be used at the joint and the distance between them is to be reduced to 19.7 inches (50 centimetres) or less.

(3). Both fish-plates should be of strong angular section and their joint cross-section should have a large moment of inertia, in order to give considerable stiffness to the joint ; for this reason it is advisable to give them an additional bend at the bottom.

(4). When determining the cross-section of the rail, we should take care to have the head of the rail of such size as to offer an increased surface of support for the fishplates ; and the angle this surface makes with the horizontal should not become too great.

The use of a heavier rail necessitates the use of a more substantial fish-plate.

(5). It is recommended to increase the length of the fishplates and to use 6 bolts instead of 4.

(6). The diameter of the bolts is generally to be taken as 0.98 inch (2.5 centimetres) and the « Grover » washer is recommended as the best means of preventing the nuts from working loose.

(7). An attempt should be made to improve the system of joints by using better material for the fishplate itself, and by giving more care to its manufacture.

(8). It is of much importance to counteract the pernicious effect on the rails at the joints by employing a stronger method for fixing the rail to the sleepers adjoining the joint. For this purpose chairs and holding down plates are used; also angular fish-plates screwed to the sleepers adjoining the joint.

(9). It is advisable to fill up with packing the spaces that are formed between the rails and the fish-plates.

(1). The system of joints used should give sufficient protection against creeping of the rails.

To effect this it is recommended to make the lower bent portion of the angular fish-plate butt against the two sleepers at the joint, or else to let the lower angle of the fish-plate take against the foundation or bed-plate.

SECTION III.

Strengthening of the permanent way.

If the existing permanent way shows itself too weak for the stresses produced by the trains, or if it does not answer the requirements of an intended increase in the traffic, it will be necessary to strengthen it.

When it is found that reconstruction in order to make the line stronger is necessary, the question should be considered whether it would be better to replace the existing method of construction by an entirely new one, or whether the successive strengthening of various parts of it will be sufficient.

In order to reply to this question it will be necessary to make a detailed examination of the static condition of the present method of construction and its relation to the requirements to be met. This examination should show clearly whether the various component parts of the superstructure or which of them do, or do not, satisfy the requirements as far as capacity for carrying load and rigidity are concerned; it will show which parts, if any, have to be strengthened or entirely replaced.

In answering this question its economical side should receive due consideration.

If the examination results in establishing that it is justifiable to strengthen the line, all the principles set forth for the construction of a new line should be decisive.

For strengthening the road we might in particular have recourse to the following methods :

(1). *Improvement of ballast.*

This constitutes the most effective means of giving greater firmness to the road.

The condition of the ballast is dependent on that of the sub-soil, and to improve it, it is necessary : —

(*a*). To ensure that the sub-soil is completely drained.

(*b*). To have the proper amount and size of the ballast suited to the nature of the sub-soil.

(*c*) To use a hard ballast completely permeable by water.

The combination of all these measures will result in raising the value of the coefficient of ballast. In consequence, other things being equal, the sinking of the sleepers in the ballast will be diminished and the stiffness will be increased. Hence the strains of the material of the rail and of the sleeper will be diminished.

(2). *Replacing the sleepers.*

In the case of older constructions which require strengthening the sleepers are generally of wood. This material has undergone deterioration where it has been subjected to pressure by the mechanical actions of the rail and of the means of attachment continued during a series of years; in some cases even partial destruction has taken place. Atmospheric agencies have induced decay. When a road has got into this condition some sleepers will already have been replaced. The rails are then irregularly supported by new sleepers and by sleepers partly worn, and consequently the amount they will sink will vary.

This state of affairs will result in producing higher strains in the materials of the superstructure, so calling into play different reactions of the line on the vehicles, which reactions, again, increase still further these stresses.

When a line in this condition has to be dealt with, the complete renewal of the sleepers on entire sections is advisable. The first point to be decided in such a case is the nature of the sleepers to be used.

If we simply wish to strengthen the superstructure, retaining the old partially worn rails, we ought to continue to use the economic system of wooden sleepers, but we must consider what dimensions these should have.

In former times the only functions of the sleepers that were recognised were those of serving as a support to the rail, and of receiving the means of fastening; the importance of the sleepers in distributing the load on the ballast was not appreciated at its full value, and those that were used had neither sufficient length nor width.

When it is intended to proceed with the reconstruction of a line, which is to be efficiently strengthened, it will in cases be necessary, as shown in the note « The Slepeer and its Bearing on the Ballast » to use sleepers of another type 8 feet 10.3 inches (2.70 metres) long and 10.24 inches (26 centimetres) or more wide. The use of such sleepers will result in a greater rigidity of the road and will reduce the stresses on the rails and on the ballast.

Exceedingly good results are obtained with a reconstruction when bad parts of the ballast are renewed and improved at the same time that such new sleepers are put in.

(3). *Increase of the number of sleepers.*

In older systems of construction the space between the sleepers was often rather considerable and spaces of 3 feet to 3 feet 4 inches (92 to 103 centimetres) are frequently to be found. These methods of construction may have sufficed for vehicles of small wheel load and speed, even when lighter rails were used.

Since then the growth of the wheel load and the increased wheel pressure due to the dynamic action of express traffic, has not only required a rail of greater capacity for carrying load, but also an increase in the area of the surface of the rail bearing on the sleeper, in order to better distribute the higher pressure on the ballast obtained by the higher wheel pressures.

With this aim an especially efficient means consists in increasing the number of sleepers per rail, which amounts to diminishing the distance between them.

As has been previously established, the resistance of the rails to deflection is directly proportional to the moment of inertia of their cross-section and to the modulus of elasticity of their material, but is inversely proportional to the cube of distance between the sleepers.

$$B = \frac{6EI}{a^3}.$$

Consequently, the resistance of the rail will be increased if the distance between the sleepers is diminished. The resistance varies inversely as the cube of the distance between the sleepers.

In certain cases, the reduction of the space between the sleepers can lead to an increase in the resistance of the rail, to an extent which could otherwise only be obtained if the cross-section of the rail were largely increased at a disproportionately excessive cost.

But it is not only the resistance of the rail which gains by this measure; the increased number of the sleepers and the increase in consequence of the area of support on the ballast result in a considerable increase in the stiffness of the road, and in a considerable diminution in the cost of the maintenance of the superstructure.

Attention has been drawn elsewhere to the unfavourable action exercised on the rail by motors with axles close together. It has been shown that in cases where a very great load is, owing to the shortness of wheel-base, only distributed over a short piece of rail, the proper distribution of pressure on the ballast can only be obtained by one means, viz. increasing the number of sleepers.

In America, where very heavy rolling stock with a great number of wheels often close together is used, this measure had to be adopted. Roads constructed with so called « Goliath » rails weighing 100 lbs per yard (50 kilograms per metre) are even laid on sleepers 24 inches (60 centimetres) apart.

This method of increasing the strength of the road by reducing the distance between the sleepers appears to be specially advisable in the case of mountain railways, on which locomotives of eight or more wheels are often used for heavy trains.

(4). *Improvement in the method of fastening the rails.*

When an older construction of permanent way is to be strengthened to render it capable of carrying express traffic it will generally be necessary to renew and increase the means of fastening. When the renewal of the sleepers is undertaken at the same time that the superstructure is strengthened, the replacement of the fastenings is an obviously consequent step.

More particularly instead of the old method of using dog-spikes, screw-spikes alone will be used on a line used for express traffic. Also, in order to relieve the sleeper and the screw-spikes or spikes every sleeper will be protected by a bed-plate, and the number of the fastenings will be increased to correspond to the increased strength required.

(5). *Improvement of the joints.*

Joints on the more modern roads are justly considered the weak point. All the more is this the case with an old and worn road, where the fish-plates as well as the rails have already suffered through traffic. To strengthen such a road with a view to carrying express traffic will therefore require particular care in the improvement of the fish-joints.

When an otherwise strong road has weakened joints it becomes necessary to strengthen these to make it serviceable. This has given rise to the use of the following special measures :—

(*a*). On the older-constructed lines weak, flexible fish-plates and bolts with a diameter of less than 0·787 inch (20 millimetres) are generally used. The greater demands made by the traffic necessitate fish-plates of a stiffer cross-section and bolts of the larger diameter of 0·866 to 0·984 inch (22 to 25 millimetres).

The use of bolts of this size necessitates enlarging the holes in the rails.

(*b*). In consequence of the heavy wear and tear that takes place in the fish-plates and in the rails at the points marked *a*, *a'*, *b*, *b'* in the sketch here given (fig. 6), the joints become prèmaturely worn out owing to the formation of gaps.

Now if new fish-plates are applied this will only improve matters at the points marked as far as the fish-plate is concerned, but the damaged points in the rail are unaltered. It is necessary to fill up these gaps, whether of the rails alone or of the

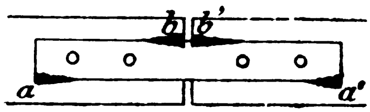


Fig. 6.

old fish-plate as well if these are kept in use. For this purpose, the packing pieces proposed by me and shown in the diagram (fig. 7) are used.

This packing is made of different thicknesses as required according to the size of the gaps and is fixed into the joint so as to become part of it, and so restore the original conditions for a time.

When this packing in turn becomes worn or the gaps are increased, it will only be necessary to change the packing.

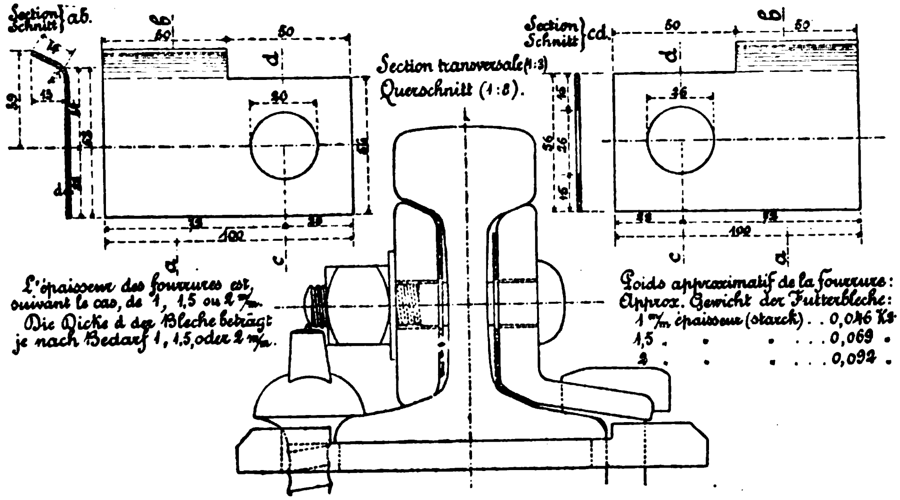
(*c*). Coüard has proved that when, on lines laid on the Vignoles system, a wheel passes over a joint, the rail which is being left suffers a greater torsional stress than the other; the effect of this torsion is to raise the end of the first rail relatively to the end of the second, so that the wheel falls from the first rail on to the second. Through these repeated shocks the rail ends suffer injury which in many cases is sufficient to make renewal necessary although the rails are otherwise in good condition.

In my opinion, the method in which Vignoles rails are fixed by dog-spikes or screw-spikes is insufficient to counteract this tendency to torsion. Greater resistance to this tendency will be obtained by a more rigid method of fastening such as chairs, tension-plates, or holding-down plates, and by such means the blows due to passing vehicles will be reduced.

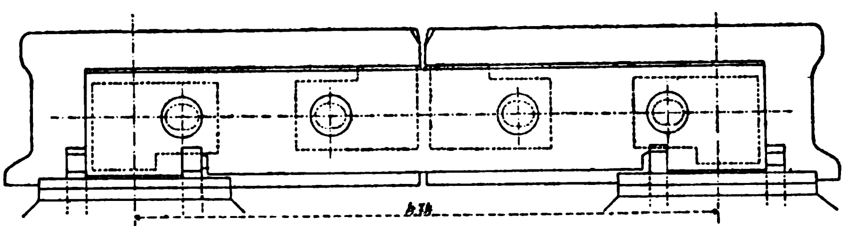
My earlier observations extending over a period of 10 years showed me that in the case of a road laid with iron sleepers according to the « Heindl » system (which employs tension-plates, cramp-plates, and bolts), the joints were more satisfactory than those on other roads where the rails were fixed to the sleepers by means of spikes or screw-spikes.

These observations induced me to experiment on various sections of line carrying

Welding plates for old permanent way constructions on the Emperor Ferdinand Northern line.



External view of the complete arrangement (1 in 6)



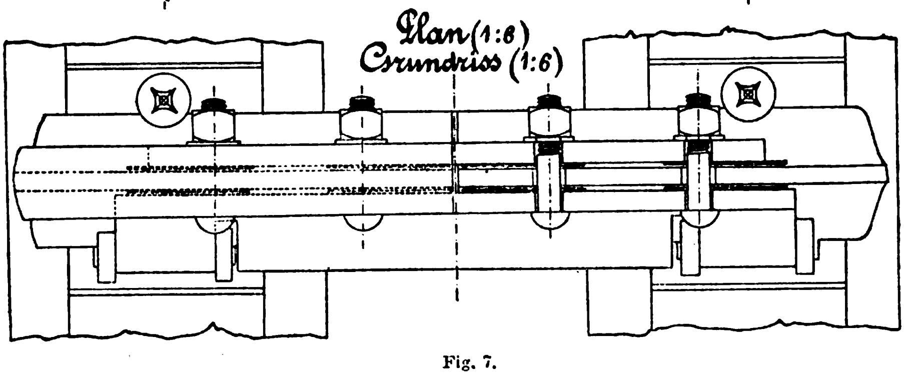


Fig. 7.

EXPLANATION OF FRENCH TERMS : *Section transversale* = cross section (1 in 3). *L'épaisseur des fourrures est suivant le cas* = the plates have a thickness varying. *Poids approximatif de la fourrure* = approximate weight of the plate.

heavy traffic, which were twenty years old, and also on several new ones. Tension plates were fixed to the two sleepers adjoining the joint and the « Heindl » system was used there while the ordinary method of fastening was retained for the remaining sleepers.

The results obtained by this somewhat strange construction were so favourable that I have recommended its application to strengthen the superstructure of a line dating from the seventies for which Bessemer rails of excellent quality had been supplied.

(*d*). In order to prevent creeping of the line, the joint is generally connected with the fastening points adjoining it. In the case of new fish-plates, it is advisable to let the lower flanges of the angular fish-plate come down far enough to take against both edges of each of the bed plates on the sleepers adjoining the joints. Or, instead of this forked arrangement, the flange of the fish-plate can be made to bear at its two extremities against the side of the sleepers.

Other arrangements which are used for the same purpose have been shown elsewhere.

I may add that in the case of joints provided with tension plates a much slighter tendency to creeping is observed owing to the more complete securing of the rail, accompanied by diminished movement of the sleepers. Indeed, there is but little tendency to creeping in all systems of superstructure where a better means of fastening has been adopted.

In the table appendix VI, a special instance is taken which sets forth the results obtained by the application of the means suggested above (1-4, section III) for strengthening the road and shows how the stresses on the line and its strength are affected.

CONCLUDING REMARKS.

The question under investigation consisted in setting forth the means to be adopted for strengthening the superstructure of the permanent way desirable in view of increased speeds. But to absolutely determine the type of construction for a road suitable for high speeds is impossible, because the increased stresses due only to increased speed have not, either by theory or experiment, been determined with a sufficient degree of accuracy.

Our investigations could only be based on the stresses due to increased dead loads, which can be calculated; but the influence the speed has in increasing these stresses could only be determined qualitatively and not quantitatively.

We have thus only been able to compare, under the assumption of a constant wheel pressure, the large mass of data supplied to us by the Administrations concerning the types of permanent way on sections carrying heavy traffic, and to what extent they have proved to be satisfactory. Yet we may, in spite of the different methods of construction used, observe a remarkable agreement in the capability of the road, in those cases where the demands on it and the resistance are in equilibrium. On the other hand, the very different behaviour of types of permanent way of equal value when subjected to the influence of motors built in different ways gives us a relative measure for the influence which is exercised by the method of construction of the motor (when this is at rest) on the requirements made on the road.

From this point of view, we were compelled to recognise the fact that the permanent way is a construction for a definite purpose, which has fixed limits determined by its elements and by the nature of the materials of which they consist.

Moreover, we were compelled to recognise the fact that there is no definite type of permanent way for lines intended for an express traffic.

It certainly will be necessary to remember when laying down roads for such traffic that the continual growth of the requirements made for increase of speed and of comfort calls for increased power of traction. This in its turn results in greater stresses on the road due to the vertical and horizontal pressures.

Such roads used for express traffic will accordingly require greater resistance and greater stiffness, and the fastenings should also be increased in number and in strength.

In considering how far such measures are to be extended, it has to be borne in mind that the types of permanent way as they have been developed up to date do not have the desirable property of being able to be adapted to the varying requirements of the traffic; when these demands are increased beyond certain limits, the cost of maintenance is the first to suffer, and then the safe working of the traffic is endangered.

Some Administrations allow for this fact, by keeping the requirements of the traffic with regard to load and speed within definite limits that are not exceeded. Others construct roads to have a maximum of resistance, and strengthen the whole construction or parts of it to the greatest practically attainable limits, and thus the road is furnished with a power of resistance in excess of present requirements.

When investigating this, special importance was attached to the necessity of considering the structure as a whole, and to the fact that it is useless to strengthen one part of it when the other parts have reached the limit of their strength.

In this investigation, the sleeper and the ballast are of primary importance, and it was established that an increase in the weight of the rail and in the moment of resistance of its cross-section is only justifiable when it is accompanied by an increase in the number of sleepers which receive the pressure and transmit it to the ballast.

It has been established in this investigation that a road of maximum capacity will have approximately the following elements of construction :—

The *ballast* should have a thickness of not less than 15·75 inches (0·4 metre) consisting of readily permeable material resting on dry sub-soil, so that even under less favourable conditions such as wet weather, etc., the ballast will still have a coefficient $K = 108{\cdot}4$ ($C = 3$).

Sleepers of wood or mild steel should be 8 feet 10·3 inches (2·7 metres) long, 10·24 inches (0·26 metre) wide on their lower face, and should have a cross-section such that $\frac{E' I'}{10^8} \geqq 5$ and should allow the rail to be firmly fixed.

Rails should be of a homogeneous hard and tough steel; they should be 9·84 to 13·12 yards (9 to 12 metres) long and have a cross section whose moment of resistance is about 12·20 cubic inches (200 cubic metres).

The *space between the sleepers* should not exceed 19·69 inches (0·50 metre) at the joint and 31·50 inches (0.80 metre) over the rest of the rail. The further reduction of the latter dimension allows, for greater wheel pressures, the use of 7·87 or 8·86 tons (8 or 9 tonnes); but this method is open to objections.

The transverse forces increased by higher speeds should be provided for by increasing the number of the fastenings (of the rail to the sleeper) to 3 or 4 in each case, and by correspondingly strengthening these by the use of screw-spikes, bed-plates, chairs, etc.; also by improving and strengthening the fish-joints.

A road thus constructed in which all the dimensions and arrangements are based on theory and experience, will offer the maximum resisting capacity that it is practically possible to obtain.

That this maximum is not much in excess of the resistance which is obtained in roads constructed on methods at present in use has been shown above; indeed, in some methods of construction the size and arrangement of certain parts go beyond those here proposed.

The great cost of maintenance which is met with, shows that the requirements due to the traffic have reached or exceeded the limit of the power of resistance.

Steps to be taken for dealing with greater requirements are already being discussed or prepared.

There are no means of strengthening the lines in such a way as to satisfy such demands, resulting as they do in exceeding the natural limits of the capacity for resistance; for an increase in the number and size of the sleepers combined with an increase in the weight of the rail, is not justifiable from the economic point of view; and the most efficient method, namely increasing the gauge of the line, is out of the question.

The only course *left open then is to improve the method of construction of the locomotives.*

It is in the power of the locomotive superintendent to utilise to the greatest possible extent the capabilities of the line for adhesion and traction by constructing locomotives which with increased wheel pressure shall show decrease in dynamic action.

With regard to this, it was shown that locomotives with six wheels coupled are to be avoided; that wheels should not be too close together; that leading and trailing wheels should be lightly loaded; and that inside cylinders should be adopted; these are the measures which give the most favourable conditions for the permanent way, and allow the wheel pressures to be increased.

In offering this report for discussion at the fifth meeting of the International Railway Congress, we express the opinion that it should deal only with the general principles contained in it, while each Administration should determine for itself to what extent it can with advantage apply these principles.

APPENDIX

Rails.

APPENDIX I.

Table compiled from data received from the managements showing the dimensions and particulars of rails used in their strongest constructions.

Number.	Name of railway	French State.	Paris-Orleans.	Company of the Austro-Hungarian State Railways.	Kaiser Ferdinands Nordbahn.	Austrian-Southern.	Egyptian.	French Western.	Dutch.	Meridional-Adriatic.	French Southern.	Belgian State.	Paris-Lyons-Mediterranean.	French Northern.	Saint-Gothard.
		6·89 tons (7 tonnes) and under.						Over 6·89 tons (7 tonnes).							
	Load on locomotive wheels (tons)	6·15	6·45	6·79	6·79	6·89	6·89	6·94	7·18	7·37	7·38	7·38	7·51	7·55	7·68
	Load on locomotive wheels (kilog.)	6,250	6,550	6,900	6,900	7,000	7,000	7,050	7,300	7,490	7,500	7,500	7,635	7,675	7,800
1	Type of rail	Bullheaded	Bullheaded	Vignoles.	Vignoles.	Vignoles.	Vignoles.	Bullheaded	Vignoles.	Vignoles.	Symmetrical double headed.	Vignoles.	Vignoles.	Vignoles.	Vignoles.
2	Weight per unit of length (lbs per yard)	80·6	85·7	66·5	71·1	68·5	84·7	88·7	77·8	72·6	76·6	104·8	96·7	90·7	92·7
	Weight per unit of length (kilog. per metre)	40·0	42 5	33·0	35·3	34·0	42 0	44·0	38·6	36·0	38·0	52·0	48·0	45·0	46·0
3	Dimensions. Height (ins)	5·71 / 5·24	5·71 / 5·24	4·92 / 4·57	5·00 / 4·61	5·04 / 4·65	5·51 / 5·01	5·59 / 5·12	5·12 / 4·65	5·12 / 4·72	5·27 / 4·80	5·71 / 5·24	5·59 / 5·12	5·67 / 5·20	5·70 / 5·24
	Dimensions. Height (millimetres)	145 / 133	145 / 133	125 / 116	127 / 117	128 / 118	140 / 128	142 / 130	130 / 118	130 / 120	134 / 122	145 / 133	142 / 130	144 / 132	145 / 133
	Dimensions. Length (yards)	12·03	12·03	9·84	9·84	10·94	13·12	13·12	10·71	9·84	12·03	9·84	13·12	13·12	13·12
	Dimensions. Length (metres)	11·0	11·0	9·0	9·0	10·0	12·0	12·0	9·8	9·0	11·0	9·0	12·0	12·0	12·0
4	Cross section. Moment of inertia I (sq. ins by sq. ins)	30·27 / 23·30	29·35 / 23·83	20·73 / 16·77	22·85 / 18·35	22·44 / 17·97	34·53 / 27·60	30·35 / 23·78	26·15 / 21·21	24·21 / 18·71	23·94 / 17 99	42·50 / 33·56	38·07 / 31·61	38·10 / 29·60	39·40 / 30·46
	Cross section. Moment of inertia I (sq. cm. by sq. cm.)	1259·9 / 970	1221·6 / 992	863 / 698	951 / 764	934 / 748	1437·5 / 1149	1263·6 / 990	1085 / 883	1008 / 779	998·7 / 749	1769 / 1397	1585·5 / 1316	1586·1 / 1232	1640 / 1268
	Cross section. Moment of resistance Z (cub. ins)	10·01 / 8·73	9·32 / 8 30	8·24 / 6 90	8·97 / 7·57	8·76 / 7·32	12·19 / 10·31	10·35 / 9·09	9·58 / 8·73	9·26 / 7·38	9 08 / 7·20	14·65 / 12·20	13·61 / 11·71	12·50 / 10·13	13·55 / 10·86
	Cross section. Moment of resistance W (cub. cm.)	164 / 143	152·7 / 136	135 / 113	147 / 124	143·5 / 120	199·7 / 169	169·7 / 149	157 / 143	151·7 / 121	148·8 / 118	240 / 200	223 / 192	204·8 / 166	222 / 178
5	Material. Class	Bessemer S. basic process.	Bessemer S. acid process.	Bessemer S.	Basic Bessemer or Martin.	Martin S.	Bessemer S.	Bessemer or Martin S.	Bessemer S.	Acid Bessemer or Martin.	Acid Bessemer or Martin.	Steel.	Martin S.	Bessemer or Martin S.	Bessemer S.
	Material. Tensile strength (tons per sq. in.)	44·4 / 50·8	44·4 / 50·8	34·9	34·9 / 42 5	41·9	44·4 / 45·7	44·4	39·4	35·5	49·5 / 62·2	38·1	44·4	45·4	41·3
	Material. Tensile strength (kilog. per sq. cm.)	7000 / 8000	7000 / 8000	5500	5500 / 6700	6600	7000 / 7200	7000	6200	5600	7800 / 9800	6000	7000	7150	6500
	Material. Elongation	3 %	10 to 15 %	15 %	14·5 % 23 %	17 %	11 %	8 %	19.5 %	20 %	15 to 4 %	13 %	12 %	15.4 %	20 %

Sleepers.

APPENDIX II.

Table giving the material, dimensions and spacing of the sleepers used by the managements of the lines, and also the method of securing the rails.

Number.	NAME OF RAILWAY		French State.	Paris-Orleans.	Company of the Austro-Hungar. State Railways.	Kaiser Ferdinands Nordbahn.	Austrian Southern.	Egyptian.	French Western.	Dutch.	Meridional Adriatic.	French Southern.	Belgian State.	Paris-Lyons-Mediterranean.	French Northern.	Saint-Gothard.
			6·89 tons (= 7 tonnes) and under.						Above 6·89 tons (= 7 tonnes).							
	Load on locomotive wheels	tons.	*6·15*	*6·45*	*6·79*	*6·79*	*6·89*	*6·89*	*6·94*	*7·18*	*7·37*	*7·38*	*7·38*	*7·51*	*7·55*	*7·68*
		kilog.	*6,250*	*6,550*	*6,900*	*6,900*	*7,000*	*7,000*	*7,050*	*7,300*	*7,490*	*7,500*	*7,500*	*7,635*	*7,675*	*7,800*
1	Material of sleeper		Mild steel, oak or pine.	Oak.	Oak.	Oak.	Oak.	Oak and baltic fir.	Oak and beech.	Mild steel, oak and redfir.	Oak.	Oak and pine.	Wood.	Oak and beech.	Oak and beech.	Soft basic steel.
2	Dimensions. Length (= $2l$)	(feet)	8·20	8·86	8·20	8·86	7·87	8·92 8·53	8·86	8·53	8·53	8·53 8·86	8 53	8·53	8·53	8·20
		(metre)	2·50	2·70	2·50	2·70	2·40	2·72 2·60	2·70	2·60	2·60	2 60 2·70	2·60	2·60	2·60	2 50
	Width (= b)	(ins)	9·45 8·66	8·66	11·81	10 24	10·24	10·00 9·45	8·66 11·81	10·24	9·45	9·84 11·81	11·02	7·87	10·24	8·62
		(cm.)	24 22	22	30	26	26	25·4 24	22 30	26	24	25 30	28	20	26	21 9
	Thickness	(ins)	3·15 5·51	5·91	5·91	6·30	6·30	5·00 5·91	5 12 5 51	5·91	5·51	4·72 5·12	5.51	5·91	5·12	3·35
		(cm.)	8 14	15	15	16	16	12·7 15	13 14	15	14	12 13	14	15	13	8 5
3	Cross section. Moment of inertia I′.	(sq. in. × sq. in.)	4.04 120.8	148·7	147·1	184·3	153·3	104·2 169·0	95·2 120·8	175·7	131·8	107·5	103·9	135·1	174 4	5·50
		(sq. cm. × sq. cm.)	168 5030	6188	6125	7672	6380	4336 7031	3963 5030	7312	5488	4475	4326	5625	4760	229
	Moment of resistance	Z (cub. in.)	1·83 43·8	50·3	46·7	55·2	43·8	38·9 57·2	36·5 43·8	59·5	47 8	43·7	32·6	45·8	53 6	2 42
		W (cub. cm.)	30 718	825	766	905	717	638 937	598 718	975	7·84	716	534	750	879	39·7
	Characteristic of material $\frac{E'I'}{10^8}$	(lbs. × sq. in)	0·97 1·71	2·12	2·08	2·63	2·19	1·47 2·39	1·37 1·71	2·49	1·88	1·54	1·47	1.91	1.64	1·33
		(kg. × sq. cm).	2·85 5·0	6·2	6·1	7·7	6·4	4·3 7·0	4·0 5·0	7·3	5·5	4·5	4.3	5·6	4·8	3·9
4	Distance between sleepers (centre to centre)	(inches)	32·30	32·22	33·86	30·71	34·65	32·13	29·45	36·42	33·86	38·74	31·50	28·46	31 50	31·90
		(cm.)	82	81·8	86	78	88	81·6	74·8	92·5	86	98·4	80	72·3	80	81
5	Support between rail and sleeper		Chair.	Chair.	Bed plate.	Bed plate.	Bed plate.	Nil or Bed plate.	Chair.	Nil or Bed plate.	Bed plate.	Chair.	Bed plate.	Bed plate.	Felt slab.	Nil.
6	Fastening		Screw-spikes and bolts.	3 screw-spikes.	1 screw-spike, 2 dog-spikes.	1 screw-spike, 2 dog-spikes.	Dogspikes.	2 or 3 screw-spikes.	Screw-spikes	Dogspikes.	Dogspikes.	Screw-spikes	Screw-spikes	4 screw-spikes.	3 screw-spikes.	Tension plates and bolts.
7	Number of sleepers	(per mile)	2049	2049	1967	2146	2093	2012	2415	1806	1967	1756	2146	2415	2146	2415
		(per km).	1273	1273	1222	1333	1300	1250	1500	1122	1222	1091	1333	1500	1333	1500
8	Embedded surface of sleeper (1)	(sq. feet per yard).	6·92 6·01	6·61	7·21	8·19	5·98	7·69 6·50	7·79 10·63	6·32	6·35	5·91 7 73	8·08	6·50	7·50	6·37
		(sq. metres per kilometre).	703 611	672	733	832	608	781 660	792 1080	642	645	600 786	821	660	762	647

(1) This item refers to the lower surface of the sleepers under which the ballasting is packed.

APPEN

Fish-joints. **Table giving dimensions**

N°	NAME OF RAILWAY		French State.	Paris-Orleans.	Company of the Austro-Hungarian State Railways.	Kaiser Ferdinands Nordbahn.	Austrian Southern.
			6·89 tons (7 tonnes) and under.				
	Load on locomotive wheels	(tons)	*6·15*	*6·45*	*6·79*	*6·79*	*6·89*
		(kg.)	*6,250*	*6,550*	*6,900*	*6,900*	*7,000*
1	Section of fish-plate 	inner	II	II	II	II	I
		outer	II	II	III	III	III
2	Length of fish-plate	inner (ins.)	...	...	18·50	19·69	21·65
		inner (mm.)	...	...	470	500	550
		outer (ins.)	...	...	23·23	21·77	23·23
		outer (mm.)	...	...	590	553	590
3	Section. Moment of inertia I.	inner (sq. ins. × sq. ins.).	18·81	17·92	3·08	3·46	1·46
		outer (sq. ins. × sq. ins.).			6·77	5·69	5·81
		inner (sq. cm. × sq. cm.).	783	746	128·1	143·9	61
		outer (sq. cm. × sq. cm.).			281·9	232·7	242
	Section. Moment of resistance	inner (Z cub. ins.).	6·83	...	1·51	1·56	0·91
		outer (Z cub. ins.).			3·09	2·75	2·63
		inner (W cub. cm.).	111·9	...	24·7	25·5	14·9
		outer (W cub. cm.).			50·7	45	44
4	Weight of fish-plates	inner (lbs.)	Per pair: 41·9 lbs. (19 kg.)	Per pair: 41·9 lbs. (19 kg.)	15·9	15·9	10·4
		inner (kg.)			7·2	7·2	4·7
		outer (lbs.)			24·3	19·2	20·7
		outer (kg.)			11·0	8·7	9·4
5	Material. Class		Cast steel.	Medium hard steel.	Wrought iron.	Steel casting.	Soft Bessemer steel.
	Material. Tensile strength	(tons per sq. in.)	...	...	...	26·2 37·4	... ...
		(kg. per sq. cm.).	...	...	...	4130 5900	... ...
6	Bolts. Number of bolts		4	4	4	4	4
	Bolts. Diameter	(ins.)	0·984	0·984	0·748	0·866	0·866
		(mm.)	25	25	19	22	22

DIX III

and material of fish-joints.

Egyptian.	French Western.	Dutch.	Meridional Adriatic.	French Southern.	Belgian State.	Paris-Lyons-Mediterranean	French Northern.	St-Gothard.
	Over 6·89 tons (7 tonnes).							
6·89 *7,000*	*6·94* *7,050*	*7·18* *7,300*	*7·37* *7,490*	*7·38* *7,500*	*7·38* *7,500*	*7·51* *7,635*	*7·55* *7,675*	*7·68* *7,800*
II	IV	II	II	I	II	II	II	II
II	IV	II	II	II	II	II	II	II
21·65 550	18·11 460	... ...	28·94 735	21·26 540	28·74 730	31·49 800	25·59 650	23·62 600
21·65 550	18·11 460	... ...	28·94 735	17·72 450	28·74 730	31·49 800	25·59 650	23·62 600
3·81 3·81	8·71 8·71	... ...	3·16 3·16	11·83	7·29 7·09	4·46 4·46	... ...	4·70 4·70
158·5 158·5	362·6 362·6	... ...	131·7 131·7	491	302·7 295·3	185·7 185·7	... ...	195·6 195·6
1·78 1·78	3·12 3·12	... ...	1·52 1·52	... ...	2·83 2·73	2·00 2·00	... ...	2·11 2·11
29·2 29·2	51·1 51·1	... ...	24·9 24·9	... ...	46·3 44·7	32·7 32·7	... ...	34·5 34·5
20·7 9·4	17·6 8·0	... ...	22·0 10·0	9·5 4·3	48·5 22·0	34·0 15·4	... ...	22·0 10·0
20·7 9·4	17·6 8·0	.. ....	22·0 10·0	18·1 8·2	46·3 21·0	34·0 15·4	... ...	22·0 10·0
Steel.	...	...	Martin steel.	Hard steel.	Good iron or soft steel.	Steel.	...	...
28·5 34·8	...	...	31·7	...	22·2 28·5	... ...	... ...	... ...
4500 5500	...	...	5000	...	3500 4500	... ...	... ...	... ...
4	4	4	5	4	4	6	4	4
1·004 25·5	0·984 25	... ...	0·984 25	0·787 20	0·984 25	0·984 25	0·984 25	0·984 25

APPEN

TABLE giving the stress and resistance of

Number.	NAME OF RAILWAY		French State.		Paris-Orleans.	Company of the Austro-Hungarian State Railways.	Kaiser Ferdinands Nordbahn.
			6·89 tons (7 tonnes) and under.				
	Load on locomotive wheels.	(tons)	6·15		6·45	6·79	6·79
		(kg.)	6,250		6,550	6,900	6,900
1	Material of sleeper		Iron.	Wood.	Wood.	Wood.	Wood.
2	Class of rail		Bullheaded.		Bullheaded.	Vignoles.	Vignoles.
	Section of rail . . . Moment of inertia. I	sq. ins. × sq. ins.	30·27 / 23·83		29·35 / 23·83	20 73 / 16 77	22·85 / 18·35
		sq. cm. × sq. cm.	1259·9 / 970		1221·6 / 992	863 / 698	951 / 764
	Moment of resistance. Z	(cub. ins.)	10·00 / 8·73		9·32 / 8·30	8·24 / 6·90	8 97 / 7·57
	W	(cub. cm.)	164 / 143		152·7 / 136	135 / 113	147 / 124
3	Coefficient of ballast	K	108·4		108·4	108·4	108·4
		C	3		3	3	3
4	Distance between sleepers (centre to centre). .	(ins.)	32·23		32·22	33·86	30·71
		(cm.)	82		81·86	86	78
5	Quantities used in calculations. $B = \frac{6EI}{a^2}$	$\left(\frac{\text{tons}}{\text{ins.}}\right)$	58·27 / 41·87		56·79 / 46·01	34·60 / 28·03	51·10 / 40·88
		$\left(\frac{\text{kg.}}{\text{cm.}}\right)$	23308 / 17947		22715 / 18400	13840 / 11210	20440 / 16352
	$D = (n)\,K \times b \times l$	$\left(\frac{\text{tons}}{\text{ins.}}\right)$	19·70	21·61	20·67	25·62	24·53
	$= (n)\,C \times b \times l$	$\left(\frac{\text{kg.}}{\text{cm.}}\right)$	7880	8646	8270	10246	9813
	$\gamma = \frac{B}{D}$		2·96 / 2·28	2·70 / 2·07	2·75 / 2·22	1·350 / 1·094	2 08 / 1·66

DIX IV.

the permanent way due to a dead load.

Austrian Southern.	Egyptian.	French Western.	Dutch.	Meridional Adriatic.	French Southern.	Belgian State.	Paris-Lyons-Mediterranean.	French Northern.	St-Gothard.
		Above 6·89 tons (7 tonnes).							
6·89 *7,000*	*6·89* *7,000*	*6·94* *7,050*	*7·18* *7,300*	*7·37* *7,490*	*7·38* *7,500*	*7·38* *7,500*	*7·51* *7,635*	*7·55* *7,675*	*7·68* *7,800*
Wood. Vignoles.	Wood. Vignoles.	Wood. Bullheaded.	Wood. Vignoles.	Wood. Vignoles.	Wood. Symmetrical double headed.	Wood. Vignoles.	Wood. Vignoles.	Wood. Vignoles.	Iron. Vignoles.
22·44 / 17·97	34·53 / 27·60	30·35 / 23·78	26·15 / 21·21	24·21 / 18·71	23·94 / 17·99	42·50 / 33·56	38·07 / 31·61	38·10 / 29·60	39·40 / 30·46
934 / 748	1437·5 / 1149	1263·6 / 990	1085 / 883	1008 / 779	996·7 / 749	1769 / 1397	1585 / 1316	1586·1 / 1232	1640 / 1268
8·76 / 7·32	12·19 / 10·31	10·35 / 9·09	9·58 / 8·73	9·26 / 7·38	9·08 / 7·20	14·65 / 12·20	13·61 / 11·71	12·50 / 10·13	13·55 / 10·86
143·5 / 120	199·7 / 169	169·7 / 149	157 / 143	157·7 / 121	148·8 / 118	240 / 200	223 / 192	204·8 / 166	222 / 178
108·4	108·4	108·4	108·4	108·4	108·4	108·4	108·4	108·4	108·4
3	3	3	3	3	3	3	3	3	3
34·65	32·13	29·45	36·42	33·86	38·74	31·50	28·46	31·50	31·89
88	81·6	74·8	92·5	86	98·4	80	72·3	80	81
34·95 / 27·96	67·46 / 53·97	77·00 / 60·32	34·96 / 28·31	40·41 / 31·12	26·67 / 20·00	88·12 / 69·61	107·00 / 84·80	79·00 / 61·37	78·70 / 60·60
13980 / 11184	26986 / 21589	30797 / 24129	13983 / 11326	16165 / 12447	10670 / 8002	35242 / 27811	42791 / 35517	31598 / 24544	31477 / 24237
21·46	22·69	23·53	23·60	21·58	24·86	24·41	18·15	22·94	18·57
8586	9077	9414	9440	8632	9945	9764	7261	9176	7426
1·63 / 1·30	2·97 / 2·38	3·27 / 2·56	1·48 / 1·20	1·87 / 1·44	1·07 / 0·80	3·61 / 2·85	5·89 / 4·89	3·44 / 2·67	4·24 / 3·26

Number	NAME OF RAILWAY		French State (i)	French State (ii)	Paris-Orleans.	Company of the Austro-Hungarian State Railways.	Kaiser Ferdinands Nordbahn.
			6·89 tons (7 tonnes) and under.				
	Load on locomotive wheels.	(tons)	*6·15*		*6·45*	*6·79*	*6·79*
		(kg.)	*6,250*		*6,550*	*6,900*	*6,900*
6	Maximum pressure of rail	(tons)	3·200 / 3·235	3·211 / 3·249	3·363 / 3·394	3·632 / 3·743	3·362 / 3·356
		(kg.)	3252 / 3287	3263 / 3302	3418 / 3449	3742 / 3804	3416 / 3614
7	Rail. — Bending moment M	(inch tons)	69·70 / 65·51	38·23 / 61·01	71·70 / 68·15	67·77 / 62·98	67·28 / 63·60
		(kg. × cm.)	179900 / 169100	176100 / 165200	185055 / 175900	171492 / 162530	173655 / 164140
	Rail. — Stress . . . . . σ	(tons per sq. in.)	6 97 / 7·51	6·82 / 7·34	7·70 / 8·21	8·07 / 9 13	7 50 / 8·41
		(kg. per sq. cm.)	1097 / 1182	1074 / 1156	1212 / 1293	1270 / 1438	1181 / 1324
8	Sleeper. — Bending moment M′	(inch tons)	14 15 / 14·31	17·03 / 17·23	17 83 / 17·99	16·77 / 17 06	17·86 / 18·90
		(kg. × cm.)	36530 / 36930	43950 / 44480	46027 / 46446	43300 / 44040	46107 / 48770
	Sleeper. — Stress . . . . . σ′	(lbs per sq. in.)	17320 / 17510	724 / 732	791 / 801	8[illegible]4 / 818	724 / 767
		(kg. per sq. cm.)	1218 / 1231	50·9 / 51·5	55 8 / 56·3	56·5 / 57·5	50·9 / 53·9
9	Maximum pressure on ballast . . p_r	(lbs per sq. in.)	20·8 / 21·0	17·9 / 18·4	19 8 / 20·1	18·6 / 18 8	16 6 / 17·6
		(kg. per sq. cm.)	1·46 / 1·48	1·26 / 1·29	1 39 / 1·41	1·31 / 1·32	1·17 / 1·24
10	Maximum sinking in ballast . . . . y_r	(ins.)	0 193 / 0 193	0·165 / 0 169	0·181 / 0 177	0·173 / 0·173	0·153 / 0·161
		(cm.)	0 49 / 0·49	0·42 / 0·43	0·46 / 0·47	0·44 / 0·44	0 39 / 0·41
11	Mean cost of maintenance. — in working days	(per yard)	.		.	0·165	0·137
		(per metre)	.		.	0·18	0·15
	Mean cost of maintenance. — in money	(in pence per yard)	.		.	2·74	1·90
		(kreutzers p. metre)	.		.	15	10·4

Austrian Southern.	Egyptian.	French Western.	Dutch.	Meridional Adriatic.	French Southern.	Belgian State.	Paris-Lyons-Mediterranean.	French Northern.	St-Gothard.
		Above 6·89 tons (7 tonnes).							
6·89 *7,000*	*6·89* *7,000*	*6·94* *7,050*	*7·18* *7,300*	*7·37* *7,490*	*7·38* *7,500*	*7·38* *7,500*	*7·51* *7,635*	*7·55* *7,675*	*7·68* *7,800*
3·689 / 3·850	3·137 / 3·301	3·051 / 3·221	3·880 / 4·104	3·916 / 3·980	4·075 / 4·690	3·813 / 3·846	3·014 / 3·105	3·301 / 3·488	3·947 / 3·978
3749 / 3912	3183 / 3355	3101 / 3273	3943 / 4171	3979 / 4045	4141 / 4766	3875 / 3908	3063 / 3155	3355 / 3544	4011 / 4043
72·35 / 68·34	77·80 / 73·79	73·40 / 69 37	77·42 / 73·36	78·41 / 73·34	77·94 / 72·66	85·32 / 80 94	86·23 / 83·42	86·42 / 81 60	92·88 / 87·88
186764 / 176380	200803 / 1[illegible]0460	189430 / 179044	199620 / 189340	202[illegible]78 / 189300	201179 / 187550	220200 / 208900	222566 / 215300	223065 / 210595	239720 / 2[illegible]6800
8·26 / 9·33	6·39 / 7·16	7·09 / 7 63	8·08 / 8·41	8·47 / 9·93	8·59 / 10·09	5·83 / 6·67	6·34 / 7·12	6·92 / 8·06	6·86 / 8·09
1301 / 1470	1006 / 1127	1116 / 1202	1273 / 1324	1334 / 1564	1352 / 1589	918 / 1050	998 / 1121	1089 / 1269	1080 / 1274
15·57 / 16·25	15·63 / 16·45	15·50 / 16·45	19·33 / 20·45	19 28 / 19·60	22·12 / 23 90	18·31 / 18·46	15 02 / 15 46	16·03 / 16·94	17·86 / 18 00
40177 / 41940	40342 / 42463	40225 / 42452	49900 / 52780	49775 / 50600	57100 / 61700	47250 / 47640	38760 / 39900	41374 / 43714	46100 / 46470
796 / 794	613 / 614	878 / 926	728 / 770	903 / 917	1135 / 1225	1259 / 1269	735 / 757	670 / 707	1651 / 1666
56·0 / 58·5	43·1 / 45·3	61·7 / 65·1	59·2 / 54·1	63·5 / 64·5	79·8 / 86·1	83·5 / 89·2	51·7 / 53·2	47·1 / 49·7	1161 / 1171
23·5 / 24·5	17·4 / 18·2	15·6 / 16·5	20·6 / 21·8	22 8 / 23·0	22·2 / 23·0	19·5 / 19·6	20·8 / 21·5	17 9 / 18·9	27·4 / 27 7
1·65 / 1·72	1·22 / 1·28	1·10 / 1·16	1·45 / 1·53	1·60 / 1·62	1·49 / 1·62	1·37 / 1·38	1·46 / 1·51	1·26 / 1·33	1·93 / 1·95
0·217 / 0·224	0·161 / 0·169	0·146 / 0·154	0·189 / 0·201	0·209 / 0 213	0·197 / 0·213	0·181 / 0·181	0·193 / 0·197	0·166 / 0 173	0·252 / 0·256
0·55 / 0·57	0·41 / 0·43	0 37 / 0·39	0 48 / 0 51	0·53 / 0·54	0·50 / 0·54	0·46 / 0·46	0·49 / 0·50	0·42 / 0·44	0·64 / 0·65
0·183	.	.	0·183	0·329 — 0·366	.	0·137	.	0·183	.
0·20	.	.	0·20	0·36 — 0·40	.	0·15	.	0·20	.
9·15	.	.	7·32	.	.	3·44	.	.	.
50	.	.	40	33	.	18 8	.	.	.

Stress on fish-plates.

Table giving the

Numbers	NAME OF RAILWAY / CLASS OF RAIL			Company of the Austro-Hungarian State Railways.	Kaiser Ferdinands Nordbahn.	
	CLASS OF RAIL			Vignoles.	Vignoles. — Short fish-plates.	Vignoles. — Long fish-plates.
1	Maximum load on wheel of locomotive		(tons) (kg.)	6·79 6000	6·79 6900	6·79 6900
2	Rail	Moment of inertia I	(sq. in. × sq. in.) (sq. cm. × sq. cm.)	20·73 863	22·85 951	22·85 951
		Moment of resistance	Z (cub. ins.) W (cub. cm.)	8·24 135	8·97 147	8·97 147
3	Sleeper	Width b	(ins.) (cm.)	11·8 30	10·2 26	10·2 26
		Half length l	(ins.) (cm.)	49·2 125	53·1 135	53·1 135
		Moment of inertia I'	(sq. in. × sq. in.) (sq. cm. × sq. cm.)	147·2 6125	184·3 7672	184·3 7672
4	Outer fish-plate	Length	(ins.) (cm.)	23·2 59·0	21·7 55·3	28·7 73·0
		Weight	(lbs.) (kg.)	24·2 11·0	19·1 8·7	27·2 12·4
		Moment of inertia	(sq. in. × sq. in.) (sq. cm. × sq. cm.)	6·78 281·94	5·60 232·7	5·60 232·7
		Moment of resistance	(cub. cm.) (cub. cm.)	3·09 50·7	2·75 45·0	2·75 45·0
5	Inner fish-plate	Length	(ins.) (cm.)	18·5 47·0	19·6 50·0	28·7 73·0
		Weight	(lbs.) (kg.)	15·8 7·2	15·8 7·2	23·3 10·6
		Moment of inertia	(sq. in. × sq. in.) (sq. cm. × sq. cm.)	3·08 128·14	3·46 143·9	3·46 143·9
		Moment of resistance	Z (cub. in.) W (cub. cm.)	1·51 24·7	1·56 25·5	1·56 25·5
6	Space between sleepers centre to center	Maximum	(ins.) (cm.)	33·8 86	30·7 78	30·7 78
		At fish-joint	(ins.) (cm.)	20·3 51·6	18·7 47·4	18·7 47·4
		Next to the fish-joint	(ins.) (cm.)	31·6 80·4	29·7 75·5	29·7 75·5
7	Coefficient of ballast		K =	$\frac{108·4}{289·0}$	$\frac{108·4}{289·0}$	$\frac{108·4}{289·0}$
			C =	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$
8	Stress according to Zimmermann	At the outer	(tons per sq. in.)	11·64 8·75	11·70 8·67	11·23 8·07
			(kg per sq. cm.)	1833 1378	1843 1366	1769 1271
		At the inner	(tons per sq. in.)	10·86 8·17	12·74 9·44	12·23 8·79
			(kg. per sq. cm.)	1711 1286	2007 1487	1925 1331

Note. — The French Southern is adopting a stronger fish-plate; but the dimensions are not stated.

DIX V.

stress on fish-plates.

Austrian Southern.	Egyptian.	French West.	Meridional Adriatic.	French Southern.	Belgian State.	Paris-Lyons-Mediterranean.	St-Gothard.
Vignoles.	Vignoles.	Double headed.	Vignoles.	Double headed.	Vignoles.	Vignoles.	Vignoles. — Iron sleepers.
6·89 7000	68·9 7000	6·94 7050	7·37 7490	7·38 7500	7·38 7500	7·51 7635	7·68 7800
22·44 934	34·54 1437·5	30·36 1263 6	24·22 1008	23·95 996·7	42·50 1769	37·86 1585·5	39·41 1640
8·76 143·5	12·19 199·7	10·36 169·7	9·26 151·7	9·08 148·8	14·65 240	13·61 223	13·55 222
10·2 26	9·8 25	10·2 26	9·4 24	10·8 27·5	11·0 28	7·8 20	8·6 21·9
47·2 120	51·1 130	53·1 135	51·1 130	53·1 135	51·1 130	51·1 130	49·2 125
153.2 6380	168·8 7031	104·9 4368	131·9 5488	107·5 4475	103·9 4326	135·2 5635	5·51 229
23·2 59·0	21·6 55·0	18·1 46·0	28·9 73·5	17·7 45·0	28·7 73·0	31·4 80·0	23·6 60·0
20·7 9·4	20·7 9·4	17·6 8·0	22 10	11·6 5·3	46·2 21	33·8 15·4	22 10
5·82 242	3·81 158·5	8·72 362·6	3·17 131·7	1·43 59·6	7·10 295·3	4·47 185·7	4·70 195 6
2·68 44 0	1·78 29·2	3·12 51·1	1·52 24·9	0·95 15·5	2·73 44·7	2·00 32·7	2·11 34·5
21·6 55·0	21·6 55·0	18·1 46·0	28·9 73·5	20·2 54·0	28·7 73·0	31·4 80·0	23·6 60·0
10·3 4·7	20·6 9·4	17·6 8·0	22 10·0	9·4 4·3	48·4 22 0	33·8 15·4	22 10·0
1·47 61	3·81 158·5	8·71 362·6	3·16 131·7	1·43 59·6	7·27 302·7	4·46 185·7	4·70 195·6
0·91 14·9	1·78 29·2	3·12 51·1	1·52 24·9	0·95 15·5	2·83 46·3	2·00 32·7	2·11 34·5
34·6 88	32·1 81·6	29·4 74·8	33·8 86	38 7 98·4	31·5 80	38·5 72·3	31·9 81
20·1 51	22·7 57·6	23·6 60 0	24·2 61·4	23·6 60	23·8 60·4	21·5 54·6	13·4 34
31·0 78·7	32·1 81·6	25·2 64·0	29·7 75·5	38·6 98·0	27·6 70	23·6 60	24·7 62·8
$\frac{108\cdot4}{289\cdot0}$	$\frac{108\cdot4}{289\cdot0}$	$\frac{108\cdot4}{289\cdot0}$	$\frac{108\cdot4}{289\cdot0}$	$\frac{108\cdot4}{289\cdot0}$	$\frac{108\cdot4}{289\cdot0}$	$\frac{108\cdot4}{289\cdot0}$	$\frac{108\cdot4}{289\cdot0}$
$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$
15·62 11 35	15·82 11·33	10·78 8·94	18·72 13·45	21·22 15·18	12·59 9·83	16·45 12·69	13·75 10·85
2460 1788	2492 1784	1697 1408	2949 2118	3343 2389	1983 1548	2590 1999	2165 1708
11·69 8·50	15·82 11·33	10·78 8·94	18·72 13·45	21·22 15·18	12·46 9·73	16·45 12·69	13·75 10·85
1841 1338	2492 1784	1697 1408	2949 2118	3343 2389	1963 1532	2590 1999	2165 1708

APPEN

Table showing sinking of sleepers, stresses on rails and sleepers, and pressure on ballast, in different
section corresponding to a moment of inertia I = 213·2 sq. in. × sq. in. (867·5

Number.	STATE OF PERMANENT WAY TO BE STRENGTHENED.	PARTICULARS OF SLEEPERS. Halflength of sleeper. l		Width of sleeper. b		Moment of inertia. I'		Moment of resistance. Z	W	Coefficient of ballast. K	C	Distance between sleepers. Centre to centre.		Load on wheels	
		Inches.	Cm.	Inches.	Cm.	Sq. in. × sq. in.	Sq. cm. × sq. cm.	Cub. in.	Cub. cm.	...	...	In.	Cm.	Tons.	Kilog.
1	Existing permanent way requiring to be strengthened	47·25	120	9·84	25	132·3	5508	41·37	678	108·4	3	35·4	90	6·89	7000
2	Strengthened by means of ballast . . .	...	. .	...	...	...	...	...	...	180·7	5	...	...	...	...
3	Strengthened by substituting sleepers of new normal pattern	53·16	135	10·24	26	184·3	7672	55·22	905	108·4	3	...	...	...	...
4	Combination of methods 2 and 3 . . .	...	...	...	...	...	...	...	...	180·7	5	...	...	...	...
5	Strengthened by increasing the number of sleepers	47·25	120	9·84	25	132·3	5508	41·37	678	108·4	3	30·7	78	...	...
6	Combination of methods 2 and 5 . . .	...	...	...	...	...	...	...	...	180·7	5	...	...	...	...
7	Combination of methods 3 and 5 . . .	53·16	135	10·24	26	184·3	7672	55·22	905	108·4	3	. .	...	...	...
8	Combination of methods 2, 3 and 5. . .	...	...	...	...	...	...	...	...	180·7	5	...	...	...	. .

DIX VI.

systems of superstructure with rails weighing 71 lbs per yard (35·2 kilog. per metre) with a cross sq. cm. × sq. cm) and a moment of resistance Z = 8·31 cub. in. (W = 136·2 cub. cm,).

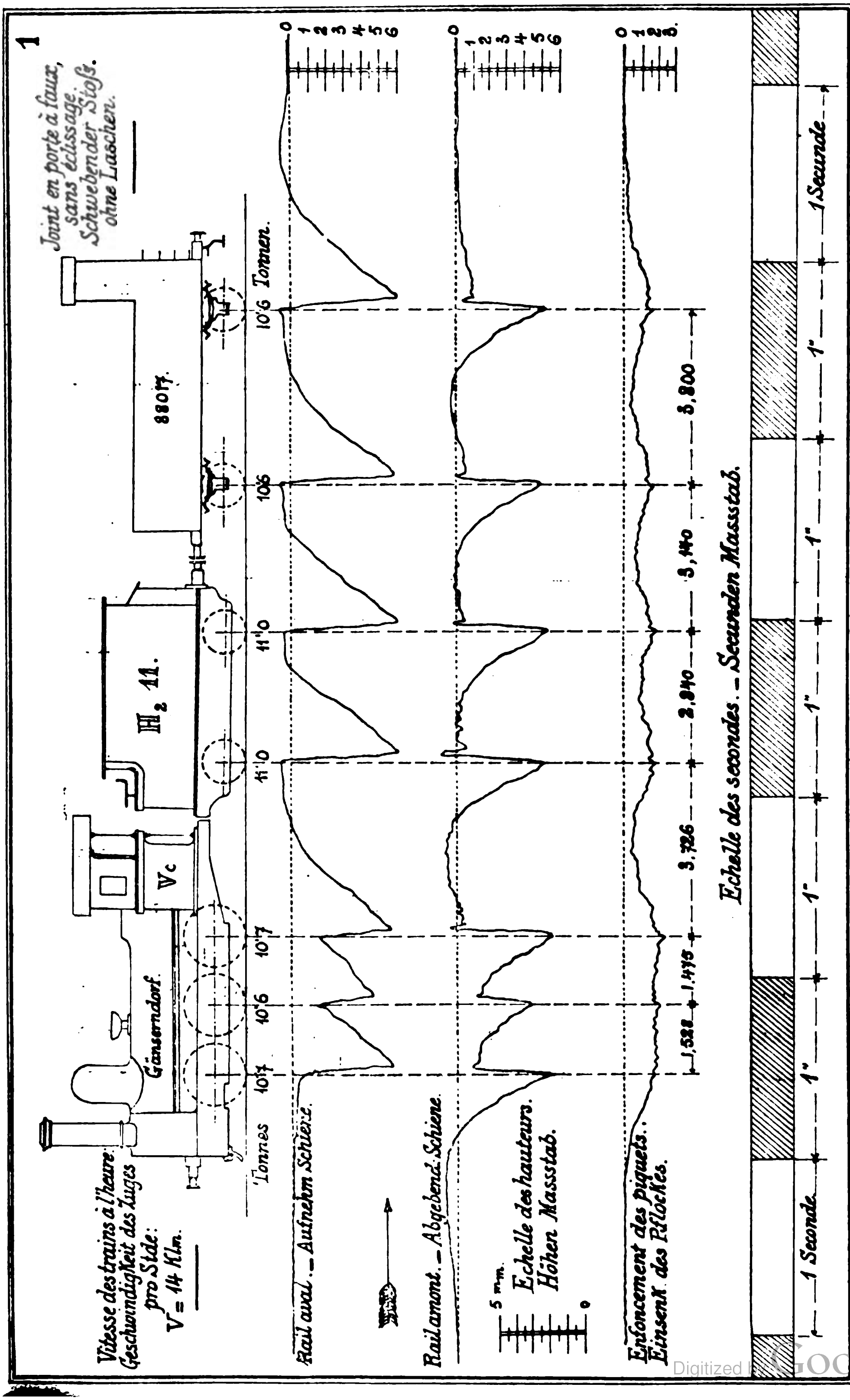
Pressure of rail.		Maximum sinking of sleeper.		BENDING MOMENT AND STRESS. On the rail. M		On the rail. σ		On the sleeper. M'		On the sleeper. σ'		Pressure on ballast.	
Tons.	Kilog.	In.	Cm.	Tons. Inch.	Kilog. × cm.	Tons per sq. in.	Kilog. per sq. cm.	Inch. Tons.	Kilog. × cm.	Lbs per sq. in.	Kilog. per sq. cm.	Lbs per sq. in.	Kilog. per sq. cm.
3·660	3719	0·224	0·5683	76·73	198032	9·23	1454·0	15·38	39708	834	58·6	24·25	1·7049
3·990	4054	0·149	0·3771	67·59	174445	8·13	1280·8	16·34	42175	865	62 2	26·82	1·8855
3·778	3839	0·172	0·4376	71·19	183740	8·57	1349·0	20 05	51808	814	57·2	18·67	1·3128
4·290	4359	0·122	0·3085	63·18	163077	7·60	1197·4	21·99	56761	892	62·7	21·94	1·5425
3·587	3645	0·219	0·5570	73·83	190576	8·88	1399·0	15·08	38921	816	57·4	23·77	1·6710
3·674	3733	0·137	0·3472	65·37	168716	7·87	1238·7	15·05	38838	815	57·3	24·69	1·7360
3·634	3692	0·166	0·4209	68·78	177599	8·28	1304·0	19·31	49828	784	55·1	17·96	1·2627
3·826	3887	0·108	0·2751	60·96	157334	7·34	1155·2	19·61	50614	795	55·9	19·56	1·3755

APPENDIX VII

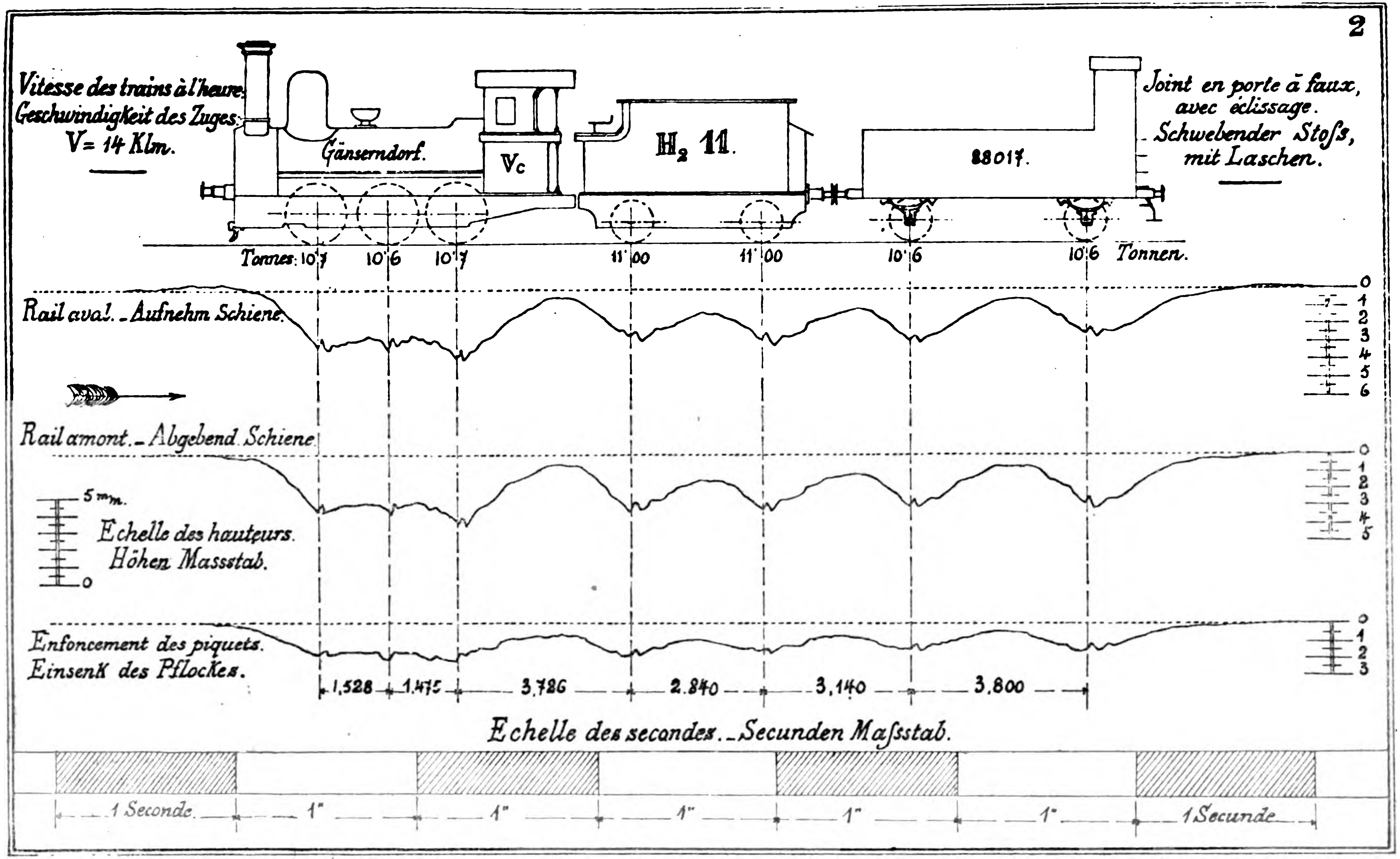
Diagrams showing the movements of the rail-ends and of the peg to which the scale is fixed at the fish-joint during the passage of a train.

BEILAGE VII

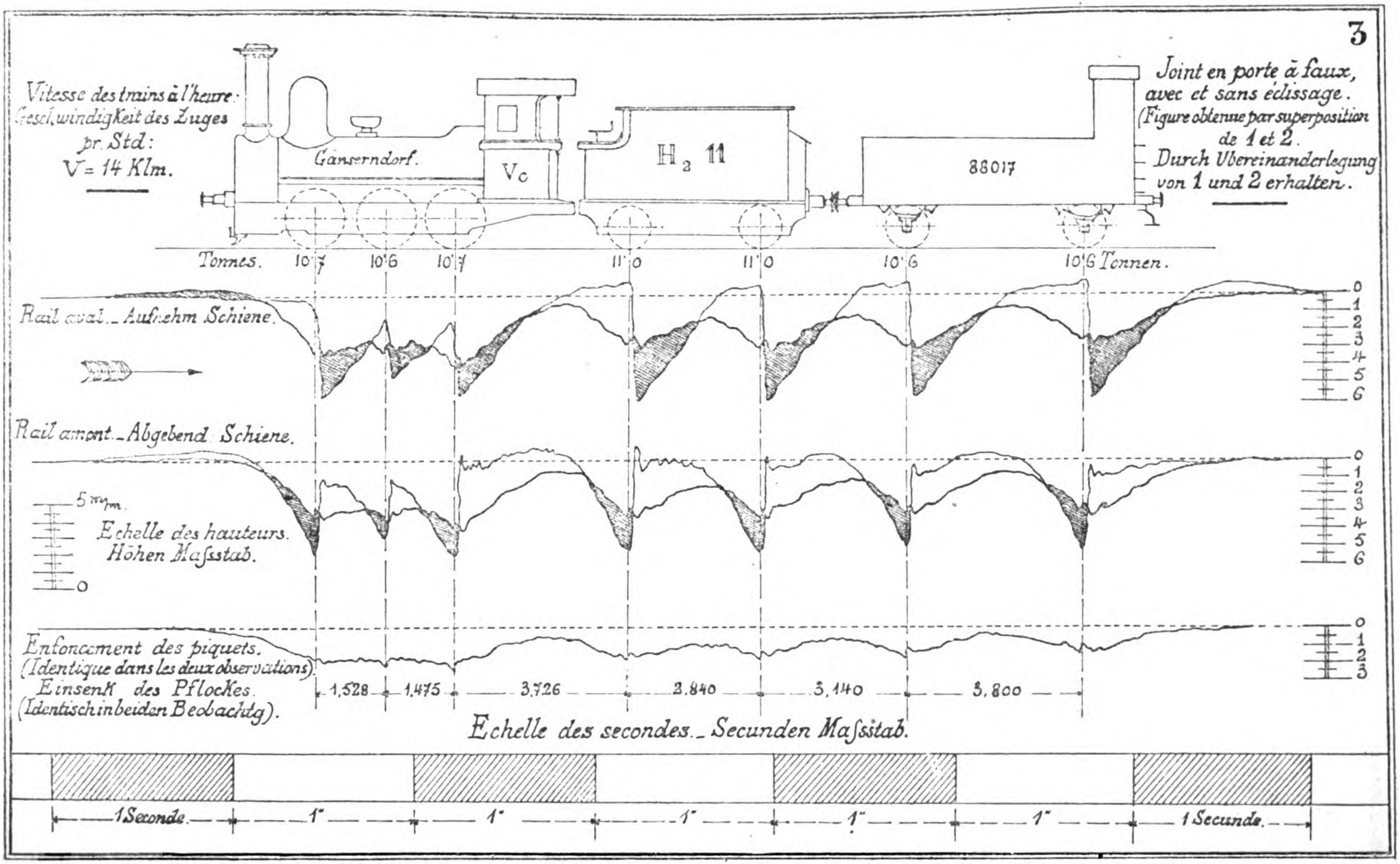
Diagramme der Einsenkungen der Schienenenden und des Pflockes, bei Befahren des Stosses durch einen Zug.



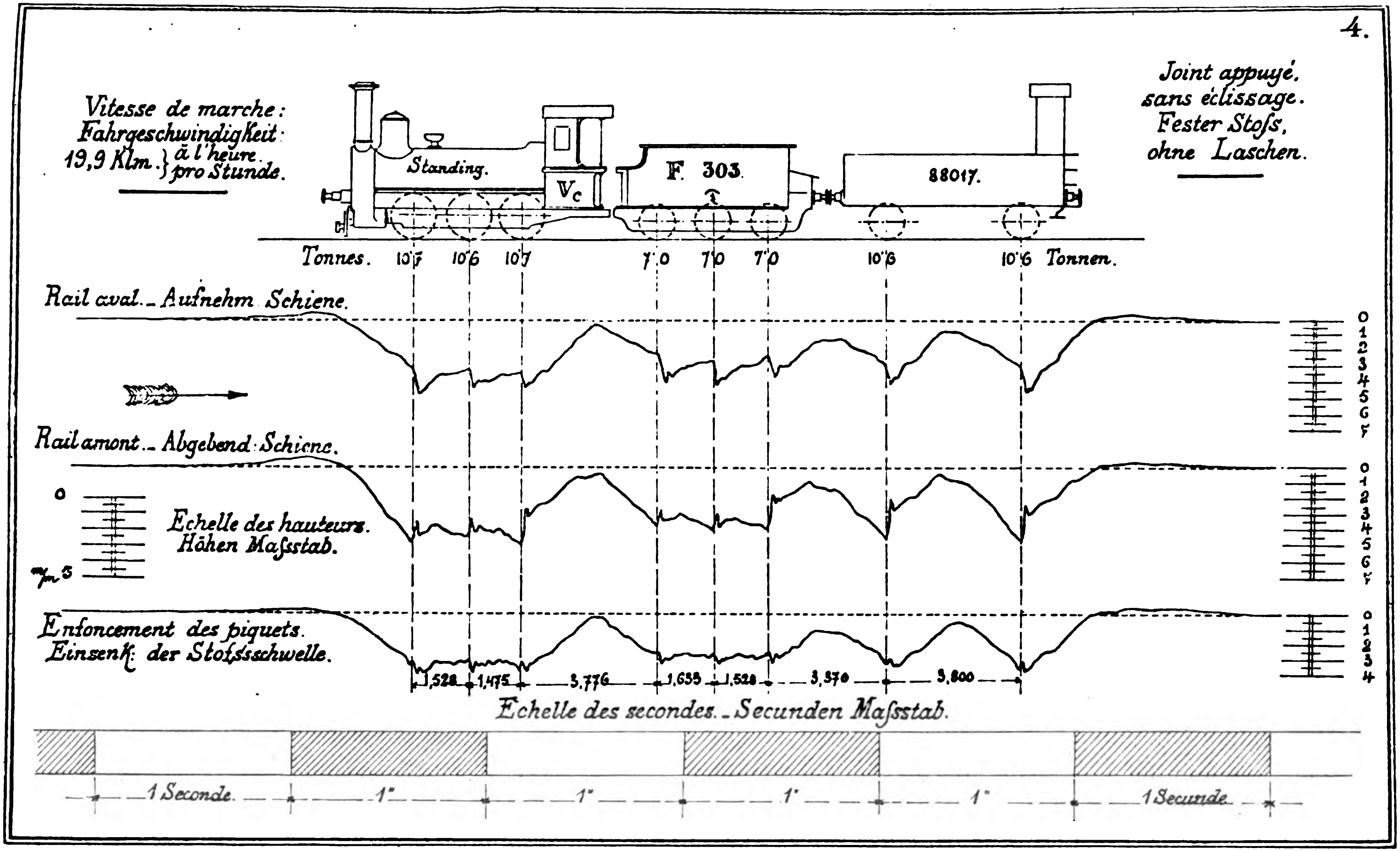
EXPLANATION OF GERMAN TERMS. — *Geschwindigkeit des Zuges pro Stunde : V = 14 klm.* = Speed of the train per hour : V = 8·70 miles. *10·7 tonnen* = 10·53 tons; *10·6 t.* = 10·43 t.; *10·7 t.* = = 10·53 t.; *11·0 t.* = 10·83 t.; *10·6 t.* = 10·43 t. *Schwebender Stoſs ohne Laschen* = Suspended fish-joints, without fish-plates. *Aufnehm Schiene* = Facing end of rail. *Abgebend Schiene* = Trailing end of rail. *Höhen Massstab* = Scale in millimetres. *Einsenk. des Pflockes* = Movement of peg to which scale is fixed. *1,528 millimetres* = 5·01 feet; *1,475 m.m.* = = 4·84 f.; *3,726 m/m.* = 12·24 f.; *2,840 m/m.* = 9·32 f.; *3,140 m/m.* = 10·30 f.; *3,800 m/m.* = 12·47 f. *Secunden Massstab* = Scale of seconds. *1 Secunde* = 1 second.



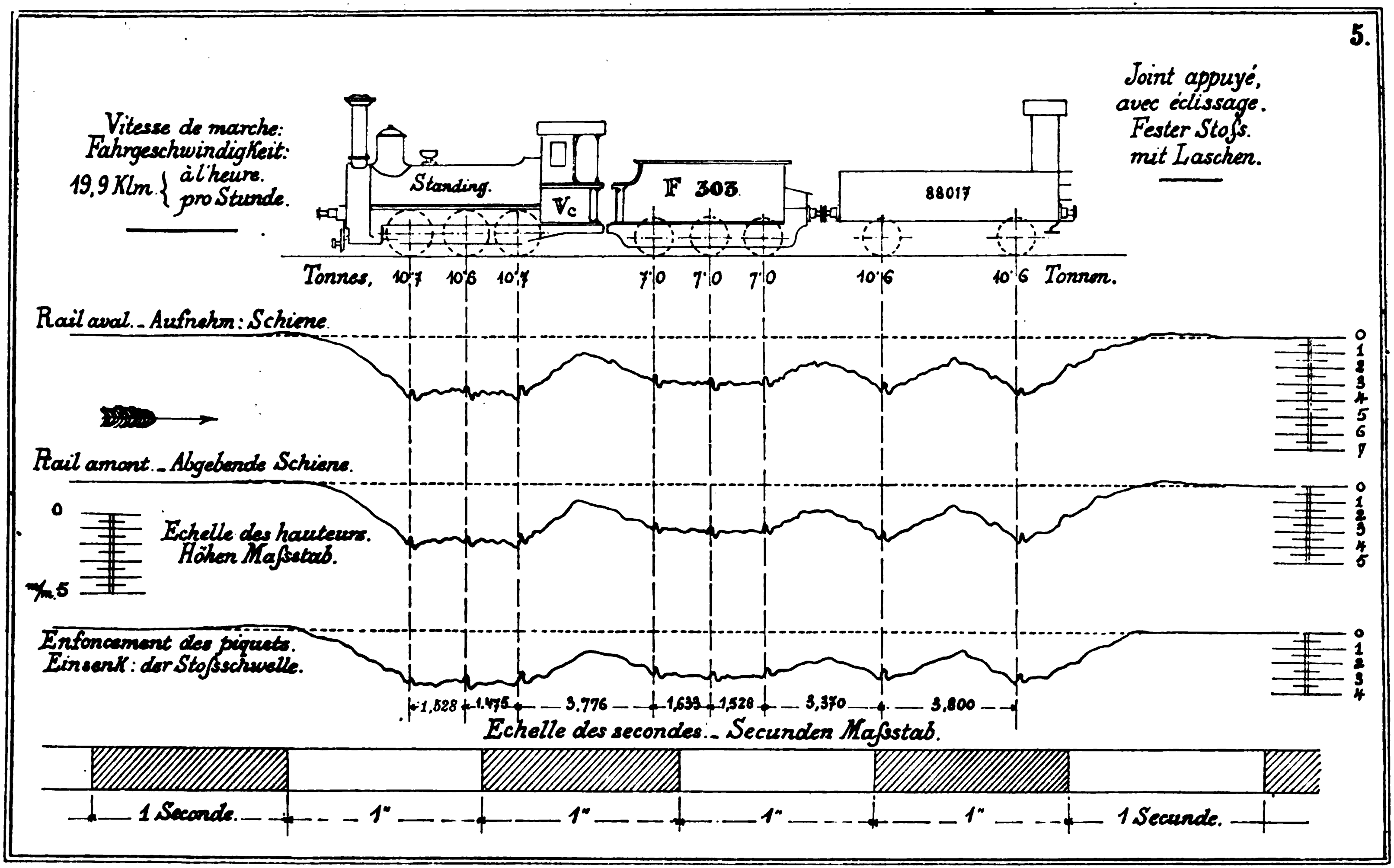
EXPLANATION OF GERMAN TERMS. — *Geschwindigkeit des Zuges : V = 14 klm* = Speed of the train per hour : V = 8·70 miles. *10·7 tonnen* = 10·53 tons; *10·6 t.* = 10·43 t.; *10·7 t.* = 10·8 t. *11·00 t.* = 10·83 t.; *10·6 t.* = 10·43 t. *Schwebender Stofs, mit Laschen* = Suspended fish-joint, with fish-plates. *Aufnehm Schiene* = Facing end of rail. *Abgebend Schiene* = Trailing end of rail. *Höhen Massstab* = Scale in millimetres. *Einsenk. des Pflockes* = Movement of peg to which scale is fixed. *1,528 millimetres* = 5·01 feet; *1,475 m/m.* = 4·84 f. *3,726 m/m.* = 12·24 f.; *2,840 m/m.* = 9·32 f.; *3,140 m/m.* = 10·30 f.; *3,800 m/m.* = 12·47 f. *Secunden Massab* = Scale of seconds. *1 Secunde* = 1 second.



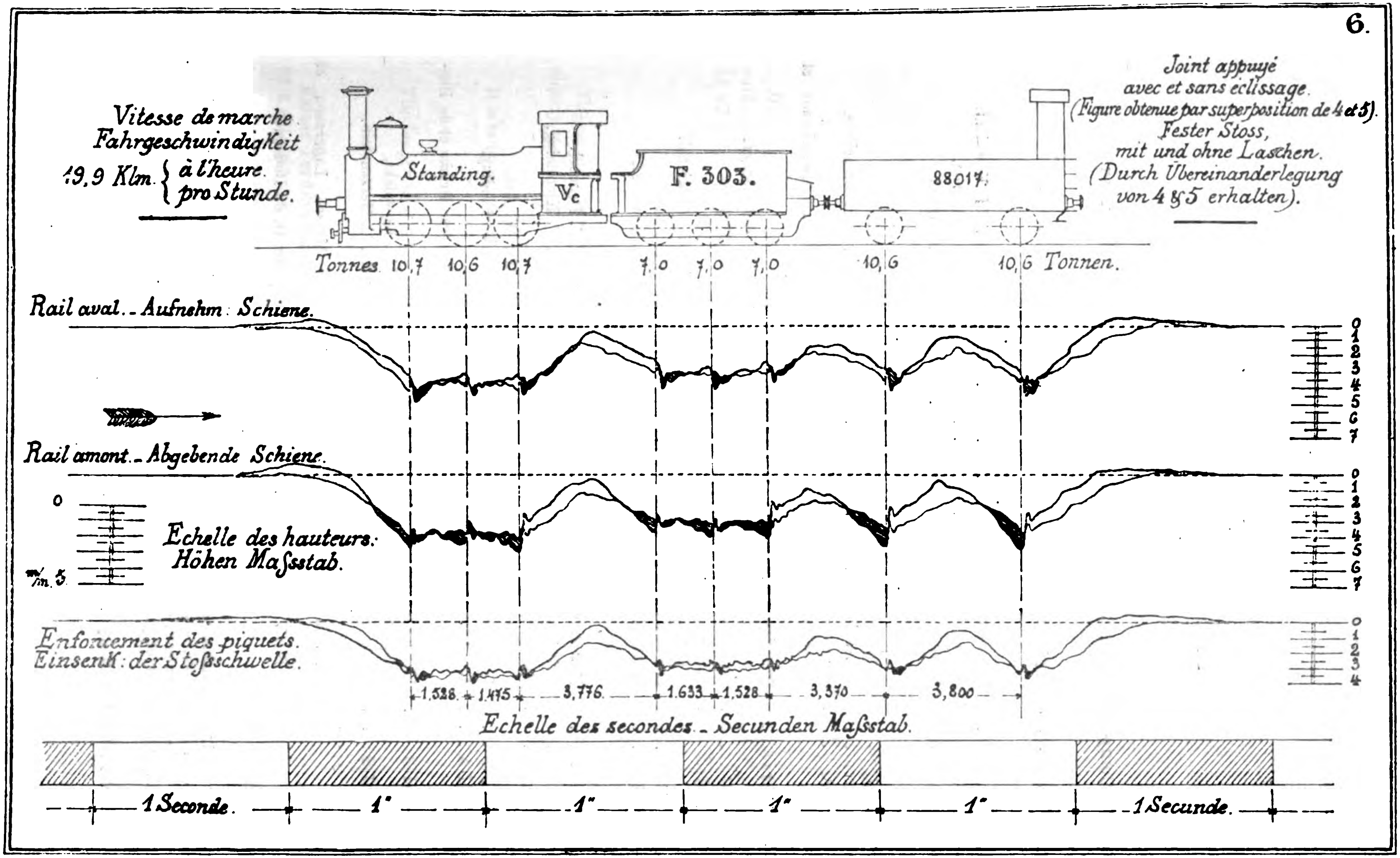
Explanation of German terms. — *Geschwindigkeit des Zuges pro Stund V = 14 klm.* = Speed of the train per hour: V = 8·70 miles. *10·7 tonnen* = 10.53 tons; *10·6 t.* = 10·43 t.; *10·7 t.* = = 10·53 t.; *11·0 t.* = 10·83 t.; *10·6 t.* = 10·43. *Durch Übereinanderlegung von 1 und 2 erhalten* = Suspended fish-joint with and without fish-plates, obtained by super-imposing 1 and 2. *Aufnehm Schiene* = Facing end of rail. *Abgebend Schiene* = Trailing end of rail. *Höhen Masstab* = Scale in millimetres. *Einsenk. des Pflockes (identisch in beiden Beobachtg)* = = Movement of peg - identical in both cases. *1,528 millimetres* = 5·01 feet; *1,475 m/m.* = 4·84 f.; *3,726 m/m.* = 12·24 f.; *2,840 m/m.* = 9·32 f.; *3,140 m/m.* = 10·30 f.; *3,800 m/m.* = 12.47 f. *Secunden Masstab* = Scale of seconds. *1 Secunde* = 1 second.



Explanation of German terms. — *Fahrgeschwindigkeit : V = 19·9 klm. pro Stunde* = Speed of the train per hour : V = 12·36 miles. *10·7 tonnen* = 10·53 tons; *10·6 t.* = 10·43 t.; *10·7 t.* = = 10·53 t.; *7·0 t.* = 6·89 t.; *10·6 t.* = 10·43 t. *Fester Stoss, ohne Laschen* = Supported fish-joint without fish-plates. *Aufnehm Schiene* = Facing end of rail. *Abgebend Schiene* = Trailing end of rail. *Höhen Masstab* = Scale in millimetres. *Einsenk. der Stofsschwelle* = Movement of peg by which scale is fixed to sleeper. *1,528 millimetres* = 5·01 feet; *1,475 m/m.* = 4·84 f.; *3,776 m/m.* = 12.39 f.; *1,633 m/m.* = 5·36 f.; *1,528 m/m.* = 5·01 f.; *3,370 m/m.* = 11·06 f.; *3,800 m/m.* = 12·47 f. *Secunden Masstab* = Scale of seconds. *1 Secunde* = 1 second.



EXPLANATION OF GERMAN TERMS. — *Fahrgeschwindigkeit : V = 19·9 klm pro Stunde* = Speed of the train per hour : V = 12·36 miles. *10·7 tonnen* = 10·53 tons; *10·6 t.* = 10·43 t.; *10·7 t.* = = 10·53 t.; *7·0 t.* = 6·89 t.; *10·6 t.* = 10·43 t. *Aufnehm. Schiene* = Facing end of rail. *Abgebende Schiene* = Trailing end of rail. *Höhen Masstab* = Scale in millimetres. *Einsenk. der Stosschwelle* = Movement of peg by which scale is fixed to sleeper. *1,528 millimetres* = 5·01 feet; *1,475 m/m.* = 4·84 f.; *3,776 m/m.* = 12·39 f.; *1,633 m/m.* = 5·36 f.; *1,528 m/m.* = 5·01 f.; *3,370 m/m.* = 11·06 f.; *3,800 m/m.* = 12·47 f. *Secunden Masstab* = Scale of seconds. *1 Secunde* = 1 second.



Explanation of German terms. — *Fahrgeschwindigkeit : V = 19·9 klm pro Stunde* = Speed of the train per hour : V = 12·36 miles. *10·7 tonnen* = 10·53 tons; *10·6 t.* = 10·43 t.; *10·7 t.* = = 10·53 t.; *7·0 t.* = 6·89 t.; *10·6 t.* = 10·43 t. *Fester Stoss, mit und ohne Laschen. (Durch Uebereinanderlegung von 4 und 5 erhalten* = Supported fish-joint with and without fish-plates, obtained by super-imposing 4 and 5. *Aufnehm. Schiene* = Facing end of rail. *Abgebende Schiene* = Trailing end of rail. *Höhen Massstab* = Scale of millimetres. *Einsenk. der Stofsschwelle* = Movement of peg by which scale is fixed to sleeper. *1,528 millimetres* = 5·01 feet; *1,475 m/m.* = 4·84 f.; *3,776 m/m.* = 12·39 f.; *1,633 m/m.* = 5·36 f.; *1,528 m/m.* = 5·01 f.; *3,370 m/m.* = 11·06 f.; *3,800 m/m.* = 12·47 f. *Secunden Massstab* = Scale of seconds. *1 Secunde* = 1 second.

APPENDIX VIII.

Bibliography.

Compte rendu général of the International Railway Congress.

I. — *Brussels Session 1885.*

Question I.	Types des voies ferrées.	Report by Mr. Lebon.

II. — *Milan Session 1887* (1).

Question II	Traverses métalliques	Report by Mr. A.-M. Kowalski.
— IV.	Entretien des voies	Report by Mr. L. Piéron.
— VI.	Voies très fatiguées	Report by Mr. Siegler.

III. — *Paris Session 1889* (1).

Question I-A.	Qualité du métal des rails	Report by Mr. Bricka.
— I-B.	Usure des rails d'acier	Report by Mr. L. de Busschere.
— II-A	Comparaison des voies à double bourrelet et des voies Vignoles.	Report by Messrs. Bemelmans et Bruneel.
— II-B	Fixation des rails Vignoles aux traverses en bois	Report by Mr. Hohenegger.
— II-C	Éclissage des rails	Report by Mr. Piéron.
— II-D	Lignes parcourues par des trains rapides.	Report by Mr. Jules Michel.
— VII-B . . .	Les bris des rails	Report by Mr. Bricka.
— VII-C . . .	L'entretien des voies métalliques. . .	Report by Mr. Kowalski.

IV. — *St. Petersburg Session 1892* (1).

Question III.	Entretien des voies.	Report by Mr. F. Bruneel.
— IV.	Effort des bandages sur les rails . . .	Report by Mr. V. Klemming.
— V-A	Relation entre la voie et le matériel roulant.	Report by Mr. W. Ast.
— VI.	Voies des trains rapides.	Report by Sir G. Findlay.
— VIII-A . . .	Les bris des rails et l'usure des rails d'acier	Report by Messrs. Bricka et de Busschere.
— VIII-B . . .	L'entretien courant des traverses métalliques	Report by Mr. Kowalski.
— VIII-C . . .	Les traverses en bois	Report by Mr. V. Herzenstein.
— IX.	Passage dans les courbes	
	A. Matériel roulant	Report by Messrs. Lancrenon et J. Morandiere.
	B. Voie	Report by Mr. G. du Bousquet.

Bulletin de la Commission internationale du Congrès des chemins de fer, vol. VIII, N° 5, May 1894, p. 347, 348. « Les progrès de la technique de l'exploitation des chemins de fer allemands dans les dernières années. » Meeting of the German Railway Technical Verein held at Strasburg in June 1893. Question 4 of group I : Strengthening of the track. (Verstærkung des Geleises.)

(1) The articles referred to all appeared also in the *Bulletin du Congrès*.

APPENDIX IX.

(Summary of the Replies of the Managements belonging to the Congress to the questions asked.)

We now proceed to give a summary of the most important data received in answer to our questions; and we desire to express our sincere thanks to the different Managements for the trouble and care they have taken in giving us this information.

Preliminary note.

Description of railways here taken into consideration : These questions only refer to railways on which there is a regular service of trains travelling at a speed of more than 31·07 miles (50 kilometres) per hour.

I. — Name of the railway.

1st *Name of the line, or of the section of the line.*

The name of the line or of the section of the line to which the following facts apply is to be clearly stated.

2nd *Number of tracks.*

It is to be stated, whether the line has one, two or more tracks.

3rd *Length.*

The length in use for traffic should be stated.

Kaiser Ferdinands Nordbahn. — Total mileage, 293·7 miles (472·7 kilometres); single line, 53·2 miles (85·6 kilometres) (18 p. c.); double line, 240·5 miles (387·1 kilometres) (82 p. c.).

Privileged Austro-Hungarian State Railway Co. — Total mileage, 438·7 miles (706 kilometres); single line, 196·7 miles (316·6 kilometres) (45 p. c.); double line, 242·0 miles (389·4 kilometres) (55 p. c.).

Austrian Southern Railway. — Total mileage, 1,053·7 miles (1,695·5 kilometres); single line, 630·4 miles (1,014·6 kilometres) (60 p. c.); double line, 423·1 miles (680·9 kilometres) (40 p. c.).

Meridional Railway. Adriatic System. — Total mileage, 1,761·6 miles (2,835 kilometres); single line, 1,359·5 miles (2,188 kilometres) (77 p. c.); double line, 402·01 miles (647 kilometres) (23 p. c.)

Italian Mediterranean System. — Total mileage, 1,511·7 miles (2,432·9 kilometres); single line, 899·0 miles (1,446·8 kilometres) (59·5 p. c.); double line, 612·7 miles (986·1 kilometres) (40·5 p. c.).

French State Railways. — Total mileage, 1,463·9 miles (2,356 kilometres); single line, 1,212·3 miles (1,951·9 kilometres) (83 p. c.); double line, 251·1 miles (404·1 kilometres) (17 p. c.).

Paris, Lyons and Mediterranean Railway. — Total mileage, 535·6 miles (862 kilometres); double line, 530·6 miles (854 kilometres) (99 p. c); single line, 4·97 miles (8 kilometres) (1 p. c.).

French Southern Railway. — Total mileage, 295·7 miles (476 kilometres); double line, 295·7 miles (476 kilometres) (100 p. c.).

Paris-Orleans Railway. — Total mileage, 361·6 miles (582 kilometres); double line, 361·6 miles (582 kilometres) (100 p. c.).

(The management remarks in its letter sent in reply to the questions that a speed of at least 34·17 miles (55 kilometres) is authorised throughout its system.)

French Northern Railway. — Total mileage, 369·1 miles (594 kilometres); double line, 369·1 miles (594 kilometres) (100 p. c.).

French Western Railway. — Total mileage, 2,815·4 miles (4,530·9 kilometres); single line, 1,667·8 miles (2,683·6 kilometres) (59 p. c.); double line, 1,147·8 miles (1,847·3 kilometres) (41 p. c.).

Belgian State Railways. — Total mileage, 474·2 miles (763·3 kilometres); double line, 474·2 miles (763·3 kilometres) (100 p. c.).

Dutch Railway Co. — Total mileage, 17·9 miles (28·8 kilometres); double line, 17·9 miles (28·8 kilometres) (100 p. c.).

Egyptian Railways. — Total mileage, 514·5 miles (828 kilometres); single line, 363·5 miles (585 kilometres) (71 p. c.); double line, 151·0 miles (243 kilometres) (29 p. c.).

Russian State Railways (St. Petersburg to Warsaw). — Total mileage, 799·6 miles (1,286·7 kilometres); single line, 92·8 miles (149·4 kilometres) (11·6 p. c.); double line, 706·6 miles (1,137·3 kilometres) (88·4 p. c.).

II. — Traffic on the lines.

1st *Class of train.*

The different classes of trains which run on the line are to be given here :— passenger trains :— express, through, stopping, and mixed; goods trains :— fast and slow; besides these, special passenger trains and special goods trains for certain materials (such as slate, chalk, stone, coal, ore, farm produce, etc.).

Vide 3rd.

2nd *Average composition of trains, and construction of vehicles.*

A sketch for each sort of train, showing the average composition, gross weight, weight per wheel, and space between each pair of wheels, etc., is to be given.

Vide appendix X.

What is the method of construction adopted for the engines and carriages of express trains?

a) Locomotives : fixed leading wheels or bogie, relative position of wheels to the fire-box, number and position of cylinders (inside or outside).

Kaiser Ferdinands Nordbahn. — Bogie, four-ocupled wheels, driving axle in front of fire-box, coupled axle under fire-box, two outside cylinders.

Privileged Austro-Hungarian State Railway Co. — Leading and trailing wheels with radial axle boxes, the trailing axle under the fire-box, driving and coupled axles in front of fire-box, two outside cylinders.

Austrian Southern Railway. — Bogie, four-coupled wheels, the coupled axle under the fire-box, two outside cylinders.

Gothard Railway. — Three types : 1st Bogie and six-wheels coupled, the third axle under the fire-box; 2nd bogie and four-wheels coupled, coupled axle behind the fire-box; 3rd six-wheels coupled, the third axle under the fire-box. The compound locomotives of type 1st have in some cases three, in others four cylinders. Those of the other two types have two outside cylinders.

Meridional Railway. Adriatic System. — Three types : 1st Leading wheels, four-coupled wheels driving axle in front of the fire-box, coupled axle under the fire-box; 2nd bogie, driving and coupled wheels as in type 1st; 3rd six-wheels coupled (position of cylinders not stated).

French State Railways. — Fixed leading wheels, four-coupled wheels, all axles in front of fire-box, two outside cylinders in front of the leading axle.

Paris, Lyons and Mediterranean Railways. — Since the winter of 1893-94, only locomotives converted into bogie engines have been used for expresses. They have four-wheels coupled, one axle in front of, the other behind, the fire-box, and two outside cylinders. (See note of Mr. Baudry, on the conversion of express engines P.-L.-M. into bogie engines, 1894, January number of the *Revue générale*).

French Southern Railway. — The leading axle has horn blocks inclined at 1 in 16, allowing a transverse play of 5/8 inch (16 millimetres); four-wheels coupled, one axle in front of, the other behind, the fire-box. Two outside cylinders placed nearly equally between the leading and driving axles.

Paris-Orleans Railway. — Locomotives without bogies, with eight wheels, the middle four of which are coupled, the leading and trailing axles are provided with inclined horn blocks so as to allow transverse play. The engines have generally two outside cylinders.

French Northern Railway. — Bogie, and four-wheels coupled; the driving axle in front of, the coupled axle behind, the fire-box. In some types the latter axle is under the fire-box. Most of the types have two cylinders; two types of compound engines have four cylinders.

French Western Railway. — Since 1889, the locomotives have had bogies, and the fire-box comes down between the coupled pairs of wheels. Inside cylinders above the bogie.

Belgian State Railways. — Two types : 1st On level roads a pair of leading wheels with radial boxes, four intermediary coupled wheels, and the trailing axle under the fire-box, two inside cylinders; 2nd on lines with steep gradients, a pair of leading wheels with radial boxes, six-wheels coupled, the third axle under the fire-box, two inside cylinders.

Dutch Railway Co. — Bogie, four-wheels coupled, two inside cylinders.

Egyptian Railways. — One pair of leading wheels, four-wheels coupled, the driving axle in front of, the coupled axle under the fire-box.

Russian State Railways (St. Petersburg to Warsaw). — Compound bogie engine, with four driving wheels; fire-box placed between the two pairs of coupled axles, two outside cylinders.

b) Passenger carriages : number and distance apart of the wheels; **rigid axle-boxes, radial axle-boxes or bogies. Types of wheel, and nature of the materials entering into their construction, and arrangement of the springs.**

Kaiser Ferdinands Nordbahn. — Two types : 1st Intercommunication carriages with six-wheels; distance between axles, 14 feet 9 1/8 inches + 14 feet 9 1/8 inches = 29 feet 6 1/4 inches (4·5 metres + 4·5m etres = 9 metres); radial axle-boxes. The middle axle has longitudinal play. 2nd Intercommunication carriages with four wheels; distance between axles, 15 feet 6 5/8 inches to 18 feet 1/2 inch (4·74 to 5·5 metres). Fixed axles. Both types have wheels with wrought iron spokes, and are fitted with laminated springs with adjustable supports.

Privileged Austro-Hungarian State Railway Co. — Three types : 1st Four-wheeled carriages having a lateral play of 3/4 inch (20 millimetres) to each side; distance between axles, 16 feet 7/8 inch to 17 feet 5/8 inch (4·9 to 5·2 metres); 2nd four-wheeled carriages with radial boxes; distance between axles, 18 feet 1/2 inch (5·5 metres); 3rd six-wheel coaches with radial boxes; distance between axles, 11 feet 5 3/4 inches + 11 feet 5 3/4 inches = 22 feet 11 1/2 inches (3·5 metres + 3·5 metres = 7 metres). Wheels with wrought iron solid bodies, or with wrought iron spokes; wheels of Martin cast steel, cast under pressure, tyres of Martin steel. All the carriages are carried on laminated suspension springs by intermediary oval links, or suspension links inclined at 45° to the horizontal.

Austrian Southern Railway. — Two types : 1st Carriages with four-wheels with fixed axle-boxes. Axles 15 feet 9 inches (4·8 metres) apart; 2nd carriages with four wheels, with radial boxes, axles 18 feet 8 1/2 inches (5·7 metres) apart. Wheels with wrought iron spokes, or wrought iron solid bodies, with axles and tyres of cast steel. The springs are arranged with adjustable suspension links.

French State Railways. — Two types : 1st In two express trains from Chartres to Bordeaux, eight-wheeled bogie carriages are used. Distance between bogies, 36 feet 1 inch (11 metres); space between bogie axles, 7 feet 10 1/2 inches (2·4 metres); 2nd on the other lines, and for all other trains, four-wheeled carriages, with fixed axle boxes, and axles 12 feet 3 1/2 inches (3·75 metres) apart. The wheels have cast solid bodies. (No information is given as to arrangement of springs.)

French Southern Railway. — All the passenger carriages are four wheeled, with axles from 14 feet 9 inches to 19 feet 1/4 inch (4·5 to 5·8 metres) apart. The axles are fixed; but at the same time some transverse and some longitudinal play is allowed by the horn plates to the axle-box.

The wheels have solid bodies with tyres fixed by « Mansell » rings. The axles and bodies are of iron, the tyres of steel. The suspension springs rest on top of the axle-boxes, they are attached to the frame by twin tie-rods.

Paris-Orleans Railway. — Two types : 1st Four-wheeled carriages with axles 18 feet 1/2 inch (5·5 metres) apart; 2nd eight-wheeled carriages on two bogies; distance between centres of bogies, 36 feet 10 1/2 inches (11·24 metres).

French Northern Railway. — Four-wheeled and also eight-wheeled carriages. Distance between axles, 8 feet 8 1/4 inches to 18 feet 8 1/2 inches (2·65 to 5·7 metres).

French Western Railway. — The carriages have four-wheels, always with fixed axle-boxes; space between the axles generally 12 feet 4 inches (3·76 metres); in the case of newer coaches, 18 feet 1/2 inch and 19 feet 4 1/4 inches (5·5 and 5·9 metres).

The wheels have solid iron bodies, the tyres and the axles are of steel. The springs, fixed to the top of the grease-box, are attached to the vehicles by means of inclined links.

Belgian State Railways. — Two types : 1st Six-wheeled carriages; distance between axles, 11 fee 5 3/4 inches + 11 feet 5 3/4 inches = 22 feet 11 1/2 inches (3·5 metres + 3·5 metres = 7 metres); 2nd eight-wheeled carriages on two bogies 29 feet 10 inches (9·1 metres) apart from centre to centre; space between the axles of the bogie, 7 feet 2 5/8 inches (2·2 metres). Wheels either with spokes or with a solid body of iron plate corrugated. The bosses are of iron, and the tyres of steel. The six-wheeled carriages have ordinary laminated springs; rubber blocks are interposed between the under frame and the body.

In the bogie carriages, the bodies are supported on the bogies by means of springs normal to the longitudinal axis of the carriage.

Dutch Railway Co. — Two types : 1st Six-wheeled carriages with corridors at the side; first and last axle 26 feet 3 inches (8 metres) apart; 2nd six-wheeled carriages with first and last axle 22 feet 11 1/2 inches (7 metres) apart.

Egyptian Railways. — Two types : 1st Four-wheeled carriages with axles 10 feet 11 7/8 inches (3·35 metres) apart; 2nd six-wheeled carriages with axles of from 10 feet + 10 feet = 20 feet (3·05 metres + 3·05 metres = 6·10 metres) to 11 feet 5 3/4 inches + 11 feet 5 3/4 inches = 22 feet 11 1/2 inches (3·5 metres + 3·5 metres = 7 metres) apart.

Russian State Railways (St. Petersburg to Warsaw). — There are no special carriages for express trains. The carriages used on express trains are six-wheeled; distance between axles = 10 feet 6 1/4 inches + 10 feet 6 1/4 inches = 21 feet 1/2 inch (3·202 metres + 3·202 metres = 6·404 metres). Iron wheels with spokes; the springs are hung in the usual way.

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c) Method of coupling (draw-gear).

Kaiser Ferdinands Nordbahn. — Old stock : screw coupling with hook and safety-chains (in accordance with the technical conventions of the Association of German Railway Managements). New stock : double screw couplings, without safety chains.

Privileged Austro-Hungarian State Railway Co. — All the new locomotives have screw couplings with springs.

The draw-gear of the older carriages is made with screw couplings after the manner of the standard coupling of the Association, and with two safety chains; on the new carriages, without safety-chains, it is made by means of a screw coupling.

Austrian South Railway. — Screw couplings and safety-chains.

French State Railways. — The coupling is made by means of a draw hook and two safety chains.

French Southern Railway. — The coupling is made by means of an ordinary coupling and two safety chains. The carriages are provided with four spring-buffers.

Paris-Orleans Railway. — The coupling is made by means of a draw-hook acting on a draw-spring, which has an initial pressure of 2·36 tons (2,400 kilog.).

French Western Railway. — The vehicles carry two spring-buffers and are drawn by means of a screw coupling acting on a draw-spring. Besides this they are provided with two safety chains at each end.

Belgian State Railways. — The ordinary coupling is made by means of a screw coupling and two safety chains. The draw-springs and buffer springs are laminated.

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Dutch Railway Co. — The couplings are made in accordance with the technical conventions of the Association of German Railway Managements.

Russian State Railways (St. Petersburg to Warsaw). — Ordinary screw couplings placed in the longitudinal axis of the carriages, with safety chains at each side.

3rd *Annual average traffic on lines, classified according to kind of train.*

Average actual speed in miles (and kilometres) per hour.

Kaiser Ferdinands Nordbahn.

	Speed on different sections.		Mean (V.).	
	Miles.	Kilom.	Miles.	Kilom.
Expresses	30·8 39·8	49·5 64·0	35·5	57·1
Special expresses	29·8 34·9	48·0 56·2	32·9	52·9
Passenger (ordinary)	21·2 24·9	34·2 40·1	24·0	38·6
Special passenger (ordinary)	21·2 24·9	34·2 40·1	24·2	38·9
Fast goods	19·2 20·4	30·9 32·9	19·6	31·5
Ordinary goods	11·2 13·5	18·1 21·8	11·9	19·2
Coal	11·2 13·5	18·1 21·8	12·3	19·8

Privileged Austro-Hungarian State Railway Co.

	Speed on different sections.		Mean (V.).	
	Miles.	Kilom.	Miles.	Kilom.
Orient-Express	36·0	58	36·0	58
Expresses	28·0 37·9	45-61	...	...
Ordinary passenger	21·7 28·0	35-45	...	...
Local	18·6 21·7	30-35	...	...
Slow passenger	16·2	26	16·2	26
Mixed	17·4	28	17·4	28
Fast goods	12·4 22·4	20-36	...	...
Ordinary goods	12·4 17·4	20-28	...	..

Austrian Southern Railway.

	Speed on different sections.		Mean (V.).	
	Miles.	Kilom.	Miles.	Kilom.
Expresses	23·0 34·8	37-56	...	...
Ordinary passenger	18·0 25·5	29-41	...	...
Mixed	14·3 24·8	23-40	...	...
Fast goods	9·9 18·0	16-29	...	...
Ordinary goods	8·7 18·0	14-29	...	...

Meridional Railway Adriatic System.

The average speeds are given including stops.

	Speed on different sections.		Mean (V.).	
	Miles.	Kilom.	Miles.	Kilom.
Expresses	24·2 40·4	39-65	40·1	64·5
Through	21·1 34·8	34-56	29·5	47·5
Semi-through	18·6 28·6	30-46	...	...
Ordinary passenger	14·9 23·0	24-37	...	...
Mixed	13·0 18·6	21-30	15·8	25·4
Goods also carrying passengers	9·9 19·3	16-31	13·4	21·5
Goods	6·2 13·0	10-21	10·1	16·2

French State Railways.

	Miles.	Kilometres.
Expresses	37·3	60·0
Ordinary passenger, Mixed, Light	29·5	47·5
Goods	12·4	20·0

French Southern Railway.

	Miles.	Kilometres.
Fast expresses (Rapides)	47·8	77
Ordinary expresses	42·3	68
Ordinary passenger	36·0	58
Mixed	31·1	50
Goods	18·6	30

Paris-Orleans Railway.

	Miles.	Kilometres.
Fast expresses (Rapides)	46·6	75
Ordinary expresses, passenger and mixed	31·1 37·3	50-60
Goods	15·5	25

French Northern Railway.

The average speed of the trains reaches its highest point, 54·7 miles (88 kilometres) an hour, on the section of line between Creil and Amiens, and falls to 40·4 miles (65 kilometres) an hour between Boulogne and Calais.

French Western Railway.

	Miles.	Kilometres.
Fast expresses (Rapides)	43·5 46·6	70-75
Ordinary expresses	40·4 43·5	65-70
Ordinary passenger	28·0 37·3	45-60
Mixed	24·8 31·1	40-50
Express goods	31·1 37·3	50-60
Fast goods	18·6 24·8	30-40
Ordinary goods	12·4 18·6	20-30

Dutch Railway Co.

	Miles.	Kilometres.	
Expresses	41·0	66·0	
Through.	39·5	63·5	
Ordinary passenger	28·8	46·3	Including stops.
Light.	16·5	26·5	

Egyptian Railways.

	Speed on different sections.		Mean (V).	
	Miles.	Kilom.	Miles.	Kilom.
Expresses.	23·6 37·3	38-60	32·1	51·7

Russian State Railways.

	Miles.	Kilometres.
Fastest expresses and mail	33·5	54
Ordinary mail and passenger	26·1	42
Mixed	20·5	33
Goods, military and workmen's.	15·5	25

The annual number of trains in each direction; for double lines, the annual number of trains running on the down line I to be given (from. . . . . to. . . .) and the number of trains on the up line II.

Note. — The Managements not having, for the most part, furnished us with entirely separate statements about the traffic on the line in both directions, we have given here the mean number of trains Z which have traversed every mile (kilometre) of each section (vide I) per year.

If for a given section of the line, and for the different kinds of trains running on it :—

k = The length of the line in miles (kilometres);

z = The average number of trains which have run over the length of line k;

v = The average speed,

we find for a number of different sections of the line the mean :—

$$Z = \frac{\Sigma (z \cdot k)}{\Sigma (k)} \text{ and } V = \frac{\Sigma (z \cdot k \cdot v)}{\Sigma (z \cdot k)}$$

Kaiser Ferdinands Nordbahn.

	On different sections.	Mean (Z).
Expresses	1460-2190	1531 (17·5 %)
Special expresses	11-57	45 (0·5 %)
Passenger (ordinary)	1555-4380	1807 (20·6 %)
Special passenger (ordinary)	18-54	44 (0·5 %)
Fast goods	0-1460	964 (11·0 %)
Ordinary goods.	1530-1959	1675 (19·1 %)
Coal.	0-3289	2692 (30·8 %)
		8758 (100 %)

Privileged Austro-Hungarian State Railway Co.

	The entire line (vide I) has been traversed.	
	On different sections.	Mean (Z).
Expresses	0-1682	927 (20·4 °/₀)
Ordinary passenger	730-4239	1523 (33·6 °/₀)
Slow passenger	0-1220	93 (2·0 °/₀)
Mixed	0-365	18 (0·4 °/₀)
Goods	889-4552	1976 (43 6 °/₀)
		4537 (100 °/₀)

Besides these, these sections of line have been partially traversed by the following trains :—

Expresses	0-393	The mean cannot be calculated from the information given.
Ordinary passenger	0-3184	
Slow passenger	0-1919	
Mixed trains	0-730	
Goods trains	0-6013	

Meridional Railway Adriatic System.

	On different sections.	Mean (Z).
Expresses	0-730	139 (2·5 °/₀)
Through	730-1460	1044 (19·1 °/₀)
Special passenger	2-71	22 (0·4 °/₀)
Ordinary and semi-through trains	730-4380	1859 (34·1 °/₀)
Mixed	0-2555	755 (13·9 °/₀)
Goods also carrying passengers	0-874	180 (3·3 °/₀)
Goods	155-3410	1004 (18·4 °/₀)
Special goods	21-1306	451 (8·3 °/₀)
		5454 (100 °/₀)

French State Railways. — Total number of trains for the different sections, 2,227 to 16,709. No information as to kinds of trains.

French Southern Railway. — In 1893, the section between Bordeaux and Langon of the Bordeaux-Cette line has been traversed in each direction by about 7,400 trains.

Paris-Orleans Railway. — On an average each line is annually traversed by 10,950 trains.

French Western Railway.

	On different sections.	Mean (Z.).
Fast expresses (Rapides)	730- 4380	2054 (6·6 °/₀)
Ordinary expresses	1825- 6935	3581 (11·5 °/₀)
Through	365- 9855	3938 (12·6 °/₀)
Ordinary passenger	1460-12045	3982 (12·8 °/₀)
Light	0-8030	3563 (11·5 °/₀)
Parcel trains	365- 4380	2258 (7·3 °/₀)
Goods	2190-17520	11756 (37·7 °/₀)
		31132 (100 °/₀)

Besides these, some pick-up goods trains, of which the number is not given, have been run over different sections.

Dutch Railway Co.

	Mean (Z.).
Expresses	3650 (21·75 %)
Through	3650 (21·75 %)
Ordinary passenger	3650 (21·75 %)
Light stopping	2190 (13·05 %)
Fast goods	2555 (15·2 %)
Goods	1095 (6·5 %)
	16790 (100 %)

Egyptian Railways.

	On different sections.	Mean (Z.)
Expresses	182-1065	665

The number of trains on the sections with most traffic is, for 1893, as follows :—

Expresses	212-1065
Ordinary passenger	509-2052
Mixed	365-380
Goods	455-4412

Russian State Railways.

Number of trains for the year 1893 :—

Expresses, imperial, special for private persons and on Company's service	322
Expresses and fast mail trains	1273
Ordinary mail and passenger	5252
Mixed	1095
Goods, military and workmen's	32736
	40678

4th *Wear of the line due to the action of the brakes.*

Information is to be given with regard to the average length of line that is traversed by trains of each sort with the brake on, together with the average number of wheels braked and the weight on them.

French Southern.

On the average, one stoppage takes place in the case of :—

Expresses	every 31·1 miles (50 kilometres).
Fast	— 12·4 — (20 —).
Ordinary passenger and mixed	— 3·7 — (6 —).
Goods	— 5·6 — (9 —).

In order to stop passenger trains, it is necessary to apply the brakes for about 547 yards (500 metres); in the case of mixed and goods, about 875 yards (800 metres). Express, fast and ordinary passengers are furnished with continuous brakes; mixed and goods have (including tender) 12 wheels braked.

French Western Railway. — The wear on the rails at the stations where all the trains stop is on an average twice, at a maximum four or six times, as great as on the other parts of the line, and on these other parts the wear averages 0·295 to 0·345 inch (0·75 to 0·80 millimetre) per 100,000 trains.

III. — Construction of the permanent way.

1st *Rails.*

The following are to be given :—

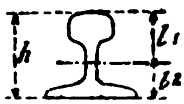
The cross-section of the rail (flat bottomed, symmetrical and unsymmetrical double headed).

The moment of inertia. . . . . I = sq. in. × sq. in. (I_1 = sq. cm. × sq. cm.).

The moment of resistance. . . . . . . $Z = \frac{I}{y_1}$ = cub. inch ($W = \frac{I}{l_1}$ = cub. cent.).

Length of rails . . . . L = feet (L = metres).

Depth of rails . . . . h = inches (h = millimetres).



Position of neutral axis $\begin{cases} y_1 = \text{inches } (l_1 = \text{millimetres}). \\ y_2 = \text{inches } (l_2 = \text{millimetres}). \end{cases}$

Weight of rails . . . . W = lbs per yard (G = kg. per metre)

NAME OF RAILWAY.	CROSS SECTION OF RAIL.	I	I_1	$Z=\frac{I}{y_1}$	$W=\frac{I}{l_1}$	L		h		y_1 inches.	l_1 mm.	y_2 inches.	l_2 mm.	W lbs per yard.	G kg. per metre.
		sq. in. × sq. in.	sq. cm. × sq. cm.	cub. in.	cub. cm.	feet.	metres.	inches.	mm.						
Kaiser Ferdinands Nordbahn	Flat-bottomed	22·86	951	8·97	147	29·5 41·1	9 12·5	5·00	127	2·51	64·62	2·46	62·38	71·1	35·3
Privileged Austro-Hungarian State Railway Company	Do.	20·74	863	8·24	135	29·5	9	4·92	125	2·52	64	2·40	61	66·5	33
Austrian Southern Railway	Do.	22·45	934	8·76	143·5	32·8	10	5·04	128	2·56	65·1	2·48	62·9	68·5	34
Gothard Railway	Flat-bottomed, section IV	39·40	1640	13·55	222	39·4	12	5·71	145	2·80	71·1	2·91	73·9	92·7	46
	Do. section IVa for tunnels	42·76	1780	14·71	241	39·4	12	5·79	147	2·87	73	2·92	74·0	96·7	48
Meridional Railway Adriatic System	Flat-bottomed, type 1	24·22	1008	9·26	151·7	29·5	9	5·12	130	2·62	66·46	2·50	63·54	72·6	36
	Do. type 2	23·19	965	9·03	148	39·4	12	4·92	125	2·56	65	2·36	60	72·6	36
Italian Mediterranean System	Flat-bottomed, section A, type n° 2, 1 F C and V⁴	24·22	1008	9·26	151·7	19·7 29·5 39·4	6 9 12	5·12	130	2·62	66·46	2·50	63·54	72·6	36
	Flat-bottomed, section B, type M	23·19	965	9·03	148	19·7 20·7 39·4	6 6·3 12	4·92	125	2·56	65	2·36	60	72·6	36
Sicilian Railway	Flat-bottomed	24·22	1008	9·26	151·7	29·5	9	5·12	130	2·62	66·46	2·50	63·54	72·6	36
French State Railways	Bull-headed	30·27	1259·9	10·01	164	36·1	11	5·71	145	2·69	68·3	3·02	76·7	80·6	40
	Double-headed symmetrical	22·33	929	8·54	140	36·1 18·0	11 5·5	5·21	132·4	2·61	66·2	2·60	66·2	76·6	38
	Do. do.	21·17	881	8·27	135·5	21·3	6·5	5·12	130	2·56	65	2·56	65	70·5	35
	Flat-bottomed	...	...	...	...	21·3	6·5	5·12	130	2·87	73	2·24	57	70·5	35
Paris, Lyons and Mediterranean	Flat-bottomed	38·09	1585·5	13·61	223	39·4	12	5·59	142	2·80	71·03	2·79	70·97	96·7	48
French Southern Railway	Double-headed symmetrical	23·95	996·7	9·06	148·8	36·1	11	5·27	134	2·64	67	2·64	67	76·6	38
Paris-Orleans Railway	Bull-headed	29·36	1221·6	9·32	152·7	36·1	11	5·71	145	2·56	65	3·15	80	85·7	42·5
French Northern Railway	Flat-bottomed	38·12	1586·125	12·50	204·84	39·4	12	5·67	144	3·05	77·43	2·61	66·57	90·7	45
	Bull-headed	30·37	1263·6	10·36	169·7	39·4	12	5·59	142	2·66	67·53	2·93	74·47	88·7	44
French Western Railway	Double-headed symmetrical	22·59	940	8·82	144·6	39·4 26·2	12 8	5·12	130	2·56	65	2·56	65	78·1	38·75
	Flat-bottomed	19·09	794·4	7·66	125·5	26·2	8	4·92	125	2·43	61·71	2·49	63·29	60·5	30
Belgian State Railways	Flat-bottomed	42·50	1769	14·65	240	generally 29·5 a few are 19·7	9 6	5·71	145	2·90	73·72	2·81	71·28	104·8	52
Dutch Railway Company	Do.	26·07	1085	9·58	157	32·1	9·8	5·12	130	2·40	61	2·72	69	77·8	38·6
Egyptian Railways	Double-headed symmetrical, type 1-2	19·94	829·9	7·91	129·7	42·0	12·8	5·04	128	2·52	64	2·52	64	71·9	35·7
	Flat-bottomed, type 3, old section	23·62	982·7	8·95	146·7	21·0	6·4	4·92	125	2·64	67	2·28	58	69·5	34·46
	Flat-bottomed, type 4	25·35	1054·9	9·61	157·5	26·2 39·4	8 12	5·16	131	2·64	67	2·52	64	74·6	37
	Flat-bottomed, type 5	34·54	1437·5	12·0	199·7	39·4	12	5·51	140	2·83	72	2·68	68	84·7	42
Russian State Railways (St. Petersburg to Warsaw)	Flat bottomed	21·26	884·8	8·37	137·2	28·0	8·534	5·00	127	2·54	64·51	2·46	62·49	65·5	32·5

Metal : class and process of manufacture (acid or basic ; Martin steel).

Tensile strength. . . . . F = tons per sq. in. (= kg. per sq. cm.)
Contraction of area . . . C = per cent.
Elongation. . . . . . . D = per cent.

Kaiser Ferdinands Nordbahn.

Martin basic steel .	F. . .	34 9 42·5 (5,500 6,700)	according to manufacturer's tests.
	C. . .	20·5 53·3	
	D. . .	14·5 23	

Privileged Austro-Hungarian State Railway Co.

Bessemer steel	F	34·9 (5,500)
	D	15

Austrian Southern Railway.

Martin steel	F	4·19 (6,600)
	D	17

Gothard Railway.

Basic steel produced in converter.	F (average)	41·3 (6,500)
	D (average)	20

Meridional Railway. Adriatic System.

Acid Bessemer or Martin steel.	F (average)	35·6 (5,600)
	D (average)	20

Italian Mediterranean System.

Acid Bessemer or Martin steel also iron.	F	34·9 38·1 (5,500-6,000)
	D (above).	18

Sicilian Railway.

Only steel manufactured by the Bessemer or Martin process.

French State Railways.

Basic Bessemer	F	44·5 50·8 (7,000-8,000)
	D (about).	8
Acid Bessemer	F	47·6 (7,500)
	D	11
Iron	... ...	...

Paris, Lyons and Mediterranean Railway.

Martin steel	F (average)	44·5 (7,000)
	D	12

French Southern Railway.

Hard steel produced by the acid Bessemer or Martin process.	F . .	49·5 62·2 (7,800-9,800)	Manufacturer's tests.
	D . .	4-15	

Paris-Orleans Railway.

Acid Bessemer steel	F	44·5 50·8 (7,000-8,000)
	D	15-10

French Northern Railway.

Bessemer or Martin steel	F	45·4 (7,150)
	D	15·40

French Western Railway.

Bessemer or Martin Steel acid and basic.	F, at least 44·5 (7,000)
	D, at least 8 for a length of 3·94 inches (10 cm.).

Belgian State Railways.

Steel; class not specified, but it must satisfy these conditions :—	F	at least 38·1 (6,000)
	D	at least 13

Dutch Railway Co.

Bessemer steel	F	39·4 (6,200)
	D	19·5

Egyptian Railways.

Mild or Bessemer steel	F	39·4 (6,200)
	C	37
	D	25
Iron	...	...
Bessemer steel	F	42·5-47 (6,700-7,400)
	C	23
	D	14
Bessemer steel	F	44·5-45·7 (7,000-7,200)
	C	14
	D	11

There is no intention of substituting Martin or Thomas steel for the Bessemer.

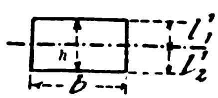
2nd *Sleepers.*

The material should be named.

(In the case of iron or steel sleepers the tensile strength F and the elongation D should be given.)

The cross section.

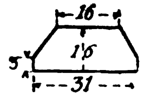
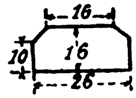
Weight per sleeper	w = pounds (g = kilograms).
Width of under surface	b = inches (b = centimetres).
Thickness	h = inches (h = centimetres).
Length	l = feet (l = metres).
Moment of inertia	I_1 = sq. in. × sq. in. (I_1 = sq. cm. × sq. cm.).
Moment of resistance	$Z_1 = \frac{I_1}{y_1'}$ = cub. in. ($W_1 = \frac{I}{l_1'}$ = cub. cent.).



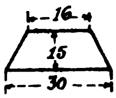
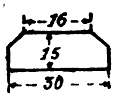
Position of neutral axis	y_1' = inches (l_1' = centimetres).
	y_2' = inches (l_2' = centimetres).

Kaiser Ferdinands Nordbahn.

Oak treated with chloride of zinc.

	Section	w (g).	b.	h.	l.	I_1.	Z_1 (W_1).	y_1' (l_1').	y_2' (l_2').
Old section		226·8 (102·9)	12·20 (31)	6·30 (16)	7·87 (2·4)	193·00 (8034)	55·10 (903)	3·51 (8·9)	2·79 (7·1)
New section		284·4 (129·0)	10·23 (26)	6·30 (16)	8·86 (2·7)	184·30 (7672)	55·22 (905)	3·33 (8·47)	2·97 (7·53)

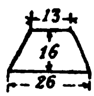
Privileged Austro-Hungarian State Railway Co.

	Section	w (g).	b.	h.	l.	I_1.	Z_1 (W_1).	y_1' (l_1').	y_2' (l_2')
Oak.	 	176·4 about (80)	11·81 (30)	5·91 (15)	8·20 (2·5)	147·12 (6125)	46·73 (766)	3·15 (8)	2·76 (7)

Austrian Southern Railway.

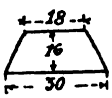
Oak, larch, and beech. The two latter are impregnated with sulphate of copper or chloride of zinc.

Intermediary sleepers :—



	w (g).	b.	h.	l.	I_1.	Z_1 (W_1).	y_1' (l_1').	y_2' (l_2').
Oak	147·7-180·8 (67-82)							
Larch	108·0-160·9 (49-73)	10·23 (26)	6·30 (16)	7·87 (2·4)	153·27 (6380)	43·75 (717)	3·51 (8·9)	2·79 (7·1)
Beech	143·3-160·9 (65-73)							

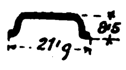
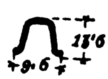
Sleepers at fish-joints :—



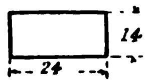
	w (g).	b.	h.	l.	I_1.	Z_1 (W_1).	y_1' (l_1').	y_2' (l_2').
Oak	178·6-220·5 (81-100)							
Larch	132·3-198·4 (60-90)	11·81 (30)	6·30 (16)	7·87 (2·4)	195·53 (8140)	57·11 (936)	3·43 (8·7)	2·87 (7·3)
Beech	169·7-198·4 (77-90)							

Gothard Railway.

Soft, basic metal. . . . . { F = 28·21 (4450) / D = 27 } Average.

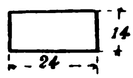
	Section	w (g).	b.	h.	l.	I_1.	Z_1 (W_1).	y_1' (l_1').	y_2' (l_2').
Standard section . . .		147·2 (66·8)	8·62 (21·9)	3·35 (8·5)	8·20 (2·5)	5·50 (229)	2·42 (39·7)	1·08 (2·733)	2·27 (5·767)
Deep section		147·2 (66·8)	3·78 (9·6)	5·35 (13·6)	8·20 (2·5)	14·77 (615)	4·81 (78·8)	2·28 (5·8)	3·07 (7·8)

Meridional Railway. Adriatic System.



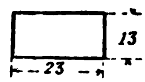
	(w) g.	b.	h.	l.	I_1.	Z_1 (W_1).	y'_1 (l_1').	y'_2 (l_2').
Oak . . .	176·3	9 45	5·51	8·53	131·84	47·84	2·76	2·75
	(80)	(24)	(14)	(2·6)	(5488)	(784)	(7)	(7)

Italian Mediterranean System.



	w (g).	b.	h.	l.	I_1.	Z_1 (W_1).	y_1' (l_1').	y_2' (l_2').
Oak . . .	176·3	9·45	5·51	8·53	131·84	47·84	2·76	2·75
	(80)	(24)	(14)	(2·6)	(5488)	(784)	(7)	(7)

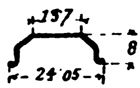
Sicilian Railway.



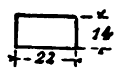
	w (g).	b.	h.	l.	I_1.	Z_1 (W_1).	y_1' (l_1').	y_2' (l_2').
		At least.	At least.					
Oak . . .	Not given.	9·05	5·12	8·53	101·16	39·54	2·56	2·56
		(23)	(13)	(2·6)	(4211)	(648)	(6·5)	(6·5)

French State Railways.

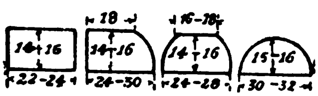
1st Soft mild steel sleepers . . . . { F = 28·5 (4500) / D = 20 } At least.



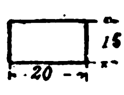
w (g).	b.	h.	l.	I_1.	Z_1 (W_1).	y_1' (l_1').	y_2' (l_2').
127 8	9 46	3·15	8·20	4 04	1·83	0 96	2·19
(58)	(24·05)	(8)	(2·5)	(168)	(30)	(2·447)	(5·553)



	w (g).	b.	h.	l.	I_1.	Z_1 (W_1).	y_1' (l_1').	y_2' (l_2').
2nd Oak . .	Not given.	8 66	5·51	8·53-8·86	120·83	43·81	2·76	2·75
		(22)	(14)	(2·6-2·7)	(5030)	(718)	(7)	(7)
	Do.	9·06	5·91	8·53 8·86	155·40	52·66	2·95	2·96
		(23)	(15)	(2·6-2·7)	(6469)	(863)	(7·5)	(7·5)
3rd Fir :	Do.	10·63	5·91	8·53-8·86	156·32	49·79	3·14	2·76
		(27)	(15)	(2·6-2·7)	(6508)	(816)	(7·97)	(7·03)
	Do.	10·24	5·91	8·53-8·86	150·00	47·65	3·15	2·76
		(26)	(15)	(2·6-2·7)	(6245)	(781)	(8)	(7)
	Do.	12·20	6·10	8·53-8·86	152·18	43·44	3·50	2·60
		(31)	(15·5)	(2·6-2·7)	(6335)	(712)	(8·9)	(6·6)



Paris, Lyons and Mediterranean Railway.

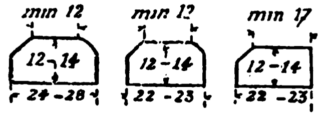


	w (g).	b.	h.	l.	I_1.	Z_1 (W_1).	y_1' (l_1').	y_2 (l_2').
Oak and beech .	Not given.	7·87	5·91	8·53	135·12	45·77	2·95	2·96
		(20)	(15)	(2·6)	(5625)	(750)	(7·5)	(7·5)

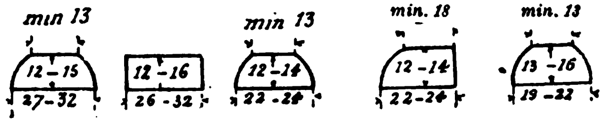
French Southern Railway.

Oak and fir.

Sections of oak sleepers . . . . . .



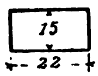
Sections of fir sleepers . . .



For the average sleeper :—

	w (g).	b.	h.	t.	I_1.	Z_1 (W_1).	y_1' (l_1').	y_2' (l_2').
Oak . . .	176·3 (80)	9·84 to 11·81	4·72 to 5·12	8·53 to 8·86	107·50 (4475)	43·69 (716)	2·36 to 2·56	2·36 to 2 56
Fir . . .	154·3 (70)	(25) to (30)	(12) to (13)	(2·6) to (2·7)			(6) to (6·5)	(6) to (6·5)

Paris-Orleans Railway.

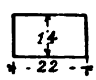
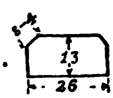
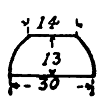
		w (g).	b.	h.	t.	I_1.	Z_1 (W_1).	y'_1 (l'_1).	y'_2 (l'_2).
Oak		Not given.	8·66 (22)	5·91 (15)	8·86 (2·7)	148·65 (6188)	50·34 (825)	2·95 (7·5)	2·96 (7·5)

French Northern Railway.

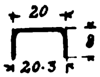
	b.	h.	t.
Oak and beech creosoted.	10·24 (26)	5·12 (13)	8·53 (2·6)

French Western Railway.

1st Wooden sleepers; oak and beech. Oak sleepers from heart not creosoted; those with sap wood are creosoted, as are all beech sleepers.

		w (g).	b.	h.	t.	I_1.	Z_1 (W_1).	y'_1 (l'_1).	y'_2 (l'_2).
Rectangular from heart.		Oak 176·3-187·4 (80-85). Beech 187·4-198·4 (85-90).	8·66 (22)	5·51 (14)	8·86 (2·7)	120·83 (5030)	43·81 (718)	2·76 (7·0)	2·76 (7·0)
With sap wood . . .			10·23 (26)	5·12 (13)	8·86 (2·7)	104·94 (4368)	39·78 (652)	2·48 (6·3)	2·64 (6 7)
Half round			11·81 (30)	5·12 (13)	8·86 (2·7)	95·21 (3963)	36·49 (598)	2·51 (6·37)	2·61 (6·63)

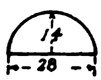
2nd Metal sleepers; since 1889, 5,000 sleepers have been on trial.



	w (g).	b.	h.	l.	I_1.	Z_1 (W_1).	y'_1 (l'_1).	y'_2 (l'_2).
Without chairs	123·4 (56)	7·99 (20 3)	3·15 (8)	8·20 (2·5)	4·00 (166·6)	1·74 (28·5)	0·85 (2·16)	2 30 (5·84)
With 2 cast chairs	238·4 (108)							

Belgian State Railways.

Wood, of half round section; a certain number are partially flattened at the top surface.



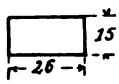
	w (g).	b.	h.	l.	I_1.	Z_1 (W_1).	y'_1 (l'_1).	y'_2 (l'_2).
Belgian oak	187·4 about (85)	11·02 (28)	5·51 (14)	8·53 (2·6)	103·92 (4326)	32·58 (534)	3·19 (8·1)	2·32 (5·9)
Foreign oak	176·4 (80)							

Dutch Railway Co.

1st Metal sleepers, soft mild steel: F = 30·4 (4,800)

	w (g).	l.
Intermediary sleepers	86·0 (39)	8·53 (2·6)
Sleepers at fish joint	105·8 (48)	

2nd Wooden sleepers; oak and red fir.

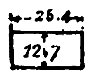
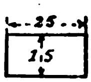
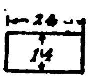


	w (g).	b.	h.	l.	I_1.	Z_1 (W_1).	y'_1 (l'_1).	y'_2 (l'_2).
Oak	176·4 (80)	10·23 (26)	5·91 (15)	8·53 (2·6)	175·65 (7312)	59·49 (975)	2·95 (7·5)	2·95 (7·5)
Red fir	154·3 (70)							

Egyptian Railways.

1st Wooden sleepers for flat-bottomed rails; Baltic and Turkish fir. Turkish and Austrian oak.

Intermediary sleepers.

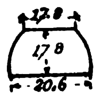
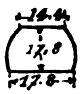
		w (g).	b.	h.	l.	I_1.	Z_1 (W_1).	y'_1 (l'_1).	y'_2 (l'_2).
Baltic fir creosoted		137·3 (62·3)	10·00 (25·4)	5·00 (12·7)	8·92 (2·72)	104·16 (4336)	41·68 (683)	2·50 (6·35)	2·50 (6·35)
Turkish fir		131·1 (59·5)	9·84 (25)	5 91 (15)	8·53 (2·6)	168·90 (7031)	57·17 (937)	2·95 (7·5)	2·95 (7·5)
Oak		180·8 (82)	9·45 (24)	5·51 (14)	8·53 (2·6)	131·83 (5488)	47·84 (784)	2·76 (7·0)	2·76 (7·0)

2nd Cast-iron pot sleepers for double-headed rails. — Diameter, 22·05 inches (0·56 metre). Weight, 114·6 lbs (52 kilog.) each.

3rd Steel cross sleepers. Up to the present time none of these have been used. In 1893 some steel sleepers were ordered for a piece of line 3·7 miles (6 kilometres) long from Boyenval, Ponsard & C°, of Paris. These are to be 8 feet (2·45 metres) long, and are to weigh 167·5 to 169·7 lbs (76 to 77 kilog.) each. The steel is to have a tensile strength of 28·57 to 31·75 tons per sq. inch (45 to 50 kilog. per sq. millimetres), with a maximum elongation of 22 % on a length of 7·87 inches (200 millimetres). The limit of elasticity to be between 15·24 and 19·05 tons per sq. inch (24 and 30 kilog. per sq. millimetre). These sleepers have not yet been delivered.

Russian State Railways (St. Petersburg to Warsaw).

Fir :

		w (g).	b.	h.	l.	I_1.	Z_1 (W_1).	y'_1 (l'_1).	y'_2 (l'_2).
Type 11. Sleepers at fish joint.		Not given.	8·11	7·01	8·75	240·80	67·67	3·56	3·43
			(20·6)	(17·8)	(2·667)	(10023)	(1109)	(9·04)	(8·72)
Type 12. Intermediary sleepers.		Not given.	7·01	7·01	8·75	215·60	60·22	3·58	3·41
			(17·8)	(17·8)	(2·667)	(8974)	(987)	(9·09)	(8·67)

Note. — On the St. Petersburg-Gatchina section, which is 27·34 miles (44·8 kilometres) long, all the sleepers are of type n° 11; on the rest of the line, the sleepers next the suspended fish joints are of type No. 11, and the intermediary sleepers are of type No. 12.

3rd *Attachment of rails to sleepers.*

It should be stated whether the rails are fixed directly to the sleepers, or by means of chairs, chair-plates, bed or foundation plates, wedges, etc.; also how the rail is fixed to the sleeper or to the intermediary piece (dog-spikes, screw-spikes, clips, etc.) and how, in the latter case, the intermediary piece (chairs, plates, etc.), is fixed to the sleeper (spikes, screw-spikes, screws, treenails, bolts, etc.).

Kaiser Ferdinands Nordbahn. — Bed plates are interposed between the rail and the sleeper. Since 1893, wedge shaped plates are used. The rails are fixed to the sleeper by two dog-spikes on the outside, and a screw-spike on the inside. Since 1893, chair-plates have been used which are fixed to the sleepers by four dog-spikes, the sleepers in this case not being adzed. A wedge is interposed between the rail and the sleeper, and the rail is fixed to the chair-plate by means of two bolts and nuts and clips.

The use of these chair-plates is limited to the two or four sleepers adjoining the fish-joint.

Privileged Austro-Hungarian State Railway Co. — Bed plates are invariably interposed between the rails and the sleepers; one screw-spike is used on the inside, and one or two dog-spikes on the outside. The packing-plates are not fixed directly to the sleeper.

Austrian Southern Railway. — The rail rests directly on the sleeper in some cases, in others on bed-plates. The rail and the bed-plate are fixed to the sleeper by means of dog-spikes.

Gothard Railway. — The rails rest directly on the metal sleepers (without plates), and they are fixed by means of two bolts and clips.

Meridional Railway Adriatic System. — The rail rests on the sleeper with an iron bed-plate interposed, and is held by means of dog-spikes (two per bed-plate).

Italian Mediterranean System. — As a rule, the rails rest on a bed-plate. Rails and bed-plates are fixed to the sleepers by means of dog-spikes.

Rails of the present normal type 39·4 feet (12 metres) long are held by means of screw-spikes; there are two per bed-plate.

In type V^4, however, rails section A and 19·7 and 29·5 feet (6 and 9 metres) long, the bed-plate on the sleepers next the fish-joint has three holes, and three fastenings are used.

In type I, rails section A and 39·4 feet (12 metres) long, double tie-plates are used at the fish-joints, which firmly unite the two sleepers between which they are placed, and are fixed to them by means of six screw-spikes.

Sicilian Railway. — The rail rests on the adzed sleeper with an ordinary bed-plate interposed. Rail and bed-plate are fixed to the sleeper by means of two dog-spikes.

French State Railways. — I. *Bull-headed rails of* 80·6 *lbs per yard (*40 *kilograms per metre).* — The rails are secured in the chairs by oak or steel keys; the chairs rest directly on the sleepers (oak, pine, or steel).

The chairs are fixed : 1st to wooden sleepers by three screw-spikes. In the case of two of these screw-spikes, conical wooden bushes are interposed between the screw-spike and the holes in the chair to prevent their becoming oval; 2nd to steel sleepers by two bolts.

II. *Symmetrical double-headed rails of* 76·6 *lbs per yard (*38 *kilograms per metre).* — The method of attachment is the same, with the exception that the chairs are fixed to the sleepers with only two screw-spikes.

III. *Double-headed rails of the « Charentes » type of* 70·6 *lbs per yard (*35 *kilograms per metre).* — Secured as in case II.

IV. *Flat-bottomed rails of* 70·6 *lbs per yard (*35 *kilograms per metre).* — The rails rest directly on the sleepers and are fixed with two galvanised steel screw-spikes.

Paris-Lyons-Mediterranean Railway. — The flat-bottomed rail 39·4 feet (12 metres) long is supported on 18 sleepers by bed-plates, each fixed by four screw-spikes.

See note of M. Jules Michel, « On the attachment of rails to wooden sleepers. The question of screw-spikes » (June 1893 number of the *Revue générale des chemins de fer*), and « On the stability of railroads. Experiments on the resistance of different parts of the road to vertical forces » (May 1885 number of the *Revue générale*).

French Southern Railway. — The rails rest on cast iron chairs secured to the sleepers by screw-spikes. The rails are held in the chairs by oak keys, or by steel keys of the « David » pattern.

Paris-Orleans Railway. — The rails rest on cast iron chairs secured to the sleepers by three screw-spikes.

French Northern Railway. — The rails bear directly on the sleepers which are adzed to receive them. A layer of tarred felt 0·2 in. (5 millimetres) thick is interposed between the metal and the wood. The rail is fixed to each sleeper by means of three screw-spikes. Alternate sleepers have two screw-spikes outside and one inside, and one outside and two inside.

French Western Railway. — The double-headed rails are keyed into the cast-iron chairs, which are fixed to the sleepers by means of screw-spikes.

The same plan is adopted for lines taking a heavy traffic that are laid with Vignoles rails. On Vignoles roads less heavily worked the rails are fixed directly to the sleepers by means of screw-spikes, and chairs are only used on sharp curves (see par. No. 4 infra).

In the newer methods of laying these different systems hardened cast steel keys are used, which have the advantage of maintaining a constant pressure independent of the temperature, and of the state of moisture of the atmosphere.

In the case of metal sleepers, the chairs are cast on having a lug on each side which holds the sleeper as the casting contracts; in addition to which the chair is secured by the cast iron filling up holes of 0·98 inch (25 millimetres) diameter drilled in the sleeper.

Belgian State Railways. — The rail rests on the sleeper by means of bed-plates. The rail is fixed to the sleeper by means of screw-spikes which pass through the bed-plate.

There are no bed-plates on the sleepers next to the fish-joint (suspended joints).

Dutch Railway Co. — *a*) *Metal sleepers.* — The *bent* sleepers receive the rail directly. They are fixed by means of hooks (*crapauds*) (Vautherin system), there are two of these on the inside and one on the outside; the two former are fixed with steel keys. On the *straight* sleepers, the rails rest on packing-plates which give the rail the desired inclination. They are fixed by bolts and clips.

b) *Wooden sleepers.* — The rail rests directly on the sleeper, and is fixed with dog-spikes.

Egyptian Railways. — Of the 321·87 miles (518 kilometres) laid with Vignoles rails up to the end of 1893, there are 29·82 miles (48 kilometres) which are provided with bed-plates. On the other 292·1 miles (470 kilometres), the rail rests directly on the sleepers (Turkish oak or fir). Bed-plates were introduced in 1893, and for the future they will be used on all new lines and for renewals.

The Vignoles rails are fixed to the sleepers by means of two screw-spikes.

Where Baltic fir sleepers are employed, two and three screws-pikes are used alternately, except that three are used on the sleepers next the fish-joints.

The double-headed rails are fixed to the cast-iron pot-sleepers by means of wooden or spiral iron keys, and between each pair of pot-sleepers there is a tie-rod which is held by spring keys.

Russian State Railways (St. Petersburg to Warsaw). — On the whole extent of the principal double line between St. Petersburg and Gatchina, 27·84 miles (44·8 kilometres), the rails rest on the sleepers by means of bed-plates, and the rail is fixed to each sleeper by four dog-spikes. On the rest of the St. Petersburg and Warsaw line, particularly between the stations of Gatchina and Warsaw, and on the Landvarovo and Wergebolowo section, the rails are placed directly on the intermediary sleepers, and secured by two dog-spikes 5·90 inches (150 millimetres) long.

Bed-plates are used on the sleepers next the fish joints, and the rails are then fixed with four dog-spikes 5·90 inches (150 millimetres) long.

4th. *Methods of attachment in special cases, particularly on curves.*

Particular arrangements, if any, to which recourse is had to increase the resistance to the lateral stresses (such as additional parts, head supports, etc.) are to be specially mentioned.

Meridional Railway. Adriatic System. — No special arrangements are provided at curves of large radius on lines traversed by trains running at a higher speed than 31·07 miles (50 kilometres) per hour. On the line from Bologna to Pistoia, which has heavy gradients and sharp curves and which is traversed by trains running at 24·85 miles (40 kilometres) per hour, drawn by very heavy locomotives, blocks of wood are used to counteract the lateral displacement of the road. These blocks bear at one end against the rail or the end of the sleeper, and at the other end against a wall built at the side of the line. Stakes of wood are also used, which are driven into the subsoil, and against which the ends of the sleepers press on the outer edge of the curve.

French State Railways. — When double-headed rails rest on longitudinal sleepers (bridges, pits, etc.), they are fixed with special chairs having four holes. No special method is used for curves. On certain lines, however, metal keys are preferred to wooden ones for use on curves.

Paris, Lyons and Mediterranean Railway. — The curves have a radius of not less than 24·85 chains (500 metres), and no special measures are taken.

French Southern Railway. — Up to the present, no special measures have been taken for fixing the chairs to the sleepers. At curves of small radius a pattern of chair, with a large base with three holes for screw-spikes, is now being tried with a view to preventing lateral displacement of the rail.

French Northern Railway. — On curves of small radius, Barbarot keys are being used to increase the resistance to canting of the outer rail.

French Western Railway. — On lines laid with chairs, no special method is employed. When Vignoles rails are attached directly to the sleepers, the line is strengthened in the case of sharp curves, of 24·85 chains (500 metres) radius or less, by using chairs on the fourth and seventh sleeper in each length of rail.

Belgian State Railways. — The lines laid with rails weighing 114·6 lbs (52 kilograms) behave very well when their resistance to canting is considered. (The rails are laid without any inclination.)

Dutch Railway Co. — With iron sleepers no special steps are taken to support the head of the rail. On roads with wooden sleepers, where the curves are sharp, wooden struts or supports are sometimes used.

Egyptian Railways. — On curves of more than 24·85 chains (500 metres) radius it is not generally considered necessary to take special measures for strengthening the line. On two curves of which the radius is only 19·88 chains (400 metres), additional screw-spikes are used because the line had spread from 4 feet 8·45 inches to 4 feet 8·88 inches (1·434 to 1·445 metre).

In the superstructure on pot-sleepers, all the pot-sleepers on curves are provided with tie-rods. For the last ten years, all the pot-sleepers in use have been provided with tie-rods.

No other special methods are employed.

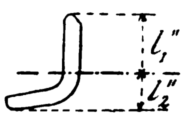
Russian State Railways (St. Petersburg to Warsaw). — On curves of 27·5 chains (553·4 metres) radius and less, additional spikes are used on some intermediary sleepers.

5th *Fish-joints.*

Method of fastening flat fish-plates, angular fish-plates, and bridge fish-plates.
Number and diameter in inches (millimetres) of the fish-plate bolts.
Holes in fish-plates, whether punched or drilled.

Metal of the fish-plates :—

Weight . . . . W = pounds (G = kilograms).
Length . . . . l = inches (l = millimetres).
Moment of inertia . . . . I_2 = sq. in. × sq. in. (I_2 = sq. cm. × sq. cm.)
Moment of resistance . . . . $Z_2 = \frac{I_2}{y_2''}$ = cub. in. ($W_2 = \frac{I_2}{l_1''}$ = cub. cm.)



Position of neutral axis y_1'' = inches (l_1'' = millimetres).
y_2'' = inches (l_2'' = millimetres).

Tensile strength . . . . F = tons per sq. in. (F = kg. per sq. cm.).
Reduction of area . . . . C per cent.
Elongation . . . . D per cent.

Kaiser Ferdinands Nordbahn. — The outside fish-plate has two flanges; the inside one, only one. The fish-bolts are four in number and 0·87 inch (22 millimetres) in diameter. Since 1894, the bolt holes are drilled. The fish-plates are of mild steel.

	W (G).	l.	I_2.	Z_2 (W_2).	y_1'' (l_1'').	y_2'' (l_2'').
Outside fish-plate	19·18	21·77	5·59	2·75	2·04	1·87
	(8·7)	(553)	(232·7)	(45·0)	(51·9)	(47·5)
Inside one	15·87	19·68	3·45	1·56	2·22	1·45
	(7·2)	(500)	(143·9)	(25·5)	(56·5)	(37·0)

F . . . . 26·22 to 37·46 (4130 to 5900)
C . . . . 27.7 to 57·5
D . . . . 18·5 to 28·0
} According to manufacturer's tests.

Note. — In the attachment made with chairs and packing-plates fish-plates with six bolts are also used. Their length is 28·74 inches (730 millimetres). The outside fish-plate weighs 27·28 lbs (12·4 kilograms); the inside one, 23·32 lbs (10·6 kilograms).

Privileged Austro-Hungarian State Railway Co. — The outside fish-plate has two flanges, the inside fish-plate one. There are four bolts, and their diameter is 0·748 inch (19 millimetres). The fish-plates are of wrought iron.

	W (G).	l.	I_2.	Z_2 (W_2).	y_1'' (l_1'').	y_2'' (l_2'').
Outside	24·25	23·23	6·77	3·09	2·18	1·96
	(11·0)	(590)	(281·94)	(50·7)	(55·6)	(49·9)
Inside	15·87	18·50	3·08	1·51	2·04	1·39
	(7·2)	(470)	(128·14)	(24·7)	(51·9)	(35·5)

Austrian Southern Railway. — The outside fish-plate has two flanges; the inside one is flat. Four bolts; diameter 0·866 inch (22 millimetres). Fish-plates of soft Bessemer steel.

	W (G).	l.	I_2.	Z_2 (W_2).	y_1'' (l_1'').	y_2'' (l_2'').
Outside	20·76	23·23	5·81	2·69	2·16	1·86
	(9·42)	(590)	(242)	(44)	(54·8)	(47·2)
Inside	10·36	21·66	1·46	0·91	1·61	1·61
	(4·7)	(550)	(61)	(14·9)	(41·0)	(41·0)

Gothard Railway. — Simple angular symmetrical fish-plate. Four bolts; diameter 0·984 inch (25 millimetres). The bolt holes are punched.

W (G).	l.	I_2.	Z_2 (W_2).	y_1'' (l_1'').	y_2'' (l_2'').
22·05	23·62	4·70	2·11	2·24	1·57
(10)	(600)	(195·6)	(34·5)	(56·75)	(39·75)
Per fish-plate.		Per fish-plate.			

Meridional Railway. Adriatic system. — Simple angular symmetrical fish-plates. Two types, one with five bolts, the other with four. Diameter of bolts in both cases, 0·984 inch (25 millimetres). The bolt-holes are drilled. Fish-plates of Martin steel.

	W (G).	l.	I_2.	Z_2 (W_2).	y_1'' (l_1'').	y_2'' (l_2'').
Type 1	22·05	28·94	3·16	1·52	2·07	1·48
	(10)	(735)	(131·7)	(24·9)	(52·79)	(37·51)
Type 2	19·8	25·51	2·84	1·40	2·01	1·42
	(8·7)	(648)	(118·2)	(23·0)	(51·22)	(36·18)
	Per fish-plate.		Per fish-plate.			

F = 31·7 (5000).

Italian Mediterranean System. — Simple angular symmetrical fish-plates. Of section A there are three types, No. 2, 1 FC, and V^4. Of section B there is one type, M. Type No. 2 has five bolts, the rest have four, of 0·98 inch (25 millimetres) diameter. For some years past the fish-plates have been of mild steel.

	W (G).	l.	I_2.	Z_2 (W_2).	y_1'' (l_1'').	y_2'' (l_2'').
No. 2.	22·05	28·93	3·16	1·52	2·07	1·47
	(10)	(735)	(131·7)	(24·9)	(52·79,	(37·51)
1 FC	17·63	19·21	4·92	2·04	2·41	1.92
	(8)	(488)	(205)	(33·4)	(61·35)	(48·90)
V^4.	19·84	24·96	3·40	1·61	2·11	1·45
	(9)	(634)	(141·6)	(26·4)	(53·61)	(36·89)
M.	19·18	25·51	2·84	1·40	2·01	1·42
	(8·7)	(648)	(118·2)	(23·0)	(51·22)	(36·18)

Sicilian Railway. — Simple angular symmetrical fish-plates. Four bolts, diameter 0·98 inch (25 millimetres). Bolt-holes are drilled. Fish-plates made of wrought-iron of the best quality.

	W (G).	l.	I_2.	Z_2 (W_2).	y''_1 (l_1'').	y''_2 (l_2'').
Outside	17·63	19·21	4·92	2·04	2·41	1·92
	(8)	(488)	(205)	(33·4)	(61·35)	(48·90)
Inside.	24·25	27·95	4·92	2·04	2·41	1·92
	(11)	(710)	(205)	(33·4)	(61·35)	(48·90)

Specified tensile strength F = 21·6 (3400).

French State Railways. — The bull-headed rails of 80·6 lbs per yard (40 kilograms per metre) are joined by simple angular fish-plates of cast steel. The weight of a pair of fish-plates is 41·8 lbs (19 kilograms). There are four bolts, 0·98 inch (25 mill.) in diameter. The holes are drilled or punched.

The moment of inertia of the pair of fish-plates is 18·81 sq. inches × sq. inches (783 sq. cent. × sq. cent.) and the moment of resistance 7·26 cubic inch (119 cubic centimetres). The symmetrical rails weighing 76·61 lbs per yard (38 kilograms per metre) are joined by flat fish-plates. The weight of the pair is 23·76 lbs (10·8 kilograms). The fish-plates are held together by four bolts 0·98 inch (25 millimetres) in diameter.

The holes are either drilled or punched.

The moment of inertia of the pair is 5·60 sq. inches × sq. inches (134·4 sq. cent. × sq. cent.) and the moment of resistance 2·32 cubic inches (38 cubic centimetres).

The symmetrical rails weighing 70·61 lbs per yard (35 kilograms per metre) of the « Charentes » type are joined by flat fish-plates weighing 19·8 lbs (9 kilograms) the pair, and four bolts 0·94 inch (24 millimetres) in diameter.

The Vignoles rails weighing 70·61 lbs per yard (35 kilograms per metre) are joined by flat fish-plates weighing 22·4 lbs (10·2 kilograms) the pair, and four bolts 0·98 inch (25 millimetres) in diameter.

Paris, Lyons and Mediterranean Railway. — Suspended fish-joint. Simple angular symmetrical fish-plate, of steel; angle bearing on bed-plates and fastened to sleepers by four screwsp-ikes.

There are six bolts of 0·98 inch (25 millimetres) diameter.

W (G).	l.	I_2.	Z_2 (W_2).	y_1'' (l_1'').	y_2'' (l_2'').
33·95	31·49	4·46	2·00	2·25	1·42
(15·4)	(800)	(185·7)	(32·7)	(57·16)	(36·15)
Per fish-plate.		Per fish-plate.			

French Southern Railway. — Two types of fish-joints :

1stly. On the greater part of the system, two flat symmetrical fish-plates of hard steel, with four bolts 0·787 inch (20 millimetres) in diameter. The holes are drilled ;

2ndly. Inside fish-plate flat; outside fish-plate increasing in strength towards the bottom. The fish-plates are of steel, and there are four bolts 0·787 inch (20 millimetres) in diameter.

		W (G).	l.	I_2.	Z_2 (W_2)	y_1'' (l_1'').	y_2'' (l_2'').
1st type	Outside	11·68 (5·3)	17·71 (450)	2·86 (119·2) Per pair.	1·89 (31)	1·51 (38·5)	1·51 (38·5)
	Inside	9·46 (4·3)	21·26 (540)				
2nd type	Outside	18·07 (8·2)	17·71 (450)	11·8 (491) Per pair.	...	...	..
	Inside	9·46 (4·3)	21·26 (540)		...	...	...

Paris-Orleans Railway. — Fish-plates of steel of medium hardness having an angular shape, of which the angle curves under the rail. Four bolts 0·98 inch (25 millimetres) in diameter.

$G = 41 \cdot 88\ (19)$
$I_2 = 17 \cdot 92\ (746)$ } per pair of fish-plates.

French Northern Railway. — Inside and outside angular fish-plates having a length of 25·59 inches (650 millimetres), fastened by four bolts 0·98 inch (25 millimetres) in diameter.

French Western Railway. — (1) Bull-headed rails. Deep fish-plates on both sides, with four bolts 0·98 inch (25 millimetres) in diameter.

(2) Symmetrical double-headed rails. Flat fish-plate on the outside; deep one on the inside; four bolts 0·98 inch (25 millimetres) in diameter.

(3) Vignoles rails. Flat fish-plate on the outside; deep one on the inside; four bolts 0·87 inch (22 millimetres) in diameter.

The bolt-holes are drilled in each case.

		W (G).	l.	I_2.	Z_2 (W_2).
(1)	Outside	17·63 (8·0)	18·11 (460)	8·71 (362·6)	3·12 (51·1)
	Inside	17·63 (8·0)	18·11 (460)	8·71 (362·6)	3·12 (51·1)
(2)	Outside	9·92 (4·5)	17·71 (450)	1·43 (59·5)	0·91 (14·9)
	Inside	16·68 (7·57)	18·11 (460)	8·41 (349·9)	3·02 (49·3)
(3)	Outside	8·87 (4·025)	17·71 (450)	1·60 (66·5)	0·97 (15·9)
	Inside	17·48 (7·930)	18·51 (470)	6·22 (258·8)	2·41 (39·5)

Belgian State Railways. — The fish-plates are regular and made of mild steel or good iron. The bolt-holes are drilled. There are four bolts 0·98 inch (25 millimetres) in diameter.

	W (G).	l.	I_2.	Z_2 (W_2).	y_1'' (l_1'').	y_2'' (l_2'').
Outside	46·29 (21)	28·74 (730)	7·09 (295·3)	2·73 (44·7)	2·60 (66·1)	1·44 (36·7)
Inside	48·50 (22)	28·74 (730)	7·27 (302·7)	2·82 (46·3)	2·57 (65·4)	1·47 (37·4)

F =	Minimum for steel	28·6 (4500)	Specified.
	Minimum for iron.	22·2 (3500)	
D =	Minimum for steel.	20	
	Minimum for iron.	20	

Dutch Railway Co. — As a general rule, and on curves particularly, angular fish-plates are used. On some parts of the lines, flat fish-plates are still used. The holes are drilled; there are four bolts.

Egyptian Railways. — Types 1 and 2 : flat fish-plates made of steel are used on both sides.
Type 3 : flat fish-plates made of iron are used on both sides.
Type 4 : flat fish-plate on the inside, angular fish-plate on the outside. Both made of steel.
Type 5 : angular fish-plates made of steel on both sides.
In each case there are four punched bolt-holes; the bolts used are 0·87 to 1·00 inch (22·2 to 25·5 millimetres) in diameter.

F = 28·5 to 34·9 (4500 to 5500)	Specified.
C = at least 30	
D = 20 to 28	

		W (G).	l.	I_2.	Z_2 (W_2).	v_1'' (l_1'').	v_2'' (l_2'').
Types 1 and 2		10·47	17·91	1·25	0·83	1·51	1·51
		(4·75)	(455)	(52·4)	(13·6)	(38·5)	(38·5)
Type 3		...	...	1·63	1·01	1·61	1·61
		...	...	(67·9)	(16·6)	(41)	(41)
Type 4	Outside	20·72	21·65	3·81	1·78	2·13	1·36
		(9·4)	(550)	(158·5)	(29·2)	(54·23)	(34·77)
	Inside	...	19·68	2·07	1·26	1·65	1·65
		...	(500)	(86·5)	(20·6)	(42 00)	(42·00)
Type 5		20·72	21·65	3·81	1·78	2·13	1·36
		(9·4)	(550)	(158·5)	(29·2)	(54·23)	(34·77)

Russian State Railways (St. Petersburg to Warsaw). — The fish-joint is made as follows :—

a) Two angular fish-plates of rolled iron 22·992 inches (584 millimetres) long and 0·709 inch (18 millimetres) thick, weighing 18·05 lbs (8·19 kilograms) each. The bolt-holes are punched.

b) Four bolts 4·37 inches (111 millimetres) long, 0·866 inch (22 millimetres) in diameter; weight, 1·21 lb (0·545 kilogram) each.

c) Two bed-plates 7 inches (178 millimetres) long, 7 inches (178 millimetres) wide, 0·551 inch (14 millimetres) thick, and weighing 7·22 lbs (3·276 kilograms) each.

d) Eight spikes 5·91 inches (150 millimetres) long, 0·59 × 0·59 inch (15 × 15 millimetres) in section, and weighing 0·75 lb (0·262 kilogram) each.

In order to prevent the nuts from working loose, washers of hardened material, according to the Mitens system, are used of late. The holes in the bed-plates are drilled.

6th *Ballast and subsoil.*

The nature of the ballast and its quality are to be described.

Kaiser Ferdinands Nordbahn. — The ballast on 19 p. c. of the line is gravel not screened; on 53 p. c. the ballast is screened gravel from a river-bed or gravel-pit and on 28 p. c. the ballast is of broken stone.

Privileged Austro-Hungarian State Railway Co. — Broken stone or pit gravel. The pit gravel is unsatisfactory as it offers too little resistance to the displacement of the superstructure.
In a great many cases, it was necessary to add sand.

Austrian Southern Railway. — Ordinary pit gravel or river gravel, and broken stone.

Gothard Railway. — The ballast and the subsoil in general leave little or nothing to be desired.

Meridional Railway. Adriatic System. — The ballast is composed of river gravel, screened pit gravel or of broken stone.

Italian Mediterranean System. — Screened gravel and broken stone. The question cannot be answered exactly on account of the number of different conditions existing on different sections of the line.

French State Railways. — The ballast varies on different sections and even on the same section. It is sand, gravel or broken stone. The sand is partly shingle and is taken from quarries in the vicinity of the line. The gravel comes either from the sea-shore, or from the beds of rivers (Loire, Sèvres, etc.), or from old river-beds.

The broken stone is flint granite or limestone, and comes from quarries situated near the line. It is crushed until small enough to pass through a mesh of 2·36 inches (6 centimetres). Before being used, it is freed from earthy matter, foreign substances, and broken pieces less than 0·78 inch (2 centimetres) at their smallest dimension.

Paris, Lyons and Mediterranean Railway. — The ballast preferred is broken stone.

French Southern Railway. — The ballast is as a rule composed of gravel and pure sand, freed from earthy matter, all stones which are more than 3·15 inches (8 centimetres) in their widest part being removed.

Stone broken small enough to pass a mesh of 2·36 inches (6 centimetres) is also used on certain sections.

Paris-Orleans Railway. — Ballast of river sand, pit sand or broken stone.

French Northern Railway. — The ballast used is that which can be obtained in the locality in which it is required; hard, not glassy slag; angular stones either by themselves or mixed with fine gravel; hard broken stone; in all cases a ballast which after a time become firm and consolidated, and yet allows the water to drain through it.

French Western Railway. — The choice of ballast is usually governed by the position of the quarries. Sand, either screened or unscreened, is used as ballast mixed with gravel and broken stone; but preference is given to hard limestone, crushed and passed through a 2·36 inches (6 centimetres) mesh.

Belgian State Railways. — The ballast generally used is broken stone, preferably sand-stone and porphyry which is obtained as a waste product in making pavingstones.

Dutch Railways. — The ballast is composed of a bed of pure sand, on top of a layer of gravel 3·94 to 5·91 inches (10 to 15 centimetres) thick.

Egyptian Railways. — In Egypt there is, properly speaking, very little line laid on actual ballast. The Benha-Ismaïlia line (21·75 miles [35 kilometres] double line, 49·7 miles [80 kilometres] single line) is the only one on which a definite bed of ballast has been used. For each yard (metre) of the single line, 25·83 cubic feet (0·8 of a cubic metre) of gravel has been used.

All the rest of the system is laid on the natural soil with the exception of about 37·28 miles (60 kilometres) of double line which has a foundation of sand and broken stone.

Russian State Railway (St. Petersburg to Warsaw). — On the whole line, the ballast consists of coarse quartz mixed with plenty of gravel. On the section from St. Petersburg to Gatchina, the bed of the ballast is covered by broken stone so as to prevent the formation of dust by trains.

The thickness of the ballast under the bottom of the sleepers is to be stated.

Kaiser Ferdinands Nordbahn. — 3·94 to 9·45 inches (0·1 to 0·24 metre).

Austro-Hungarian Privileged State Railway Co. — 9·45 inches (0·24 metre).

Austrian South Railway. — 11·81 inches (0·30 metre).

Meridional Railway. Adriatic System. — The thickness of the ballast is about 19·68 inches (0·5 metre) of which 9·84 inches (0·25 metre) is below the sleeper.

Italian Mediterranean System. — About 7·87 inches (0·2 metre).

French State Railways. — The thickness of the ballast beneath the bottom of the sleeper varies. At present, it is 8·66 to 9·84 inches (0·22 to 0·25 metre) for wooden sleepers; for metal sleepers, it is 15·74 inches (0·40 metre).

French Southern Railway. — 7·87 inches (0·20 metre).

Paris-Orleans Railways. — At least 11·81 inches (0·30 metre).

French Northern Railway. — The formation level is 19·69 inches (50 centimetres) lower than the upper surface of the rail.

French Western Railway. — 9·84 to 11·81 inches (0·25 to 0·30 metre).

Belgian State Railways. — Average 13·38 inches (0·34 metre).

Dutch Railways. — On those parts of the line where the road is not laid on pure sand, the formation level is 23·6 inches (60 centimetres) below the upper surface of the rail.

Egyptian Railways. — 3·94 inches (0·10 metre).

Russian State Railways (St. Petersburg to Warsaw). — 14·33 inches (0·364 metres).

Facts relating to the ballast and subsoil, considered with regard to their dryness and draining properties.

Kaiser Ferdinands Nordbahn. — Subsoil almost everywhere impermeable; dry on all the embankments and in most of the cuttings.

Privileged Austro-Hungarian State Railway Co. — The draining-away of the water is not restricted by earthen banks. On damp clay soils ditches filled with rubble are provided for draining.

Austrian Southern Railway. — The subsoil must always be kept dry. Special arrangements for draining are provided where the conditions are unfavorable.

Meridional Railway. Adriatic System. — The quality of the ballast and its hardness vary much, as an attempt is of course made to use the gravel or stone found in the vicinity of the line.
The nature of the subsoil is also very variable.

French Southern Railway. — The subsoil is of very variable quality, it is composed, according to circumstances, of loam, clay, loamy sand, or rock.

French Northern Railway. — When the subsoil is clayey, the depth of the ballast is sometimes increased. But generally it is better to improve the sub-soil by drains, rubble and deep trenches.

French Western Railway. — The want of permeability in the subsoil can be remedied by using broken and not weathered hard stone (scree) or by screened gravel, especially if the formation level has been previously drained.

Belgian State Railways. — The ballast of broken stone is perfectly permeable and helps to give the road stability and resistance. The thickness of the ballast is increased if the sub-soil is wet.

Dutch Railway Co. — For a length of line of about 6·21 miles (10 kilometres), the sub-soil is sandy; on the rest of the line, it contains turf.

Russian State Railways (St. Petersburg to Warsaw). — The quality of the ballast is recognised to be better than that on other Russian Railways. The ballast is perfectly permeable and no attempt has been made to replace it by ballast of better quality. The subsoil of the northern part of the line, that is to say, from St. Petersburg to the 371rst mile (560th verst), consists principally of clay; on the southern part, that is to say, from the 371rst mile (560th verst) to Warsaw and Wergebolovo, the subsoil is chiefly sandy.

Resistance to compression.

French Northern Railway. — No experiments have been made on this subject, but it is considered that the resistance of the ballast used is sufficient.

French Western Railway. — No experiments have been made on this subject, but with the materials used as ballast, a good resistance is obtained as soon as the road has become properly settled.

Whether the different lines have chiefly embankments or cuttings.

Kaiser Ferdinands Nordbahn. — 76 p. c. of the line consists of embankments, 24 p. c. of cuttings. About a quarter of the cuttings are damp.

Privileged Austro-Hungarian State Railway Co. — The embankments predominate greatly.

Austrian Southern Railway. — Embankments and cuttings succeed each other.

French Northern Railway. — The total length of cuttings is about the same as that of the embankments.

French Western Railway. — The predominance of embankments or cuttings varies on different sections of the line.

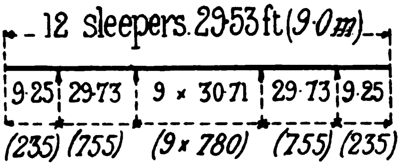
Dutch Railway Co. — The embankments are much the more numerous.

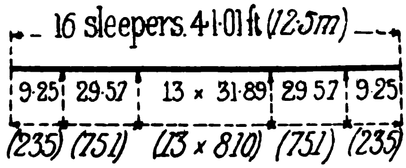
Russian State Railways (St. Petersburg to Warsaw). — 29 p. c. cuttings. 71 p. c. embankments.

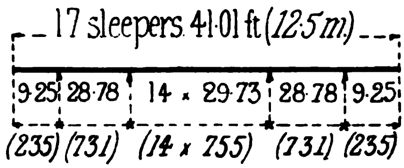
Length of rails in feet (metres), and distance between sleepers in inches (millimetres).

(Best indicated by sketches.)

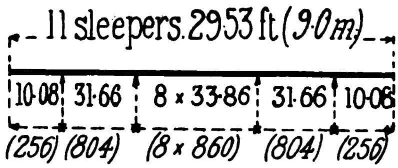
Kaiser Ferdinands Nordbahn.



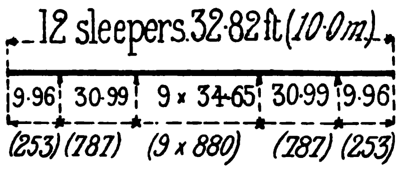




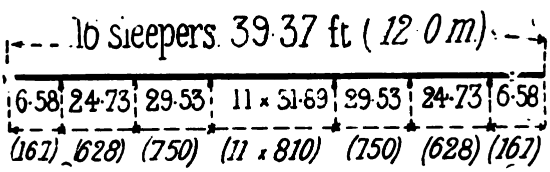
Privileged Austro-Hungarian State Railway Co.



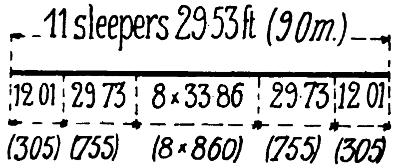
Austrian Southern Railway.

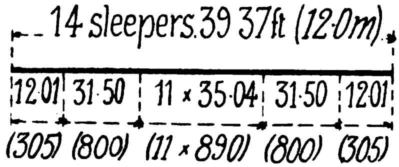


Gothard Railway.



Meridional Railway. Adriatic System.

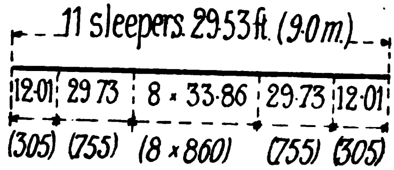


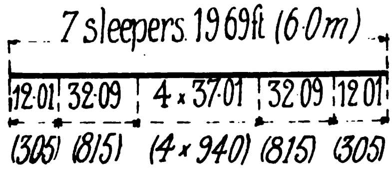


Italian Mediterranean System.

No. 1 group, profile A.

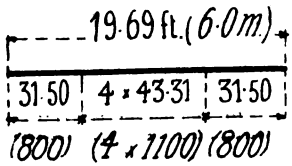
Type No. 2. Steel.



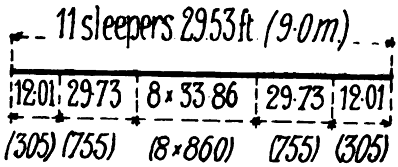


Type No. 2. Iron.

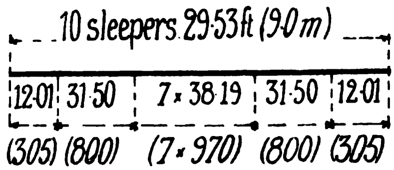
7 spaces, sleepers under ends.



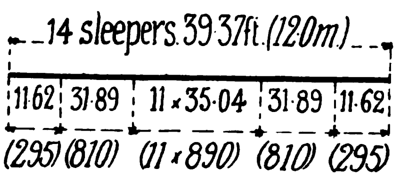
1. ***Type V^1. Steel.***



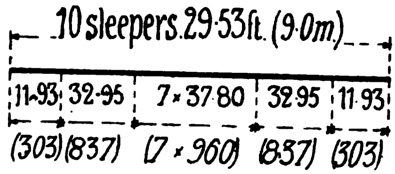
1. ***Type. Steel.***



1. ***Type. Steel.***

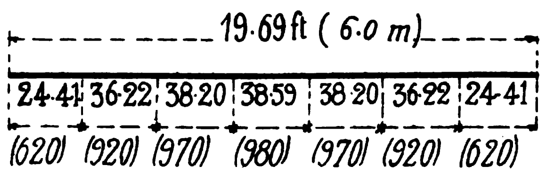


Type V4. Steel.



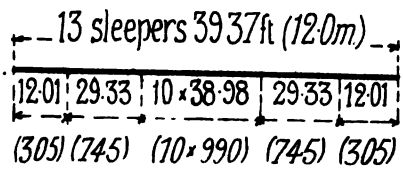
Type V4. Steel or iron.

7 spaces, sleepers under ends.



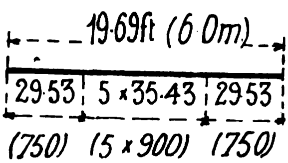
No. 2 group, profile B.

Type M. Steel.

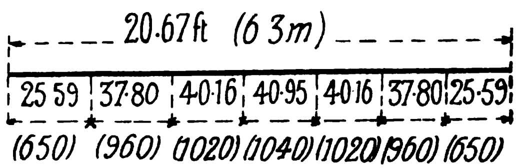


Type M. Steel or iron.

7 spaces, sleepers under ends.

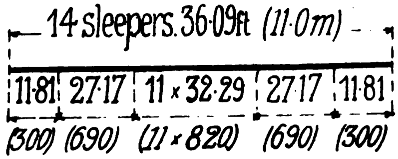


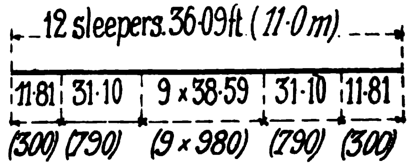
7 spaces, sleepers under ends.



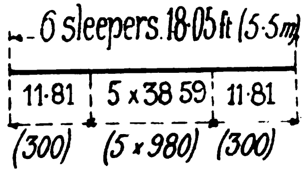
French State Railways.

Bull-headed rails, 80·6 lbs per yard (40 kilograms per metre).

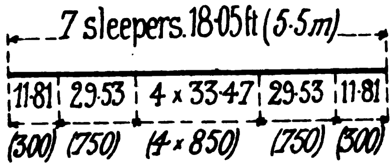


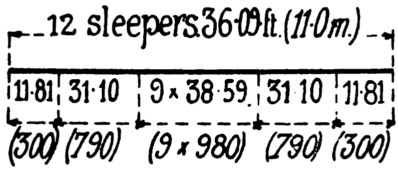


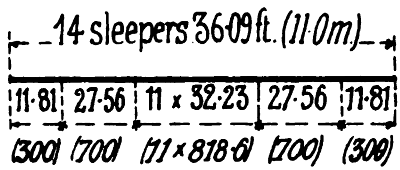
Bull-headed rails, 76·6 lbs per yard (38 kilograms per metre).



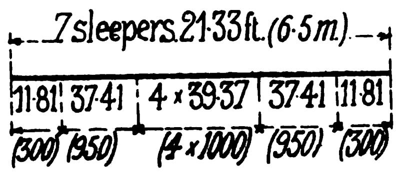
Bull-headed rails of 76·6 lbs per yard (38·0 kilograms per metre).



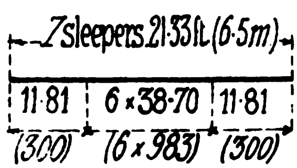




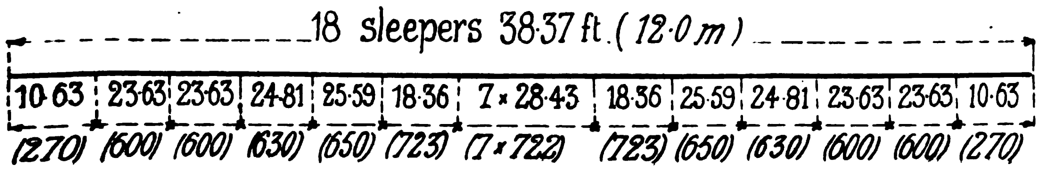
Bull-headed rails of 70·6 lbs per yard (35·0 kilograms per metre).



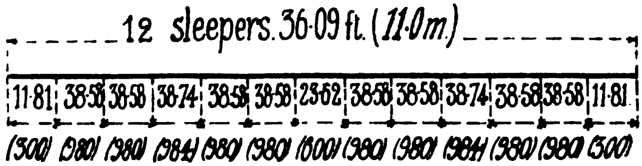
Vignoles rails.

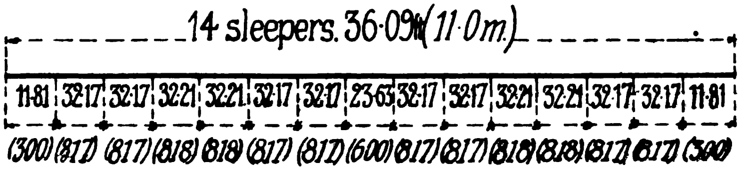


Paris-Lyons-Mediterranean Railway.



French Southern Railway.



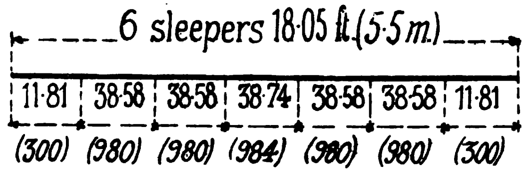


These modes of laying the road are used :

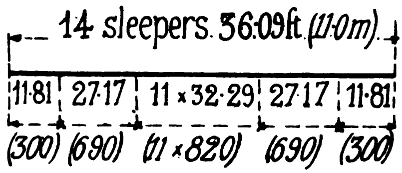
1st On steep inclines;

2nd On sharp curves.

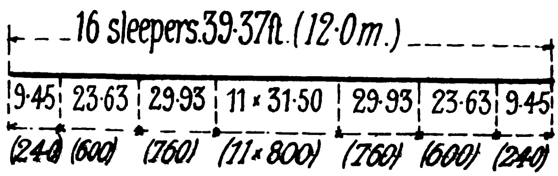
The two sleepers in the centre of the rail are, like those at the fish-joint, placed 23·6 inches (60 centimetres) apart, so that when a 36·09 feet (11·0 metres) rails breaks, it can be replaced at once by two of 18·05 feet (5·5 metres) thus :



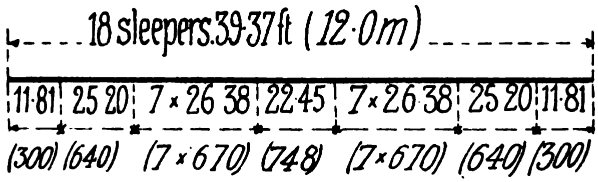
Paris-Orleans Railway.

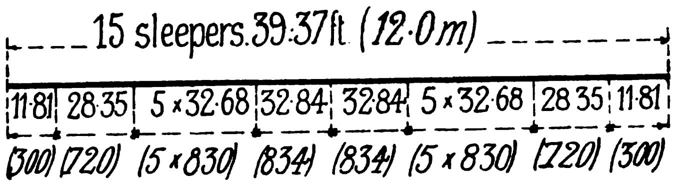


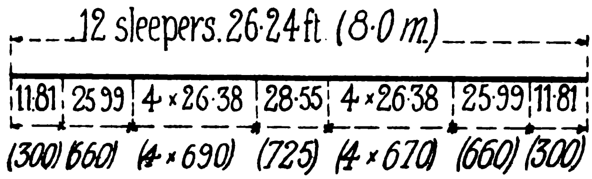
French-Northern Railway.



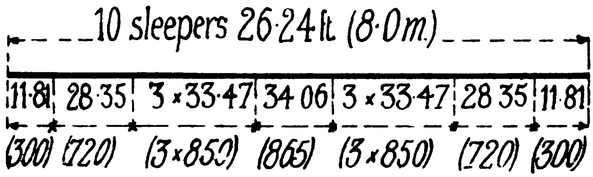
French-Western Railway.



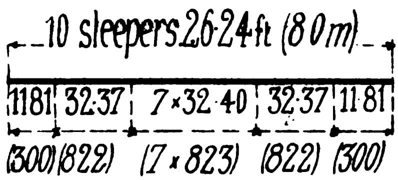




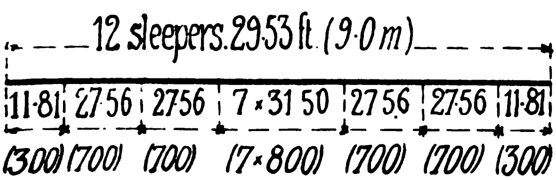
Bull-headed rails.

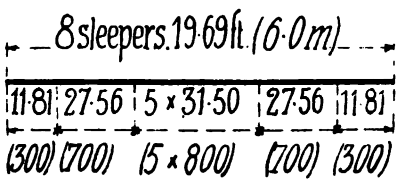


Vignoles rails.

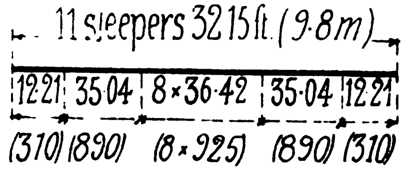


Belgian State Railways.



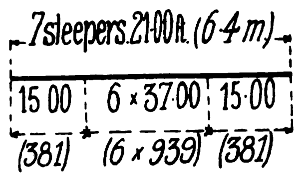


Dutch Railway Co.

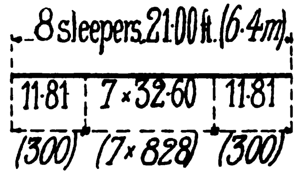


Egyptian Railways.

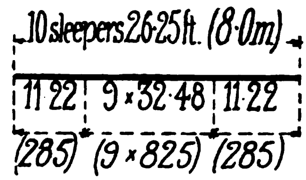
Type 1 and 2, cast iron pot sleepers.



Type 3, wooden sleepers.

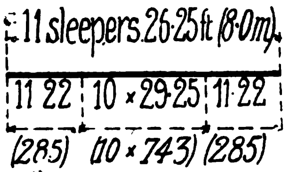


Type 4, wooden sleepers.

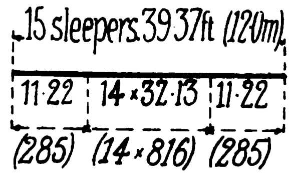


Roads with wooden sleepers.

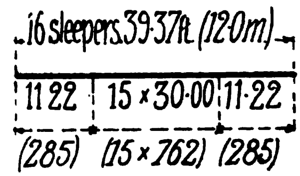
Type 4, used on curves equal to or more than 23·61 chains (400 metres) radius.



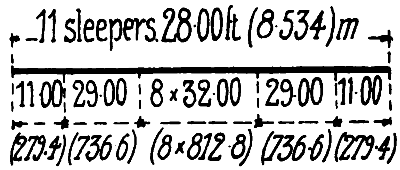
Type 5, used on curves less than 23·61 chains (400 metres) radius.



Type 5, used on curves more than 23·61 chains (400 metres) radius.



Russian State Railways (St. Petersburg to Warsaw).



IV. — Maintenance of the permanent way.

1st *Frequency of repair.*

It is to be stated how often on an average each line is adjusted; especially whether this is with the object of bringing the line to its proper level or to its proper direction.

Kaiser Ferdinands Nordbahn. — For the lines taken all together, the permanent way is on an average adjusted twice a year, principally with the object of bringing the line to its proper level.

Privileged Austro-Hungarian State Railway Co. — Omitting small repairs 25 to 30 p. c. of the whole line is adjusted every year, so that each part of the line is thoroughly adjusted once every three years, or at the least once every four years.

Austrian Southern Railway. — As a general rule those sections of the line used for express traffic which are thoroughly adjusted last for two years.

Meridional Railway, Adriatic System. — Since 1892, the practice of general inspections has been in force. The interval between one of the inspections and the next is one or two years depending on the amount of the traffic on the line.

It must not be forgotten that in spite of this there are always some small repairs to be done.

French State Railways. — The repair of the permanent way is carried out by general periodic inspection.

The general inspection begins each year on March 15th or later, and is continued without interruption until the hot weather sets in, up to June 15th at least. It is recommenced on September 1st to the 15th and is continued until November 15th at least. During the period fixed for it, the general inspection is carried on without interruption as far as possible from one district to another. At the beginning of each inspection, the work is begun at the point where the preceding inspection left off.

At the general inspection, the line is put into perfect order in such a way that it may remain as long as possible without requiring further attention.

The length of time of a complete revision and for carrying out the various works connected with it vary according to the length of time the line has been made, and the traffic on it. In every case, the sleepers which would come to their limit of wear within the year, the chairs and the screw-spikes which are no longer of use, and the fish-plate bolts whose threads are worn, are replaced; the straightening of the rails and the packing of the sleepers is attended to with care, and they are relaid wherever the levelling or stability of the road may require it; the ballast is also cleared of all weeds which may be in it.

French Northern Railway. — The line is repaired under the system to which the name flying inspection is given, it is impossible to say how many times a year it is rectified.

If we use the method of general inspection, the interval for this is 1, 2, and also 3 years, according to the age of the road, the method of its construction, and the amount of traffic on it.

French Western Railway. — The system known as flying inspection is used.

It consists of repairing the road at isolated points, or on parts of a greater or less length, when defects of a certain degree of importance come into existence either accidentally or in the regular way.

It is not easy to say how often on an average each line is adjusted in a year. The number of times is very variable, and depends on the amount of the traffic, the longitudinal section of the line, the age of the materials, the quality of the ballast, the nature of the subsoil, etc., etc.

In general, we have only to restore the line to its proper level at the fish-joints which sink more than the rest of the line.

On certain gradients of great length the direction of the line has to be frequently re-established.

*

Belgian State Railways. — The general adjustment has on an average to be made once a year. It is undertaken with the object of adjusting the line to its proper level, and at the same time to the right direction.

Dutch Railway Co. — At least twice a year.
The additional work is principally with the object of adjusting the level.

Egyptian Railways. — Owing to the absence of a ballast-foundation and to the high level of the water in the trenches at the side, the road very easily loses its level and shape; this also depends on the locomotives that are used.
It is impossible to give any particular information on this point.

Russian State Railways (St. Petersburg to Warsaw). — The permanent way is adjusted and renewed as required; a complete repair of the whole system, or by sections, is never made.
There are no statistics giving the exact number of repairs per unit distance per year, but we can assume on the whole that the repairs on the gradients are executed not less than three times a year, namely in the spring, when sleepers are changed, and in the autumn; the re-establishing of the line in its proper direction is done at least four times a year.

2nd *Cost of repair.*

The annual cost of repairing the road is to be given per yard in pence and in number of days' labour required (per metre in kreutzers and days).

Kaiser Ferdinands Nordbahn. — Mean : 1·902 d., 0·137 day (wages, material for road excluded).

Privileged Austro-Hungarian State Railway Co. — Mean : 2·743 d., 0·165 day (wages, all material excluded).

Austrian Southern Railway. — Cost for renewal : 9·144 d., 0·183 day.

Meridional Railway. Adriatic System. — Mean : 6·035 d., 0·329 to 0·366 day.

French State Railways. — The expenses of repair vary on different sections between 2·743 and 11·702 pence per yard (0·305 and 1·348 franc per metre).
From the data given it is impossible to deduce the mean.
No information is given as to the number of days.

Paris, Lyons and Mediterranean Railway. — No information with regard to the cost of maintenance, and the number of days work required.
[The total costs for maintenance, exclusive of renewals, supervision, and wages in general have been £ 437.4 s. 3 d. per mile (6,850 francs per kilometre), or on an average 4 s. 11·62 d. per yard. In this figure, 1 s. 1·17 d. per yard may be taken as the cost of the labour, maintenance and renewal of the road and works and of the tools required.]

French Northern Railway. — It is estimated that on an average at the chief revision 6·5 to 7·6 yards (6 to 7 metres) are adjusted per man per day; and that taking into account the occasional repairs also necessary this will amount to about 5·5 yards (5 metres) per man per day. This is excluding the repairs to subsoil and the renewal of the ballast or of the superstructure.

French Western Railway. — The repairs are as a rule carried out by gangs consisting of four plate-layers in charge of a foreman. Each gang has to repair 2·48 miles (4 kilometres) of double line or 3·73 miles (6 kilometres) of single line. Besides these repairs the gangs have to keep the fences in order, clean out the ditches, to look after the fixed apparatus at the stations in their district, to do the fogging, and to look after the timber yards.

The importance of this service varies much on the different lines; extra men are added to the gangs at various times of the year.

A foreman receives on an average £ 48 (1,200 francs) a year, a plate-layer £ 36 (900 francs) a year.

Belgian State Railways. — Mean : 3·292 d , 0·137 day.

As an average we may reckon that one man per 0·62138 mile (1 kilometre) can do the ordinary repairs of a double line. The men work in gangs composed of four men for every 2·48 miles (4 kilometres) of road.

The average wage of the plate-layers composing the gang is 22·9 pence per day (fr. 2·40); that of the foreman 24·8 to 26·7 pence per day (fr. 2·60 to fr. 2·80).

Dutch Railway Co. — Mean : 8·230 d., 0·183 day.

(There is one plate-layer per 0·9321 mile [1·5 kilometre] of single line.)

Egyptian Railways. — Mean : 5·303 d., 0·302 day.

(The total of the wages and salaries of the inspectors, foremen, plate-layers, smiths, and other men employed by the day in the maintenance and repair of the whole line and of the sidings.)

The total expense in the service of the line for maintenance and repair including the bridges, station-buildings, servants' houses, is 20·30 pence per yard.

Russian State Railways (St. Petersburg to Warsaw). — The average annual expense for the whole line for the last three years, 1891, 1892 and 1893 :—

a) Workmens' wages	£ 35,208· 8 s. 9 d.	338,001 roubles.
b) For packing ballast	5,755·10 s. 5 d.	55,253 —
c) For renewing sleepers	33,068· 8 s. 9 d.	317,457 —
d) For renewing rails	35,267· 5 s. 10 d.	338,566 —
e) For repairing fish joints	7,821· 9 s. 2 d.	75,086 —
f) For adjusting ballast where driven into subsoil	1,559·15 s. 10 d.	14,974 —
Total for the year	£ 118,680·18 s. 9 d.	1,139,337 roubles.

Besides the expense of £ 7,821·9 s. 2 d. (75,086 roubles) for the repair to the joints (replacing those which are worn out), on an average during the years 1891, 1892 and 1893, £ 16 592 3 s. 9 d. (159,285 roubles) per year were spent for the replacement of flat fish-plates by angular fish-plates.

The annual expense per yard of the line may be estimated at £ 4.17 s. 11 d. (47 roubles per metre) for labour and materials.

V. — Supplementary information.

1st *Curves and gradients.*

Super-elevation and widening of the gauge applied; results of observations and trials made to determine whether they are satisfactory.

Note. — In the following formulae :—

α = super-elevation in inches.
(H = — in metres.)
(h = — in millimetres.)
β = widening of gauge in inches.
(e = — in millimetres.)
γ = distance between centres of rails in inches.
(s = — — in metres.)
δ = gauge of line in inches.
(S = — in metres.)
ε = maximum speed in feet per second.
($C = c$ = — in metres per second.)
(v = — in kilometres per hour.)
(g = acceleration due to gravity, 9·81 metres.)
ζ = radius of curve in chains.
(R = — in metres.)

Kaiser Ferdinands Nordbahn. — The super-elevation is determined by the formula : —

$$\alpha = \frac{\varepsilon^2 \cdot \gamma}{\zeta \times 2124} \qquad \left(H = \frac{s \cdot c^2}{g \cdot R}\right)$$

but it may not exceed 4·92 inches (125 millimetres).

The widening of the gauge is as follows :

If ζ is :	then β is :	(If R is :	then e is
7·46 to 12·43.	1·10	150 to 250.	28
12·43 — 16·15.	1·02	250 — 325.	26
16·15 — 19·88.	0·94	325 — 400.	24
19·88 — 23·61.	0·87	400 — 475.	22
23·61 — 27·34.	0·79	475 — 550.	20
27·34 — 31·07.	0·71	550 — 625.	18
31·07 — 34·80.	0·63	625 — 700.	16
34·80 — 39·76.	0·55	700 — 800.	14
39·76 — 47·22.	0·47	800 — 950.	12
47·22 — 54·68.	0·39	950 — 1,100.	10
54·68 — 64·62.	0·31	1,100 — 1,300.	8
64·62 — 74·56.	0·24	1,300 — 1,500.	6
74·56 — 87·00.	0·16	1,500 — 1,750.	4
87·00 — 99·42.	0·08	1,750 — 2,000.	2
Above 99·42.	0·00	Above 2,000.	0)

At the commencement of the curve, the full super-elevation and the full increase of the gauge should have been attained.

These super-elevations and widenings have on the whole proved satisfactory.

In 1891, experiments have been begun on super-elevation according to the formulae :—

$$\alpha = 1{\cdot}503 \times \frac{\varepsilon}{\zeta} \qquad \left(h = \frac{700v}{R}\right)$$

and $\alpha = 1 \cdot 074 \times \frac{\iota}{\zeta}$ $\left(h = \frac{500v}{R}\right)$

and on widening of gauge according to the formula: —

$$\beta = 0 \cdot 001458 - 0 \cdot 0005898 \, \zeta^2 \qquad \left(e = \frac{(1{,}000 - R^2)}{27{,}000}\right)$$

Privileged Austro-Hungarian State Railway Co. — The super-elevation is determined by the formula:—

$$\alpha = 0 \cdot 0277344 \times \frac{\iota^2}{\zeta} \qquad \left(H = 0 \cdot 01177 \times \frac{v^2}{R}\right)$$

but it may not exceed 5·71 inches (145 millimetres).

The widening is determined by the formula:

$$\beta = \frac{26\ 035}{\zeta} - 0 \cdot 3937 \qquad \left(e = \frac{13{,}302}{R} - 10 \text{ millimetres}\right)$$

but it may not exceed 1·18 inch (30 millimetres).

With this arrangement, the wear of the rails, and particularly the inner one, at the curves, seems comparatively large; a reduction in the super-elevation and a decrease in the widening seem to be indicated.

Austrian Southern Railway. — The super-elevation is slightly greater than that shown by the formula:—

$$\alpha = \frac{\iota^2 \gamma}{\zeta \times 2124} \qquad \left(H = \frac{s \, . \, c^2}{g \, . \, R}\right)$$

but it may not exceed 5·91 inches (150 millimetres).

The widening of the gauge is as follows:

If ζ is:	then β is:	(If R is:	then e is
7·46 to 13·92	1·02	150 to 280	26
14 91 — 17·40	0·94	300 — 350	24
18·64 — 22·37	0·79	375 — 450	20
24·85 — 32·31	0·63	500 — 650	16
34·80 — 44 74	0·47	700 — 900	12
49 71 — 62·14	0·31	1,000 — 1,250	8
74·56 — 87·00	0·16	1,500 — 1,750	4
Above 99·42	0·00	Above 2,000	0)

The latter rule has only been in use for the last year.

Meridional Railway. Adriatic system. — The super-elevation is determined by the formula:—

$$\alpha = \frac{\iota^2 \gamma}{\zeta \times 2124} \qquad \left(H = \frac{s \, . \, c^2}{g \, . \, R}\right)$$

but it may not exceed 5·51 inches (140 millimetres).

The widening of the gauge:

If ζ = or < 19·88	ten β = 0·59	(If R = or < 400	then e = 15
19·88 to 24·85	= 0·39	400 to 500	= 10
24·85 to 32·31	= 0·20	500 to 650	= 5
> 32.31	= 0 00	> 650	= 0)

The ordinary gauge is 4 feet 8·89 inches (1·445 metre).

Italian Mediterranean System. — The super-elevation is determined by the formula :

$$\alpha = \frac{\varepsilon^2 \delta}{\zeta \times 2124} \qquad \left(H = \frac{S \cdot c^2}{g \cdot R}\right)$$

but it may not exceed 5·51 inches (140 millimetres).

The widening of the gauge :

If $\zeta < 19{\cdot}88$ . . . . then β	=	0.59	(If R < 400 . . . . . then e	=	15
19·88 to 24·85 . . .	=	0·39	400 to 500	=	10
24·85 to 32·31 . . .	=	0·20	500 to 650	=	5
> 32·31	=	0·00	> 650	=	0)

The ordinary gauge is 4 feet 8·89 inches (1·445 metre).

French State Railways. — The super-elevation is determined by the formula :—

$$\alpha = 1{\cdot}957 \times \frac{V}{\zeta} \qquad \left(H = \frac{V}{R}\right)$$

where $V = 50$ when ε is $> 45{\cdot}57$ and $< 54{\cdot}68$
(v is > 50 and < 60)

and $V = 60$ when ε = or $> 54{\cdot}68$
(v = or > 60)

On double lines the super-elevation calculated from this formula is :—

1st Reduced by one-fourth in curves situated on a rising gradient of at least 1 in 143 (7 millimetres per metre), when the beginning of these curves is at least 546·8 yards (500 metres) from the beginning of the gradient;

2nd Increased by one-fourth in curves situated on a falling gradient of at least 1 in 143 (7 millimetres per metre).

One half of the super-elevation is attained at the commencement of the curve. The elevation begins 48·1 yards (44 metres) before the commencement of the curves when the super-elevation does not exceed 3·94 inches (10 centimetres) and 72·2 yards (66 metres) when it does exceed this amount.

Experiments are being made to ascertain whether it would not be better to have two-thirds of the super-elevation at the commencement of the curve, and to attain this by giving the rails an inclination of 1 in 667 (1·5 millimetre per metre).

The keys which secure the rails to the chairs are driven in the down direction of the gradient.

The gauge is the same on curves as on straight parts of the road.

Paris, Lyons and Mediterranean Railway. — The super-elevation is determined by the formula :—

$$\alpha = 2{\cdot}147 \times \frac{\varepsilon}{\zeta} \qquad \left(H = \frac{v}{R}\right)$$

but it may not exceed 5·91 inches (150 millimetres).

(See note of Mr. Jules Michel on measures taken to facilitate running round curves. *Revue générale*, December 1893.)

Paris-Orleans Railway. — The super-elevation is determined by the formula :—

$$\alpha = 0{\cdot}02781 \times \frac{\varepsilon^2}{\zeta} \qquad \left(H = \frac{0{\cdot}0118 v^2}{R}\right)$$

On curves the gauge is widened 0.39 inch (10 millimetres).

French Northern Railway. — The super-elevation is determined by the formula :—

$$\alpha = 1957 \times \frac{n}{\zeta} \qquad \left(H = \frac{1{,}000 \cdot n}{R}\right)$$

where $n = 0{\cdot}04$ for lines used for slow trains;
0·05 — trains of medium speed;
0·075 — expresses.

These super-elevations seem to answer very well.

The widening of the gauge :

If ζ is 22·37 to 12·43 then $\beta = 0{\cdot}39$ (If R is 450 to 250 . . then $e =$ 10
< 12.43. . . . . . . $= 0{\cdot}59$ (< 450 . . . . $=$ 15)

French Western Railway. — Super-elevation : on embankments the rail at the side of the slope is raised 0·79 inch (2 centimetres). In addition the outer rail is raised on curves by the amount determined by the formula :

$$\alpha = 0{\cdot}0278 \times \frac{\varepsilon^2}{\zeta} \qquad \left(H = 0.153\,\frac{C^2}{R}\right)$$

The super-elevation must commence at least 100 α (100 H) before the beginning of the curve and must attain its full extent on the straight part of the line. It has not been considered necessary to widen the gauge on curves.

Belgian State Railways. — The super-elevation is determined by the formula :—

$$\alpha = \frac{\varepsilon^2\,\delta}{\zeta \times 2124} \qquad \left(H = \frac{S\,.\,C^2}{g\,.\,R}\right)$$

In addition the following formula :—

$$\alpha = \frac{105{\cdot}68}{\zeta} \qquad \left(H = \frac{54}{R}\right)$$

has been used as an experiment to give the « standard » super-elevation.

This « standard » super-elevation is increased by one-fourth for all curves round which trains of a higher speed than 37·28 miles (60 kilometres) per hour run; it is reduced by one-fourth for all curves where the speed does not exceed 24·86 miles (40 kilometres) per hour.

The super-elevation adopted is called the « practical » super-elevation; in no case may it exceed 5·91 inches (150 millimetres).

Since 1887, the Belgian State has entirely abolished widening the gauge in curves of a radius equal to or greater than 24·85 chains (500 metres) laid with rails weighing 104·8 lbs per yard (52 kilograms per metre).

The same is the case at places where a line branches off at a radius of 22·37 chains (450 metres) or more.

Dutch Railway Co. — Super-elevation :

The speed is reduced to	where ζ equals	and α applied is	(where R equals)	(and h applied is)
0·988	248·50	0·51	5,000	13
0·985	198·80	0·63	4,000	16
0·98	149·10	0·83	3,000	21
0·97	99·42	1·18	2,000	30
0·96	74·56	1·57	1,500	40
0·94	49·71	2·24	1,000	57
0·925	39·76	2·76	800	70
0·9	29·82	3·46	600	88
0·88	28·45	3·98	500	101
0·85	19·88	4·21	400	107
0·8	14·91	5·47	300	139

The widening of the gauge:

If ζ is 49·71 to 19·88. . then β =	0·20	(If R is 1,000 to 400 . . then e =	5
19·88 to 14·91. . . . =	0·39	400 to 300 . . . . =	10
14·91 to 7·46. . . . =	0·83	300 to 150 . . . . =	21)

Egyptian Railways. — The super-elevation is determined by the formula:—

$$\alpha = 2 \cdot 147 \times \frac{\epsilon}{\zeta} \qquad \left(H = \frac{v}{R}\right)$$

but it may not exceed 6·30 inches (160 millimetres).

The full amount of super-elevation is required at the commencement of the curve; and the inclination of the outer rail to obtain this result may not exceed 1 in 200 (5 millimetres per metre).

Up to the present there has been no widening of the gauge at curves.

Russian State Railways (St. Petersburg to Warsaw). — The super-elevation is determined by the formula:—

$$\alpha = 0 \cdot 030145 \times \frac{\epsilon^2}{\zeta} \qquad \left(H = \frac{12 \cdot 792\, v^2}{R}\right)$$

On all main lines, it is now assumed that ϵ = 68 (v = 74·67). No experiments have been made to determine the accuracy of the formula.

The full super-elevation of the outer rail is continued throughout the curve; the raising of the outer rail is begun 1,000 α (1,000 h) before the commencement of the curve.

Movement of rails on gradients. Creeping.

Kaiser Ferdinands Nordbahn. — On double lines creeping generally takes place on both roads in the direction the trains travel; on single lines in the direction in which there is the greater number of and more heavily loaded trains; it is immaterial whether the gradient is rising or falling.

On curves the inner rails generally move in the same direction as the outer rails, and generally in the same direction as the trains, or in the direction of the heavier traffic.

The greatest rate of movement observed (after one year) has been 10·24 inches (260 millimetres) for one year. The greatest absolute movement has been 16·54 inches (420 millimetres) in 7 years.

The greatest displacement of a fish-joint relatively to the one on the opposite rails has been 12·21 inches (310 millimetres) in 6 years. Creeping has been frequently accompanied by enlargement of the gauge up to 0·276 inch (7 millimetres).

The fish-joint usually remained during the creeping in its normal position relative to the two sleepers adjoining it.

In most cases some of the dog-spikes have had their heads bent and even broken off by the displacement; some angular fish-plates have also been torn out, principally on iron bridges. In a great many cases, and particularly on heavy gradients on a double line, it has been noticed that the lower flanges of the angular fish-plates have mounted the bed-plates near them.

As a rule, the sleepers next the sleepers adjoining the fish-joint have also been displaced from their normal position.

When the movement had reached a certain point, steps had to be taken to improve the road (replace the sleepers at the joint to their proper position, force back the rails, or put in dog-spikes differently, replace standard rails by those used for curves).

The creeping of the rails is less on sleepers packed with a ballast of broken stone than on those packed with a ballast composed of gravel from a river or gravel-pit.

Austrian Southern Railway. — In many cases, very considerable creeping tackes place on heavy gradients. The movement is counteracted by the use of angular fish-plates, but these are not quite sufficient when the gradients are steep. For this reason the road must often be adjusted. A trial of broken joints answered fairly well, but on steep inclines the movement was not prevented.

Italian Mediterranean System. — No precise observations have been made with regard to the creeping on gradients; it is however reduced to a nearly negligible amount by the different methods of attachment in use (dog-spikes on the two sleepers near the joint, and fish-plates which bear against the tie-plates which are firmly fixed to each other). (*Vide* III, 3.)

French Northern Railway. — The rails creep in the direction of the trains which pass over them, and in addition in the downward direction of the gradient.

The repairs executed at the regular inspection prevent the creeping from becoming excessive.

French Western Railway. — To counteract creeping, the inside fish-plate is made long enough to enable its extremities to bear against the base of the chairs on the sleepers adjoining the fish-joint.

Belgian State Railways. — On the steep gradients of Luxemburg, it was necessary at some places to add a third screw spike to the fish-plate on each sleeper adjoining the fish-joint in order prevent creeping. At gradients the middle part of the rail is secured by two means of attachment per 29·53 feet (9 metres) rail.

Any creeping would thus affect four sleepers, and on the steepest gradients the road is immoveable.

Dutch Railway Co. — The rails creep in certain places, particularly where there are iron sleepers.

Egyptian Railways. — No particular observations have been made on creeping on gradients; the question is treated generally. The importance of creeping in Egypt is shown by the fact shat the subject is always under consideration; and also by the methods adopted in different types of superstructure to counteract it.

In Egypt the creeping of the rails invariably takes place in the direction of the traffic, and both rails creep; the right-hand rail moves from two to five times faster than the left-hand rail. No exception to this rule has been observed; nor has any difference due to curves, gradients, or direction of the line, been determined.

The creeping is as a rule greater in summer than in winter.

On a single line, with traffic in both directions, creeping is very much more noticeable than on a double line.

1854 type of road laid with pot-sleepers. — The creeping of the rail is very great on this type of road when wooden keys are used.

For the right-hand rail a movement of 0·866 inch (22 millimetres) per month has been recorded and on soils which have little resistance it has been as much 1·969 inch (50 millimetres).

Spiral keys which were used alternately with wooden keys, did not prevent creeping; but when spiral keys only were used the creeping was prevented sufficiently.

These are now used exclusively on the 87·0 miles (140 kilometres) of double line between Birket-el-Sab and Alexandria.

Vignoles rails, 1889 type. — The system adopted to arrest the creeping of the rails (check-keys fixed at the extremity of the rail) has been found unsuitable and ineffective. On one point where the ballast was of sand, the displacement has reached 1·378 inch (35 millimetres) in a month. Elsewhere where the ballast is of gravel, the displacement of the rails on this type of road in a period of 25 months has been at the rate of 0·315 to 0·591 inch (8 to 15 millimetres) per year for the right-hand rail and 0 to 0·315 inch (0 to 8 millimetres) for the left-hand rail.

The extent of the creeping naturally depends to a great extent on the nature of the ballast employed and on the care with which the screw-spikes have been screwed up. The use of packing plates increases the efficiency of the screw-spikes and prevents the rail from being forced into the sleeper.

Vignoles rails, 1893 type. — The angular fish-plates and angular stops have during five months checked creeping. It is however necessary to continue these experiments.

Russian State Railways (St. Petersburg to Warsaw). — With respect to creeping the road behaves in a satisfactory way on the gradients.

2nd *Materials of the superstructure.*

Results of observations made with regard to the use of hard or soft metal (rails, fish-plates). Influence of the process of manufacture of the metal.

Kaiser Ferdinands Nordbahn. — Since 1891, some trials have been made on the behaviour of the rails. No results have as yet been determined. Trials, begun in 1895, are being made on the behaviour of the fish-plates.

Privileged Austro-Hungarian State Railway Co. — A hard, elastic, tenacious metal gives the best results.

Austrian Southern Railway. — The whole of the material of the superstructure is of Martin steel only.

Meridional Railway. Adriatic System. — Material of the same strength having always been used for the different parts of the superstructure, no opportunity has arisen to determine the effect of different degrees of hardness.

Italian Mediterranean System. — The necessity has been recognised of not using too soft metal for the rails so as to prevent the wear of the head of the rails, and to prevent the rails taking a set between the points of support.

French State Railways. — The rails actually in use are exclusively made of cast steel, manufactured either by the Siemens-Martin, or by the Bessemer process. The steel must be of the best quality, with fine grain, dense, hard, and tenacious, capable of being hardened; it should contain more than 0·3 p. c. of carbon, and less than 0·11 p. c. of phosphorus.

Paris, Lyons and Mediterranean Railway. — Experience has shown that hard but not brittle steel which is required for rails can only be prepared in the Siemens-Martin furnace.

The Thomas process (removal of phosphorus) gives a material which is too soft and contains large blowholes; consequently it wears away much more rapidly than steel produced by the acid process. Thus, for instance, fifty rails of dephosphorised steel were taken up after six years and three months service; the average wear of the head was 0·575 inch (14·6 millimetres).

The rails of acid steel which had previously been in the same place had been in use for nine years and a half, and their average wear was 0·472 inch (12 millimetres).

The best material for fish-plates is steel of a medium degree of hardness, so that they may wear away quicker than the rails which are more difficult to replace and more expensive (1).

French Southern Railway. — Hard steel is exclusively used for the manufacture of rails and fish-plates. This metal behaves very well and wears slowly.

(1). *Revue générale*, August 1889; A. Hallopeau, « Note on the quality of steel for rails and their accessories ».

Paris-Orleans Railway. — It has been noticed that the head of rails of steel of a medium degree of hardness flatten out under the action of the traffic. Nothing of this sort happens with rails of hard steel.

French Northern Railway. — No opinion can as yet be formed on this subject, as there are not yet sufficient data.

French Western Railway. — As a rule, rails of hard metal are used; however, rails weighing 88·7 lbs per yard (44 kilograms per metre) of specially soft steel were laid down in 1891 in the tunnel of Pissy-Poville (1 mile 650 yards, 2,204 metres) on the line from Paris to Havre.

But these rails have been in service too short a time for an interesting conclusion to be drawn from the observations on them up to the present.

Belgian State Railways. — No trials have been made on this subject.

The rails are of steel of a medium degree of hardness. The « bridge » fish-plates are of soft steel or of iron.

Egyptian Railways. — A higher tensile strength than 44·4 to 47·6 tons per square inch (70 to 75 kilograms per square millimetre) is not specified even in the case of Vignoles rails weighing 84·7 lbs per yard (42 kilograms per metre).

Breakages happening during unloading, while being laid down, or afterwards have been extremely rare, and the proportion has not exceeded 1 per 40,000 rails since 1889.

The analyses of some broken rails seem to indicate that the breakages are due to wrong proportions of the chemical constituents, such rails contained 0·56 p. c. of silicon instead of 0·06 p. c., as specified by the conditions. These defective rails have very probably been made with the first ingot of the charge which is often of a different composition. To detect such in order to test them, and if necessary reject them, it has been determined to specify in future that the rails are to be stamped with the number of the ingot.

Of about 5,000 double-headed rails ordered in 1891, several hundred were used for points and crossings; and a great number have been found to be too hard to be worked with tools or cut up into lengths.

The analysis of the rails on their delivery was as follows : —

Carbon	0·375 per cent.	Phosphorus	0·054 per cent.
Silicon	0·064 —	Manganese	1·449 —
Sulphur	0·058 —		

The tensile strength was 39·4 to 40·0 tons per square inch (62 to 63 kilograms per square millimetre).

The limit of elasticity was 24·1 to 27·3 tons per square inch (38 to 43 kilograms per square millimetre).

The elongation was 24 to 25 p. c. on a piece 1·97 inch (5 centimetres) long.

The reduction of area was 37 to 38 p. c.

The analysis of several of the rails found to be too hard to be used for points gave the following results : —

Carbon	0·615 per cent.	Manganese	2·139 per cent.
Silicon	0·118 —	Arsenic	0·021 —
Sulphur	0·059 —	Copper	0·071 —
Phosphorus	0·053 —		

Tensile strength, 53·3 to 54·0 tons per square inch (84 to 85 kilograms per square millimetre)
Elongation, 1·6 to 3 p. c. on a piece 1·97 inch (5 centimetres) long.
Reduction of area, 0 to 5 p. c.

There is then every reason to believe that we have had on our line since 1891 a large number of double-headed rails having a tensile strength of 54·0 tons per square inch (85 kilograms per square millimetre).

The number of breakages due to the loading or happening during the laying has been insignificant; it does not reach more than one in 4,000.

No breakage has been caused by the action of the trains.

No other material than soft Bessemer steel has been tried for fish-plates during the last ten years.

3rd *Fish-joints.*

Results of observations on fish-joints, especially comparative data as to different methods of construction, and as so different materials with the same construction.

Kaiser Ferdinands Nordbahn. — There are only data with reference to the old type B used from 1872 to 1886.

Statistics show that the rails are more apt to break near the fish-joint when this becomes slack owing to the wear of the fish-plates.

Out of the total number of rails broken the proportion that was broken (of type B) near the fish-joint was : —

19·6 p. c.	in 1888.	51·8 p. c.	in 1891.
27·5 —	in 1889.	33·1 —	in 1892.
32·4 —	in 1890.	39·5 —	in 1893.

In 1893, packing-pieces were introduced with the object of filling up the slack between the fish-plates and rails.

This filling-up has been considered necessary on 37,440 joints out of a total of 149,758, or on 25·2 p. c.; and the following packing pieces have been used : —

119,746	packings	0 0394 inch	(1 millimetre) thick.
60,646	—	0·0591 —	(1·5 —) —
6,265	—	0·0787 —	(2 —) —

Or altogether 186,657 packings, or on an average about 5 pieces per fish-joint, of a mean thickness of 0·0472 inch (1·2 millimetre).

Privileged Austro-Hungarian State Railway Co. — The defects of the suspended fish joint in use show themselves by the settling of the sleepers next the fish-joint.

The raising of these entails somewhat considerable expense.

Experiments have been made with sleepers next the fish-joint bedded in sand, but we cannot give any verdict as to the result of the experiment.

Gothard Railway. — The type of fish-joint in use has always been considered unsatisfactory, and will be replaced by a stronger method of construction as soon as one giving better results can be found. It has been attempted with some success to remedy the defects of the fish-joints by placing the sleepers next the joint closer together; although these sleepers could only be packed from one side they are as well bedded as the others.

Meridional Railway. Adriatic System. — In order to prevent creeping, it was found necessary to use angular fish-plates with notches for the dog-spikes instead of flat fish-plates.

Italian Mediterranean System. — It has been observed that at the joints there is a noticeable amount of wear of the contact-surfaces of the fish-plates, particularly in the middle. Hence during the last year or two it became necessary.

The wear mentioned above — although much less in proportion — is nevertheless always appreciable.

French State Railways. — It has been noticed that broken joints give less good results than the usual arrangement.

French Southern Railway. — In order to increase the strength of the fish-joints, stronger fish-plates have been introduced (See par. 5. Section III); the results, however, cannot yet be determined, the adoption of this type being too recent.

French Northern Railway. — Strong fish-plates are indispensable for obtaining a good fish-joint, but it is not to be expected that absolute rigidity can be obtained by the use of strong fish-plates alone. The fish-plate can support the rail, but cannot form one whole with it.

It is expected that full rigidity can be obtained by bringing the adjoining sleepers close together, and packing them very well.

It is for this reason that in the new system of superstructure the distance of the sleepers from centre to centre, adjacent to the fish-joint, has been reduced to 18·90 inches (48 centimetres).

French Western Railway. — A system of fish-joint with support has been tried experimentally and appears to be satisfactory. This consists of a cast chair screw-spiked to the sleepers next the fish-joint; the two rail ends are supported on this chair. One steel fish-plate with six bolts secures the rail ends to the chair. Definite results have not yet been obtained owing to the short time this fish-joint has been in use.

Dutch Railway Co. — The angular fish-plates give satisfaction, and are gradually replacing the flat fish-plates.

Egyptian Railways. — We have lately adopted angular fish-plates. The increased rigidity of the joints which results from this is very considerable. Another advantage due to the angular fish-plates is the diminution of creeping. (See section V, 1.)

4th *Special constructions.*

Special constructions to increase the resistances to longitudinal and transverse stresses, and their efficiency (tie-rods, outside supports for the head of the rail, broken joints, etc.).

Kaiser Ferdinands Nordbahn. — Apart from the chair-plates, described in section III, 3, by which it is attempted to procure a better method of attachment, a reduction of canting of the rail, and also an increase of resistance to the lateral forces, other special constructions are not used.

Privileged Austro-Hungarian State Railway Co. — Several methods have been tried experimentally to prevent creeping. Sleepers next the fish-joint have been secured to the adjoining sleepers by a fastening of the shape of a St. Andrews' cross; flat iron plates, or angle-irons placed parallel to the direction of the road, have been used to connect the ends of the sleepers.

The first arrangement has given entirely satisfactory results on a gradient of 1 in 28·6 (35 millimetres per metre) on a local line with heavy traffic on the down grade.

The second arrangement has also given good results in several instances.

To keep the gauge to standard the « Seidl » cross-tie has been used experimentally and has also given good results.

French State Railways. — On lines where the rails are laid on longitudinal sleepers, these latter are connected by means of U-shaped iron tie-rods to increase the resistance to lateral stresses.

Paris, Lyons and Mediterranean Railway. — The adoption of two pairs of tie-plates for a rail 39·4 feet (12 metres) long, to increase the resistance to the longitudinal displacement.

French Southern Railway. — To increase the resistance to lateral stresses the Company have placed on the lines used for express trains and heavy traffic, two additional sleepers per 36·1 feet (11 metres) length of rail on curves of less than 19·88 chains (400 metres) radius, and on gradients of 1 in 50 (20 millimetres per metre) or more.

The distance between the sleepers has thereby been reduced from 38·58 to 32·17 inches (980 to 817 millimetres). The Company also uses chairs with a broad base weighing 31·96 lbs (14·5 kilograms).

In order to prevent lateral displacement of the outer rail on curves, a trial is being made of a chair with a broad base, having three holes for screw-spikes.

French Western Railway. — No special method of construction beyond that of strengthening the fish-plates is used. In certain cases, however, the lateral displacement has been counteracted successfully, in the case of double roads, by connecting the sleepers of the two roads with tie-rods.

It has also been attempted to increase the resistance of the sleepers to lateral movement by driving wooden blocks into the ground at their extremities.

Belgian State Railways. — Check-plates have been used to counteract creeping.

Another method of successfully overcoming the longitudinal stresses consists in joining together a series of sleepers by iron tie-rods.

Dutch Railway Co. — Tie-rods are not used; on some curves, wooden stakes are used.

5th *Behaviour of the superstructure.*

Statements showing whether the line answers the requirements of the traffic, or whether it is intended to modify its construction as a whole, or in detail; giving reasons and particulars.

Kaiser Ferdinands Nordbahn. — The existing superstructures are sufficient for the actual requirements (weight on the wheels, 6·89 tons (7 tonnes); maximum speed, 49·71 miles (80 kilometres).

The modifications which have taken place up to the present (see section V-7) have been caused by the increased amount of necessary repair, by the rapid wear of the road, and by the increased number of fractures of the rails. Their principal object is to bring about a reduction in the expenses of maintenance, and an improvement of the fish-joints; these are recognised generally in all methods of construction of superstructure as the weak point.

Privileged Austro-Hungarian State Railway Co. — The superstructure fully answers the actual requirements. Some small modifications only are contemplated, and are intended to improve the bedding of the sleepers.

Austrian Southern Railway. — The road of the newest standard with two bed-plates per sleeper, answers all the conditions required by the increased speed of the trains. At the present time, no further modifications are contemplated.

Meridional Railway. Adriatic System. — The present superstructure fully satisfies all requirements of the traffic.

Italian Mediterranean System. — The methods described above are quite satisfactory on lines that have easy gradients, or not too heavy a traffic. But it is recognised that they are not strong enough for lines used for fast trains, with a heavy traffic, and on which there are steep gradients and long tunnels.

It is for these reasons that a stronger method of construction will be tried shortly in the long tunnel of Ronco, where the conditions of traffic and gradient are severe.

French State Railways. — In order to meet the increased weight of the locomotives, a commencement was made in 1892 to replace the rails weighing 76·6 lbs per yard (38 kilograms per metre) by rails weighing 80·6 lbs per yard (40 kilograms per metre). At the same time, the number of sleepers has been increased on lines with express trains by one per rail of 18 feet (5·5 metres), and two per rail of 36 feet (11 metres).

For the same reason, the surface of the base of the chairs has been increased, and the number of the screw-spikes has been raised from two to three, in order to distribute the pressure of the chair on the sleeper as uniformly as possible.

Paris, Lyons and Mediterranean Railway. — No modifications are in contemplation.

French Southern Railway. — The road answers very well for the traffic that it takes; no modification of the present system is contemplated.

Paris-Orleans Railway. — The road described is expected to resist a heavy traffic for a long time.

French Northern Railway. — It is not expected that the method of superstructure described will require alteration.

Whether this is a solid and lasting road (as is hoped) cannot be determined till several years have elapsed.

French Western Railway. — For lines, or sections of lines traversed by express trains and used for heavy traffic, bull-headed rails 39·37 feet (12 metres) long and weighing 88·7 lbs per yard (44 kilograms per metre) have been adopted. These rest on eighteen sleepers generally, or in exceptional cases on fifteen.

This is based on the following considerations:

1° The weight on a pair of wheels of the locomotive has risen from 10·83 tons (11 tonnes) to 12·80 (13 tonnes) and even to 14·76 tons (15 tonnes);

2° The speed of the express trains has risen from 37·28 miles (60 kilometres) an hour to 43·50 and 46·61 miles (70 and 75 kilometres) an hour, and the drivers in order to make up lost time are allowed to run up to 55·93 miles (90 kilometres) an hour;

3° The steel rails wear uniformly, and the amount of wear may attain 0·591 inch (15 millimetres) without necessitating their condemnation.

The thickness of the head of the rail has been increased by 0·472 inch (12 millimetres) to allow for wear.

An amount of wear of 0·669 inch (17 millimetres) can therefore be allowed without being injurious instead of 0·197 inch (5 millimetres) on the original rails of 78·1 lbs per yard (38·75 kilograms per metre).

On the other hand, reversing the steel rail which has come to its extreme degree of wear, is no longer possible, hence the adoption of the bull-headed section.

The section of the new rails allows us to use the same chairs as those used with the rails weighing 78·1 lbs per yard (38·75 kilograms per metre).

Belgian State Railways. — The road laid with rails weighing 104·8 lbs per yard (52 kilograms per metre) answers the requirements of a very heavy traffic, especially on the line from Brussels to Antwerp, and from Brussels to the Grand Duchy of Luxemburg.

No modification is contemplated.

Dutch Railway Co. — At present, there is no intention of modifying the superstructure; the road satisfies the requirements of the traffic.

Egyptian Railways. — The construction of the road laid with pot-sleepers and spring keys has adequately answered the requirements of the traffic. Without ballast it forms a good road, easy to keep in order and giving smooth running. Its higher cost, estimated in 1888 at £ 329 and in 1891 at £ 302 more per mile than that of the 1889 type of Vignoles roads, is the chief reason for their disuse. Pot-sleepers are not suitable on damp soils, or where a gravel ballast is necessary.

Russian State Railways (St. Petersburg to Warsaw). — The type of road in use on this line fully satisfies the requirements of the traffic. No change is contemplated.

6th *Dynamic action of the trains.*

Results obtained in everyday practice, or from special experiments (lateral and vertical forces).

Methods and apparatus used to determine the forces exerted on the superstructure by the vehicles.

Kaiser Ferdinands Nordbahn. — See ante, account of experiments for determining photographically the movement of the rails.

Paris, Lyons and Mediterranean Railway. — Vide Coüard on experimental researches on the conditions of stability of lines laid with steel rails (*Revue générale*, October and December 1887, July 1888, and September 1889).

Belgian State Railways. — Vide the communications on experiments concerning the flexibility of the road made by M. Huberti. (Account of the proceedings of the International Railway Congress, volume 3, question XXXIII, page 13.)

7th *Measures taken to give existing lines greater capacity.*

Is it proposed, in view of an increase of speed in the immediate future, to strengthen the superstructure, or to alter the method of construction of the vehicles?

What methods of construction have already been adopted, and with what result?

Kaiser Ferdinands Nordbahn. — A higher speed than 55·92 miles (90 kilometres) an hour is not permitted by law, so that at present there is no reason to think of measures to be taken to make a higher speed possible.

Up to the present the measures adopted to give existing lines the requisite resistance are as follows:

1st The number of sleepers has been raised from eleven to twelve for rails 29·52 feet (9 metres) long, which reduced the space between the sleepers to 2 feet 6·71 inches (78 centimetres). (See section III-7.)

2nd The sleepers employed are 8 feet 10·3 inches (2·7 metres) long, instead of 7 feet 10·5 inches (2·4 metres). (See section III-2.)

These two measures will diminish the sinking of the sleepers into the ballast and hence a firmer road and a smaller cost of maintenance will result.

3rd The use of wedge-shaped bed-plates in order to avoid the necessity of adzing the sleeper, thus tending to the preservation of the latter. (See section III-3.)

4th The adoption of a standard length for the rails of 41 feet (12·5 metres), instead of 29·52 feet (9 metres), in order to reduce the number of fish-joints.

5th The use of chair-plates to increase the supporting surface, and improve the attachment of the rails to the sleepers, in order to obviate the injurious torsion that the rail experiences at the fish-joint. (See section III-3.)

6th The use of fish-plates of a harder mild steel in order to reduce the wear of the bearing surfaces of the fish-plate to a minimum.

7th Drilling instead of punching the bolt-holes, in order to strain the metal as little as possible, and thus reduce the chance of breakage.

8th Increasing the diameter of the bolts from 0·748 inch to 0·866 inch (19 to 22 millimetres).

9th Increasing the length of the fish-plates, and in consequence, the number of the bolts from four to six per fish-joint, in order to obtain a better contact between the rail and the fish-plate, and obtain more useful service from the latter. (See section III-5.)

10th In the case of superstructure with chairs and plates, to make the inner fish-plate take against the clip-plate so as to resist creeping more effectually and to prevent the bending of the bolts.

11th The use of packing pieces in the case of the fish-joints which have become loose. (See section V-3.)

Results showing the success of the measures have not yet been determined.

However, an advantageous result has already been obtained by increasing the number of sleepers, as the number of those becoming loose has been decreased, and the cost of maintenance has been reduced. It is intended to use fish-plates of a somewhat stronger section; both fish-plates to bear against the plates (wedge shaped and chair-plates), which will give a maximum resistance to creeping. This, however, has not yet been carried out.

Meridional Railway. Adriatic System. — On some sections, the number of sleepers per rail has been raised from 10 to 11 for lines having rails 29·52 ft. (9 metres) long, and from 13 to 14 for lines with rails 39·37 ft. (12 metres) long.

Paris, Lyons and Mediterranean Railway. — The adoption of bogie-engines for express trains. (*Revue générale*, January 1894.)

The locomotives of the 1879 type with two coupled axles in front of the fire-box and with leading and trailing wheels, have been converted into bogie-engines with the driving axle in front of the fire-box and the coupled axle behind it.

The boiler was shortened, the diameter of the boiler tubes was increased, the fire-box and the cylinders were brought nearer the centre of gravity; the wheel base was lengthened.

All these modifications combine to increase the steadiness of running, and to diminish the lateral stresses.

The weight of the locomotive in running order has been diminished by 1·132 ton (1,150 kilograms). The shortening of the boiler has been accomplished without reducing its output or increasing the consumption of fuel, by the substitution of tubes of 2·559 inches (65 millimetres) external diameter for those of 1·969 inch (50 millimetres) external diameter.

These converted locomotives have reduced the time from Paris to Marseilles 535·7 miles (862 kilometres) by 14 to 56 minutes.

The average speed is 38·96 miles (62·7 kilometres) to 39·48 miles (63·53 kilometres) per hour. The load is 206·7 tons (210 tonnes). Perfectly smooth running is obtained, even up to a speed of 71·46 miles (115 kilometres) per hour.

Paris-Orleans Railway. — The management in its letter of reply to the questions asked gives the following information.

*

Putting on one side, the Vignoles rails weighing 60·5 and 72·6 lbs per yard (30 and 36 kilograms per metre), which we are gradually doing away with; the standard road on our system is one with symmetrical double-headed rails weighing 76·6 lbs per yard (38 kilograms per metre) with a suspended fish-joint, and chairs weighing 20·94 lbs (9 5 kilograms) each.

Before 1884, the length of the rails was 18 feet (5·5 metres) carried on six sleepers. Since 1884, we only use rails 36 feet (11 metres) long, and we have 2,485 miles (4,000 kilometres) of single line laid with them. The rail of 36 feet (11 metres) rests on twelve sleepers.

In 1889, we adopted a new type of strengthened superstructure, with bull-headed rails weighing 84·7 lbs per yard (42 kilograms per metre) and a chair of 83·6 lbs (18 kilograms).

The strengthened chair fits the ordinary rail weighing 76·6 lbs per yard (38 kilograms per metre); the strengthened rail fits our ordinary chairs used for rails weighing 76·6 lbs per yard (38 kilograms per metre).

Both types of road were described in the *Revue générale des chemins de fer* for July 1892, in an article which gave the reasons relating to the stronger construction.

This type of strengthened superstructure will be gradually substituted for the old type on our main line from Paris to Bordeaux (361·7 miles [582 kilometres] of double line).

We change the chairs independently of the rail when we renew the sleepers. We have up to the present put in heavy rails on half the line, and heavy chairs on a fifth of it.

We have also put in the strengthened form of superstructure at certain special points, such as large tunnels and long iron bridges.

The fact of the two types being interchangeable allows us to make local additions to the strength of the line. We thus apply the heavy rail with the ordinary chair on certain sections at a gradient, where the number and weight of heavy trains descending the gradient with the brakes on cause exceptional wear.

We also use the heavy chairs and ordinary rails on sharp curves of 19·88 chains (400 metres) radius and less on gradients. Also we have recourse to a third method of strengthening the road, viz, increasing the number of sleepers.

At the present time, we have 1,101 miles (1,772 kilometres) of single line provided with seven sleepers instead of six per rail 18 feet (5·5 metres) long.

We do not intend to carry this system of strengthening the road any farther; it introduces considerable extra cost for maintenance.

French Western Railway. — As already stated, the construction of the line has been strengthened by substituting bull-headed steel rails weighing 88·7 lbs per yard (44 kilograms per metre) for symmetrical double-headed steel rails weighing 78·1 lbs per yard (38·75 kilograms per metre). In addition, methods for strengthening the fish-joints are being considered. The fish-joint described in section V, 3, is the first step in our experiments.

Belgian State Railways. — The type of road with a rail 104·8 lbs per yard (52 kilograms per metre) having great resistance, there has been no occasion to consider this question up to the present.

Dutch Railway Co. — No changes are intended in the near future either in the permanent way, or in the construction of the locomotives.

Egyptian Railways. — No steps have been taken to increase the resistance offered by the roads laid with pot-sleepers, but our Administration has decided to completely renew the 128 1/2 miles (207 kilometres) of double line between Cairo and Alexandria, and the work has been already begun.

Vignoles rails weighing 84·7 lbs per yard (42 kilograms per metre) with two angular fish-plates at each fish-joint, will be employed. The road will be ballasted with gravel or broken stone 3·937 to 5·906 inches (10 to 15 centimetres) thick under the sleepers.

The sleepers will be chiefly oak from Asia Minor or Turkey. Judging from the 12·48 miles (20 kilometres) of road already renewed (April 1894) with Vignoles rails weighing 84·7 lbs per yard

(42 kilograms per metre), this type of road will perfectly answer all the requirements of necessary stability, even if the speed of the trains and the weight of the locomotives should be increased materially.

Russian State Railways (St. Petersburg to Warsaw). — At present, there is no intention to allow a greater speed for the trains, and in consequence the construction of the permanent way or the locomotives will not be modified.

APPENDIX X. (BEILAGE X.)

Average make up of trains.
(Durchschnittliche Zusammensetzung der Zugsgarnituren.)

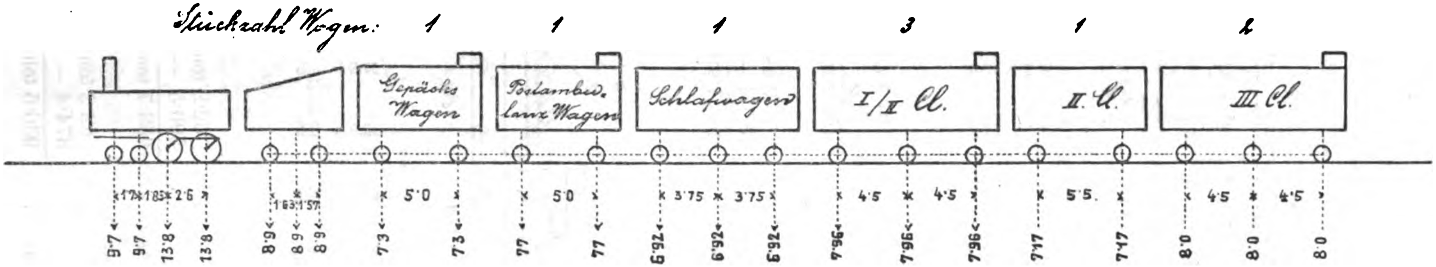
EXPLANATION.

Stückzahl Wagen . . . . Anzahl Wagen	= Numbers of cars of each kind. The figures above the different cars show how many of the kind there are on the train.
Richtung von Wien	= From Vienna.
— nach	= Towards Vienna.
Gepäckswagen	= Luggage van.
Postambulanzwagen	= Postal car.
Gekuppelter Postambulanzwagen . . .	= — Twin travelling post office.
Packmeisterswagen.	= Parcel van.
Gedeckter Güter wagen	= Covered goods wagon.
Offener Güterwagen	= Open — —
Schlafwagen	= Sleeping car.
Milchwagen	= Milk van.
Fleischwagen	= Meat van.
Kohlenwagen	= Coal wagon.
Speisewagen	= Van for market produce.
Achsdrücke	= Axle load.
Leere Wagen	= Empty wagons.
Beladene Wagen	= Loaded —
Radstand	= Distance between axles.
Im Mittel	= Average.

I. — Emperor Ferdinand Northern. (Kaiser Ferdinands Nordbahn.)

A. Vienna-Cracow line.

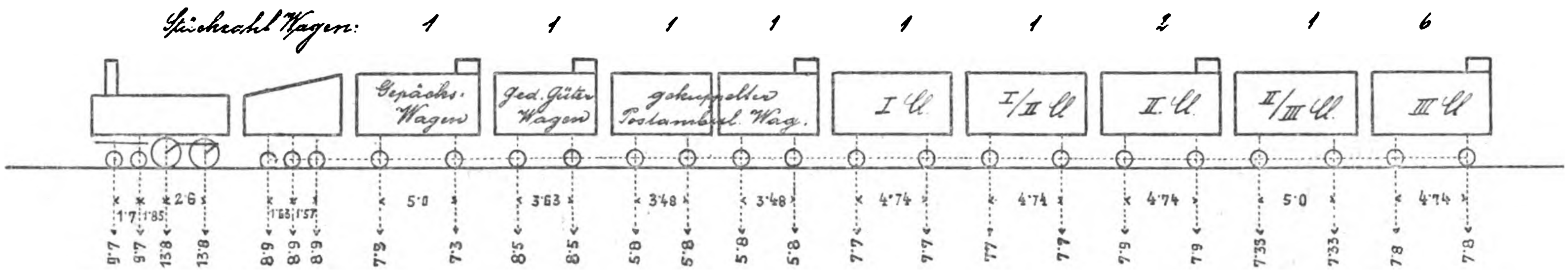
Express trains.



Gross tonnage :

Locomotive and Tender	72·5 tons	(73·7t)
Wagons	181·6 —	(184·7t)
Total. . .	254·1 tons	(258·4t)

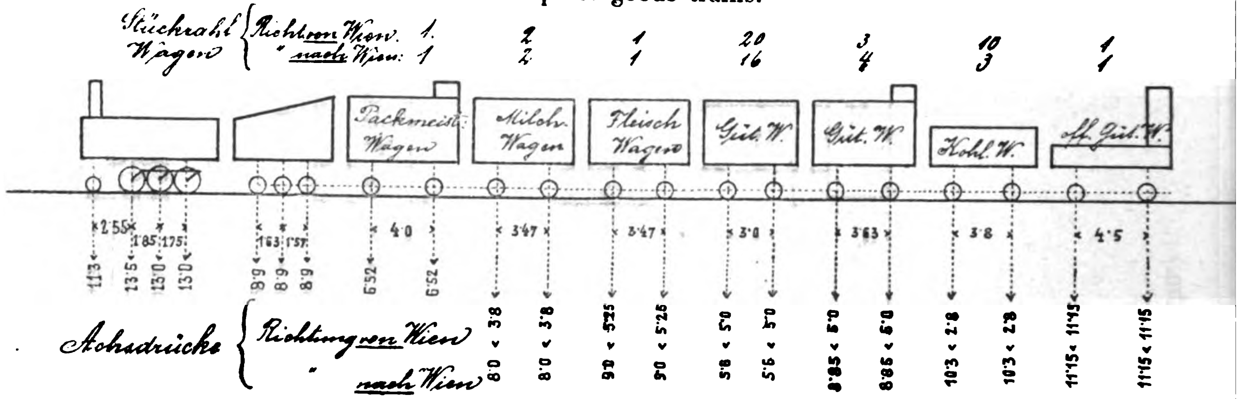
Ordinary passenger trains.



Gross tonnage :

Locomotive and Tender	72·5 tons	(73·7t)
Wagons	221·8 —	(225·5t)
Total. . .	294·3 tons	(299

Express goods trains.



Gross tonnage :

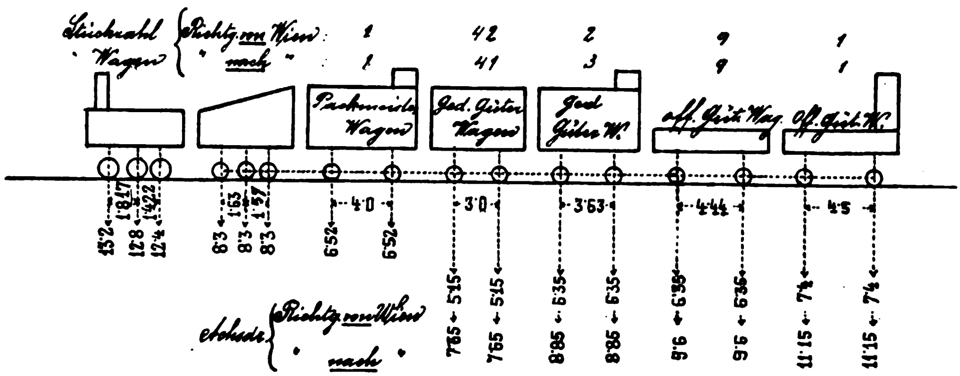
Ex Vienna.

Locomotive and Tender.	75·9 tons	(77·2ᵗ)
Wagons	347·3 —	(353·0ᵗ)
Total. . .	423·2 tons	(430·2ᵗ)

Towards Vienna.

Locomotive and Tender.	75·9 tons	(77·2ᵗ)
Wagons	390·8 —	(397,1ᵗ)
Total. . .	466·7 tons	(474·3ᵗ)

Goods trains.



Gross tonnage :

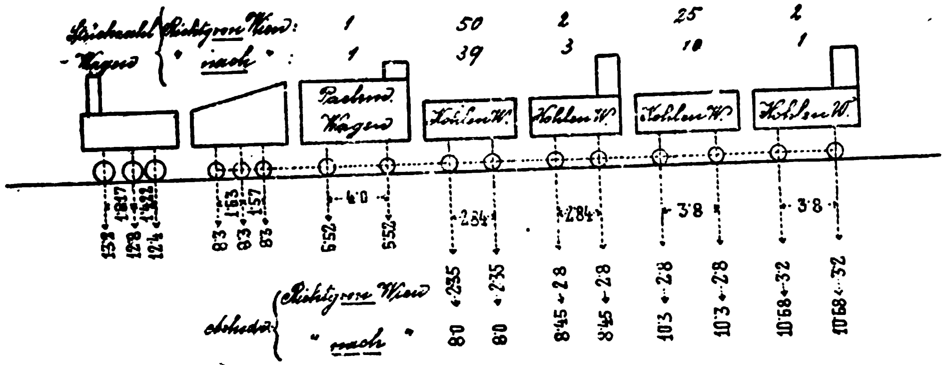
Ex Vienna.

Locomotive and Tender.	62·2 tons	(63·3ᵗ)
Wagons	590·5 —	(600·1ᵗ)
Total. . .	652·7 tons	(663·4ᵗ)

Towards Vienna.

Locomotive and Tender.	62·2 tons	(63·3ᵗ)
Wagons	874·4 —	(888·5ᵗ)
Total. . .	936·6 tons	(951·8ᵗ)

Coal trains.



Gross tonnage :

Ex Vienna.

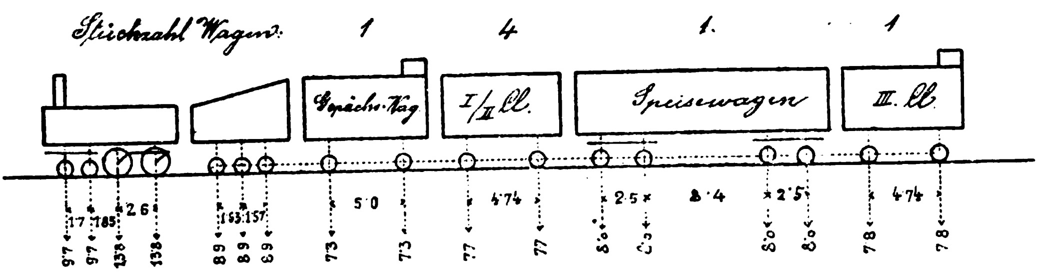
Locomotive and Tender.	62·2 tons	(63·3t)
Wagons	405·2 —	(411·9t)
Total. . .	467·5 tons	(475·2t)

Towards Vienna.

Locomotive and Tender.	62·2 tons	(63·3t)
Wagons	900·6 —	(915·1t)
Total. . .	962·8 tons	(978·4t)

B. Vienna-Brünn Line.

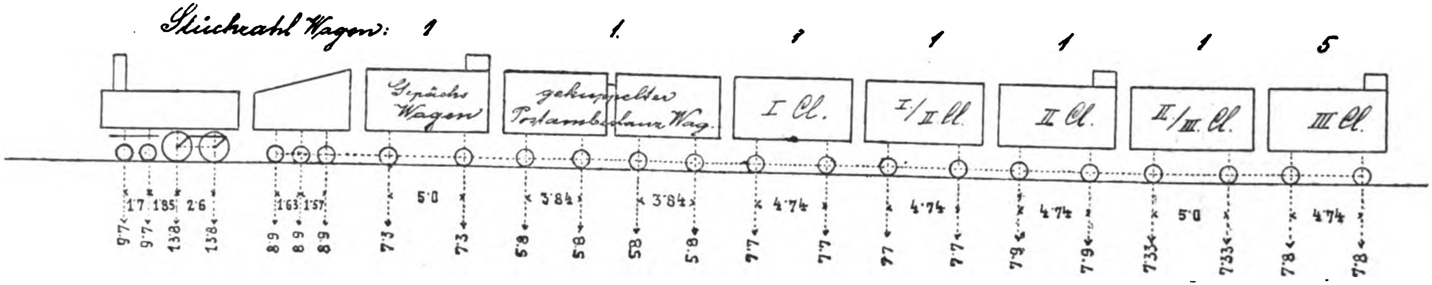
Express trains.



Gross tonnage :

Locomotive and Tender.	72·5 tons	(73·7t)
Wagons	121·8 —	(123·8t)
Total. . .	194·3 tons	(197·5t)

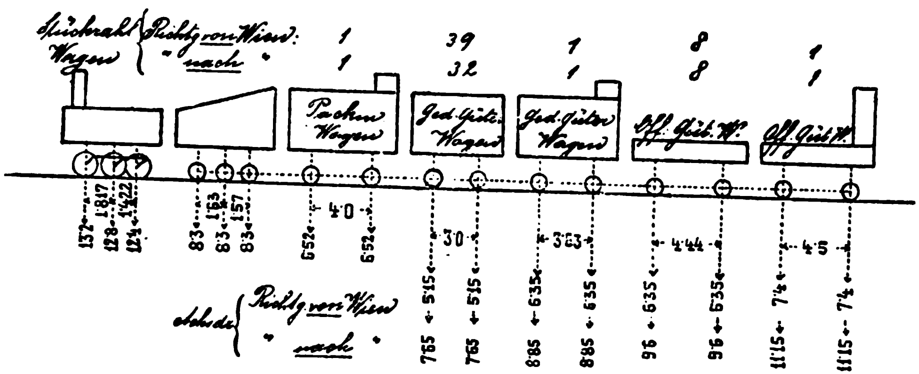
Ordinary passenger trains.



Gross tonnage :

Locomotive and Tender.	72·5 tons	(73·7ᵗ)
Wagons	174·28 —	(177·1ᵗ)
Total. . . .	246·78 tons	(250·8ᵗ)

Goods trains.



Gross tonnage :

Ex Vienna.

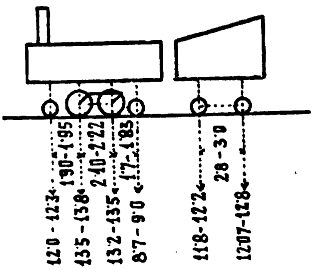
Locomotive and Tender . .	62·2 tons	(63·3ᵗ)
Wagons	535·2 —	(543·8ᵗ)
Total. . .	597·4 tons	(607·1ᵗ)

Towards Vienna.

Locomotive and Tender . .	62·2 tons	(63·3ᵗ)
Wagons	670·1 —	(680·9ᵗ)
Total. . .	732·3 tons	(744·2ᵗ)

II. — Austro-Hungarian State Railway.

Express trains.



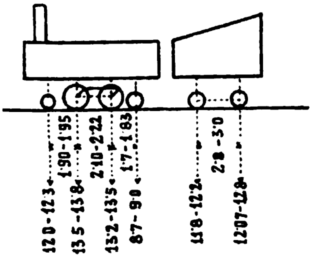
9-10 wagons with 4 or 6 wheels :

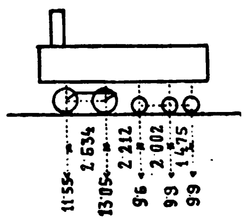
Distance between axles.	4 wheeled carriages	16-18 ft.	(4·9-5·5 *m*)
	6 wheeled carriages	11·4 + 11·4 = 22·8 ft.	(3·5 + 3 5 = 7·0*m*)
Axle load		5·43-6·06 tons	(5·53-6·17ᵗ)

Gross tonnage :

Locomotive and Tender	70·8- 71·71 tons	(72·0- 72·87ᵗ)
Wagons	104·4-124·98 —	(106·1-127·0ᵗ)
Total. . .	175·2-196·69 tons	(178·1-199·87ᵗ)

Ordinary passenger trains.





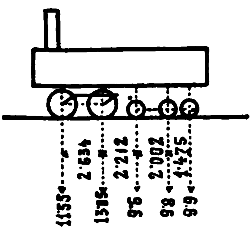
11-16 wagons with 4 wheels :

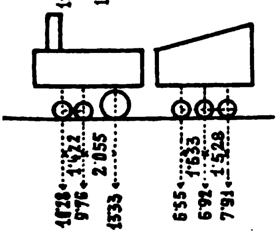
Distance between axles . . .	11·4-16 ft.	(3· 5-4·9*m*)
Axle load	4·59-5·68 tons	(4·68-5·78ᵗ)

Gross tonnage :

Locomotive and Tender .	53·0- 72·5 tons	(53·9- 72·87ᵗ)
Wagons	99·4-171·6 —	(101·0-174·4ᵗ)
Total. . .	152·4-244·1 tons	(154·9-247·27ᵗ)

Omnibus trains.





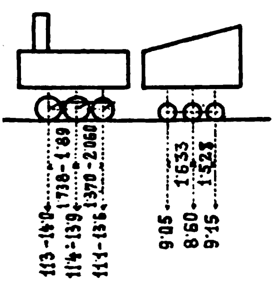
7-18 wagons with 4 or 8 wheels :

Distance between axles.	4 wheeled	11·4-16 ft.	(3·5-4·9*m*)	
	8 —	17-20·6 ft.	(5·2-6·3)	4·2-4·9 ft. (1·3-1·5*m*.)
Axle load		3·09-4·06 tons	(3·15-4·14ᵗ)	

Gross tonnage :

Locomotive and Tender	53·0- 53·87 tons	(53 9- 54·75ᵗ)
Wagons	68·7-106·78 —	(69·9-108·5ᵗ)
Total. . .	121·7-160·65 tons	(123·8-163·25ᵗ)

Mixed trains.



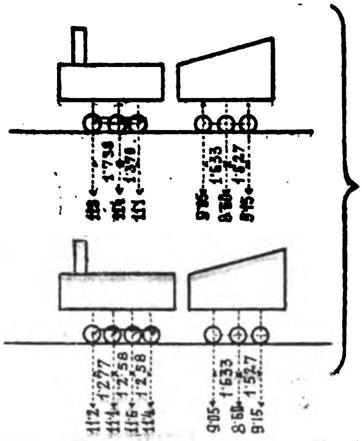
20-30 wagons with 4 wheels :

Distance between axles	11·4-16 ft.	(3·5-4·9*m*)
Axle load	4·5-5·6 tons	(4·6-5·17ᵗ)

Gross tonnage :

Locomotive and Tender	59·5- 67·2 tons	(60·6- 68·3ᵗ)
Wagons	168·0-306·0 —	(177·8-311·0ᵗ)
Total. . .	227·5-373·2 tons	(238·4-379·3ᵗ)

Express goods, goods, coal trains, etc.



37-55 wagons with 4 wheels :

Distance between axles . . . . 8· 2-14· 7 ft. (2·5 -4·5*m*)

Axle load . . . . 4·37- 5·01 tons (4·45-5·11ᵗ)

Gross tonnage :

Locomotive and Tender . . . . . 59·64- 70·9 tons (60·6- 72·1ᵗ)

Wagon. . . . . 366·79-501·9 — (372·7-510·1ᵗ)

Total. . . . 426·43-572·8 tons (433·3-582·2ᵗ)

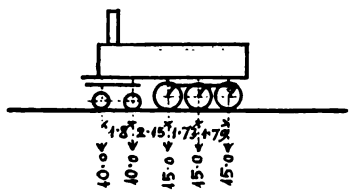
III. — Southern of Austria.

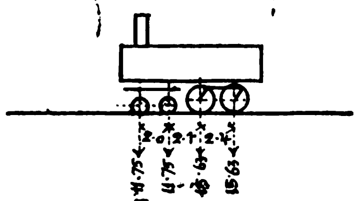
No data.

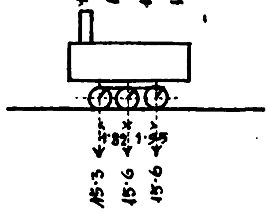
IV. — Gothard Railway.

No information was given on the make up and tonnage of the trains.

Types of express locomotives.

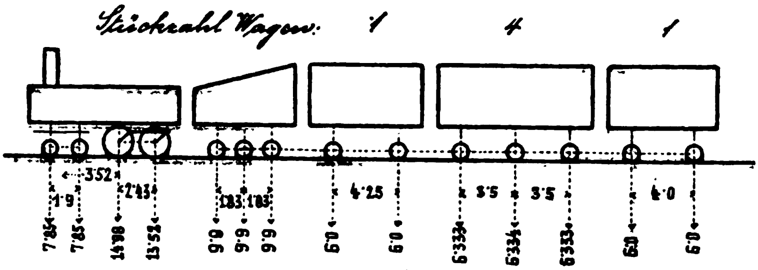






V. — Italian Meridional. Adriatic System.

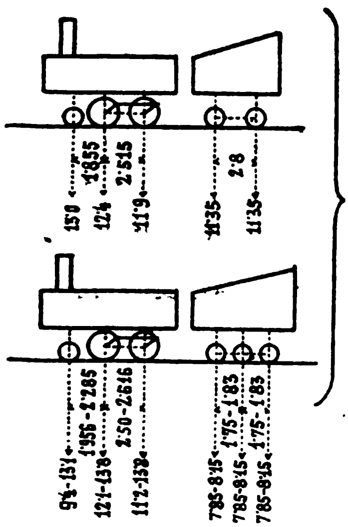
Express trains. — Milan-Bologna-Rome.



Gross tonnage :

Locomotive and Tender.	72·7 tons	(73·9ᵗ)
Wagons	98·4 —	(100 0ᵗ)
Total. . .	171·1 tons	(173·9ᵗ)

Express trains, fast and medium.



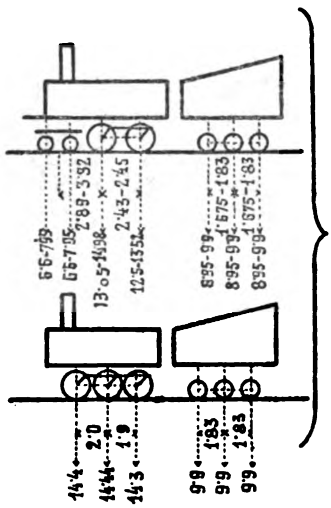
5-9 passenger cars.

1-3 goods wagons.

Axle load	Passenger cars.	4·75 tons	(4·84ᵗ)
	Goods wagons	4·47-6·405 —	(4·555-6·575ᵗ)

Gross tonnage :

Locomotive and Tender	56·23- 72·92 tons	(57·15- 74·1ᵗ)
Wagons	56·58-119·28 —	(57·5 -126·6ᵗ)
Total. . .	112·81-192·20 tons	(114·65-200·7ᵗ)



5-9 passenger cars.

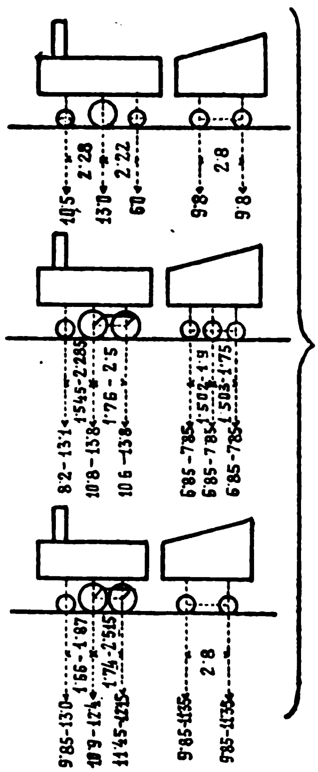
1-3 goods wagons.

Axle load.	Passenger cars.	4·75 tons		(4·84ᵗ)
	Goods wagons.	4·47-6·405	—	(4·555-6·575ᵗ)

Gross tonnage :

Locomotive and Tender.	56·23- 72·92	tons	(57·15- 74 1ᵗ)
Wagons	56·58-119·28	—	(57·5 -126·6ᵗ)
Total. . .	112·81-192·20	tons	(114·65-200·7ᵗ)

Omnibus-trains.



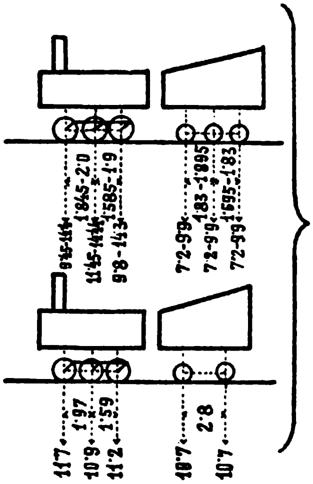
5-9 passenger cars.

4-8 goods wagons.

Axle load.	Passenger cars.	4·75 tons		(4·84ᵗ)
	Goods wagons.	4·47-6·405	—	(4·555-6·575ᵗ)

Gross tonnage :

Locomotive and Tender.	48·3 - 71·68	tons	(49·1- 72·84ᵗ)
Wagons	83·45-187·31	—	(84·8-192·33ᵗ)
Total. . .	131·75-258·90	tons	(133 9-265·17ᵗ)



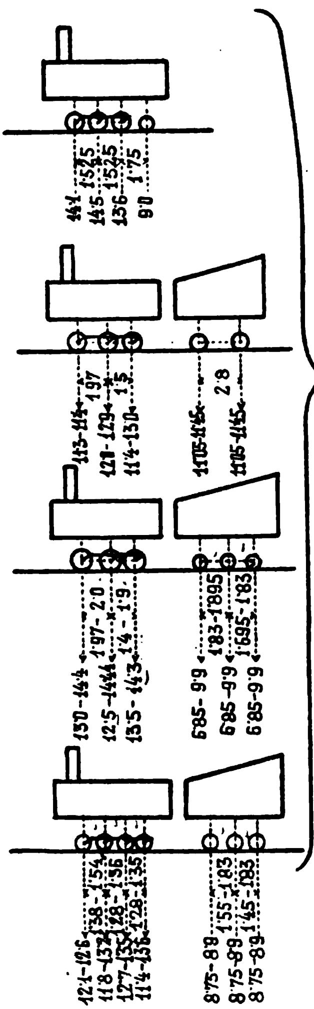
5·9 passenger cars.

4-8 goods wagons.

Axle loads.	Passenger cars . . .	4·75 tons	(4·84t)
	Goods wagons. . . .	4·47-6·405 —	(4·555-6·575t)

Gross tonnage :

Locomotive and Tender . . .	48·3 - 71·68 tons	(49·1- 72·84t)
Wagons	83·45-187·31 —	(84·8-192·33t)
Total. . .	131·75-258·99 tons	(133·9-265 17t)



Mixed trains and fast goods trains,

carrying passengers.

Mixed trains.

4- 8 passenger cars.

5-13 loaded goods wagons.

1- 7 empty goods wagons.

Axle loads.	Passenger cars . . .	4·75 tons	(4·84t)
	Loaded goods wagons.	4·47-6·405 —	(4·555-6·575t)
	Empty goods wagons.	3 14 —	(3·205t)

Gross tonnage :

Locomotive and Tender	50·3- 78·34 tons	(51·2- 79·6t)
Wagons	109.1-288·66 —	(110·9-293·3t)
Total. . .	159 4-367·00 tons	(162·1-372 9t)

Goods trains carrying passengers.

2- 7 passenger cars.

10-36 loaded goods wagons.

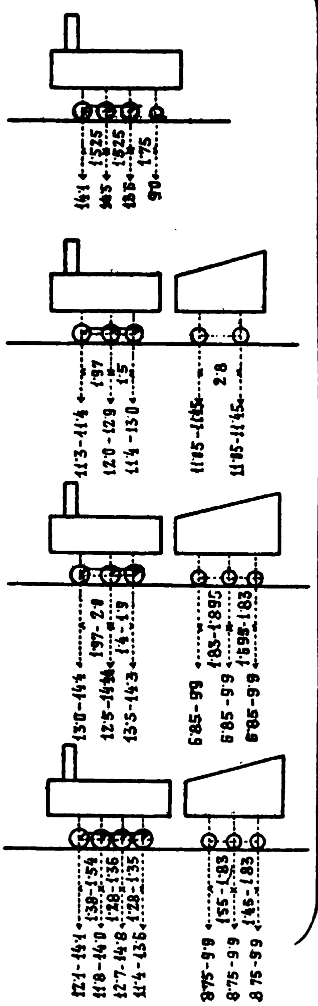
1- 9 empty goodswagons.

Axle loads.	Passenger cars . . .	4·75 tons	(4·84t)
	Loaded goods wagons.	4.47 6·405 —	(4·555-6·575t)
	Empty goods wagons.	3·14 —	(3·205t)

Gross tonnage :

Locomotive and Tender	50·3- 78·34 tons	(51·2- 79·6t)
Wagons	154 8-589 37 —	(157·3-598 9t)
Total. . .	205·1-667·71 tons	(208·5-678·5t)

Ordinary goods trains.



16-42 loaded goods wagons.

3-20 empty goods wagons :

Axle loads { Loaded goods wagons . . . 4·47-6·405 tons (4·555-6·575^t)
Empty goods wagons . . . 3·14 — (3·205^t)

Gross tonnage :

Locomotive and Tender. .	50·3- 84·3 tons	(51·2- 85·7^t)
Wagons	225·9-669·1 —	(229·6-680·5^t)
Total. . .	276·2-754·0 tons	(280·8-766·2^t)

VI. — Mediterranean of Italy.

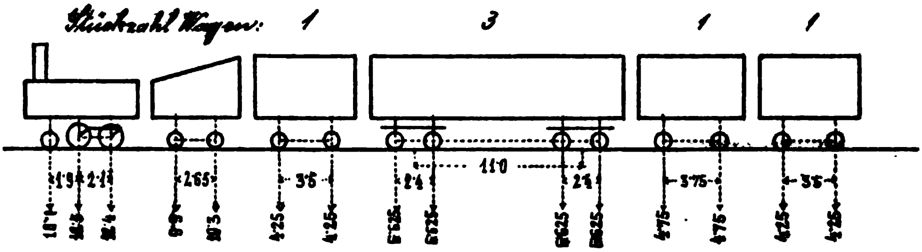
No information sent.

VII. — Sicilian Railway Company.

No information sent.

VIII. — French State Railways.

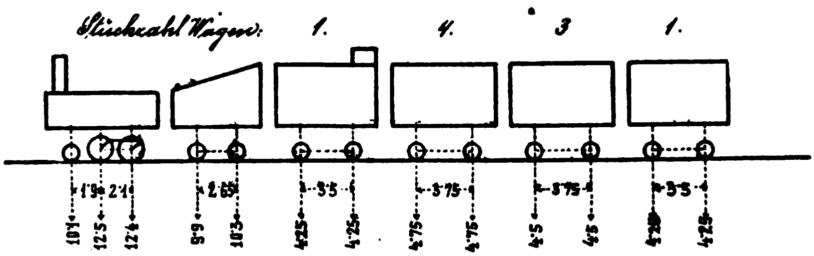
Express trains with bogie carriages.



Gross tonnage :

Locomotive and Tender.	54·3 tons	(55·2t)
Wagons	104·3 —	(106·0t)
Total. . .	158·6 tons	(161·2t)

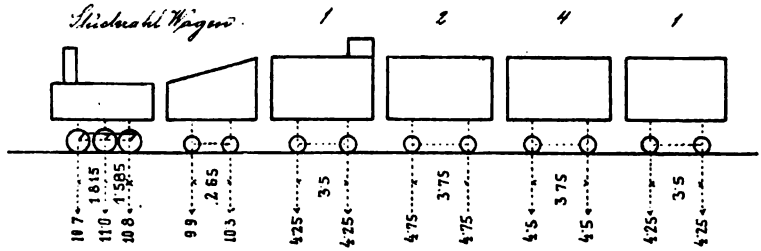
Ordinary express trains.



Gross tonnage :

Locomotive and Tender	54·3 tons	(55·2t)
Wagons	80·7 —	(82·0t)
Total. . .	135·0 tons	(137·2t)

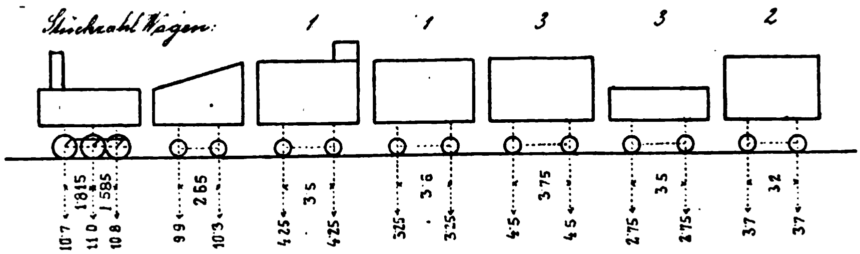
Omnibus trains.



Gross tonnage :

Locomotive and Tender	51·8 tons	(52·7t)
Wagons	70·8 —	(72·0t)
Total. . .	122·6 tons	(124·7t)

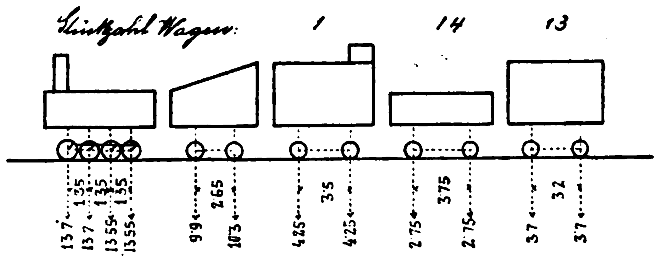
Mixed trains.



Gross tonnage :

Locomotive and Tender	51·8 tons	(52·7t)
Wagons	72·1 —	(73·3t)
Total. . .	123·9 tons	(126·0t)

Goods trains.



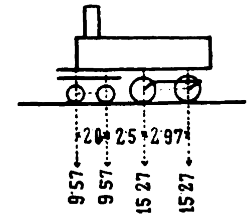
Gross tonnage :

Locomotive and Tender	73·5 tons	(74·7t)
Wagons	178·71 —	(181·7t)
Total. . .	252·21 tons	(256·4t)

IX. — Paris, Lyons and Mediterranean.

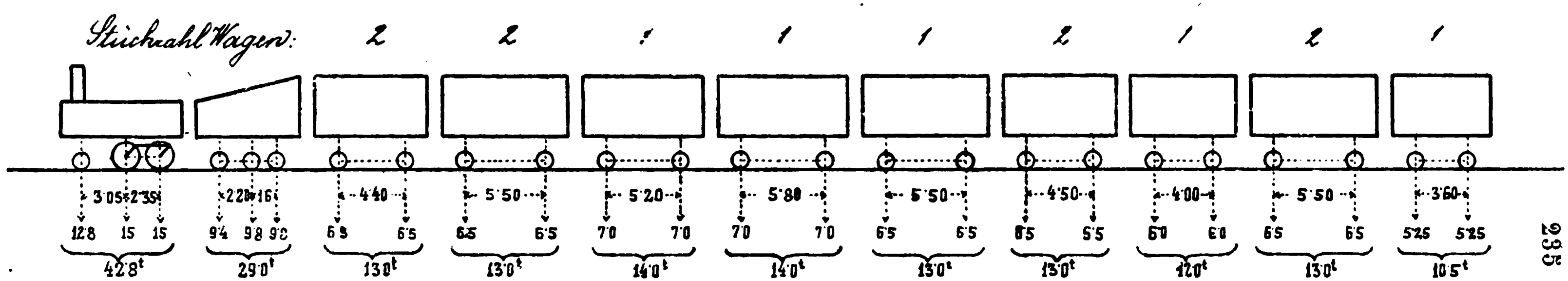
In the reply to the list of questions, we are referred to an article by Ch. Baudry (*Revue générale*, January 1894), which, however, gives no information on the make up of the trains.

The *express locomotives* in use are of the pattern shown in the adjoining diagram :—



X. — Midi (France).

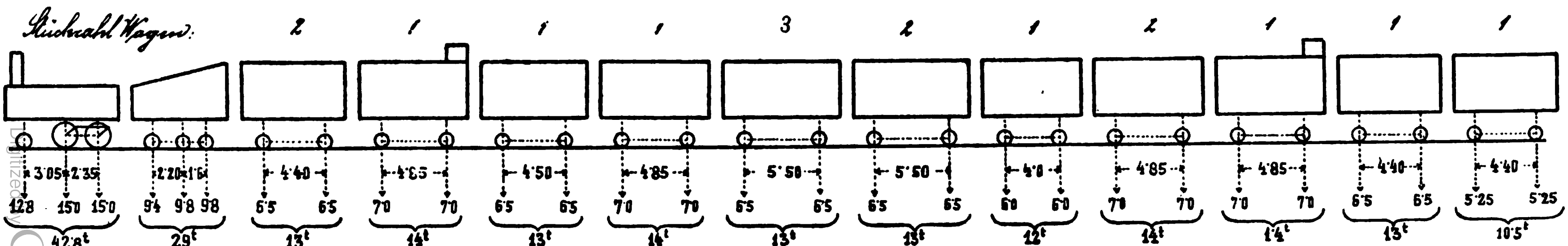
Express trains.



Gross tonnage :

Locomotive and Tender	70·65 tons	(71·8t)
Wagons	164·85 —	(167·5t)
Total. . .	235·50 tons	(239·3t)

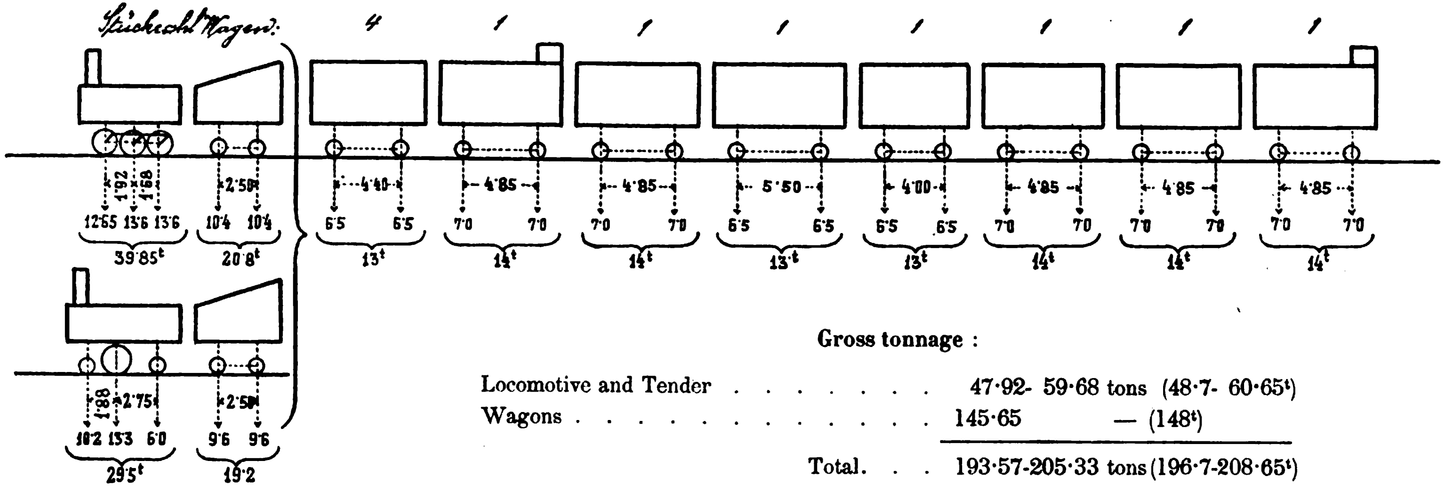
Fast trains.



Gross tonnage :

Locomotive and Tender	70·65 tons	(71·8t)
Wagons	180·59 —	(183·5t)
Total.. . .	251·24 tons	(255.3t)

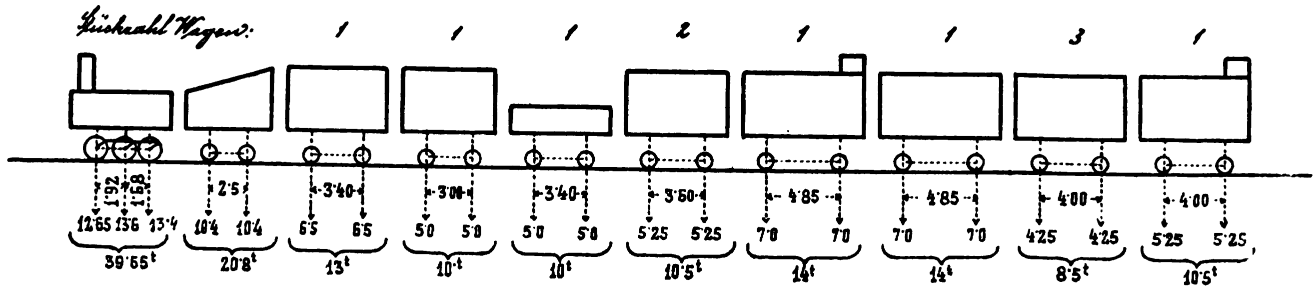
Ordinary passenger trains.



Gross tonnage :

Locomotive and Tender	47·92- 59·68 tons	(48·7- 60·65t)
Wagons	145·65	— (148t)
Total. . . .	193·57-205·33 tons	(196·7-208·65t)

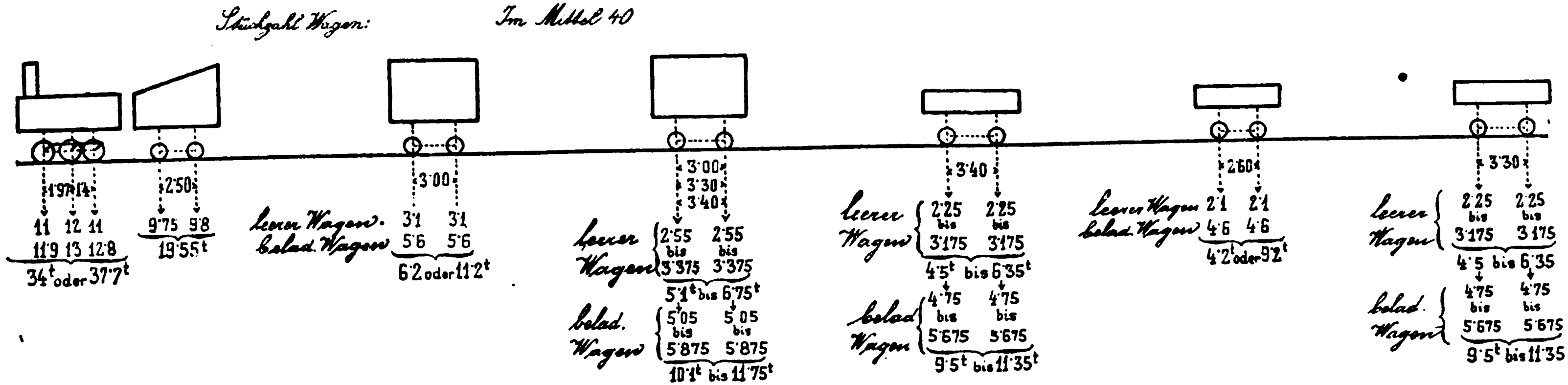
Mixed trains.



Gross tonnage :

Locomotive and Tender	59·48 tons	(60·45t)
Wagons	116·13 —	(118·0t)
Total. . . .	175·61 tons	(178·45t)

Goods trains.

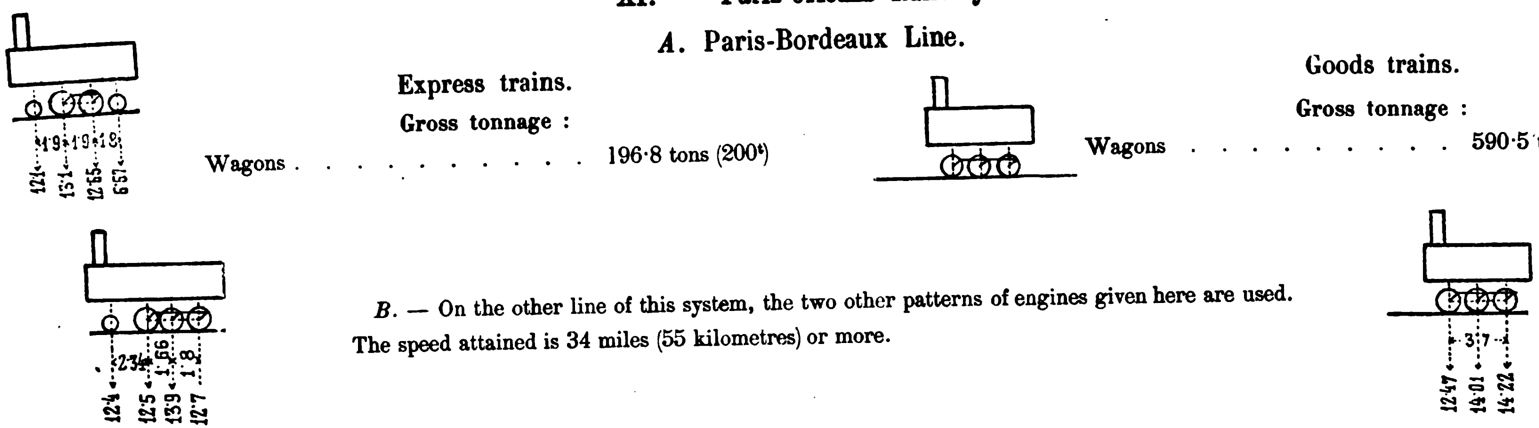


Gross tonnage :

Locomotive and Tender	52·70 tons	(53·55t)	56.33 tons	(57·25t)
Wagons	344·4 —	(350·00t)	344·4 —	(350·00t)
Total . . .	397·10 tons	(403·55t)	400·73 tons	(407·25t)

XI. — Paris-Orleans Railway.

A. Paris-Bordeaux Line.



Express trains.

Gross tonnage :

Wagons . . . . 196·8 tons (200t)

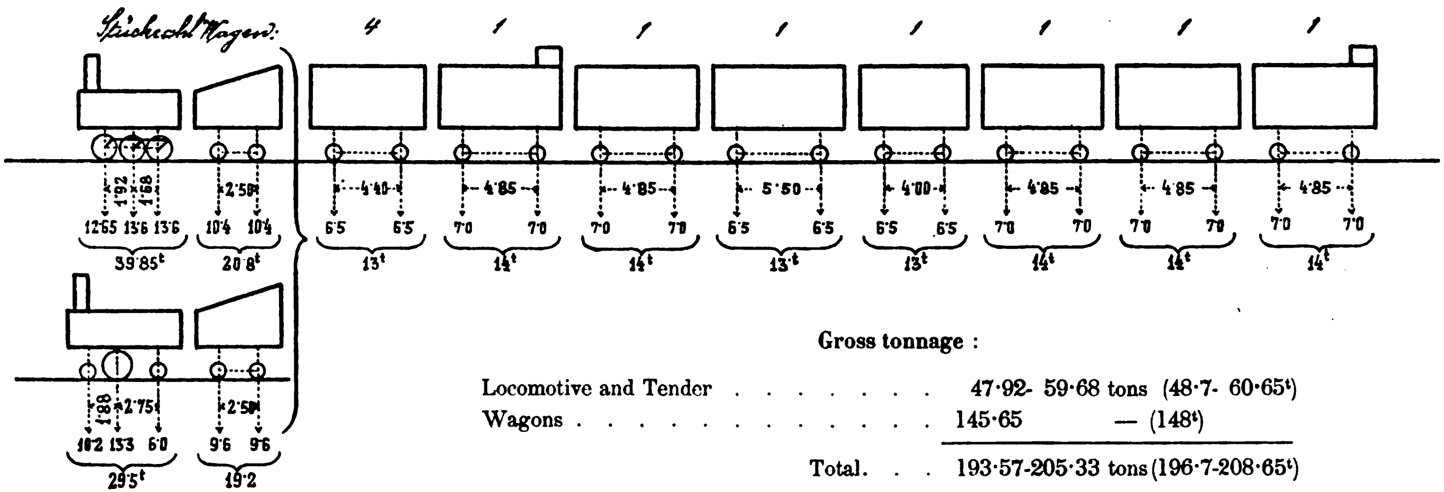
Goods trains.

Gross tonnage :

Wagons . . . . 590·5 tons (600t)

B. — On the other line of this system, the two other patterns of engines given here are used. The speed attained is 34 miles (55 kilometres) or more.

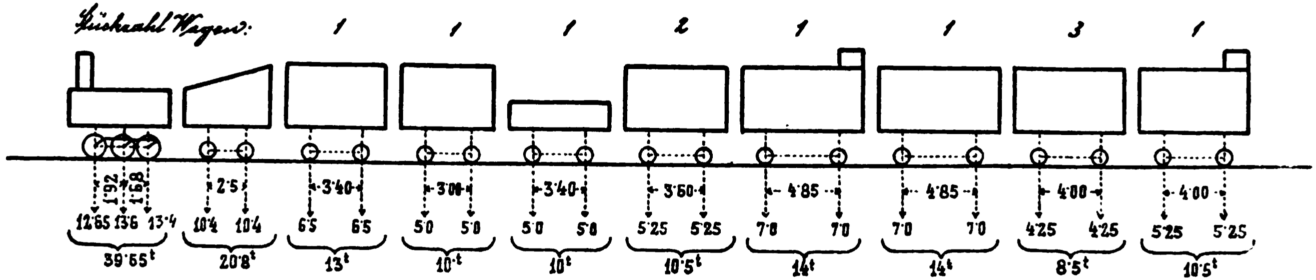
Ordinary passenger trains.



Gross tonnage :

Locomotive and Tender	47·92- 59·68 tons (48·7- 60·65t)
Wagons	145·65 — (148t)
Total. . . .	193·57-205·33 tons (196·7-208·65t)

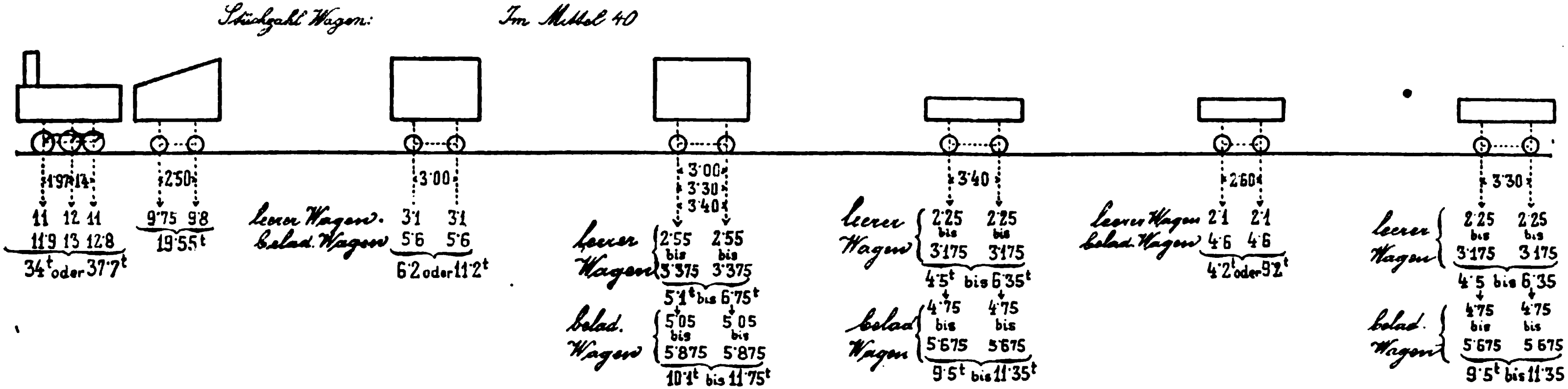
Mixed trains.



Gross tonnage :

Locomotive and Tender	59·48 tons (60·45t)
Wagons	116·13 — (118·0t)
Total. . . .	175·61 tons (178·45t)

Goods trains.

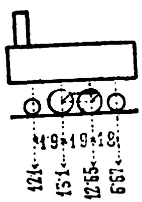


Gross tonnage :

Locomotive and Tender	52·70 tons	(53·55t)	56.33 tons	(57·25t)
Wagons	344·4 —	(350·00t)	344·4 —	(350·00t)
Total . .	397·10 tons	(403·55t)	400·73 tons	(407·25t)

XI. — Paris-Orleans Railway.

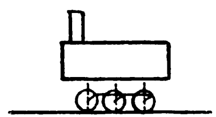
A. Paris-Bordeaux Line.



Express trains.

Gross tonnage :

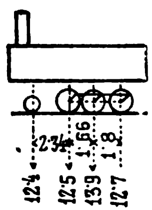
Wagons . . . . 196·8 tons (200t)



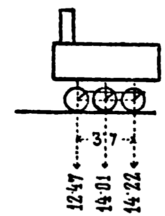
Goods trains.

Gross tonnage :

Wagons . . . . 590·5 tons (600t)



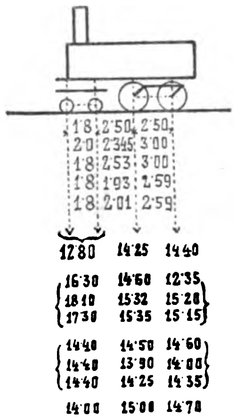
B. — On the other line of this system, the two other patterns of engines given here are used. The speed attained is 34 miles (55 kilometres) or more.

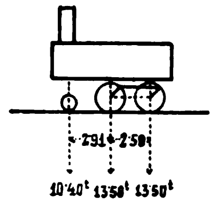


XII. — Northern of France.

The following patterns have been chosen from among our locomotive designs :—

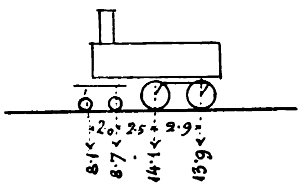
Express locomotives.



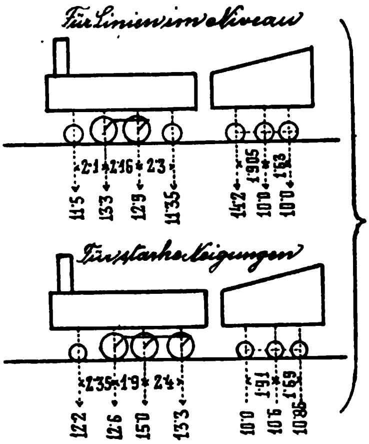


XIII. — Western of France.

Pattern of the most powerful express locomotive in use.



XIV. - Belgian State Railways.



Express trains.

6-10 wagons.

Distance between axles :—

6 wheeled	11·4 + 11·4 =	22·8 ft.	(3·5 + 3·5 = 7 *m*)
8 wheeled		29·8 —	(9·1 *m*)
Bogies		7·2 —	(2·2 *m*)

Gross tonnage :

Locomotive and Tender . . .	81·92- 83·22 tons	(83·25- 84·56t)
Wagons	92·5 -166·32 —	(94·00-169·00t)
Total. . .	174·42-249·54 tons	(177·25-253·56t)

Ordinary passenger trains.

8-11 wagons : 108·2-178·8 tons (110-181t)

Light trains.

5-8 wagons : 49·2-75·7 tons (50-77t)

Goods trains.

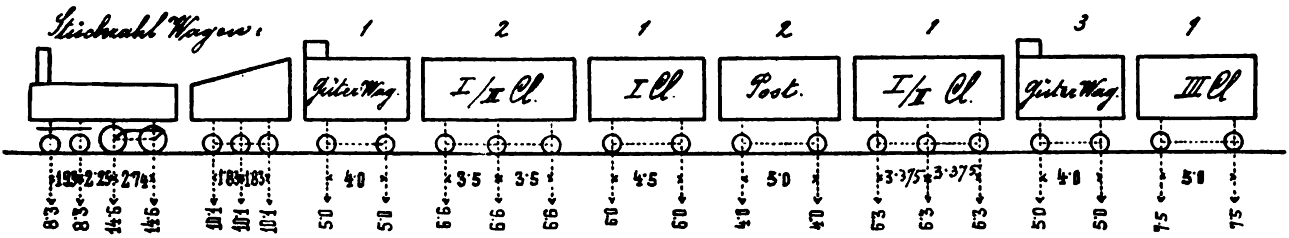
22-32 wagons : 269·66-434·03 tons (274-441t)

Railway service trains.

11-18 wagons : 120·06-351·35 tons (122-357t)

XV. — Dutch Railway Company.

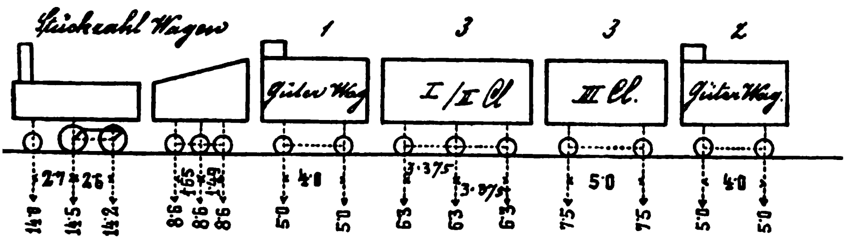
Express trains.



Gross tonnage :

Locomotive and Tender	74·88 tons (76.1t)
Wagons . . . . :	139·25 — (141.5t)
Total. . .	214·13 tons (217.6t)

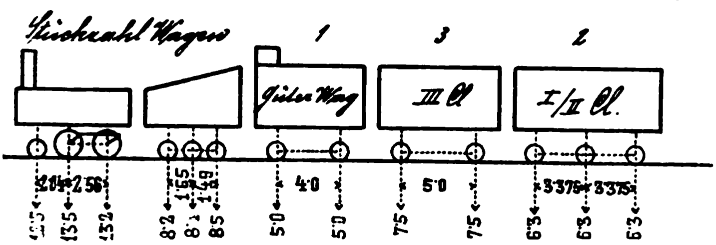
Through passenger trains.



Gross tonnage :

Locomotive and Tender.	67·41 tons (68.5t)
Wagons	129 60 — (131.7t)
Total. . .	197·01 tons (200.2t)

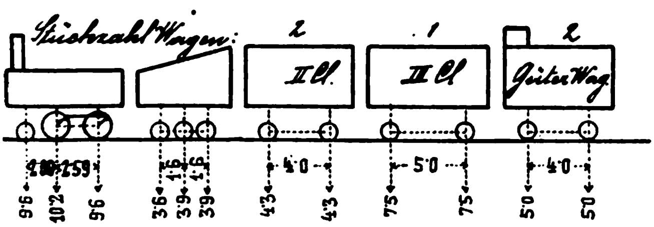
Ordinary passenger trains.



Gross tonnage :

Locomotive and Tender	63·27 tons (64.3t)
Wagons	91·32 — (92.8t)
Total. . .	154·59 tons (157.1t)

Omnibus trains.



Gross tonnage :

Locomotive and Tender	40·14 tons (40.8t)
Wagons.	51·36 — (52.2t)
Total. . .	91·50 tons (93.0t)

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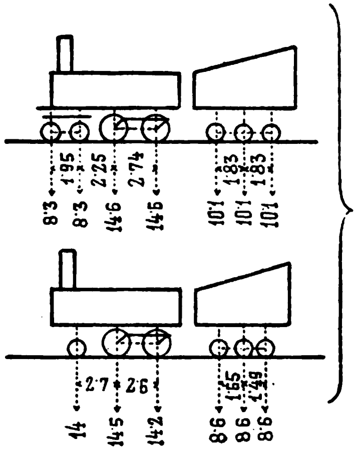
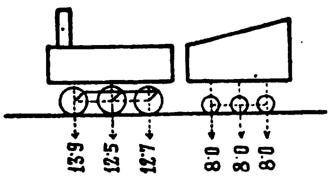


Express goods trains.

25 wagons.

Gross tonnage :

Locomotive and Tender . 67·41-74·58 tons (68·5-76·1ᵗ)



Goods trains.

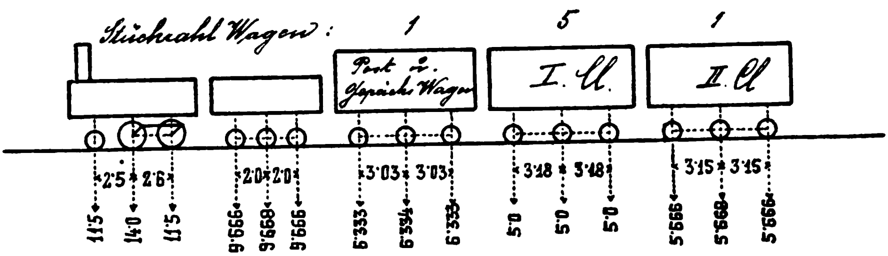
50 wagons.

Gross tonnage :

Locomotive and Tender . . . . 62·09 tons (63·1ᵗ)

XVI. — Egyptian Railways.

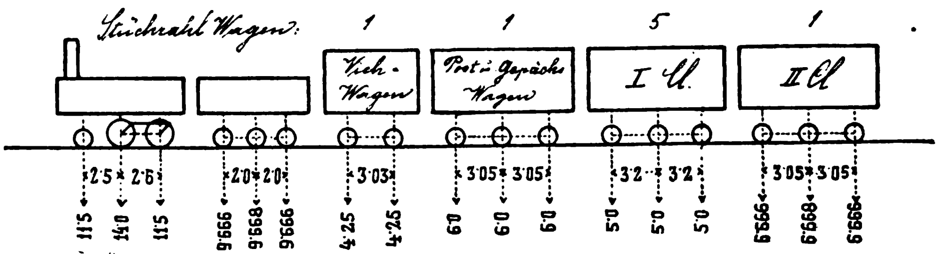
Express trains. — Cairo-Alexandria.



Gross tonnage :

Locomotive and Tender	64.9 tons (66ᵗ)
Wagons	109·24 — (111ᵗ)
Total . . .	174·14 tons (177ᵗ)

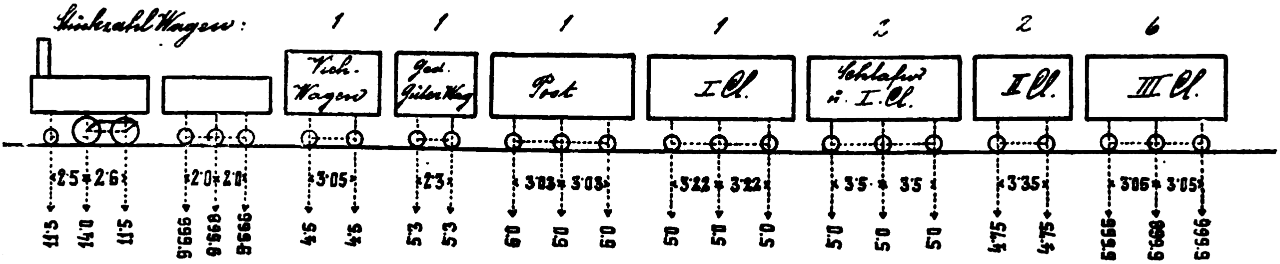
Express trains. – Cairo-Ismaïla.



Gross tonnage :

Locomotive and Tender	64·9 tons (66ᵗ)
Wagons	118·59 — (121·50ᵗ)
Total. . .	183·49 tons (187·50ᵗ)

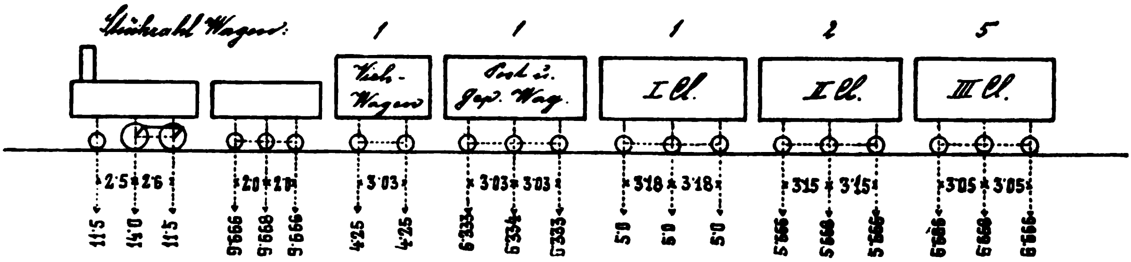
Express trains. — Cairo-Girgueh.



Gross tonnage :

Locomotive and Tender	64·9 tons	(66ᵗ)
Wagons	218·09 —	(221·6ᵗ)
Total. . .	282·99 tons	(287·6ᵗ)

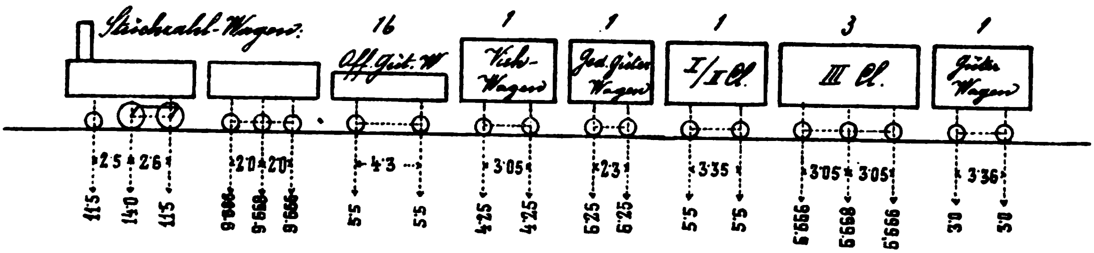
Local trains.



Gross tonnage :

Locomotive and Tender.	64·9 tons	(66·0ᵗ)
Wagons	173·70 —	(176·5ᵗ)
Total. . .	238·6 tons	(242·5ᵗ)

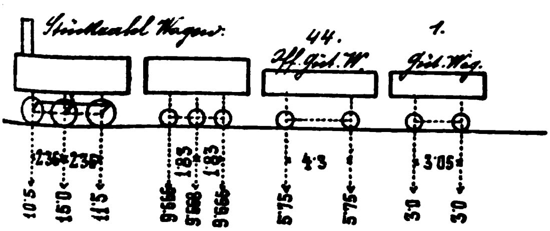
Mixed trains.



Gross tonnage :

Locomotive and Tender	64·9 tons	(66ᵗ)
Wagons	269·75 —	(274·1ᵗ)
Total. . .	334·65 tons	(340·1ᵗ)

Goods trains.

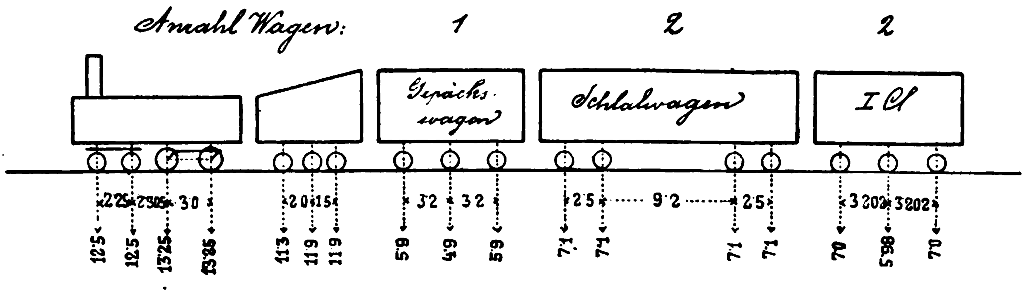


Gross tonnage :

Locomotive and Tender	64·9 tons	(66ᵗ)
Wagons	503·9 —	(512ᵗ)
Total. . .	570·8 tons	(578ᵗ)

XVII. — Russian State Railways.

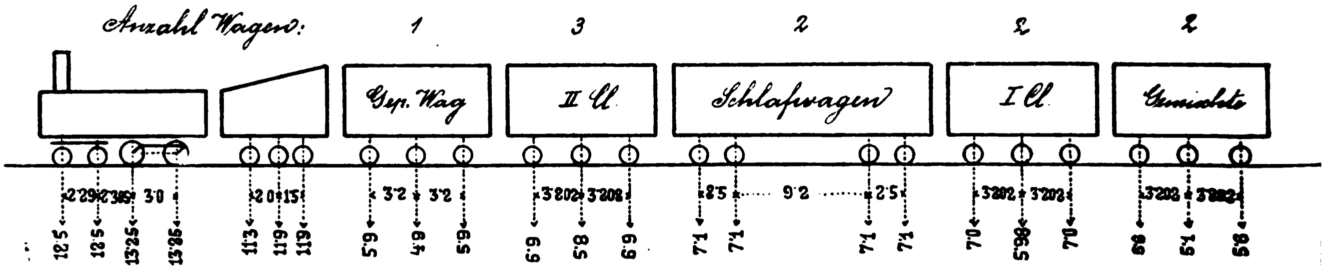
Express trains. — St. Petersburg-Viertzebolovo.



Gross tonnage :

Locomotive and Tender	85·23 tons (86·6t)
Wagons	111·66 — (113·46t)
Total . .	196·89 tons (200·06t)

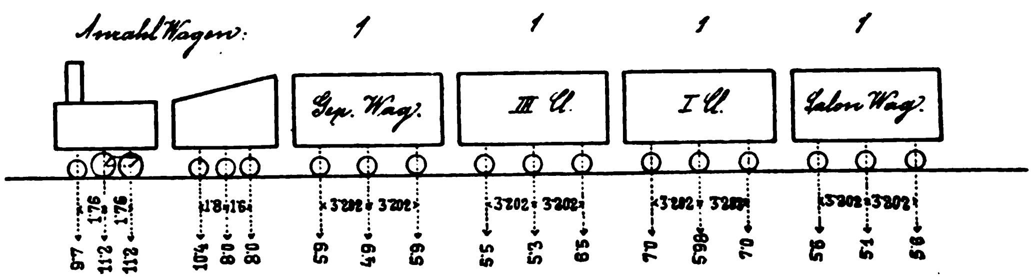
Express trains. — St. Petersburg-Vilna.



Gross tonnage :

Locomotive and Tender	85·23 tons (86·6t)
Wagons	201·61 — (204·86t)
Total. . .	286·84 tons (291·46t)

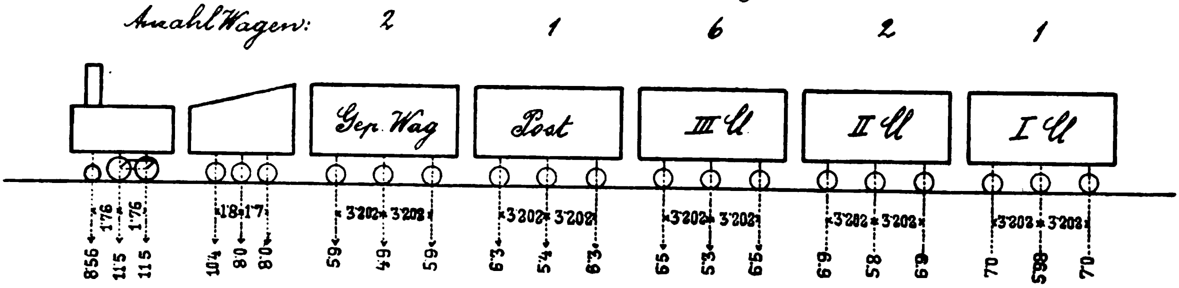
Express trains. — St. Petersburg-Warsaw.



Gross tonnage :

Locomotive and Tender	57·57 tons (58·5t)
Wagons.	70·14 — (71·28t)
Total. . .	127·71 tons (129·78t)

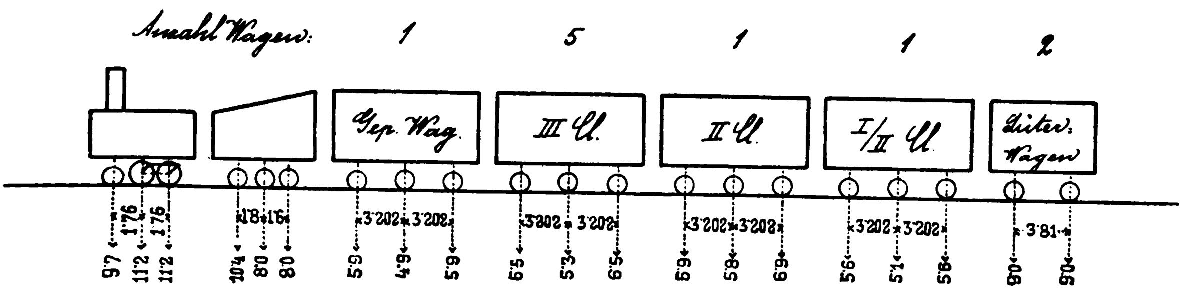
Passenger trains. — St. Petersburg-Warsaw.



Gross tonnage :

Locomotive and Tender	56·33 tons	(57·96t)
Wagons	216·89 —	(220·38t)
Total. . .	273·22 tons	(278·34t)

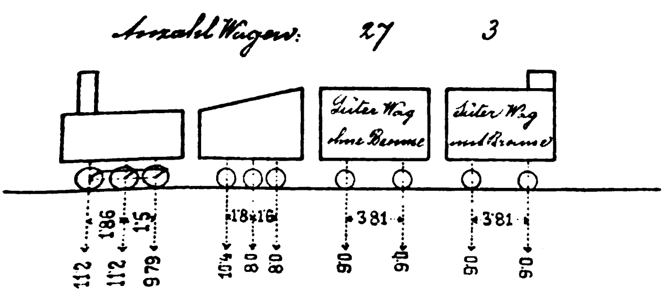
Mixed trains. — Bielostok-Warsaw.



Gross tonnage :

Locomotive and Tender	57·57 tons	(58·5t)
Wagons	178·13 —	(180·1t)
Total. . .	235·70 tons	(238·6t)

Goods trains.



Gross tonnage :

Locomotive and Tender .	57·66 tons	(58·59t)
Wagons	531·4 —	(540·00t)
Total. . .	589·06 tons	(598·59t)

SECTIONAL DISCUSSION

July 1, 1895, at 10 a. m.

—

PRESIDENT : RICHARD JEITTELES

Mr. Ast, *reporter for non-English speaking countries.* (In French.) — The requirements of the travelling public as to speed and comfort make it the duty of Administrations to investigate with the greatest care what measures ought to be taken to satisfy these wants and still maintain the principles of economy and safe working. Before all things they must consider the manner in which the permanent way is laid, the construction and weight of engines, and not forget the relations which the road and the load on it bear to one another.

The International Railway Congress has previously taken up these subjects and reports written by extremely capable engineers have to a great extent helped to solve the question.

The question which appears first on this session's programme is of the highest importance.

Having been called upon by the International Commission to report on what has been done by Administrations in other than English speaking countries, I have endeavoured to solve the following problem :—

" To what extent does the ordinary construction of the permanent way, on lines " upon which trains travel at high speed, fulfil present requirements, and by what " means can it be modified to satisfy increased requirements? "

My duty, according to the wording of the question as adopted by the International Commission, was to define a system of permanent way suitable for lines traversed by fast trains, and to show methods of gradually strengthening existing roads so as to permit of an increase in the speed of trains.

The section and composition of the rail, the rail connections, the sleepers and ballast must therefore all be taken into consideration.

I have found the field well prepared by the former discussions of this Congress.

I studied the information contained in the Congress publications and I was led to analyse them. To this I have added my own personal experience and embodied the whole in two notes published in the *Bulletin* under the following titles: " La question de la superstructure, " and " Les traverses de chemin de fer et leur assise ".

In these two notes, I have endeavoured to show that it is impossible to strengthen the permanent way beyond a certain limit.

The boundary line is, to begin with, drawn by it being necessary to use certain definite materials for ballast and foundation, and secondly by the dimensions and number of the sleepers, which are limited by the gauge of the line and because they must be laid far enough apart to allow of their being properly packed.

The note on " Les traverses et leur assise " is intended to point out the great importance of sleepers and how they are laid in railway construction.

The table giving information on the relative resistance of sleepers shows that for fifty sleepers in use the coefficient of resistance varies as one to ten and that the length of the upper surface of sleepers varies as one to two.

The point is of all the more importance in that the pressure of the ballast corresponds with the dimensions of the sleepers and how the latter are distributed, and in that it is the pressure on the ballast which is what primarily affects the cost of maintaining the permanent way.

If it be admitted that a good road is proved so by maintenance being easy and cheap, we arrive at the conclusion that in the construction of a good line it is above all necessary to thoroughly investigate the principles that govern the arrangement of the sleepers and ballast.

These principles are discussed in the two above-mentioned notes which, so to speak, constitute an essential part of my report. As they contain the theoretic principles accepted at the present time, it remains for us to consider the results of practical experience.

With this object in view, I sent out a detailed list of questions to Administrations affiliated to the Congress on the construction of and strain on main line permanent way, and upon how it stands traffic.

A large number of Administrations have sent in very full information and I look upon it as a very pleasant duty to tender them my most hearty thanks.

This information I have put together in the appendices to my report, and I must express my sincere regret that the time at my disposal has not allowed me to derive therefrom all the advantage which a more profound analysis would have enabled me to secure from different points of view.

It is somewhat difficult to find any common basis upon which to compare methods of construction, for these differ according to the conditions under which they exist.

I had to give up the idea of basing my comparison on cost of maintenance, especially as several of the replies on this point were incomplete.

I was obliged therefore to confine myself to comparing the different methods of permanent way construction and their principal elements, and to take as a basis *their theoretic carrying capacity.*

The information received in reply to the detailed list of questions does not enable one to draw any definite conclusions upon what a typical permanent way should be.

In fact, the methods of construction employed by the different companies vary extremely, and most striking differences exist in the figures supplied on the weight of the rails, the number of the sleepers, the dimensions of the latter, the area of the packing, etc.

At first sight one might be tempted to think that the figures were proportioned to the strain on the road, but a closer investigation shows this not to be the case. In the same way we find great differences in the way the rails are fastened to the sleepers.

If we analyse the various methods of construction, we find that where double-headed rails are used there is a tendency to increase the weight of the chairs; where the Vignoles rail is used there is tendency to increase the number of fastenings and to give the preference to screw-spikes rather than bolts.

The use of chairs and saddle-plates for Vignoles rails must also be noted.

From the replies of the Administrations it is not possible to deduce that the double-headed should be preferred to the Vignoles rail.

Among the measures recommended to ensure secure fastening of rails on curves we must in the first place note increase in the number of sleepers.

The joints are still recognised as the weak point of a road and no essentially novel method of construction has been described.

To prevent creeping some Administrations suggest means tending to make several sleepers hold together firmly by using flat bars of iron.

Nor do the replies we have received entitle us to draw any conclusions on the qualities and manufacture of steel; the specifications of the different Administrations vary within wide limits and the breaking strain required varies from 35 to 62 tons per square inch (55 to 98 kilograms per square millimetre).

We also find a marked tendency to use hard steel exclusively instead of soft steel in the manufacture of rails.

I have in vain sought to arrive at a definite conclusion as to the experience derived from the use of rails manufactured by the Bessemer process, the basic process and by either of the two processes in the Martin furnace.

However it must be observed that most railways use steel manufactured either by the Bessemer acid process or by the Martin furnace process. It would be a good thing if the Congress were to deal especially with the specifications for rail manufacture.

No new experiments have been made since the last Congress to determine the dynamic action of vehicles which has often been discussed at our meetings.

In order to compare the methods of constructing the permanent way as described to us, I have examined them in detail and estimated the strain on the constituent parts produced by a stationary load corresponding to the engines running on the lines in question.

The results so obtained concerning the strain on and resistance of the elements of the permanent way allow of our instituting a certain degree of comparison and of our forming an idea of the manner in which these roads act under a passing train.

From this investigation we may draw the following conclusions :—

For lines traversed by express trains running at 50 miles (80 kilometres) an hour and with loads on an axle of as much as 14 tons, the use of rails weighing from 65 to 70 lbs per yard (32 to 35 kilograms per metre) will suffice.

On lines where the load per axle for express trains exceeds 14 tons and where an increased load and speed have to be provided for, rails weighing 80 lbs (40 kilograms) and upwards must be used.

In any case one must have sleepers of sufficiently large dimensions, sufficiently close-spaced to allow of the rails being securely fastened, the strain on the rail and the pressure on the ballast being decreased and maintenance being easy and economical.

After this preliminary investigation I have been able to attack the essential question, namely the determination of the rules which ought to be laid down in the construction of a typical road for lines used for express traffic.

At first sight it would appear that this problem could not be solved if we take into consideration the great variation in the circumstances peculiar to each line.

However, after mature consideration, I think we must face the fact that the requirements of traffic are ceaselessly increasing and that they will still go on increasing.

This being so, it must be acknowledged that the permanent way of the future ought to be invariable and capable of coping with the unceasing development of traffic.

On the other hand, it has been shown that the limit of the carrying capacity of roads does not much exceed the capacity of the ordinary roads as they are at present.

These two propositions being granted, I think I am justified in formulating as a suggestion based on this idea that the typical road ought *as far as possible to be capable of coping with the maximum capacity that can be reached.*

I base this conclusion not only on the resolutions which have been accepted upon this question at previous sessions, but also on the information lately furnished by affiliated Administrations.

The object of an elaborate analysis on these points was to bring together the component parts of the permanent way in such a manner as to constitute an organic whole with a uniform capacity.

If the meeting agrees with my views, I propose that we should decide that the principles in constructing a permanent way which is as near the limit as can practically be attained should be as follows :—

"1st A layer of readily permeable ballast with a minimum thickness of "15 3/4 inches (40 centimetres) resting on a perfectly drained subsoil;

"2nd Wood or steel sleepers 8 feet 10 inches (2m70) long and 10 1/4 inches "(26 centimetres) broad at their base. The section of the sleeper must be such as "to allow of the rail being securely fastened.

"The adoption of a uniform type of sleeper as in England would be highly "desirable.

"3rd Rails to be of homogeneous, hard and tough steel, from 30 to 40 feet "(9 to 12 metres) long, and with a section whose moment of resistance should be at "least W = 12·20 cubic inches (200 cubic centimetres). These rails should "weigh 80 lbs per yard (40 kilograms per metre) or more;

"4th If suspended joints are used the sleepers at the joints should not be more "than 19 11/16 inches (50 centimetres) apart and the distance between the sleepers "should nowhere exceed 31 1/2 inches (80 centimetres).

"The result of such spacing would be that not only would there be the necessary "means for secure fastenings, but provision would also be made for the strain on "the rail and pressure on the ballast within reasonable limits.

"In sections with curves of small radius or with steep gradients, where the loads "per axle amount to from 8 to 9 tons, the American method of still further "increasing the number of sleepers will be followed;

"5th In the attachment of rails to sleepers, two essentially different types of road "must be dealt with, the Vignoles and the double-headed rail.

"With increase of speed, the strain on the fastenings increases very rapidly and "special attention must be paid to this point on express lines.

"It cannot be denied that with regard to this no better method of fixture can be "found than a strong chair. It would therefore seem logical to try to find some "method of fastening Vignoles rails in some similar way, either by saddle-plates "(tie-plates — *plaques de serrage*) or by increasing the number of screw-spikes;

"6th So far no absolutely satisfactory method of constructing the joints has been "found.

"Experience has, however, shown that the injurious effects on the joints can be "decreased by making the rail more rigid and improving the methods of fixation."

The above typical permanent way is by no means all that could be wished. It has been carried out on many lines, and I wish to point out that except in certain cases *we can advance no further and that the resistance of such a road almost attains the limit which can be attained in practice.*

We must therefore turn to the mechanical engineer whose business it will be to try and increase the power of his locomotives without increasing the strain on the permanent way. (*Cheers.*)

Mr. Hunt, *reporter for English speaking countries* (1).

Types of permanent way. — As regards the type of permanent way, the railways in the United Kingdom are almost universally adopting bull-headed steel rails, keyed into chairs fastened to transverse sleepers by means of treenails, spikes or screws, or combinations of these fastenings. The type of permanent way adopted in America consists of flat-bottomed rails resting directly on transverse sleepers and fastened to them principally by means of spikes.

Strengthening of permanent way. — With regard to the strengthening of permanent way so as to permit of an increased speed of trains, the railway Companies in the United Kingdom have, for some years past, been gradually increasing the weight of their rails, the weight and the bearing area on the sleepers of their chairs, and shortening the spaces between the sleepers; but most of the principal Companies do not contemplate any further strengthening of the roads, as their latest standards of permanent way are fully capable of taking the highest speeds that can be obtained with the present rolling stock.

So far as the permanent way of the Lancashire and Yorkshire Railway Company is concerned, I consider it fully capable of taking safely trains at a speed of 100 miles (160 kilometres) per hour, when the road is straight, or on curves with large radii. I do not think it at all likely that any speed in excess of this will be reached in the future, inasmuch as the weight and dimensions of the locomotives necessary for attaining higher speeds would be such as to involve the strengthening of many of the iron underbridges, the enlargement of the overbridges and tunnels now in existence, and the partial reconstruction of portions of the railways themselves to ease the sharper curves; the cost of which would be prohibitive.

The American railways have been and are evidently strengthening their rails with a view to suit high speeds, but none, except the New York Central and Hudson River Railroad Company, state that they intend to further strengthen their road with a view to still higher speeds.

As to the permanent way itself, I propose now to deal with the detailed questions in the order given in the instructions given by the Brussels Commission so far as they relate to railways in Great Britain and Ireland.

Rails. — The section of rail usually adopted is the steel bull-headed rail, the bull-head being much larger than the bottom member, to allow for wear and tear, the bottom member being made sufficiently strong, after allowing for oxidation, to form with the top member when worn down a sufficiently strong girder to carry the rolling load.

In England, the weight of the rail varies from 80 to 92 lbs, in Scotland from 77 to 90 lbs, and in Ireland from 74 to 85 lbs per lineal yard. There are some rails weighing 100 lbs to the yard, but these are few in number.

(1) This speech is an abstract of Mr. Hunt's report, but the parts marked with two vertical lines are new.

The weight of the rails on the Lancashire and Yorkshire line is 86 lbs per lineal yard, and I am of opinion that this weight need not be increased, as it is desirable, in relaying the road, that the whole of its constituent parts should be relaid together, and nothing would be gained by having a rail which would outlive the sleeper.

No absolute weight per yard appears to be adopted to which rails may be worn down before being renewed, the general condition of the whole of the materials forming the permanent way, and other varying circumstances, being taken into consideration in determining when the road should be renewed. The renewals, when they take place, are usually in long lengths, and the material recovered, when not too far worn, is utilised for repairs and sometimes renewals of branch lines, loop lines and sidings.

The rails on the Lancashire and Yorkshire line wear down on the average at the rate of about one pound per annum, and could be safely left in the main line for about 20 years, but inasmuch as the total length of sidings on this line is 70 p. c. of the main, a large quantity of material is required for repairing their sidings. The main line road is never left in long enough to wear down to the minimum safe weight, as it is considered better, when repairs are required for sidings, to take out of the main line the materials for the repairs of the sidings, replacing them with new road. By this means, the main line is always kept in first class order.

As regards the calculations of the strains imposed on rails by the rolling load, as the various stresses cannot be ascertained sufficiently accurately to enable a rail to be designed on the same scientific principles as a girder would be, it is considered by English engineers that close and careful observations of the effects produced upon the road by the rolling loads which pass over it | will disclose its weakest parts, and a tolerably accurate judgment can be thereby formed as to the extent to which it is desirable to strengthen it.

Mode of manufacture and nature of rail metal. — From the replies received, it is clear that most of the railway Administrations have their rails rolled from steel manufactured by the Bessemer acid process, although some of them return the Bessemer process without stating whether it is the acid process or the basic process. The only Companies who, in their specification, permit the use of the basic process, are the Manchester Sheffield and Lincolnshire and the North Eastern.

The London and North Western, the Manchester Sheffield and Lincolnshire, the Caledonian, and the North British Companies have a specification for the Siemens-Martin acid process.

I have had no personal experience in steel rails rolled from steel manufactured by the Basic process since 1884, when we bought a few of them. These rails were unsatisfactory, and most of them had to be taken out of the road after only a little over five year's wear, the defects being chiefly in the webs cracking in a straight fracture extending for some 5 to 10 feet in length.

The Basic process admits of the use of an inferior iron ore for the manufacture of the steel, but this process may have been improved since 1884.

The Siemens-Martin process is too expensive to be used for manufacturing steel for rails.

With reference to the testing of rails, all Companies, except the Cambrian, test their rails by blows produced by various weights falling from various heights on various lengths of rail supported on bearings from 3 feet to 3 feet 6 inches apart. The amount of permanent deflection varies in each case in proportion to the weight used and the height from which that weight is dropped.

Some railway Companies, in addition to this, test the rails as girders, suspending dead weights from the centre, and specifying the deflections which will be allowed under the test of certain weights.

The chemical tests do not appear generally to form part of the specification for rails, only four Companies giving a more or less detailed specification of the chemical analysis. The Great Northern Railway of Ireland state that they test their rails chemically, but do not give particulars of their requirements.

The breaking weight in tons per square inch is only specified by five Companies. The extension per cent is only specified by three Companies, and the contraction of area per cent is only specified by one Company.

It appears, therefore, from these returns, that the railway Companies mainly rely on the falling weight test to determine the quality of the rail manufactured for them.

As to the relative merits of hard and soft steel, only five Companies give any information, and of these five, four lean to the use of mild steel as being less liable to fracture and therefore ensuring a greater measure of safety.

The steel used for the rolling of rails should neither be too hard nor too soft. Hard steel is brittle and consequently liable to break on the road, and also damages the wheel tyres when they are skidding or partially skidding on the rails, and of course, too soft a steel would wear out too quickly.

A rail with a proportion of carbon of ·3 to ·4 p. c. giving a tensile strain of about 40 tons per square inch, will meet all requirements.

Rail connections. — The form of joint universally adopted in the United Kingdom is a suspended one, the rails being connected by two fish-plates bolted together through the rails by four fish-bolts.

With the exception of the Great Western and London and North Western Railways, whose fish-plates are 20 inches long, all the Companies adopt a fish-plate 18 inches long. Much longer fish-plates than these were in use some years ago, but there seems to be a general opinion that the fish-plates should be as short as possible in order to bring the chairs and sleepers at the joints as near as possible, and in reply to the question as to whether this form of joint gives satisfaction, 16 out of 19 Companies state that it does.

As to the shape of the fish-plates in use, they may be divided into two classes, viz., plates whose depth is the distance between the top and bottom flange of the rail, and plates whose depth is increased to the underside of the bottom flange, and even deeper, in some instances underlapping the rail. The sections of this class of fish-plates are shown in the book of diagrams. 10 Companies use the former class, and 9 Companies use different sections of the second class. There are no suggestions as to how the joint could be improved.

I have had no personal experience in the use of the deeper fish-plates, as I have never tried them. I consider that if our fish-plates, filling between the top and bottom flanges of the rail, are kept tight up to the underside of the bull-head and the top of the lower member of the rail, it is the best form of joint that can be used.

All the railways (so far as their bull-headed rails are concerned) support the rails in chairs fastened to transverse sleepers, using various kinds of fastenings. The Great Northern Railway of Ireland for their flat-bottomed rails, and the Great Southern and Western Railway of Ireland, fasten their flat-bottomed rails direct to the sleepers by means of fang bolts and spikes.

The weight of the chairs used by the different Companies varies considerably, the smallest weight being that of the South Eastern Railway, 37 lbs, the heaviest being that of the Lancashire and Yorkshire Railway, which weighs 56 lbs.

The bearing area of the chair on the sleeper also varies considerably, the smallest area being that of the South Eastern Railway, viz., 70 square inches, the largest being that of the Manchester Sheffield and Lincolnshire Railway which has a bearing area of 117 square inches.

The only Companies who place felt between the chair and the sleeper throughout their systems are the Cambrian and the London and North Western Railways. The London Brighton and South Coast Railway use it in special tunnels where the noise is excessive. No other Company uses a packing of any kind between the chair and the sleeper.

The pattern of the chair on each side of the joint used by any Company is the same as that of the rest of the chairs in the road.

The number and kind of fastenings for attaching the chairs to the sleepers varies with almost every Company.

Keys and sleepers. — Of the eighteen companies who use the chair road, eleven of them use oak for their keys, two use teak and oak, one teak only, one pine and one elm. Eight Companies compress their keys, and ten do not. All the Companies are keying on the outside of the rail, except the Furness Railway and the Great Northern Railway of Ireland, but the former are now gradually adopting outside keying.

Baltic red wood is the timber most generally used for sleepers, although some Companies use Memel, Riga red wood, Scotch fir, red pine. Every Company creosotes its sleepers.

The lengths of sleepers are 8 feet 11 inches or 9 feet and the breadth 10 inches and the thickness 5 inches.

The distance apart of the sleepers on the several lines is shown on the plates.

Although metal sleepers have been put down in some places, notably on the

London and North Western Railway, they do not seem to have found favour with the railway Companies of the United Kingdom. The London and North Western Railway have not put any down since 1888; the Great Eastern and London and South Western Companies have experimented with a few, but are not continuing their use.

Ballast. — The ballast used by the various Companies, details of which are given in appendix E of the report varies according to the locality through which the lines pass. The bottom ballast generally consists, in districts where it can be obtained, of large hand-packed stones, but where this cannot be obtained slag, burnt clay, and ashes are used. For top ballast various materials are used, viz : —

Broken stone, gravel, slag, chippings, ashes and cinders screened and unscreened, and Thames gravel; the best material in each district consistently with economy being obtained, so as to get the best drainage possible.

The practice of laying ballast above the level of the top of the sleeper varies a good deal.

With reference to the American, Indian and Australian railways, as I have had no experience in the use of these types of permanent way, I do not feel justified in expressing any opinion upon it, but I have no doubt there will be delegates, in the room, for these countries who will willingly give the meeting explanations as to their experiences in the types of road adopted by them.

The President. (In French.) — Question I is a very wide one and I think we ought to confine the discussion within limits as far as possible.

As you will have noticed the reporters have not dealt with rails laid on metallic sleepers; they have especially brought before us the track in ordinary use, namely a line laid on wooden sleepers, suitable for express trains.

As regards speed there are marked differences between the two reporters who deal respectively with non-English speaking countries and English speaking ones.

Mr. Ast has told us that on the continent trains travelling at 50 miles (80 kilometres) an hour are regarded as very fast trains and that a speed of 75 miles (120 kilometres) is never exceeded.

On the other hand, Mr. Hunt has told us that in England and America trains run at much higher speed, such as 100 miles (160 kilometres) an hour and even more. (*Laughter.*)

Mr. Ast has defined for us in his report what in his opinion may be looked upon as a typical permanent way, but though it has been adopted in several countries it is not perfection, and he wishes you to recognise the fact that the resistance of this typical road approaches the limit that can be attained in practice and that except in certain cases we can make no improvement upon it.

Mr. Hunt, on the other hand, asserts that the type of road almost universally adopted by the railway Companies of the United Kingdom is suitable for trains running at very high speeds. He believes that it would be superfluous to strengthen the road with a view to increased speed, which latter does not depend upon the permanent way, but upon the locomotive engineers.

It is then upon these two points that discussion should first bear.

Mr. von Leber, Austrian Ministry of Commerce. — I should like to ask Mr. Hunt, the English reporter, to be so kind as to explain to me the following points.

1st Mr. Hunt told us that he prefers a « mild » steel for the rails, and on the continent we prefer a hard steel. It would be well to define what I mean. The steel which is mentioned in Mr. Ast's papers has a breaking strain of often as much as 51 tons per square inch (80 kilograms per square millimetre).

That is a hard steel. I should like Mr. Hunt to define what he means by a "mild" steel.

2nd Mr. Hunt further told us that the rails on the Lancashire and Yorkshire Railway have been 20 years in use without being changed. It seems to me that this is quite too long.

3rd Then again I should like to ask Mr. Hunt if you really have in England a speed of 100 miles an hour. The greatest speed at which we travelled on the excursions was 72 miles, I think.

4th Mr. Hunt told us that the tunnels were not large enough for increasing the size and weight of the engines; it would be a very good thing if the Congress would recommend that the weight of the engines should be increased no further; I have alluded to this in my report.

Mr. Petsche, Eastern of France Ry. (In French.) — I also intended to ask Mr. Hunt if a speed of 100 miles (160 kilometres) was really a fact?

Mr. Hunt. — What I said with regard to the use of steel was that too hard a steel would not do, because it is brittle and liable to break the road, and also that too hard a steel would cut the wheel tires too much and damage them. At the same time it would be out of the question to use too soft a steel, because then the rails would wear out too quickly, and I think I gave the quality of steel containing from 0·3 to 0·4 p. c. of carbon as one that would meet the requirements of railways.

Mr. von Leber. (In French.) — It must be remembered that at previous sessions the Congress expressed the opinion that the hardest steel procurable should be used. I attach great importance to Mr. Hunt's reply for upon it depends whether the tires shall wear the rails rather than the rails wear the tires. On this point there is a kind of rivalry between permanent way and locomotive engineers.

I do not regard the question as so simple as Mr. Hunt does. Since our last meeting it has made no progress. I also beg Mr. Hunt to say whether rails really last 20 years on English roads.

Mr. Hunt. — With regard to what I have said about the rails lasting for 20 years, I have already explained that at the average rate at which our rails wear down, that is to say a lb per yard per year, they would last with safety 20 years; but then I think I went on to say that in the case of the Lancashire and Yorkshire Railway we have so many sidings to repair that instead of letting the rails live out their full life on the main line we took them out of the main line to repair the sidings, and replaced them on the main line with new rails; so that we never do wear them down to 20 years, because our requirements for sidings do not permit of our doing it. I see that when the traffic is not so heavy we have taken out steel rails which have been in 22 years, but never on the fast running lines.

With regard to the speed of 100 miles per hour I think I said that I thought that on the straight portions of our lines, and where the curves are the flattest, it would be safe to run on that permanent way at 100 miles an hour. I did not say that we had ever attained to that speed. I rather inferred from what Mr. Aspinall is saying in his paper in another section, that he could not construct a locomotive of sufficient power to run, certainly not beyond that speed, and possibly not up to it, that would pass through our existing tunnels and bridges; and therefore that is the reason why English engineers have come to the conclusion that it would not be necessary to further strengthen their road.

The President. — What is the maximum speed in England?

Mr. Hunt. — I have myself timed some of the trains on our line up to 75 miles an hour; that is only on the down gradient though.

The President. — Is that the maximum?

Mr. Hunt. — That is the maximum that I have ever noticed. I do not think that there has been any record of anything higher then that. I think I have answered all the questions.

Mr. Michel, Paris-Lyons and Mediterranean Ry. (In French.) — I should like to observe that there is nothing impossible about rails lasting for 20 years on main lines. On the line between Paris and Marseilles, 500 miles (800 kilometres) long, there are at present on about 250 miles (400 kilometres) of rails which were laid more than 20 years ago and they are still in very good condition. And yet the traffic on this road is very heavy and several fast express trains run upon it. It is true that the rails have in some places been withdrawn, not because they were all worn out, but because it was deemed advisable to strengthen certain points on the road such as long gradients of 1 in 200 (5 millimetres per metre) and steeper. Besides from time to time we required rails for sidings and for lines in stations and tunnels which had to be removed with as little delay as possible on account of their being worn. If such exceptional points of the road be excluded twenty years is not to be regarded as an excessive time for rails to last, as Mr. von Leber seems to think, provided the steel used is of good quality.

Mr. Hunt tells us in his report that some Companies use 60 foot rails. I should like to know whether this has proved satisfactory. Does not the distance which there must be between the joints cause disadvantages?

Mr. de Kounitsky, Russian Ministry of Communications. (In French.) — I should like to ask Mr. Hunt two questions :

1st What is really the greatest load on one axle in an English locomotive; and

2nd What is the greatest load on one axle in a locomotive taken into account when designing and calculating the cross section of rails in England?

Mr. von Boschan, Emperor Ferdinand's Northern of Austria Ry. (In French.) — I endorse what Mr. Michel has just said on the life of rails. There are on the railway I represent 16 miles (25 kilometres) of line laid between 1868 and 1872, which are still in excellent condition. The rails weigh 63 lbs per yard (31·5 kilograms per metre). When they are taken up it is not because, as in the case referred to by Mr. Michel, they are worn, but with a view to strengthening the road. Our Company now uses Bessemer steel rails weighing 70 lbs per yard (35 kilograms per metre).

Mr. Johnson, Great Northern Ry. — I should like to confirm Mr. Hunt's remarks with regard to the life of our rails. I took up last year rather a long length of steel rails which had been down nearly 20 years, and which were on the fast running part of our line between Grantham and Peterborough, where we often attain a speed of 72 miles an hour. Those rails were made by the Ebbw-Vale Company in Wales. In those days the ingots from which rails were rolled were well hammered under a steam hammer, and I have always been of opinion that if a good rail is required labour must be put into it. I am sorry to say that rails of that quality are not made to-day, for in most rail mills the steam hammer is not to be found, at any rate it is not used upon ingots which are intended to be rolled into rails. These particular rails I had tested chemically, and they contained about ·4 of carbon, and the analyst who tested them said that they were very dangerous rails to put down and were likely to break. I told him that they had been down 20 years and that therefore they must have been good rails. I tried in purchasing rails last year to get the same chemical constituents put into the rails; and the makers all, to the extent of half a dozen or more, put an extra £1 a ton on to the price to give me these chemical constituents, and I failed to buy the rails so constituted. The rails were purchased this year at something like £4.10.0 a ton. Of course the makers of rails cannot put much work into rails at that ridiculous price, and I am very much afraid that the rails now being put into the roads will not wear anything like 20 years.

Mr. Petsche, Eastern of France Ry. (In French.) — The life of a rail depends primarily upon the traffic. On our system we have rails which have carried 300,000 trains and are still comparatively little worn — scarcely $^1/_8$ inch (3 or 4 millimetres). We use 60 and 89 lbs rails (30 and 44 kilograms) and put the joint sleepers as close together as possible — even as near as 16 $^1/_2$ inches (42 centimetres) from centre to centre. In this way, we succeed in keeping our lines a long time in good condition and without any apparent imperfection at the joints.

The President. — A gentleman has asked Mr. Hunt if the 60 foot rails have given satisfaction?

Mr. Hunt. — I have no personal knowledge as to whether the London and North Western Railway Company are satisfied with the 60 foot rails; but I take it that they are, because they are continuing to use them. You will find in a table in the appendices to my report that they are the only Company who have adopted that length of rail.

The President. — Is there any gentleman connected with the London and North Western Railway Company who can tell us whether they are satisfied with the 60 foot rails?

Lieutenant Leggett, R. E., Board of Trade, Great Britain. — I have had some experience, as representing the Board of Trade, of seeing the rails of this length on the London and North Western Railway, and I may say that the Company are extremely satisfied with the manner in which the rails can be laid in. It is possible for four men to lay in one of these rails in about three minutes from the time the old rail is taken out to the time the new rail is put in and keyed up to about every third sleeper and fished with two bolts instead of four. That is to say, the road for the load has been sufficiently good for the traffic to pass over it at the rate of 15 miles an hour, in three minutes, and the manner in which the vehicles travel over this road in its finished state is also considered extremely satisfactory.

The President. — Do you know what is the space between the two rails?

Lieutenant Leggett, R. E. — For expansion it is necessary to allow from $^1/_8$ to $^5/_{16}$ of an inch, according to the temperature.

Mr. Wasiutynski, Warsaw-Vienna Ry. (In French.) — Reference has been made to the life of a rail and to its chemical composition, but so far the question of the metal's resistance has been neglected.

What astonishes me is that as a rule in England no tests are made to estimate the tensile resistance but only the breaking strain. On the continent, the resistance of the metal is above all things tested.

I should very much like to know the component parts of the rail of which Mr. Johnson speaks, possessing it would seem extraordinary qualities of resistance.

We know all the facts with regard to the tensile resistance and breaking strain and chemical composition of the rails manufactured on the continent. We have inserted in our specifications minute particulars as to the tests these rails must undergo and yet they are generally far inferior to the English rails of which we have just heard, spite of the fact that the latter are accepted with much less exacting formalities. There must be some secret in manufacturing a rail which can last 22 years under the conditions mentioned. What is this secret?

Mr. Belelubsky, Russian State Ry. (In French.) — I understand from Mr. Hunt's report that most railway Companies in English speaking countries roll their rails of Bessemer steel which appears to be much better, especially than basic steel.

We ought to investigate the question of the composition of the metal, for, as a contrast to what Mr. Hunt has told us, I may mention that in Russia we manufacture a great many rails of Basic-Martin steel and the results obtained are very satisfactory.

If the method of manufacture has lately altered, that is due to a most marked tendency in favour of using hard steel and because we have altered our specifications as to hardness by requiring the presence of 0·45 p. c. of carbon.

We have made tensile tests compulsory instead of only taking into consideration the breaking test. Accordingly it is of great importance to know whether Basic-Martin steel should be abandoned, and this question ought to be cleared up. As I have just said, Russian experience, far from condemning its use, is in favour of it.

Mr. Dietler, Gothard Ry. (In French.) — What we have heard is extremely interesting. I may even be allowed to say that I attach more importance to an interchange of opinions derived from our experience than to the resolutions we shall pass.

We have been talking of the length of rails, and I am surprised at learning that in England the length attains 60 feet ($18^{m}29$). It would be interesting to know for actual fact whether these have proved satisfactory, and whether such a length may be accepted as practicable. We must not lose sight of the fact that an increase in length of rail leads to decrease in the number of joints which are the weakest points of a line. The subject is then of great importance.

I accordingly beg the meeting to be kind enough to express an opinion as to whether a length of 60 feet ($18^{m}29$) can be recommended.

Again, we have spoken of the life of a rail. What was said on this point was received by me, representing as I do a railway with long tunnels and severe gradients, the Gothard railway I mean, with a certain amount of reserve.

The information supplied us on this point cannot in my opinion carry much weight, unless supported by data as to the conditions of the line to which it refers and by statistics as to the working of the line. The statistics requisite to enable us to compare lines which are not directly comparable to one another are not forthcoming, and therefore it is difficult to form an opinion on the information as to the life of rails.

I am convinced that if the rails of which Mr. Michel has spoken were laid in the St. Gothard tunnel they would not last more than 10 or 12 years.

The life of a rail undoubtedly also depends on its section, and this ought to lead us to discuss a point which up till now has been neglected, namely the relation between the weight of a rail and the strain upon it. As you will have seen in reading Mr. Ast's excellent report, the Gothard railway uses engines the load on the driving wheels of which is from 15 to 16 tons and consequently the strain upon our line is very great. I should, however, add that the number of such engines is small, and the new engines which are now being designed will probably not be so heavy. However a load of 7 $^1/_2$ tons on each wheel may be regarded as normal.

Mr. von Leber, Austrian Ministry of Commerce. (In French.) — Let us hope so.

Mr. Dietler. (In French.) — Our rails weigh 93 and 97 lbs per yard (46 and 48 kilograms per metre), but are not so heavy as the « Goliath » rails, used in Belgium, which weigh 105 lbs (52 kilograms). The 97 lb (48 kilograms) rail is used in tunnels and the 93 lb (46 kilograms) rail on the other parts of our system. If the moment of resistance of our 97 lb rail is compared with that of the Goliath rail it will be found to be the same. I should be very glad if our friends from Belgium would be good enough to tell us something about their experience of these 105 lb rails so that we may know whether there is any other gain than increased resistance to be derived from their heavier rail. We should like to know also if it is true that these rails wear out very quickly. It has been stated that the large size of the rail's head interferes with its manufacture and that this is why it wears quickly.

We required our rails to possess a high moment of resistance and therefore their height is 5 $^{11}/_{16}$ inches (0^m145) and their base 5 $^1/_8$ inches (0^m130). In this way, we procure a high moment of resistance.

The increased weight of our rails is justified on various grounds. In the first place, the sulphuric acid in our tunnels, which is produced by the coal burnt in our engines, helps to oxidise the rails very quickly. This is the cause of our using 97 lb (48 kilograms) rails in our tunnels instead of the 93 lb (46 kilograms) rail used on other parts of our line. Secondly, as I have said, our engines are very heavy.

With regard to speed, our gradients are long and very steep — e. g., 1 in 40 (25 millimetres per metre) — and going down we have no hesitation in running at high speed, but 37 miles (60 kilometres) an hour may be regarded as our maximum. On the comparatively level parts of our line, there are few straight pieces long enough to allow of the maximum speed attainable by our engines being reached. On the contrary there are stiff curves of 14 and 15 chain radii (280 and 300 metres).

It is important to know at what speed these parts of the road can be traversed. We think it depends not only on the construction of the permanent way, but also on the make of rail. For my own part I believe a speed of 43 $^1/_2$ miles (70 kilometres) or even 50 miles (80 kilometres) can be safely reached, provided that the permanent way be stable and the base of the rail be proportionate to its height. Probably for this reason the Americans have decided that the height of their rail shall be equal to its base.

These are, gentlemen, the few questions which I wish to ask in reference to the rail itself.

There are other points in the matter of permanent way upon which we want information from the experienced men belonging to this section, but for the present, in order to confine myself within the limits suggested by our president, I shall bring my remarks to a conclusion.

I must, however, add one word on the methods of strengthening the road. One very efficient method is doubtless to increase the number of the rails' supports. In regard to this I may say we use 17 sleepers to a length of 39 feet (12 metres) and at the joints the distance between the sleepers is as little as 13 $^{3}/_{4}$ inches (350 millimetres). You will see that we have neglected no means at our disposal with a view to strengthening our road.

Mr. W. Hohenegger, North West Austrian and South North German Junction Ry. (In French.) — It seems to me, gentlemen, that the only point of difference between Mr. Michel and Mr. Dietler is that of the life of a rail. Neither of them have told us what they look upon as the ordinary life of a rail, and I hope they will be good enough to enlighten the section on the point.

The Gothard Company procures rails from all parts of the world, and it is important to know what stipulations the Company lays down in its specifications.

Mr. Dietler. (In French.) — In the tunnels, the short life of our rails is due to rust; in the open line, our rails last as long as anywhere else.

Mr. Michel, Paris-Lyons and Mediterranean Ry. (In French.) — When speaking of how long rails last, of course I was not referring to rails at stations which are so much exposed to friction, nor yet to rails in tunnels which suffer from moisture and smoke. On the contrary, I expressly stated that these wore out more rapidly.

In reply to Mr. Hohenegger, the coefficient of resistance required by the Paris-Lyons-Mediterranean specifications is as a minimum 44 $^{1}/_{2}$ tons per square inch (70 kilograms per square millimetre) and the elongation of $^{1}/_{2}$ inch (12 millimetres).

The factories supply us with steel which generally has a resistance of from 46 to 50 tons per square inch (72 to 78 kilograms per square millimetre).

Mr. W. Hohenegger. (In French.) — Messrs. Michel and Dietler have just asserted that rails deteriorate in tunnels owing to rust. This is only a side issue about which we ought not to waste time.

From what we have heard we may come to the conclusion that the long life of rails in France is due to the good quality of metal used and to good construction of the constituent parts of the permanent way.

Mr. John M. Toucey, New York Central and Hudson River Railroad. — We have had a very interesting discussion and a great many points of interest have been raised this morning with which we have had to deal. Of course some things have been discussed here with which we have not met.

With regard to Mr. Johnson's experience of rails, our first experience in steel rails was in 1867, 1868, 1869 and 1870, from the firms of John Brown and Barrow of this country. They were all hard steel and we got excellent results from those rails. They were light in weight compared with what we are using now. We started with a 60 lb steel rail, 30 feet in length. Now we are up to 100 lbs.

There has been a gradual increase in perfecting the manufacture of rails in the

United States. We get almost as good a rail now without hammering the ingots as we did with hammering. The traffic upon our line, of course, most of you are familiar with; it is extremely heavy. Our cars and engines are heavy, and we have found it necessary to increase the weight of rails to meet the increased weight of the traffic, so that we are getting up gradually to 100 lbs on the main line for our passenger trains, and we are running on that line a speed varying from 60 to 100 and 102 and even 105 miles an hour. Gentlemen seem to think that that cannot be true, but nevertheless it is the fact. The Empire State Express train makes its run of 440 miles daily at a speed of about 53 miles an hour; but when we are delayed, we are compelled to increase the speed, to make up the lost time; we are seldom late in arriving at the terminus, and if we do lose time a speed of from 80 to 100 miles per hour is frequently attained. I have some statistics here, and I will read you the speed of the train as it goes along, and this is the average speed every day : 62·07 miles, 67·6, 76·27, 69·23, 69·23, 66·17, 60, 62·07, 64.28, 64·28, 61·60, 64·28, 66·6, 72, 72, 72, 69·23, 76·6, 78·26, 73·47, 76·6, 76·6, 80, 80, 80, 81·8, 76·6, 83·7, 78·26, 80, 81·8, 100, 88, 83·7, 102·86, 78·26, 78·26 The weight of the cars is 328,950 lbs, of the engine and tender 204,000 lbs, and the weight of the load 33,000 lbs. The total weight of the train, therefore, is 565,950 lbs. Our goods trains average 50 cars of 30 tons each and 2,000 feet in length with a locomotive engine weighing 60 tons, and we make a speed of from 20 to 30 miles an hour as necessity requires. There are other American roads that can do the same thing.

As regards the rails, we have gradually increased the hardness of the rails from about 30 points up to 50 or 60 points of carbon. We find that we saved money by that, and that it was a great advantage in having a hard rail. Originally the American manufacturers would not make a rail higher than 30 points, or 35, but it was so soft that its life was only 5 or 6 years. With the original Barrow rails we could count on 15 years service with the traffic that we had at that time. At the present time, however, with the traffic that we have and the heavy rail that we have got, we are not in a position to state exactly what the life of the rail will be, but we calculate 20 years. The joint question has been discussed here. We use a fish-plate, the weight of which is about 80 lbs per pair. Our rails now consist of two kinds, 80 lbs to the yard, and 100 lbs to the yard, the fish-plating being about 36 inches in length with six bolts. We have no suspended joint. We tried that some years ago, but the deflection was so great that we had to abandon it. Now we use the 36 inch fish-plate with three ties; the centre tie being under the joint. We lay the joints in the manner we call "broken"; that is, they are not opposite each other. We use an indicator car, running it on the line, so as to see what the deflections are in the track. With these 100 lb and 80 lb rails, and this long fish-plate taking three ties there is hardly any deflection perceptible at the joints; it is quite as smooth at the centre of the rail as at the joint. So we have come to the conclusion that the long fish-plate of 36 inches with three ties, and the centre one taking the joint, is the best.

I would like to say that our chief engineer, Colonel Katte, was unable to come, but he has sent one of his associates, Mr. Dudley, who is here, and he has had the entire experience of rolling these rails, specifications and everything, and if you would like to hear him, Mr. Dudley will explain the whole thing to you.

Mr. P. H. Dudley, New York Central and Hudson River Railroad. — In the manufacture of a rail at the present time the first object that we try to secure is a sound ingot. The percentage of carbon in the ingot does not make so much difference as the form in which we can hold the carbon. We desire to have a large percentage of the carbon in the form of hardening carbon, not simply cement carbon. That gives us the better wear.

For the 80 lb rails we use from 0·45 to 0·55 of 1 p. c. of carbon, — 0·15 to 0·20 of 1 p. c. of silicon, and from 1 p. c. to 1·20 of manganese. The phosphorus is limited to 0·06 of 1 p. c. The above composition gives a large percentage of the carbon in hardening form, and gives a very solid ingot.

For the 100 lb rails we increase the carbon up to 0 60 of 1 p. c. and carry the manganese from about 1·10 to 1·20 p. c., and the silicon from 0·15 to 0·20 of 1 p. c. The ingots are about fifteen inches square at the base, and the steel instead of rising at the top of the ingot actually settles, and we have ingots which are smooth and solid on the top end. These ingots are without a trace of blow holes and are very sound. The rails are all tested by the drop test with supports three feet apart; for 65 to 70 lb rails, the drop is 2,000 lbs falling 16 feet, producing a deflection of about 1·8 to 2 inches for our standard quality. For 75 to 80 lb rails the drop is 2,000 lbs falling 20 feet. The standard of deflection for the 80 lb rail is 1·55 inch, which indicates a steel of about 120,000 lbs tensile strength and elastic limits from 65,000 to 70,000 lbs. The latter is more important than the tensile strength.

As regards the stiffness of the 80 lb rail suspended on supports 30 feet apart, 100 lbs deflects it $^{113}/_{1000}$ of an inch. The modulus of elasticity for that steel is 29,500,000 lbs per square inch. Lowering the carbon in the steel, the modulus of elasticity drops.

It has been very carefully ascertained that the higher the grade of the steel the higher is the modulus of elasticity.

The deflection for the 100 lb rail with supports 30 feet apart is $^{66}/_{1000}$ of an inch — that is for a 100 lb rail 6 inches high, base 5 $^{1}/_{2}$ inches, — and is 80 p. c. stiffer than the pioneer 80 lb rail which was originally put in on the New York Central and Hudson River Railroad.

The percentage of elongation of the rails under the 20 feet drop is from 14 to 18 p. c. when the rail is placed on the side, and when the weight is dropped upon the head the elongation is about 5 p. c. The second blow will only increase it to 7 or 8 p. c., straining it in other places.

We have an indicator car to run over the track to record the deflections of the rails on diagrams (see Appendix). This car also sums up into feet and inches per mile all the undulations in the rails and gives us the condition of the steel. So the officials of the railroad can see the condition of every mile, and see whether it is possible to improve the track by labour or whether they must renew the steel.

We find that the minimum undulations on a 100 lb rail are about 1 foot 9 inches per mile and that is as low as it is possible for the trackmen to surface the track, and on the 80 lb rail it is 2 feet 6 inches. As a result in the New York Central and other Roads in the last ten years, they have reduced the undulations of the rails per mile to the lowest limits and the tracks now are as smooth as it is possible to make them, for each section of the rail. To do this, however, required many important changes in the manufacture of the rails, making them much smoother than formerly. (See in the Appendix the description of the diagrams.)

Mr. von Lenz, Emperor Ferdinand's Northern-Austrian Ry. (In French). — I should like to know from representatives of Companies which have lines with severe gradients or stations very close together, for instance a line such as that from Paris to Marseilles or " the Metropolitan ", whether observations have been made on the effect of instantaneous brakes such as the Westinghouse, Smith, etc., on the life of rails.

The President. — As it is getting late, I would suggest that we adjourn. (*Agreed.*)

— The meeting adjourned at 12·45 p. m.

July 1. 1895, at 2.15 a. m.

Mr. d'Abramson, Russian State Railways. (In French.) — I find on page 121 (English edition) of Mr. Ast's report the following passage :—

The stiffness of the rail must be taken into consideration because the load is transmitted to other sleepers than those which directly support the load on the rail. Calculations on this point show us however that when the stiffness is uniformly increased, the increase of its utility for this purpose becomes rapidly smaller and smaller. In a rail of about 90 lbs per yard (45 kilograms per metre), the limit is reached ; any further increase in the stiffness of the rail has practically no effect in distributing the load over the sleepers.

On the other hand, we read on page 129 (English edition) as follows :

From this point of view, the new cross sections of the French and Belgian railways which correspond to a weight of 92 to 100 lbs per yard (46 to 50 kilograms par metre) seem justified. This is shown in the subsequent table.

This seems somewhat contradictory.

At the St. Petersburg meeting, the Congress agreed that there was a tendency towards increasing the weight of rails ; this tendency still seems to exist.

I should therefore like to hear the opinion of our Belgian friends on the " Goliath " rail which they use.

Do they think of using rails weighing more than 105 lbs (52 kilograms) or do they share Mr. Ast's views in that this is too heavy?

Mr. de Busschere, Belgian State Railways. (In French.) — In reply to the questions asked this morning by Mr. Dietler and now by Mr. d'Abramson, I must first state that our 105 lb (52 kilograms) rails give satisfaction. They provide a good road and personally I have no fault to find with them except that they cost more than is necessary. No doubt so far as stability is concerned a rail weighing 80 or 90 lbs (40 or 45 kilograms) would have been heavy enough, but the Belgian Administration wished to have a large margin for wear. This can, with the Goliath rail, go as far as an inch (25 millimetres) and this was the main inducement for adopting the type.

The wear of this rail has already been discussed at the St. Petersburg meeting. I then stated that the crossings, diamond and acute, wore out rather quickly, and that at many places they had to be renewed after two years and even less.

The attention of the foundries which supplied them was called to the circumstance and they are trying to find methods of manufacture which will prevent rails at crossings from wearing out faster than in the ordinary road. I hope they will meet with success, but only time can show us positively how far we may expect satisfactory results.

Mr. Mantegazza, Mediterranean of Italy Ry. (In French.) — I should like to ask the meeting what it regards as the best type of permanent way for main lines to adopt.

As you are aware we have long tunnels on our line, the Mont Cenis, Ronco des Giovi, Sella, etc.

We work lines which do not belong to us. In the Ronco tunnel the Government had 73 lb (36 kilograms) Vignoles rails laid; in four years, the track had to be relaid.

We have had to take to chair-rails, and their dimensions are as follows; height 5 $^{7}/_{8}$ inches (0·150), 2 $^{13}/_{16}$ inches (0·072) for the upper and 3 $^{1}/_{2}$ inches (0·090) for the lower head. This rail weighs 90 lbs (45 kilograms) and has proved satisfactory. What I specially want to know is whether we ought to give the preference to chair-rails rather than to Vignoles in long tunnels where oxidation is to be expected.

We are in the habit of giving the rails in tunnels a coat of paint to protect them from rusting. Now they can be painted much more quickly if the rail is on chairs and on this account a chair-rail would appear to offer advantages not possessed by the Vignoles. I offer this as a suggestion to the meeting and should be pleased to hear the opinion of those present. The rails could be easily changed — a by no means unimportant point — for the longest interval between the trains is two hours.

The President. (In French.) — The question still under discussion is the weight of rails. Will any delegate give us any information on the subject? The reporter for the continent thinks there is nothing to gain by increasing the weight beyond 90 lbs (45 kilograms).

Mr. Sabouret, Paris and Orleans Ry. (In French.) — Gentlemen, the resolutions proposed tend to arrive at some relation between weight of rail and speed of trains that the road can bear.

It has been said that rails weighing from 70 to 80 lbs (35 to 40 kilograms) suit speeds of from 50 to 56 miles (80 to 90 kilometres) an hour; on the other hand, it has been stated that heavier rails, i. e. exceeding 80 lbs (40 kilograms), must be used on roads which will have to stand speeds greater than 62 miles (100 kilometres) an hour. These statements seem to be rather expressions of opinion than deductions from facts.

Indeed, if I take as an instance what happens in France, I find on the one hand that some Companies who run very fast trains — their speed reaches 74 and 87 miles (120 and 140 kilometres) an hour — use 60 lb (30 kilograms) Vignoles rails.

These Companies have trains booked at speeds of 62 miles (100 kilometres).

On the other hand, we find that other Companies which use 77 lb (38 kilograms) rails hesitate to exceed 62 miles (100 kilometres) an hour. The explanation is mainly the stability of the engines. This is why I think it would be unwise to acknowledge that there was a fixed relationship between the minimum weight of a rail and the maximum speed it could stand.

Mr. Agnellet, Northern of France Ry. (In French.) — There is a line on the Northern of France laid with 60 lb (30 kilograms) Vignoles rails upon which run trains which often exceed 62 miles (100 kilometres) an hour. The track will remain as it is for a long time yet, but we are gradually exchanging these rails for ones weighing 90 lbs (45 kilograms), because we recognise the fact that though, as it is at present, the line is suitable for heavy traffic, not only as regards tonnage but also speed, it is costly to maintain and is wanting in stability.

The 90 lb (45 kilograms) rail has been adopted in order to get a strong, stable line, capable of bearing increased speed. I think that a line with 60 lbs (30 kilograms) rails if well maintained can carry a great deal of traffic; but for the sake not only of easier running but of reducing maintenance expenses also, it is preferable to use 90 lbs (45 kilograms) rails.

The number of sleepers is a very important factor; for lines carrying the important expresses, 16 sleepers seem advisable for a 90 lb (45 kilograms) rail measuring 39 feet (12 metres); for lines carrying trains of moderate speed, 14 or 15 sleepers may be enough.

Mr. Belelubsky, Russian State Railways. (In French.) — Mr. Ast states on page 145 (English edition) of his report : *Rails should have a cross section whose moment of resistance is about 12·20 cubic inches (200 cubic centimetres).*

This implies that with rails of similar weight different moments of resistance and degrees of stability may be obtained.

In Russia, with lighter rails their section is constructed to offer greater resistance.

Accordingly, I agree with Mr. Sabouret that 60 lb (30 kilograms) rails can stand high speeds, and this depends essentially on the moment of resistance.

Mr. De Busschere, Belgian State Railways. (In French.) — On page 124 (English version) of Mr. Ast's report we find the following passage :—

A railway can certainly not be considered properly constructed when the traffic on it can only be worked with excessive repairs; and it is from this point of view that we must consider the value we have found above by calculation as the highest limit of the serviceable capacity of a line.

So Mr. Ast agrees with Mr. Agnellet, for Mr. Ast is also of opinion that for a road to be good it is not sufficient that it allows of trains running fast; it must also not cost too much to maintain.

We have lines in Belgium which stand very heavy traffic and, though they are excellent so far as stability is concerned, they cost a great deal to maintain and we are trying to reduce maintenance expenditure by strengthening them.

Mr. Agnellet. (In French.) — Observations now being made on our railway give us reason for believing that increased weight of rail means considerable economy in maintenance expenses.

Mr. von Leber, Austrian Ministry of Commerce. (In French.) — I do not think Mr. Ast's meaning has been quite grasped. He is supposed to want to establish a relation directly between speed and weight of rail. This is not quite the case.

Mr. Ast has discussed three cardinal points : 1st, Speed; 2nd, weight of rail, and 3rd, load per axle. The last is very important and I may incidentally mention that in Austria and Germany the load does not exceed 14 tons.

Taking these three points into consideration, Mr. Ast has expressed the opinion that an 80 lb (40 kilograms) rail was heavy enough to stand a speed of 50 miles (80 kilometres) per hour.

If you specify the weight per yard, the engineer will of course design the section of rail so as to obtain the best result possible.

There can be no doubt of that. I am drawing the attention of the meeting to the exact signification of Mr. Ast's deduction which it seems to me has not been clearly understood.

Mr. Dietler, Gothard Ry. (In French) — I beg to thank Mr. De Busschere for the information he has given us.

According to him, the 105 lb (52 kilograms) rail is successful, but no inconvenience would arise if it were lighter.

I may inform the meeting that Swiss engineers formally investigated this point with a view to recommending a typical strong rail for lines with heavy traffic. They came to the conclusion that for lines with the heaviest traffic a quite satisfactory line could be constructed with rails not exceeding 95 lbs (47 kilograms) in weight. They arrived at this after due consideration not only from the technical, but also from the economic point of view, a side of the question which has so far not been discussed here.

So they thought that a 95 lb (47 kilograms) rail — the heaviest rail we use — was incontestably the least costly, granted that it lasts longer — consequently the annual sinking fund is not so great — and moreover this considerably reduces expenditure on maintenance. Thus the cost, including interest on capital, is lower and in all respects the 95 lb (47 kilograms) rail seems to meet requirements most efficiently.

I have thought that what we have heard to-day from those representing different countries only bears out this conclusion.

However, I think Mr. Ast's conclusion is rather too wide, for he suggests that the weight should be between 70 and 93 lbs (35 and 46 kilograms).

Having regard to what has been said during this discussion we might raise the minimum and take 80 lbs (40 kilograms) instead of it. We should then say that a rail for a line carrying *very heavy traffic* ought to weigh between 80 and 95 lbs (40 and 47 kilograms).

Mr. von Boschan, Emperor Ferdinand's Northern of Austria Ry. (In French.) — I should like to draw Mr. Dietler's attention to the exact bearing of Mr. Ast's conclusions.

The reporter has drawn a definite distinction between lines traversed by trains running at 50 miles (80 kilometres) an hour with axle loads not exceeding 14 tons, and lines where trains run at speeds greater than 50 miles (80 kilometres) and axle loads exceed 14 tons. This accounts for the suggested difference in the weight of the rails. In the former case, that is on lines where the important expresses do not run and which do not carry very heavy traffic, he thinks 70 lb (35 kilograms) rails are suitable; in the second case he recommends rails weighing 80 lbs (40 kilograms) and upwards.

Mr. Mantegazza, Mediterranean of Italy Ry. (In French.) — I do not see why we should specify the weight of the rail, for in my opinion it is not upon the weight that quality depends. A road may be quite good with a comparatively light rail if enough sleepers are used. What ought above all to be settled is how the metal should be utilised so far as the section of the rail is concerned. These remarks apply to lines which do not carry heavy traffic. However, for lines which carry the important expresses and rolling stock with 15· ton axle-loads I think the weight of the rails should exceed 73 lbs (36 kilograms).

The President. (In French.) — I must ask you to keep the discussion within limits.

The reporter is of opinion that for lines upon which trains run at 50 miles (80 kilometres) an hour as a maximum, and the axle load does not exceed 14 tons, 70 lb (35 kilograms) rails meet all requirements. On the other hand, he thinks that as soon as this speed and load are exceeded a heavier rail must be used and its weight may reach as much as 90 lbs (45 kilograms). According to him, there is nothing to be gained by exceeding this.

Mr. Mantegazza. (In French.) — Who says so?

Mr. von Leber. (In French.) — The reporter.

The President. — The importance of this question will not escape you.

Mr. Mantegazza (In French.) — By combining the respective advantages of the double-headed and Vignoles rail, we might get a line on chairs with rails not exceeding 90 lbs (45 kilograms). This is what we have done in the Ronco tunnel.

Mr. von Leber (In French.) — It is all a question of expense.

Mr. Bruneel, Belgian State Railways (In French.) — I cannot agree with the resolution proposed by the reporter, Mr. Ast, as to the weight of rails. We cannot decide that it shall be looked upon as going too far if we use rails exceeding 90 lbs (45 kilograms) in weight for roads carrying very heavy traffic.

In arriving at the conclusions proposed, Mr. Ast relies mainly on theoretic grounds and on calculations supported, it is true, to a certain extent by the results of experience. My opinion, gentlemen, is that a limit in the weight of rails cannot be based on calculations only and that, though theory may carry weight in fixing a minimum, it cannot lead to determining a maximum weight which is not to be exceeded without being considered excessive.

But I believe I am much nearer agreeing with Mr. Ast on this point than would appear at first sight. For I read on page 143 (English edition) of the report before us the following passage :—

But to absolutely determine the type of construction for a road suitable for high speeds is impossible, because the increased stresses due to increased speed have not, either by theory or experiment, been determined with a sufficient degree of accuracy.

This opinion is expressed elsewhere in other words, for instance on page 107 (English edition), where Mr. Ast states that :—

A theoretical examination does not give us an absolute measure of the capabilities of a line.

One of the most important factors in the strain on a line is the dynamic force caused by abnormal shocks which increase considerably as the engines run faster. Upon this point we only possess approximate hypotheses which can only be regarded as near the mark and do not seem to me sufficient justification for fixing a maximum weight for rails.

So then the Congress cannot formally decide that 90 lbs (45 kilograms) should be an extreme limit that may not be exceeded. This weight is only the result of theoretic calculations based on uncertainty and no such absolute conclusions can be drawn from it.

Why then allow as a maximum 90 lbs (45 kilograms) and not 93 or 97 lbs (46 or 48 kilograms) like the Paris, Lyons and Mediterranean Company, or even 105 lbs (52 kilograms) like the Belgian State Railways?

The section ought to agree rather with the English reporter, Mr. Hunt, who says on page 7 :—

As regards the calculations of the strains imposed on rails by the rolling load, as the various stresses cannot be ascertained sufficiently accurately to enable a rail to be designed on the same scientific principles as a girder would be, it is considered by English engineers that close and careful observations of the effects produced upon the road by the rolling loads which pass over it is the best means of determining the size and shape of the rail.

I think that this is the truth and that we ought to trust rather to facts than to the results of mathematical formulae, for these can only very roughly allow for abnormal strains which to such a large extent affect the strain on the component parts of the permanent way.

Accordingly I suggest to the section that they should not fix any extreme limit, but that they should rather confirm what the Congress has already often affirmed in rather a vague way perhaps — but we all know why the conclusions of the Congress are sometimes vague — that the permanent way ought to be strengthened in proportion to the loads it has to carry, to the amount of traffic and to the speed of the trains.

Were we to fix the maximum at 90 lbs (45 kilograms) as proposed by Mr. Ast, we should be criticising, unjustly perhaps, the measures taken by the Paris-Lyons and Mediterranean, and by the Belgian State who have 97 and 105 lb (48 and 52 kilograms) rails respectively.

I think I am justified in urging that 90 lbs (45 kilograms) — a weight which after all depends for acceptance upon theoretic considerations checked, it is true, by coefficients whose value we cannot gauge — should not be accepted as an absolute maximum which cannot be passed without extravagance.

Mr. Ast, *reporter*. (In French.) — It is very difficult to give an exact figure. Each Administration can make its roads taking into consideration the circumstances of working them. But when it is a question of making a typical road, a line calculated for the fastest expresses, the following question should be put : will not circumstances require a further increase of the axle-load or a further increase in speed?

It is to meet this possibility that we ought to recommend that the section of the line should be such that, by some simple means such as additional sleepers, the rails may be able, if need be, to stand greater strain.

Experience teaches us that the rail with a moment of resistance equal to 12·20 cubic inches (200 cubic centimetres) is a rail whose weight exceeds 80 lbs (40 kilograms).

I beg you, gentlemen, to look at the typical instances I have given in my report and I feel convinced that you will adopt my proposals.

Mr. Wasiutynski, Warsaw-Vienna Ry. (In French.) — We have just been told that a relation can be established between weight of rail, axle load and speed. I grant this. But I think that the rail's section, upon which depends how the substance forming it is utilised, must be specified. Weight does not always coincide with resistance.

Besides I think the weight of a rail is subordinate to the spacing of the sleepers and that it would be a good thing to specify what the spacing is.

The President. (In French.) — Do not let us discuss the spacing of sleepers just now. We will deal with that later on.

Mr. Wasiutynski. (In French.) — Still, sir, I think we must discuss it, for otherwise the relation between weight of rail, axle load and speed will be arbitrary.

The President. — I think, gentlemen, the general discussion should be considered closed. The principal secretary, Mr. Debray, will submit for your deliberation a motion based upon the remarks already made which may serve as a groundwork for discussion.

Mr. Debray, *principal secretary.* (In French.) — The following is the motion to be considered :—

" 1st. The section agrees that, where necessary, express trains at a speed of from " 62 to 74 $^1/_2$ miles (100 to 120 kilometres) can run over a line laid with 60 lb " (30 kilograms) rails, but for various reasons and specially with a view to decrease " expenses, heavier rails are preferable;

" 2nd. The weight of rails for express lines depends upon the type of permanent " way, the speed of the trains, the methods of construction and the running of the " rolling stock;

" 3rd. For an axle-load of 14 tons and a maximum speed of 50 miles (80 kilo- " metres) an hour, 70 lb (35 kilograms) rails are heavy enough;

" 4th. If the axle-load is greater or the speed higher, heavier rails — up to 90 lbs " (45 kilograms), — should be used;

" 5th. A heavier rail than 90 lbs (45 kilograms) does not seem at present to offer " sufficient advantage to justify the increased prime cost. "

A delegate. (In French.) — I request that a slight alteration may be inserted. I propose that the words *if a road is well maintained* be substituted for *where necessary*.

We must avoid wording which would censure Administrations using 60 lb (30 kilograms) rails.

Mr. Debray. (In French.) — It is of course understood that all lines are well maintained and so there is no use in saying it.

Mr. Bell, Indian Government Railways. — May I ask whether the resolution is to refer to flat-footed rails or to double-headed rails? I take it the mere expression

40 or 80 lbs per yard, conveys but little meaning when two different classes of rails, one with chairs, and the other without, are in question.

The President. — That is the difficulty of which I spoke this morning. There are two different systems. There is the system of Vignoles and there is the English system. Have you any objection to the answer?

Mr. Bell. — Roughly speaking, sir, I hold that you should add at least 10 p. c. to the weight of rail when you speak of the flat-footed Vignoles which compares on all fours with a given double-headed rail.

The President. (In French.) — Still practice shows that trains can run at 62 miles (100 kilometres) an hour on 60 lb (30 kilograms) Vignoles rails.

If this is feasible on Vignoles rails, it is still more so with double-headed rails of the same weight.

Mr. Agnellet, Northern of France Ry. (In French.) — As worded the motion takes no count of the number of sleepers. Now this factor cannot be disregarded. As the successive supports of the road are not always of equal value the exact stability of a rail cannot be estimated. Nevertheless the spacing of the sleepers is most intimately connected with the stability of a road.

To be suitable for express trains a line laid with 60 lb (30 kilograms) rails must have its sleepers close together and they must lie on first class ballast. On the Northern of France, there are now 10 sleepers per 60 lb (30 kilograms) rail, 26 feet 2 inches (8 metres) in length and there will be 11 soon.

There can be no doubt that express trains can run on a road laid with 60 lb (30 kilograms) rails. Still it would be well to lay stress on the wording of the motion by stating that very good ballast is necessary and the sleepers need to be close-spaced in proportion as engines are heavy and speed high.

Mr. Brière, Paris and Orleans Ry. (In French.) — Gentlemen, it appears to me that several points which must be taken into account have escaped discussion. First of all a great deal depends upon curves. An instance has been given of express trains running over 60 lb (30 kilograms) rails. I believe the line in question has only a few curves of very large radii, exceeding 40 chains (800 metres). If I am mistaken I hope some one will correct me. Curve radius must be taken into account.

Secondly, we must not neglect the type of engine used. I am again referring to the line we have been considering and I find some very interesting points about it.

The engines in use upon this line have been exceedingly carefully devised. It has been no light task to succeed in running trains at 62 and 69 miles (100 and 110 kilometres) an hour over 60 lb (30 kilograms) rails.

At the outset there were difficulties, but fortunately there exists in this Company the most perfect harmony between the locomotive and permanent way departments.

The moment these fast trains began running it was found that the permanent way was getting injured. What followed?

The locomotive department, instead of making difficulties, set to work at its engines and investigated the play of their axles. Some slight alterations were made and the engines were made less rigid. Since then the permanent way has been all right. If on the contrary the locomotive department had persisted in retaining the type of engine, I think I am justified in asserting that either the engines would have had to be discarded or the permanent way would have had to be altered.

Allow me, gentlemen, to add one word more.

I believe that the cause of the special state of affairs of which we have heard lies, not in figures which explain little, but in this harmony which exists between the two departments.

An engine whose leading axle carries 16 or 18 tons may do no harm to the permanent way, while one with only a 14 ton load may prove disastrous to the same permanent way.

The whole matter is of serious import and the difficulty in solving the question ought to make us show great reserve in accepting a mathematical formula.

Calculations which may apply to one line, to such and such traffic, such a speed or such an engine will not apply to another line with similar traffic but using engines of a different pattern.

As you are aware, the action of engines on the permanent way is still a mystery. It is undoubtedly one of the questions most deserving of attention from railway engineers and unfortunately one of the least investigated.

When the locomotive department is building a new engine, one thing only is regarded : to make it very powerful. But no heed is taken as to what effect the engine will have upon the permanent way. If only one was built at a time and trials were then made it would be less serious, for it would at once be found that improvements must be made upon it so as to spare the permanent way. Unfortunately once the new pattern has been passed a whole series is built. It is only after they have been working some time that the destructive effects are recognised and it is found that the permanent way is not sufficiently resistant.

Then, instead of altering the engine, fault is found with the permanent way; it is strengthened, re-strengthened and re-strengthened ever again.

This would be unnecessary if only the engineer would remedy the defect in his engine without, however, sacrificing power. Why not graciously request the locomotive department to discover means to make some improvements in new types of engines which should result in making them less destructive to the permanent way? Would not this generally do away with the question of strengthening the road?

I hope, gentlemen, you will excuse the length of my speech, but I have tried to show you that we ought to be very careful in our expressions of opinion, for so far as engine-running is concerned, there can be no absolute rule. (*Cheers.*)

Mr. Ast, *reporter*. (In French.) — I want to say a word or two in reply to Mr. Wasiutynski, who has touched upon the spacing of sleepers.

As I have said in my report, the spacing and number of sleepers are more or less dependent on the carrying capacity of the rail. These details only affect the pressure on the ballast When a line is laid down, whether with light or heavy rails, the smaller the distance between the sleepers the less the pressure on the ballast and the more favourable it is to economy in maintenance.

The length of sleepers is a factor which should also be considered in its relation to the position occupied by the wheels of the vehicles, for this position modifies the load on the rail and the pressure on the ballast which depends on this load.

Mr. Debray, *principal secretary*. (In French.) — The President bids me propose an alteration which will meet the principle pointed out by Mr. Brière. The alteration consists in changing the order of the paragraphs.

We should commence with this one :—

" The weight of rails for express lines depends upon the type of permanent way, " the speed of the trains, the methods of construction and the running of the " rolling stock. "

If we take this first we shall meet the views of permanent way engineers without arousing hostility among locomotive engineers.

Mr. von Leber, Austrian Ministry of Commerce. (In French.) — This would mean nothing. In passing a motion like this, we are accepting a truism.

Mr. Debray. (In French.) — But immediately after would come the following :—

" The section agrees that, given favourable circumstances, express trains at a speed " of from 62 to 74 $^1/_2$ miles (100 to 120 kilometres) can run over a line laid with " 60 lb (30 kilograms) rails, but for various reasons, and specially with a view to " decrease expenses, heavier rails are preferable. "

Mr. von Leber. (In French.) — That is what we ought to begin with. (*Laughter*.)

Mr. Debray. (In French.) — Then would come §§ 3, 4, and 5 in the order I read them just now.

M. Brière, Paris and Orleans Ry. (In French.) — I think it is a mistake to say nothing about curve radii.

The President. (In French.) — We ought as far as possible to look at things from a general point of view and confine ourselves to putting on record the result of actual experience.

We have been told on the one hand that trains do run at speeds of from 62 to 69 miles (100 to 110 kilometres) an hour over 60 lb (30 kilograms) rails. On the other hand, we are informed that we can trust a 70 lb (35 kilograms) rail for lines that are to carry trains running at from 56 to 62 miles (90 to 100 kilometres) an hour.

Finally where the axle-load exceeds 14 tons and speed 62 miles (100 kilometres) we may go up to 90 lb (45 kilograms) rails.

These are the limits given us and within which the discussion ought, I think, to be kept without going into points which only concern individual Companies.

Mr. Ast, *reporter*. (In French.) — We have been told that the Northern of France accepted 90 lbs (45 kilograms) as the weight of rails.

The President. — Yes, but they still use 60 lb (30 kilograms) rails.

Mr. Agnellet, Northern of France Ry. (In French.) — The Northern Company is gradually changing from 60 to 90 lb (30 to 45 kilograms) rails.

The President. (In French.) — The Company to which I belong works main lines with heavy traffic and regards it as unnecessary to use a rail weighing more than 70 lbs (35 kilograms).

Mr. Fouan, French State Railways. (In French.) — I think it would be better not to decide upon any exact figure as to the weight for rails.

Mr. Ast says in his conclusions that a 90 lb (45 kilograms) rail is the most suitable for express lines, but has no intention of finding fault with the use of a lighter rail.

Moreover, the various French railway Administrations are endeavouring to improve the stability of their lines, to increase the weight of the rails laid on lines upon which trains run at 50 miles (80 kilometres) an hour and to make the weight a minimum of 80 lbs (40 kilograms). I therefore think it would be better to submit to the section the following resolution :—

" The section is of opinion, due account being taken of the other elements of the " permanent way and the construction of the rolling stock, that there is a general " tendency, whether it be with the object of increasing the stability of the road at " present or to meet future traffic requirements, to increase the weight of rail on " lines with expresses at over 50 miles (80 kilometres) an hour to a minimum of " roughly 80 lbs a yard (40 kilograms per metre). "

Mr. von Leber. (In French.) — I do not think we can accept Mr. Fouan's resolution as it stands. It is impossible to say that 80 lbs (40 kilograms) is a minimum when it is a fact that in many countries, and in Austria especially, 70 lb (35 kilograms) rails are used with speeds of 56 miles (90 kilometres) an hour. Mr. Brière said just now that on some railways the locomotive and permanent way departments work in harmony to the great advantage of the service. Unfortunately this is not the case everywhere. I agree with Mr. Brière that this good understanding ought always to be maintained between the two departments.

Mr. Brière thinks we should take special notice of sharp curves. This does not seem to me necessary. It is quite understood that the limits we are suggesting only refer to lines in normal circumstances. It is evident that very fast trains cannot run on lines with exceptional curves.

Mr. Brière. (In French.) — That is a mistake as proved by the fact that the Orleans runs three trains each way daily at a speed reaching 50 miles (80 kilometres) an hour over a line with curves of 15 chain radius (300 metres). (*Cries of: Vote, vote.*)

The President. — I think the section is desirous of closing the discussion.

Mr. Fouan. (In French.) — In order to satisfy Mr. von Leber, I have struck out the words "a minimum of" from my resolution. We shall therefore fix neither minimum nor maximum and we avoid condemning either rails under 80 lbs (40 kilograms) or rails over 90 lbs (45 kilograms), the Belgian Goliath rail and the 95 lb (47 kilograms) rail of the Paris and Lyons.

The President read Mr. Fouan's resolution as follows:—

"The section is of opinion, due account being taken of the other elements of the "permanent way and the construction of the rolling stock, that there is a general "tendency, whether it be with the object of increasing the stability of the road at "present or to meet future traffic requirements, to increase the weight of rails on "lines with expresses at over 50 miles (80 kilometres) an hour to roughly 80 lbs a "yard (40 kilograms per metre)."

— This was unanimously adopted and the meeting adjourned at 4·30 p. m.

July 2, 1895, at 10 a. m.

The President. — I suggest, gentlemen, that we take up Mr. Ast's separate conclusions one by one. (*Agreed.*)

"1st. A layer of readily permeable ballast, at least 15 3/4 inches (40 centimetres) "in thickness, resting on a perfectly drained sub-soil."

Mr. De Busschere, Belgian State Railways. (In French.) — Does this mean that there ought to be 15 3/4 inches (40 centimetres) of ballast underneath the sleepers? (*Interruption.*) It seems to me important to be clear on the point.

Mr. von Leber, Austrian Ministry of Commerce. (In French.) — No. It is the total thickness.

Mr. De Busschere. (In French.) — The English railways accept two feet as the total depth of the permanent way, and this depth corresponds to a depth of ballast of about 15 3/4 inches (40 centimetres).

Mr. von Leber. (In French.) — We understand 15 3/4 inches (40 centimetres) to be the total depth.

Mr. Brière, Paris and Orleans Ry. (In French.) — I am confident that on the French lines the depth of the ballast below the sleepers never exceeds 9 $^7/_8$ inches (25 centimetres).

Mr. De Busschere. (In French.) — It is different in England.

Mr. Brière. (In French.) — We cannot accept the word " minimum " in this resolution. If we were to accept the principle that the ballast must be at least 15 $^3/_4$ inches (40 centimetres) in depth, every railway Company in France would be obliged to alter its road. I also think it would be better to speak of depth below the sleeper. In France, we are accustomed to ballast above the sleepers, so that the resolution would have to read not 15 $^3/_4$ inches (40 centimetres), but 19 $^5/_8$ inches (50 centimetres). The really important thing is the depth below the sleeper. There remains the question whether a precise figure should be fixed. I do not myself think it is advisable, but if the section attaches importance to the point I must beg that the resolution may be altered to read " a minimum of from 7 $^7/_8$ to 9 $^7/_8$ inches (20 or 25 centimetres) " instead of 15 $^3/_4$ inches (40 centimetres).
I suggest therefore that the paragraph should read as follows :—

" A layer of readily permeable ballast, from 7 $^7/_8$ to 9 $^7/_8$ inches in depth below " the sleeper as a minimum, resting on a perfectly drained subsoil. "

Mr. Ast, *reporter*. (In French.) — I accept the suggestion.

Mr. J. E. Bell, Indian Government Railways. — It appears to many of us that the depth of the rail, the depth of the chair below the rail and the depth of the sleeper below the chair all form elements in that elasticity which supplements the elasticity which the ballast opposes to the rigidity of the solid ground below. Hence to merely count the depth of the ballast from the underside of the sleeper as a constant, allows variation in the total elasticity of the road and omits a very large number of the elements which are essential to that elasticity which is required. That is our position; that it would be better to count from the top of the rails to the bottom of the ballast as a constant. In the case of the Vignoles rail, we certainly lose something by omitting the chair and some suitable difference must be allowed where you use thicker sleepers and where you use thinner.

Mr. Brière. (In French.) — This would be impossible, unless we were to fix separate figures for Vignoles and for double-headed rails.

Mr. Demoulin. (In French.) — It is precisely because a greater depth of ballast is used with the Vignoles rail that Mr. Bell has made the suggestion.

Mr. Brière. (In French.) — I am clear that we must only take into consideration the depth of ballast below the sleeper.

Mr. Petsche, Eastern of France Ry. (In French.) — The French roads have only 7 $^7/_8$ inches (20 centimetres) under the sleepers, and they are excellent.

Mr. W. Hohenegger, Austrian North West and South North German Junction

Railway. (In French.) — It must not be forgotten that the depth of ballast has to be different with steel sleepers.

The President. — It is understood that we are not dealing with steel sleepers. The reporters have only discussed wooden sleepers.

I will read you the proposition made by Mr. Bell. He says :—

"It is better to count the requisite depth of the ballast from the top of the rail to "the bottom of the ballast, for the Vignoles rail with light sleepers has a very "much less elastic bed than a double-headed rail with chairs, so that by increasing "the elastic depth you substitute in effect a certain quantity of ballast for the defi-"ciency in elasticity."

Mr. W. Hohenegger. (In French.) — I do not agree with Mr. Bell. Counting the depth of the ballast from the bottom of the rail is objectionable because certain Austrian Administrations lay their lines so that the base of the rail is 1 $^9/_{16}$ inch (4 centimetres) above the sleeper. The best plan is to define the depth of the ballast below the sleeper.

Mr. d'Abramson, Russian State Railways. (In French.) — I agree that we cannot accept Mr. Bell's proposal. To do so would only confuse the issue.

— Mr. Bell's proposal was put to the vote and rejected.

— Mr. Brière's proposal being supported by the reporter was accepted.

The President. — Mr. Ast's second conclusion is as follows :—

"2nd. Wood or steel sleepers at least 8 feet 10 inches (2^m70) in length and "10 $^1/_4$ inches (26 centimetres) broad at the base. The section of the sleeper must "be such as to allow of the rails being securely fastened.

"The adoption of a uniform type of sleeper as in England would be highly "desirable."

Mr. W. Hohenegger. (In French.) — We must not, I think, push too far the length of sleepers. Almost all continental railways use sleepers of 7 feet 10 inches or 8 feet 2 inches (2^m40 or 2^m50) in length. The reporter proposes 8 feet 10 inches (2^m70). I cannot agree and I think we must be satisfied with 8 feet 2 inches (2^m50).

Mr. Petsche, Eastern of France Ry. (In French.) — I also think that 8 feet 10 inches (2^m70) is excessive. Further I consider that a width of 9 $^1/_2$ or 9 $^7/_8$ inches (24 or 25 centimetres) gives an excellent road. I suggest 9 $^1/_2$ inches (24 centimetres) instead of 10 $^1/_4$ inches (26 centimetres).

Mr. von Leber. (In French.) — It has been decided that we are not to deal with steel sleepers. Accordingly the words must be struck out of the resolution.

Mr. d'Abramson. (In French.) — I protest strongly against fixing the length of sleepers at 8 feet 10 inches (2^m70). The sleepers that we use in Russia are only

8 feet 2 inches (2^m50) long, but the wood of which they are made is 4 $^1/_2$ inches (114 millimètres) bigger than that used in western Europe.

The President. — There are two proposals, the one to fix the length at 8 feet 10 inches (2^m70) and the other to fix it at 8 feet 2 inches (2^m50).

Mr. d'Abramson. (In French.) — I object to fixing any figure.

Mr. Brière. (In French.) — I should like to know what is meant by the words " uniform type of sleeper ".

The President. — The reporter proposes to adopt as in England a standard section.

Mr. Ast, *reporter*. (In French.) — I beg you to observe that I have been asked to lay down the requirements for an ideal permanent way. Accordingly I have asked you to fix : (1), the thickness of the ballast at a minimum of 7 $^7/_8$ to 9 $^7/_8$ inches (20 to 25 centimetres) (2), the length of the sleeper at 8 feet 10 inches (2^m70), and its breadth at 10 $^1/_4$ inches (26 centimetres).

I feel bound to press upon the section the adoption of these proposals.

Mr. von Leber. (In French.) — It is an ideal railway then that we are discussing.

Mr. Ast. (In French.) — It is impossible to construct an ideal road with the sleepers at present in use.

Mr. Petsche. (In French.) — I confess I see danger in accepting Mr. Ast's proposals unconditionally.

We are really settling what an ideal road ought to be and how it should differ in the dimensions of its component parts from the existing roads that have been tested by long experience. There is danger in saying " the road of the future is so and so " for the resolutions of the Congress carry great weight.

We, French engineers, are largely controlled by our Government, and you can see therefore that it is impossible for us to accept a decision that a road suitable for fast express traffic must have sleepers 8 feet 10 inches (2^m70) in length, resting on a bed of ballast 15 $^3/_4$ inches (40 centimetres) thick. We cannot accept it because a long experience has shown us that roads resting on 7 $^7/_8$ inches (20 centimetres) of ballast with sleepers 8 feet 2 inches to 8 feet 8 inches (2^m50 to 2^m65) long and 8 $^{11}/_{16}$ to 9 $^7/_8$ inches (22 to 25 centimetres) broad are perfectly capable of carrying very heavy trains at speeds of 75 miles (120 kilometres) an hour.

It would also be a mistake to insist on a uniform type of squared sleepers as in England, where the sleepers are commonly of pine.

In France and most of the countries of western Europe, oak or beech wood sleepers are used and they cannot be regularly squared up without excessive cost.

To adopt the resolution would be contrary to the practical spirit which should guide our deliberations.

The President. — I think, I shall meet the wishes of the section if I put to the vote he different portions of Mr. Ast's second conclusion separately.

Mr. Ast proposes to fix the length of the sleepers at a minimum of 8 feet 10 inches (2^m70).

— An amendment proposes 8 feet 2 inches (2^m50).

— The amendment was accordingly put to the vote and adopted.

The President. — Mr. Ast proposes to fix the breadth at 10 $^1/_4$ inches (26 centimetres). Mr. Petsche proposes 9 $^1/_2$ inches (24 centimetres) as an amendment.

— The amendment was adopted.

The President. — Finally, Mr. Ast proposes to say :—

" The adoption of a uniform type of sleeper as in England would be highly desirable. "

Mr. Petsche. (In French.) — As I have said, the possibility of adopting a uniform type depends on the nature of the wood employed.

— The paragraph was put to the vote and rejected.

The President. — M. Ast's third conclusion reads as follows :—

" 3rd. Rails to be of homogeneous hard and tough steel from 29 $^1/_2$ to 39 $^1/_3$ feet (9 to " 12 metres) long and with a section whose moment of resistance should be at least " W = 200. These rails should weigh 80 lbs per yard (40 kilograms per metre) " or more. "

Mr. Debray. (In French.) — The section decided yesterday that the weight of 80 lbs (40 kilograms) was not to be considered a minimum. The matter was discussed and it seems to me impossible to re-open a question that has been decided.

The President. — This portion of the conclusion goes out, as the section has already settled the question of weight.

Mr. von Leber. — The term *moment of resistance* which occurs in the conclusion that has just been read is not exact. It should be *coefficient of the moment of resistance*, what the Paris Congress called *modulus of inertia*, in other words, the quotient of the moment of inertia divided by the distance of the fibres subjected to the greatest strain from the neutral axis.

I may mention that in the English translation of the report the expression *moment of inertia* is wrongly used to denote this coefficient.

The question we are discussing is complicated. We must consider the loads and the lengths of wheel-base. If you speak of the modulus of inertia, in other words of the moment of inertia divided by half the height of the rail, the question is simplified, for you only consider the resistance of the rail.

Mr. Belelubsky, Russian State Railways. (In French.) — I agree in thinking that the expression *moment of resistance* is not accurate. It would be better to use the phrase *modulus of inertia* and to put the words *moment of resistance* in brackets after it. I further think that it would be convenient to fix the moment of resistance at 200, which is the basis of Mr. Ast's calculations.

Mr. von Leber. (In French.) — As soon as ever you speak of load per axle it becomes necessary to consider the section of the rail, while if you confine yourself to giving a modulus of inertia it is a mere question of geometry.

The President. — The proposal is that the rails shall be of hard steel with a moment of resistance of at least 200.

Mr. W. Hohenegger. (In French.) — The expression *moment of inertia* implies that the section of the rail is already known and implies accordingly a large section. When a given axle load has to be carried, a rather small section must be adopted and the sleepers placed closer together.

Mr. Belelubsky. (In French.) — The table inserted at page 130 (English edition) of Mr. Ast's report shows the moment of resistance corresponding to the weight on the wheels. The table gives the result of calculations made according to the weights on the wheels and the space between the sleepers. Once we fix the space between the sleepers we obtain immediately the moment of inertia.

The President. — I would call your attention to the fact that Mr. Ast's fourth conclusion deals with the spacing of the sleepers.

Mr. Sabouret, Paris and Orleans Ry. (In French.) — Mr. Hunt mentioned that the English Companies are accustomed to fix their rail sections not by abstract calculations but by experience.

The introduction in our conclusions of questions of moment of inertia looks like a criticism of the English system which has given good results. Would it not be simpler to leave out this limitation to which certain Companies might object.

Mr. Bell, Indian Government Railways. — Does the moment of resistance in question refer to old or new rails?

The President. — New rails.

Mr. Brière. (In French.) — I suggest that all reference to the moment o inertia be omitted.

Mr. Sabouret. (In French.) — What are we to understand by the words " steel, uniformly hard and resisting "?

The President. — It means a homogeneous substance.

Mr. Sabouret. (In French.) — It might have a different meaning.

Mr. Brière. (In French.) — I propose to say a "hard and homogeneous substance".

Mr. Sabouret. (In French.) — This is contrary to the English practice.

The President. — The English members will give their opinion.

Mr. Petsche. (In French.) — We might say " homogeneous rails of suitable hardness ". (*Laughter.*)

The President. — The proposal is that the rails shall be made of steel.

Mr. Brière. (In French.) — It may suit a Company to wear out the rails rather than the tires.

We cannot ask the locomotive and carriage departments to make their tires of soft steel so as not to injure our rails.

Our English colleagues who are present do not seem to regard the question as of importance and in fact it can only be decided practically by each Company for itself.

Mr. Bell. — I would suggest to the section that it should decline to express any opinion as to the exact degree of hardness or elasticity in the material of the rail, and confine itself for the present to the decision that it should be homogeneous. (*Hear! Hear!*)

Mr. Werchovsky. (In French.) — A decision to this effect would not be in accordance with that taken at previous Congresses. You must at least add the words " not brittle ". (*Noise and interruption.*)

The President. — Is the section in favour of Mr. Bell's proposition? (*Cries of : Yes, Yes.*)

The President. — The next question is : Should any figure be given for the moment of resistance?

Mr. Bell. — It was less my wish to omit all reference to the question of hardness, than to say that we do not think the time ripe for pronouncing a definite opinion on the point. This is a little different from merely omitting the question of hardness altogether as if we had not considered the point.

I would definitely reserve our opinion both on hardness and on elasticity.

Mr. Wasiutynski, Warsaw-Vienna Ry. (In French.) — I should like to draw attention to the fact that in previous sessions rails of hard steel have been recommended. Now apparently the opinion is that soft steel is equally good. It seems to me that we must pronounce categorically and define what we mean by hard and soft steel respectively. Apparently the supporters of soft steel are in entire agreement with the supporters of hard steel. (*Laughter.*)

The President. — I hardly think so.

Mr. Bruneel, Belgian State Railways. (In French.) — We have struck out one by one from the conclusions those which were proposed to us under the third head by Mr. Ast, as we could not agree about them. There is now nothing left but the single sentence " the metal must be homogeneous " — a thing so obvious that it might have been taken for granted. We cannot leave this one sentence unless we go on to specify what we understand by it. As matters now stand we had better leave this out also. If we keep it in I am afraid that it would not give the public — well, let me say — any great respect for us.

I move therefore to leave out paragraph 3 altogether.

Nor can I agree to the proposal that has been made incidentally that we should formally express an opinion on the hardness of rail metal. This is a very complicated question. Further it is not on our agenda and the constitution of the Congress forbids the discussion of matters which are not definitely raised on the programme of the session.

There is no question more important and more contentious than that of the hardness of metal. Innumerable opinions have been expressed on it. Very likely we may have changed our own.

If the question were on the programme it would be discussed in a report which might run to great length and give rise to long and interesting discussion. I do not think we are entitled to discuss it to-day, the more so because, as I have already said, the rules of the Congress positively forbid it.

Mr. Werchovsky, Russian Ministry of Communications. (In French.)— Our decisions must not be mere generalities, and they cannot disregard our previous dealings with the question. The subject of the hardness of rails was discussed at a previous session and conclusions were arrived at. They are therefore public property and nothing prevents our re-affirming them. To my mind the question is an exceedingly important one. The hardness of the rail is one element that must be taken into consideration in laying down the conditions of a model road. It must therefore be defined just as the other conditions have been. If we confine ourselves to mere generalities I repeat our decisions will be valueless.

Mr. Brière. (In French.) — If it is thought advisable to rediscuss this point, I see no objection, but I confess I do not see the advantage.

The President. — It would imply to some extent re-opening the general discussion. Now this has been closed. I accordingly invite you to vote on the question whether a precise figure should be given for the moment of resistance.

The question was put to the vote and decided in the negative.

Mr. Bruneel. (In French.) — I move that the words " the rail metal must be homogeneous " be omitted.

The President. — The section has decided this point in adopting the motion of Mr. Bell.

Mr. Ast's 4th conclusion runs as follows :—

" If suspended joints are used the sleepers at the joints should not be more than " 19 $^{11}/_{16}$ inches (50 centimetres) apart and the distance between the sleepers should " nowhere exceed 31 $^{1}/_{2}$ inches (80 centimetres).

" The result of such spacing would be that not only would there be the necessary

" means for secure fastenings, but provision would also be made for the strain on " the rail and pressure on the ballast within reasonable limits.

" In sections with curves of small radius or with steep gradients where the loads " per axle amount to from 8 to 9 tons the American method of still further increasing " the number of sleepers will be followed."

Mr. Brière. (In French.) — I cannot accept this. More than half the roads on the Continent have sleepers 31 1/2 inches (80 centimetres) apart. It would therefore mean that all these roads must be reconstructed. That is out of the question.

I may add that if you adopt the other figure proposed by Mr. Ast, the 19 11/16 inches (50 centimetres) you are condemning all the chair-roads.

I repeat more than half the lines in Europe do not conform to the conditions that have been laid down.

It is a much vexed question whether the right way to strengthen the road is to increase the number of sleepers. Many engineers object strongly to strengthening the road by means of an element as perishable as wood which implies therefore an immense expenditure on renewals. Formerly the main element in cost of renewals was the rail. Nowadays it is the sleeper. Therefore use as few of them as possible.

My view is that sleepers should be laid sufficiently far apart to avoid further increase in cost of maintenance and renewal.

I am clear that this is not the direction in which increased strength is to be sought. (*Hear, hear!*)

Mr. Petsche, Eastern of France Ry. (In French.) — For my part, I would accept unreservedly Mr. Ast's conclusion if the first paragraph did not contain figures which might be inconvenient to certain Companies.

I think therefore the figures had better go out.

I may add that my Company is in no way opposed to increasing the number of sleepers. Thanks to the preservative processes that we adopt our sleepers of oak or beech last 25 to 30 years and their maintenance costs us very little.

Mr. Voorhees, American Railway Association. — It occurs to me it might be of interest to give some idea with regard to our track between Philadelphia and New-York. We are running trains, at a speed of about 55 miles an hour, constantly, close upon a mile a minute, for a large share of the district, and we are using a rail of 90 lbs to the yard. Our ties are 8 feet 7 inches long, 9 inches broad, and 7 inches deep. Our engines carry 11 tons on each driving wheel, and we have found it necessary to put at least 16 ties to a rail of 30 feet, or at least a maximum of 2 feet from centre to centre, in order to maintain our track sufficiently stable. I may say the road is entirely of stone ballast. We have at least 18 inches, and in many cases 24 inches beneath the base of the rail.

Mr. Werchovsky. (In French.) — Let me remind you that the distance between the sleepers depends on many considerations of which the principal are the rail-section and the load on the wheels. This question cannot be considered by itself. You must specify the circumstances to which the spacing, suggested by the reporter, applies.

The President. — That point was discussed yesterday.

Mr. Sabouret. (In French.) — I move that the figures 19 $^{11}/_{16}$ inches (50 centimetres), and 31 $^{1}/_{2}$ inches (80 centimetres) be omitted, for they can only apply to a Vignoles road. The distances suggested would not do for a chair-road. It would be much simpler to say " one of the methods ordinarily applied to strengthen the road for express trains is to space the sleepers closer together, especially at the joints. "

Mr. Batchmanoff, Russian State Railways. (In French.) — Gentlemen, permit me to say a few words on strengthening roads by means of sleepers. In Russia, we adopt this method by preference because wood is cheap and rails are dear. We therefore prefer to increase the number of sleepers rather than replace the rail.

In France, the position is quite different. There, as in many other countries, it is evidently considered preferable to get extra strength from the rail. For this reason, I agree that it is better not to specify the distance between the sleepers.

Mr. Tourtsevitz, Russian State Railways. (In French.) — On the Nicholas line of the Russian State Railways, we have calculated that the increase of the number of sleepers per mile from 2,074 to 2,564 (from 1,289 to 1,594 per kilometre) keeping a rail of 65 lbs (32 $^{1}/_{2}$ kilograms) is, so far as the rigidity of the road is concerned — that is to say, the resistance of the rails at the supporting points to vertical pressure, — equivalent to increasing the weight of the rail to 94·08 lbs (46·67 kilograms) without increasing the number of sleepers. This method is an economical one and allows of the road being very quickly strengthened.

The President. — Mr. Sabouret has just handed in his proposal. It is as follows :—

" Closer spacing of the sleepers, especially at the joints, is one of the methods ordinarily adopted to strengthen the road. "

Mr. von Leber. (In French.) — We cannot discuss a truism. It is surely not necessary to vote on this.

Mr. Werchovsky. (In French.) — I think that the number of sleepers is the element of the permanent way which it is easiest to fix. For obvious reasons there is a limit to the possible closeness of spacing. In my opinion, the Congress should fix a minimum distance.

Mr. Ast, *reporter*. (In French.) — We are all unanimous in stating that closer spacing is one of the methods employed to strengthen the road.

The opposition arises only when it is proposed to fix the distances at which the sleepers should be spaced.

It is argued that the majority of European roads would have to be altered as their sleepers are now more than 31 1/2 inches (80 centimetres) apart. Other members object to laying down a figure as they consider that the increase proposed in the number of sleepers would be very costly.

I confess that in formulating my conclusion I did not look at the matter from these points of view nor could I properly do so. In my judgement, 31 1/2 inches (80 centimetres) is the maximum spacing for a first class road.

The English Companies have been compelled to reduce this still further by reason of their very heavy traffic.

We must remember that the principal function of the sleeper is not to strengthen the rail, but to spread the weight over the ballast, to increase the number of rail fastenings and to increase the resistance to the rolling load.

I cannot therefore withdraw my proposal to fix a maximum of 31 1/2 inches (80 centimetres), centre to centre, for the spacing of the sleepers.

Mr. Werchovsky. (In French.)—Experience shows that sleepers must not be laid too close together. We must be very careful therefore in fixing the limits of spacing.

If I have correctly understood the reporter he thinks that at the joints the maximum distance of the sleepers should be 19 11/16 inches (50 centimetres).

Mr. Ast. (In French.) — Yes.

Mr. Werchovsky. (In French.) — Does this mean, in the clear?

Mr. Ast. (In French.) — No; centre to centre.

Mr. Werchovsky. (In French.) — In that case, we might discuss this figure.

Mr. Toucey, New York Central and Hudson River Railroad. — It seems to me this resolves itself right down into a practical question, whether we shall have a stiff rail, one that would carry our trains without deflection, whether we shall put sufficient stiffness in to avoid this deflection, or whether we shall still go on, as we have been going on. There are lines of course whose traffic does not require as heavy and stiff a rail as ours. There are others that do; as their traffic increases they have to increase the stiffness of their rail and the permanency of their roadway. On our line, as I told you yesterday, we are running at a high rate of speed. We increased our rail up to 100 lbs, and the moment of inertia was increased from 28 to about 48. The result was that we do not get as much deflection as we did before, and our sleepers are lasting from 15 to 20 p. c. longer than they did with light rails, because they are not cut out by this continual deflection of the rails, and we maintain the speed of the trains continuously. There are lines of course that cannot afford this until their traffic warrants it, and it would be injudicious to vote upon a question of that kind, making it obligatory for any poor line to adopt that plan. If our Company had been in a position financially, when we started some 40 years ago, we could have put down a 100 lb rail with ties 22 inches from centre to centre, and if we could have got the traffic we have got now, we would have been glad to have paid our English and German shareholders much larger dividends than we are paying now.

The President. — I will now ask you to vote on the question whether precise figures shall be specified.

— A vote was taken and it was resolved in the negative.

The President. — I now ask you to vote on Mr. Sabouret's proposition, which seems better to meet the views of the meeting.

— It was accordingly put to the vote and carried.

— The meeting adjourned at half past twelve.

July 2, 1895, at 1.30 p. m.

The President. — Mr. Ast's 5 h conclusion runs as follows :—

" In the attachment of rails to sleepers, two essentially different types of road must " be dealt with, the Vignoles and the double-headed rail.

" With increase of speed the train on the fastenings increases very rapidly and " special attention must be paid to this point on express lines. It cannot be denied " that with regard to this, the best system is to fix the rail in a strong chair. It " would therefore seem logical to try to find some method of fastening Vignoles rails " in some similar way, either by saddle plates (tie plates, *plaques de serrage*) or by " increasing the number of screw-spikes. "

Mr. Sabouret. (In French.) — Is not this a little wordy?

Mr. Dufaux, Eastern of France Ry. (In French.) — Are we to understand from this that the Vignoles rail must be laid in chairs? The Eastern of France Company uses neither chairs nor plates, but it gets a very strong Vignoles rail by spacing the sleepers at the joints only 16 $^1/_2$ inches (42 centimetres) apart, centre to centre, and using an increased number of screw-spikes with big heads.

The President. — The point seems to me quite clear.

The reporter proposes to say that the logical method is to strengthen the fastenings of the Vignoles rail by following the analogy of a chair rail and either using saddle plates or increasing the number of screw-spikes.

— Mr. Ast's proposal was put to the vote and adopted.

The President. — The 6th conclusion of Mr. Ast is as follows :—

" So far no absolutely satisfactory method of constructing the joints has been " found. Experience has, however, shown that the injurious effects on the joints

" can be decreased by making the rail more rigid and improving the methods of
" fixation."

— This conclusion was put to the vote and adopted.

The President. — It now remains, gentlemen, to deal with the conclusions of Mr. Hunt, the reporter for English speaking countries.

They are as follows :—

" 1st The type of permanent way almost universally adopted by the English rail-
" way Companies is that of a bull-headed rail laid in chairs, which are fixed to the
" sleepers by spikes, or screws, or some analogous fastening.

" 2nd That, as far as the further strengthening of the permanent way is concerned,
" in view of the increased speed of trains, the English Companies do not consider
" for the present that any further strengthening is necessary beyond that already in
" vogue."

— These conclusions were put to the vote and adopted.

The President. — Mr. Belelubsky has just handed in a resolution to the following effect :—

" Having regard to the fresh investigations in different countries and the practical
" experience that has accumulated since the Milan Congress, the question of the
" hardness of rails might with advantage be placed on the agenda for next
" Congress."

Mr. Sabouret. (In French.) — The question is implicitly dealt with in the technical information contained in Form A appended to the documents of the present session.

The President. — Mr. Belelubsky asks that the question shall be made the subject of a report, then we can discuss.

Mr. Belelubsky. (In French.) — The technical information collected by the Russian commission, presided over by Mr. Werchovsky, on the quality of steel rails, and also the practical experience of the Russian lines show the necessity of adopting a harder metal. The researches of experts in France and other countries also afford a great deal of material for the discussion of this important question. I therefore ask the section to be good enough to propose its inclusion in the programme for our next meeting.

— The proposal of Mr. Belelubsky was put to the vote and adopted.

DISCUSSION AT THE GENERAL MEETING

July 4, 1895 (afternoon).

LORD STALBRIDGE, THE PRESIDENT, IN THE CHAIR.

The President. — I call upon Mr. Debray, principal secretary of the 1st Section, to read the Section's report in French. Mr. Leslie Robinson, secretary-reporter, will afterwards read it in English.

Mr. Debray. —

« Cette question a fait l'objet de deux rapports, présentés, l'un, pour les pays de langue anglaise, par Mr. W. Hunt, le second, pour les pays de langue non anglaise, par Mr. Ast.

« Il convient de signaler immédiatement que, sur le continent européen, on considère que des trains marchant à 80 kilomètres (50 milles) à l'heure sont des trains de grande vitesse et qu'on ne dépasse guère pour le moment la vitesse de 120 kilomètres (75 milles) à l'heure.

« En Angleterre, en Amérique, on parle de trains circulant à la vitesse de 160 kilomètres à l'heure (100 milles) et même un peu plus, ce qui ferait 33 p. c. de plus que le maximum actuellement usité sur le continent européen.

« Mr. W. Hunt a donné, dans son rapport, la description des voies anglaises, irlandaises, américaines, indiennes, africaines, australiennes, usitées pour des vitesses supérieures à 40 milles (64 kilomètres) à l'heure. En Amérique, la voie est du type Vignoles; en Angleterre, elle est du type à double champignon dissymétrique.

Mr. Leslie Robinson. —

Report of the 1st Section.

" This question was the subject of two reports, one presented by Mr. Hunt, for English speaking countries; and the other by Mr. Ast, for non-English speaking countries.

" It should be stated, to begin with, that on the Continent trains with a running speed of 50 miles (80 kilometres) an hour are considered express trains, and that for the present, the maximum speed seldom exceeds 75 miles (120 kilometres) an hour.

" In England and in America, maximum speeds of 100 miles (160 kilometres) per hour are heard of, and even slightly greater speeds, that is, 33 p. c. higher than those actually attained on the Continent.

" Mr. Hunt gave in his report a description of the English, Irish, American, Indian, African and Australian roads where inclusive speeds above 40 miles (64 kilometres) per hour are met with. In America the Vignoles type of rail is used, and in England the bull-headed section.

" Il résulte des déclarations de Mr. W. Hunt, et de divers ingénieurs des pays cités ci-dessus, et la 1re section et le Congrès tout entier ont pu constater par expérience que les voies anglaises se prêtent fort bien à la circulation de trains rapides.

" La 1re section a donc pu voter à l'unanimité les conclusions présentées par Mr. W Hunt, constatations de fait, d'ailleurs.

" D'après Mr. W. Hunt, si l'on voulait obtenir une vitesse supérieure à 160 kilomètres à l'heure (100 milles), les ingénieurs de la voie ayant donné tout ce qu'ils pouvaient, ce serait aux ingénieurs de la traction de chercher à résoudre le problème d'augmenter la puissance des locomotives sans augmenter les attaques sur la voie.

" Dans les pays de langue non anglaise, spécialement sur le continent européen, où l'on se tient à des vitesses inférieures à celles de l'Angleterre et de l'Amérique, les ingénieurs de la voie n'ont sans doute pas encore donné tout ce qu'ils pourraient donner le cas échéant, mais quelques-uns pensent que les ingénieurs de la traction du continent européen ont parfois demandé trop à la voie, qu'il faut s'adresser à la fois à la traction comme à la voie pour augmenter la vitesse des trains dans des conditions convenables de sécurité et d'économie, en considérant l'ensemble de la voie et du matériel roulant.

" La 1re section a exprimé l'avis que les deux services de la voie et de la traction doivent toujours chercher à s'entendre en vue de donner aux exigences du public, notamment au point de vue de l'augmentation de la vitesse des trains, toutes les satisfactions possibles. Le Congrès appuiera certainement ce vœu de la 1re section, fait dans un esprit de bonne harmonie.

" Après avoir décrit les systèmes de renforcement de la voie employés dans les pays de langue non anglaise pour arriver à augmenter la vitesse des trains, après avoir constaté que l'on avait réalisé sur les diverses

" It follows from the statements made by Mr. Hunt and the different engineers of the above named countries, that the English permanent way is eminently suitable for express traffic, and this the 1st Section and the whole Congress have been able to see for themselves.

" The 1st Section was therefore able to approve unanimously, as expressing the actual facts, the conclusions arrived at by Mr. Hunt.

" According to Mr. Hunt, if a higher speed than 100 miles (160 kilometres) per hour is required, the permanent way engineers having done all they can, the locomotive superintendents must turn their attention to increasing the power of the locomotives without increasing the strains on the permanent way.

" In non-English speaking countries and especially on the Continent of Europe, where the speeds are inferior to those existing in England and America, the permanent way engineers have, no doubt, not yet done all they might, but some of them think that continental locomotive superintendents ask too much of the permanent way; that the locomotive and permanent way departments must be regarded as one whole, and required to accept joint responsibility for the increase of the speed of trains under conditions ensuring both safety and economy.

" The 1st Section is of opinion that the locomotive and permanent way departments ought always to co-operate to meet the requirements of the public, especially with a view to increasing the speed of trains. The Congress will certainly endorse the opinion of the 1st Section, which was put forward in a conciliatory spirit.

" After having described the systems employed in non-English speaking countries for strengthening the permanent way to enable the speed of trains to be increased, and after stating that, on various express lines, the lignes à trains rapides les conditions nécessaires pour assurer, dans les limites de vitesse ci-dessus indiquées, la circulation de trains rapides bien composés, bien conduits, Mr. W. Ast avait établi un programme complet d'un modèle de voie à adopter pour les lignes parcourues par des trains à grande vitesse.

" Le rapporteur avait eu soin d'ailleurs de faire observer que la voie modèle définie par lui était déjà réalisée sur plusieurs lignes, notamment en Angleterre; comme Mr. W. Hunt, Mr. W. Ast estimait que, sauf en certains cas spéciaux, on ne pourrait aller plus loin, que la résistance de cette voie modèle se rapproche de la limite qu'on peut pratiquement réaliser, et il invitait également les ingénieurs de la traction à chercher à augmenter la capacité des locomotives sans augmenter les attaques sur la voie.

" Le programme présenté par Mr W. Ast n'a pas été entièrement adopté par la 1re section; la majorité des membres qui ont pris part à la discussion a été d'avis qu'il n'était pas possible de faire abstraction complète de ce qui existe aujourd'hui sur le continent et de fixer un type idéal unique, non immédiatement applicable. "

necessary conditions for running well-ordered express trains within the limits of speed above noted, had been complied with, Mr. Ast laid down a complete programme of an ideal type of permanent way for lines over which express trains travel.

" The reporter observed that the ideal permanent way, as defined by him, had already been realised by many lines, and especially in England. Like Mr. Hunt, Mr. Ast thought that, except in some particular instances, it was impossible to go further, that the best existing type of permanent way is as strong as it can possibly be in practice, and he invited the locomotive superintendents to try and increase the power of their locomotives without increasing the strains on the permanent way.

" The programme presented by Mr. Ast was not adopted in its entirety by the Section. The majority of the members who took part in the discussion were of opinion that it was not possible to leave entirely out of the question what actually existed on the Continent, and to lay down a single ideal type not capable of immediate adoption. "

CONCLUSIONS

" *Pour l'Angleterre :*

" 1° Le type de voie presque universelle- " ment adopté par les compagnies de chemins " de fer du Royaume-Uni se compose de " rails d'acier à double champignon dissymé- " trique, logés dans des coussinets fixés sur " des traverses au moyen de tirefonds ou de " chevilles ou de systèmes analogues;

" 2° En ce qui regarde le renforcement " de la voie en vue de l'augmentation de la " vitesse des trains, aucune compagnie an- " glaise, pour le moment, ne considère " comme nécessaire un plus grand renforce- " ment de ses voies que celui qui est actuel- " lement réalisé.

" *For England :*

" 1st The type of permanent way almost " universally adopted by the English railway " Companies is that of a bull-headed rail laid " in chairs, which are fixed to the sleepers " by spikes, or screws, or some analogous " fastening;

" 2nd That as far as the further streng- " thening of the permanent way is concerned, " in view of the increased speed of trains, the " English Companies do not consider for the " present that any further strengthening is " necessary beyond that already in vogue.

" *Pour les pays de langue non anglaise :*

" 1° On a approuvé à l'unanimité cette " conclusion de Mr. Ast que la plate-forme " des voies parcourues par des trains de " grande vitesse devait être parfaitement " établie, absolument assainie ;

" 2° On a également reconnu à l'unanimité " qu'il fallait employer sur de telles lignes " du ballast bien perméable. Après discus- " sion, on a réduit de 40 à 20 centimètres, " comptés au-dessous de la traverse, l'épais- " seur minimum du ballast (on a pensé que " pour le moment il suffisait de considérer " des voies sur traverses en bois);

" 3° On a estimé que les traverses en bois " à employer sur des voies parcourues par " des trains de grande vitesse devaient avoir " une longueur minimum de 2m50 et une " largeur minimum d'assise de 24 centi- " mètres, se tenant ainsi un peu au-dessous " des chiffres proposés par le rapporteur et " qui étaient de 2m70 et 26 centimètres; de " plus, le profil de la traverse doit permettre " une bonne fixation des rails.

" Mr. W. Ast avait exprimé l'avis qu'il " serait très désirable que l'on adoptât des " traverses d'un type uniforme, des traverses " équarries comme on le fait en Angle- " terre.

" La majorité des membres de l'assemblée " a pensé qu'avec les bois employés sur le " continent européen, cette disposition n'était " pas admissible, qu'elle serait beaucoup trop " onéreuse ;

" 4° En ce qui concerne les rails, on a " constaté que, sous réserve de la disposition " des autres éléments de la voie et de la " constitution du matériel roulant, il y a une " tendance générale, soit pour améliorer dès " à présent la stabilité des voies, soit pour " parer au développement ultérieur de " l'exploitation, à augmenter le poids des " rails sur les lignes parcourues par des " trains d'une vitesse de plus de 80 kilo-

" *For non-English speaking countries :*

" 1st Mr. Ast's conclusion, that the per- " manent way over which express trains pass " should be well consolidated and perfectly " drained, was unanimously agreed to;

" 2nd It was unanimously agreed that on " first-class lines good permeable ballast " must be used. After discussion, the mini- " mum depth of ballast was reduced from " 15 3/4 to 7 7/8 inches (40 to 20 centimetres), " counting from the bottom side of the slee- " per. (It was not thought necessary, for " the present, to deal with other than wooden " sleepers);

" 3rd It was decided that for express lines " the minimum length of sleeper should be " 8 feet 2 inches (2m50), minimum width of " bearing on the ballast, 9 1/2 inches (24 cen- " timetres) that is, slightly under the figures " proposed by the reporter, which were 8 feet " 10 inches (2m70) and 10 1/4 inches (26 centi- " metres) respectively; and further, that the " section of the sleeper must permit of a good " fastening of the rails;

" Mr. Ast expressed the opinion that it " would be desirable to adopt a uniform type " of squared sleeper as in England.

" The majority of the meeting thought " that, considering the wood used on the Con- " tinent, this restriction was inadmissible as " being too burdensome;

" 4th As far as the rails are concerned, it " was agreed that, taking into consideration " the other elements of the permanent way " and the rolling stock, there is a general " tendency (whether with a view to increas- " ing the rigidity of the track or for coping " with a future increase in the traffic), to " increase the weight of rails over which " express trains run at a speed of over " 50 miles (80 kilometres) per hour and to

" mètres et à porter ce poids aux environs de " 40 kilogrammes [[ou plus]] (1).

" Quelques membres auraient désiré qu'on " précisât davantage, considérant, en concor- " dance avec le rapporteur, qu'on peut se " contenter d'un rail de 35 kilogrammes par " mètre courant si la vitesse ne dépasse pas " 90 kilomètres par heure et si le poids d'un " essieu ne dépasse pas 14 tonnes.

" D'autre part, on aurait constaté ce fait " que, dans ces conditions, on pourrait " marcher sans danger même avec des rails " de 30 kilogrammes par mètre courant en " avouant en même temps qu'une telle voie " ne serait pas économique au point de vue " de l'entretien.

" La 1re section a pensé qu'elle ne pouvait " traiter incidemment une question aussi " importante que celle de la composition de " l'acier à employer pour la confection des " rails, acier doux ou acier dur, cette ques- " tion intéressant d'ailleurs également les " services de la traction, car il s'agit, en fin " de compte, de savoir s'il vaut mieux user " les rails que les bandages ou inversement.

" Sur la proposition de Messrs. Wer- " chowsky (Gouvernement russe) et Bele- " lubsky (ch. de f. de l'État russe), on a " exprimé le vœu suivant :

" *La question de la dureté des rails en vue* " *de nouvelles recherches dans tous les pays* " *et des résultats pratiques obtenus depuis la* " *session de Milan pourrait être utilement* " *portée à l'ordre du jour de la sixième ses-* " *sion ;*

" 5° La question de l'écartement des tra- " verses et spécialement des traverses de " joints a fait l'objet d'une assez longue " discussion. Ne voulant pas prendre parti " entre la voie à double coussinet et la voie

(1) Les mots entre doubles crochets ont été ajoutés à la suite de la discussion en séance plénière (voir plus loin).

" raise this weight to, in round figures, 80 lbs " per yard (40 kilograms per metre) [[or " upwards]] (1).

" Some members considered that the weight " of rails should be more strictly defined, and " in conjunction with the reporter, thought " that the weight of rail need not be more " than 70 lbs per yard (35 kilograms per " metre) if the speed does not exceed 56 miles " (90 kilometres) per hour, and if the weight " on the axle does not exceed 14 tons.

" Further, the fact was noted that traffic " could be carried on under these conditions " without danger even on rails weighing " only 60 lbs per yard (30 kilograms per " metre), but that the maintenance of such a " line would be expensive.

" The 1st Section was of opinion that they " could not incidentally discuss a question of " such importance as the composition of the " steel employed in the manufacture of rails, " whether soft or hard, as this question " equally affects the locomotive department, " for after all the question is whether it is " preferable to allow the wear to take place " on the tires or on the rails.

" On the motion of Messrs. Werchovsky " (Russian Government) and Belelubsky (Rus- " sian State Railways) the following reso- " lution was passed :—

" *The question of the hardness of rails,* " *in view of the recent researches that have* " *taken place in all countries, and the expe-* " *rience obtained since the session at Milan,* " *might with advantage be put down for dis-* " *cussion at the sixth Congress;*

" 5th The question of the spacing of the " sleepers, and especially those at the rail- " joints, gave rise to a long discussion. Not " wishing to decide between the double- " headed and Vignoles section which stand

(1) The words in double brackets were added at the general meeting (see below).

" Vignoles qui, au point de vue de l'écartement à donner aux traverses, spécialement aux traverses de joints, présentent des conditions différentes, on a adopté la formule générale suivante :

" Le rapprochement des traverses et notamment des traverses de joints est un des moyens ordinairement employés pour le renforcement de la voie.

" Divers membres ont fait observer d'ailleurs que, suivant les ressources locales, il pouvait être plus économique de chercher à renforcer la voie par l'augmentation du poids du rail que par le rapprochement des traverses ; il n'y a donc rien d'absolu ;

" 6° A été votée la proposition suivante présentée par le rapporteur :

" Dans la fixation des rails sur les traverses, il faut considérer les deux systèmes absolument différents de la voie à double champignon et de la voie Vignoles.

" Avec l'augmentation de la vitesse des trains, l'attaque au moyen de fixation augmente dans une forte proportion ; il faut donc attacher une attention spéciale à ces moyens de fixation sur les voies de grands express.

" Le meilleur mode d'attache est la fixation des rails dans un coussinet robuste.

" Il est logique de développer la fixation des rails Vignoles dans un sens qui la rapprocherait de la fixation par coussinet, soit par l'emploi de plaques de serrage, soit par l'augmentation du nombre des tirefonds ;

" 7° A été également adoptée, la conclusion suivante de Mr. W. Ast :

" On n'est pas encore arrivé à une construction du joint qui réponde aux exigences sous tous les rapports.

" L'expérience a toutefois démontré qu'avec l'augmentation de la rigidité de la voie et avec l'amélioration des modes de fixation, on combat en même temps les effets destructeurs qui se produisent aux joints."

" in a different position in reference to the spacing of the sleepers, and especially those at the rail-joints the meeting adopted the following general resolution :—

" The close spacing of sleepers, and especially those under the rail-joints, is one of the ordinary means of strengthening the permanent way.

" Some members observed that, according to local conditions, it might be cheaper to strengthen the permanent way by increasing the weight of rail, rather than the number of sleepers, and therefore no definite rule could be decided upon ;

" 6th The following resolution, proposed by the reporter, was adopted :—

" When considering the fixing of the rails to the sleepers, two distinct systems have to be considered, the double-headed and the Vignoles rail.

" As the speed of trains increases, the strain on the attachment of rails to the sleepers increases very rapidly; special attention must therefore be paid to the fastenings used on express main lines.

" The best means of attachment is fixing the rails in strong chairs.

" It would seem logical to strengthen the fastenings of the Vignoles rail by following the analogy of a chair rail and either using saddle plates, or increasing the number of screw-spikes ;

" 7th The following conclusion of Mr. Ast's was also adopted :—

" A perfect form of « rail-joint » has not yet been arrived at.

" Experience has, however, proved that, simultaneously with the increased rigidity of the permanent way, and improvements in the attachments of the rails to the sleepers, the destructive action that takes place at the rail-joints is reduced."

Mr. Petsche, Eastern Railway of France. (In French.) — The 6th of the proposed conclusions says that to strengthen the Vignoles rail it should be fixed as far as possible in the same manner as the chair rail, either by using holding down plates or by increasing the number of screw-spikes. This seems to imply that the double-headed rail is better than the Vignoles rail, but from experience throughout the whole world the Vignoles rail has proved to be an excellent one. I therefore ask that the wording of the conclusion should be slightly altered.

Mr. Debray. (In French.) — The sentence in question is taken from Mr. Ast's report where he says: " It would seem logical to strengthen the fastenings of the Vignoles rail by following the analogy of a chair rail and either using saddle plates or increasing the number of screw-spikes ".

I think that the reporter will not object to a modification of the wording and the omission of " following the analogy of a chair-rail " so that instead of commencing with .. " It would seem logical, etc... "; the sentence would read as follows : " It is advisable to fix the Vignoles rail either by using saddle plates or by increasing the number of screw-spikes ".

Mr Petsche. (In French.) — There are over 430,000 miles (700,000 kilometres) of rails in the world, of which 400,000 miles (640,000 kilometres) are Vignoles rail and would thus be considered of an inferior type. This is not a reasonable way of treating the matter.

Mr. Debray. (In French.) — There is another difficulty. The paragraph alluded to by Mr. Petsche is preceded by this one : " The best means of attachment is that of fixing the rails in strong chairs. "

Mr. Jeitteles, *president of the 1st Section.* — It is the opinion of the Section.

Mr. Petsche. (In French.) — I was not present at the sectional meeting when that part of the question was discussed.

Mr. Werchovsky, Ministry of Ways of Communication, Russia. (In French.) — Gentlemen, I should like to make a remark regarding the 4th conclusion which deals with the weight and quality of rails. It has been stated that the former tends to increase, but it has also been said that there are railways with light rails so that those who read these conclusions will not understand what they mean. You must either have light rails or heavy ones, and if the tendency is to use heavy rails, no mention need be made of light ones; the conclusion is not sufficiently explicit. With regard to the quality of rails, the Section would not express an opinion as to whether the rails should be harder or softer because it was a matter of taste.

We are now at the fifth session of the Congress and at every previous session this question has been discussed. The Congress cannot in its present session ignore the work and the discussion of previous sessions. As far as I can remember, it was stated at a previous session that there was a tendency to employ hard rails and the Congress approved this tendency.

Papers have been read and discussions have taken place on the subject at previous sessions and yet after ten years and four sessions, the Congress of the fifth session would now resolve that no opinion can be given on the subject of hard versus soft rails.

This seems to me impossible.

Mr. Jeitteles, *president of the 1st Section.* (In French.) — Gentlemen, I must admit that we did not arrive at a more precise conclusion on the subject of the weight of rails, but many of you were present at the sectional meeting when we discussed the matter. It was there stated as a fact proved by experience that the present type of locomotives could be run at high speed over 60 lb (30 kilograms) rails. The engineers who made this statement added, howewer, that they are changing the rails because it costs too much in maintenance. This is stated in the report.

Other members said : " We use 70 lb (35 kilograms) rails and our engines travel at 56 miles (90 kilometres) an hour, the load per axle being as much as 14 tons, and yet we do not find it necessary to strengthen the rails. " They are satisfactory in every respect even from the point of view of economy in road maintenance. Most of the members, however, said the tendency was to increase the weight of rails, and in this opinion I concur. Both of these opinions can be mentioned without necessarily implying a contradiction. This tendency exists in every country outside England where the need of increasing the weight of rails is not felt, but on the Continent of Europe the fact is indisputable. Further, the Section has stated that rails from 80 to 90 lbs (40 to 45 kilograms) are quite sufficient for present and future requirements.

On the other hand, it was thought that the 100 lb (50 kilograms) rails adopted in Belgium were too heavy. I think this is the best summary I can give of the opinion of the Section on the matter. (*Hear! Hear!*)

With regard to the quality of the steel, we were quite aware that the matter had been dealt with at a previous session and also with what result, but the members who were present this time refused to express an opinion on the point.

Mr. Werchovsky. (In French.) — In order that the conclusion should not be too vague, could we not add that the tendency to increase the weight of rails seems justified. It seems to me that the province of the Congress is to point out the course to follow.

There may be tendencies in several directions. But it is for the Congress to point out the right tendency and to express its approval thereof.

Mr. Bruneel, Belgian State Railways. (In French.) — I do not know whether the meeting intends to enter into the discussion of this conclusion before we have the printed text before us, but it seems to me to be very rash to discuss the text merely after hearing it read out. (*Hear! hear!*)

Mr. Petsche's remark is a case in point and I could mention others which concern my own section particularly. If the meeting does not object, I should like to make a few criticisms on the conclusions of the 1st Section. This, I know, is contrary to a custom that is almost always observed, and no member of a section has, withr are exceptions, opposed in general meeting what has been approved in his section, but if I do not respect these traditions it is for special reasons, similar to those brought forward by Mr. Petsche. There has been either an omission or a misunderstanding in the conclusions as regards the weight of rails. These conclusions were proposed by Mr. Fouan and were written very hurriedly in pencil on a scrap of paper, and they were to the effect that there was a general tendency to increase the weight of rails and to carry it to " about a minimum of 80 lbs (40 kilograms) ". I confess I think, and Mr. Fouan will forgive me for saying so, that in these words about a minimum there is a lack of harmony that a resolution drawn up with deliberation would have avoided.

Unfortunately, an attempt was made to improve the wording by omitting the, in my opinion, most important word. The word minimum which was in the original text should have been retained. When was it left out? I may have been preoccupied at the moment, but certainly if I had noticed the omission at the time I should have protested. We find that the conclusions now state that " there is a tendency to advance the weight to about 80 lbs (40 kilograms) ". As far as England goes this is entirely opposed to facts for we find in Mr. Ast's report that most English railways use 85, 89 and 91 lb (42 1/2, 44 1/2 and 45 1/2 kilograms) rails.

Our amiable hosts have led the way, for England is without doubt the country of good roads and fast trains. If our conclusions state that there is this tendency to increase the weight of rails to 80 lbs (40 kilograms) we should pay a back handed compliment to our English hosts by implying that they had gone too far.

Mr. Jeitteles, *president of the 1st Section.* — The conclusion refers to the continent and not to England where the speeds are much higher. We cannot take this special case into consideration.

The President. — It is past five o'clock, so I will ask Mr. Bruneel if he would kindly postpone his remarks till to-morrow. There are other speakers besides.

Mr. Bruneel. (In French.) — I am at the disposal of the meeting.

— The meeting adjourned at 5 o'clock.

July 5, 1895, at 2 o'clock.

Lord STALBRIDGE, the President, in the chair.

The President. — Mr. Bruneel is in possession of the chair.

Mr. Bruneel, Belgian State Railways. (In French.) — Gentlemen, my remarks were interrupted yesterday by the adjournment of the sitting which had been very long and tiring. A good many members had gone away and so perhaps I may be allowed to recapitulate somewhat.

In the first place I would go back upon the special point justifying my intervention in the discussion of the conclusions to which my own section came. I said yesterday that a word which I consider quite essential had been omitted in the final form of the resolution. I added that this omission had escaped my notice and gave, as my excuse, absence of mind. But this absence of mind must have been shared by other members of the section, for since yesterday, several members of the section have told me how surprised they were when they found that the only word which led them to support Mr. Fouan's resolution had dropped out. I have since looked at the shorthand notes and I find that, at the beginning of the meeting of the following day, one of the delegates expressed his astonishment at the omission, when the minutes were read out. I observed that the word " minimum " no longer formed part of the final conclusions. Hence the surprise of several members. If the shorthand notes are correct, then the word " minimum " was dropped out by simply omitting it in reading without the attention of members being specially called to its omission.

Mr. Debray. (In French.) — I have also looked at the shorthand notes and I do not think that they will contradict me. It is the exact text of Mr. Fouan's proposition, with Mr. von Leber's amendment.

Mr. Bruneel. (In French.) — I do not think I am wrong in stating that the word " minimum " was read out several times, but in any case I consider the word as extremely important. I voted in favour of the conclusions under the impression that the word was still in the text, because, although the conclusions were not quite satisfactory from my point of view, yet they allowed us a wider margin and the Belgian State Railways practice goes beyond the limits indicated in the conclusions of the section.

However that may be, I will repeat what I said yesterday that the conclusions we are asked to adopt are directly opposed to the actual facts. I mentioned for instance the English railways. On all the great English lines the weight of rails runs up to 85, 87, 89 lbs per yard (42 $^1/_2$, 43 $^1/_2$, 44 $^1/_2$ kilograms per metre) and even to 91 lbs (45 $^1/_2$ kilograms) on the Great Western.

The President of 1st Section then said that the conclusions did not apply to English lines, but only to those of the Continent. If the discussion had not been interrupted by the adjournment at this point, I should have replied that I was quite aware of the fact, and it was one of the principal points in the argument that I propose to address to you. I will, with your permission, return to the matter presently, and I shall be obliged to members if they will kindly remind me of it if by chance I should forget it.

We are invited to state that the weight of rails on express lines reaches about 80 lbs (40 kilograms). The section has defined an express line as one where the speed attains 62 to 74 miles (100 to 120 kilometres) an hour. It is not correct to state that the weight of rails on these lines is nearly 80 lbs (40 kilograms). Such a statement would not be true any more of continental than of English lines. When I speak of continental lines I mean lines where high speeds are really attained in ordinary practice and not lines where the traffic does not require such speeds. I have gone through the weight of rails on the various systems whose speeds approach those of the English lines. I find that in France the Midi uses rails of 77 lbs (38 $^1/_2$ kilograms); the State, 80 lbs (40 kilograms); the Orleans, 85 lbs (42 $^1/_2$ kilograms); the Western, 89 lbs (44 $^1/_2$ kilograms); the Nord, 90 lbs (45 kilograms), and the Paris and Lyons, 97 lbs (48 $^1/_2$ kilograms). In Belgium the State Railways have adopted a rail weighing 105 lbs (52 $^1/_2$ kilograms). Now when I mention the great French Companies and the Belgian State railways, I have, I believe, mentioned the only systems on the Continent which are here represented on which these high speeds are reached in everyday practice.

Mr. Ludvigh, Hungarian State Railways. (In French.)— This is not a discussion for the general meeting. I do not deny the interest of the information just given us, but we have never hitherto discussed such details.

We should only be repeating in general meeting what has already been threshed out in sectional meeting.

Mr. Bruneel. (In French.) — This question was not discussed in section.

Mr. Ludvigh. (In French.) — It should have been.

Mr. Bruneel. (In French.) — Everything that tends to improve the resolutions and to prevent the Congress from committing itself to inaccurate statements may and to my mind ought to be said in general meeting. As, however, the general opinion is in favour of cutting short the discussion I will be brief. I maintain that the weight of rails on the Continent considerably exceeds 80 lbs (40 kilograms).

The President. — These details have already been discussed in section. I will ask you therefore to kindly condense your remarks.

Mr. Ludvigh. (In French.)— You might formulate your proposition and send it up.

Mr. Bruneel. (In French.) — I am surprised at the remarks made which no precedent justifies.

I have taken part in the Congress from the beginning, and I remember that in previous sessions we have on several occasions had exhaustive discussions of the detail of questions in general meeting. Be that as it may, I insist on the fact that the proposed conclusions are opposed to the opinions of many of the delegates and are opposed to actual facts, so that the Congress cannot possibly vote in favour of them.

Much heavier rails than 80 lbs (40 kilograms) are used on many continental express lines. It would be strange if a Congress composed of specialists — men who trust much more to practical experience and observations than to scientific calculations — it would be strange, I say, if this Congress were to state as a fact that which could be instantly contradicted by the statistics of many different European systems. As the President has asked me to be brief, I will sum up by requesting that the conclusions originally proposed by Mr. Fouan and which have been weakened should, on the contrary, be strengthened, and instead of saying " the meeting finds that the weight of rails is increased to about 80 lbs (40 kilograms) ", we should say that " on express lines where trains have speeds of 50 miles (80 kilometres) an hour and upwards, the weight of rails exceeds and often greatly exceeds 80 lbs (40 kilograms)." Innumerable examples prove this. The Paris, Lyons and Mediterranean Railway employs 97 lb (48 $^1/_2$ kilograms) rails and the Belgian State Railways use 105 lb (52 $^1/_2$ kilograms) rails. We cannot let it be thought that these railways have wasted money to no purpose, actually thrown it away. We, delegates of the Belgian State Railways, cannot accept such a conclusion. I am sure that those of my French colleagues who have adopted heavier rails than 80 lbs (40 kilograms), and even 90 lbs (45 kilograms) will entirely agree with me. I regret not to be able to deal with the matter in greater detail. I had much more to say, but in deference to the President's wishes, I will now conclude.

Mr. Jeitteles, *president of the 1st Section.* — Mr. Bruneel has again asserted that a word has been omitted from the text of the resolution proposed by Mr. Fouan. I must, however, mention that this modification was accepted by vote of the section, and one of its members, I believe Mr. von Leber, moved to omit the word " minimum ". If, therefore, the word has been taken out, it is no fault of mine, and the conclusion as it now stands is that which the Section passed. As far as I remember, the Section refused to fix either a minimum or a maximum for the weight of rails.

With regard to that, I believe that we shall agree with Mr. Bruneel and if, to meet his objections, the meeting thinks proper to say " a weight of about 80 lbs (40 kilograms) or upwards ", I shall not oppose it.

Mr. Bruneel. (In French.) — You might put " and sometimes considerably exceeds 80 lbs (40 kilograms) ".

Mr. Jeitteles. — We might add after 80 lbs (40 kilograms) the words " or upwards ".

Mr. von Leber. (In French.) — Let us avoid fixing any minimum weight.

Mr. de Kounitsky, Russian Ministry of Communications. (In French) — A slight modification should be made in the 4th resolution commencing : Dealing with the rails, it says that, " taking into consideration the other elements of the permanent way and the rolling stock, there is a general tendency "... After the words " elements of the permanent way and the rolling stock ", I would propose to add " and the good quality of the steel of the rails ".

This is an important point, as some works turn out very soft rails and such rails flatten at the ends after being in use for a few years. This increases the jolting and damages the tires and involves renewals of rails after a few years of service. If the steel of the rails is good, this does not happen.. Hence mention should be made of the quality of the steel.

Mr. Ludvigh. (In French.) — Of course, if you use soft rails they cannot carry the loads required, but we must assume that the quality of the materials employed is good. The proposed addition seems to me superfluous.

Mr. de Kounitsky. (In French,) — Then I must object to the words " there is a general tendency ", because in Russia this " general " tendency does not yet exist. With our very soft rails an increase in the section of the rails would be mere waste. I have another remark to make. I hold, in common with many Russian engineers, that the weight of 80 lbs (40 kilograms) should not be mentioned. We should simply confine ourselves to the statement that there is a general tendency to increase the weight of rails on express lines where the speeds attain 50 miles (80 kilometres), and there we should stop.

Many Russian engineers think that the weight should only be increased to about 80 lbs (40 kilograms) when the speeds attain nearly 62 miles (100 kilometres) an hour. We can run on ordinary sleepers at 50 miles (80 kilometres) by strengthening the attachments and the joints of the rails, and we should only require 80 lb (40 kilograms) rails when our speeds attained something like 62 miles (100 kilometres). At present in general we use 60 lb (30 kilograms) rails and on some lines we go as high as 67 lbs (33 $^1/_2$ kilograms). This is the case with the State Railways.

The President. — I will ask the meeting whether they accept the report and the resolution on question I, with the amendment accepted by Mr. Jeitteles.

— Agreed.

Mr. d'Abramson, Russian State Railways. (In French.) — I have been asked to make the following proposition to the meeting by a large number of the members of the 1st Section. For special reasons which I need not mention here, the Section was unable to adopt Mr. Ast's conclusions in their entirety. But his report is so complete and so interesting that every engineer may profit by its exhaustive study. I therefore, in the name of the members of whom I have spoken, ask the Congress to vote their hearty thanks to Mr. Ast, and I trust that the meeting will accept my resolution. (*Hear! Hear!*)

The President. — I have no doubt, whatever, that the meeting will approve of Mr. d'Abramson's proposition.

— Carried unanimously.

APPENDIX

Diagrams showing the condition of the tracks as obtained by mechanical inspection by means of P. H. Dudley's Track Indicator upon the New York Central and Hudson River Railroad and the Boston and Albany Railroad.

Communicated by P. H. DUDLEY.

1. *Comparative diagrams for the Hudson Division (New York to Albany) of the N. Y. C. and H. R. R. R. for 1891 and for 1895.*

From Grand Central Station to Mott Haven Junction, and Spuyten Duyvil to Peekskill 100 lb rails have replaced the 80 lb rails, shown on the diagram for 1891. On other portions of the line the steel is the same as shown on the diagrams, except four years must be added to the age of the steel.

From Grand Central Station to Mott Haven Junction, the line carries the traffic of three railroads.

The comparison in the undulations of the lines is very striking.

The 80 lb rails were laid with 22 inch angle splice bars — suspended joints — on the portions of the line which have since been replaced with 100 lb rails. On the other portions of the line shown by the diagrams, the 80 lb rails were laid with angle splice bars 40 inches long — a joint tie being directly under the joint — (the splice bars have since been reduced to 36 inches).

From Spuyten Duyvil to Peekskill the undulations in the 100 lb rails as shown on the diagrams are only about one-third in amount of those in the 80 lb rails they replaced, which had the 22 inch splice bars and suspended joints. The traffic was so heavy here that by labour it was impossible to maintain these joints to as high a standard as was desired.

The undulations in the 100 lb rail are now practically at the minimum value for the section.

From Peekskill to Albany the 80 lb rails were laid with three tie joints, which have held up, and notwithstanding four years service on them, the diagrams show there is but little change in the undulations of this track.

This feature has shown itself quite as marked on the other divisions of the line.

Under the heavy rails and supported joints the rails, notwithstanding a wear of the steel, the undulations in the track do not increase as rapidly as formerly on light rails and inefficient joints.

2. *Diagrams for the B. and A. R. R.*

Similar conditions are found to obtain on the heavy rails of the Boston and Albany Railroad, over their heavy gradients diagrams.

GENERAL EXPLANATIONS.

Diagrams representing various details of each track as obtained by mechanical inspection are shown upon the engraving for each division.

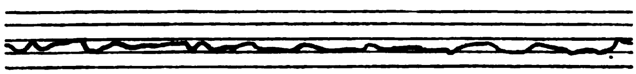
Ten years ago the first condensed diagrams were made of the condition of the track.

This year's, compared with them, show tracks not considered attainable at that time, the undulations being reduced nearly one half in amount per mile, while the stability, under a much greater traffic, has been practically doubled.

The lines representing the " Condition of Track " per mile are close approximations to the " Condition of the Steel ", and the improvement in the track on the old rails is due to the increasing skill of the trackmen in reducing some of the longer bends in the rails.

Rails in the track have definite forms as to their surface, due to bends, directly traceable to want of care in their manufacture, or to development afterward in service; the forms being some one of the types represented by cuts Nos. 7, 3, 2, or 1.

Cut No. 7 represents well-finished rails from the mills, only found in the best-surfaced tracks making a line on the original diagrams similar to that shown in cut No. 8.



CUT No. 8.

Cuts Nos. 2 and 1 represent forms of rails as developed under service.

They are not as prominent as formerly, much of the set in the rails having been reduced by the increasing skill in surfacing, materially checking the rate of irregular wear of the rails, excepting on some rails which are very soft.

Cut No. 3 is an exaggerated representation of badly finished rails from the mills, the surface being wavy, or full of short kinks, producing a more unpleasant tremor in the cars than low joints.

Cut No. 4 is an exaggerated representation of the characteristic undulations which even the smoothest rails make under the weights of the wheels of locomotives and cars.

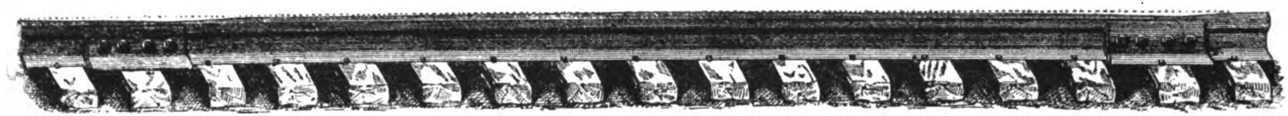
The stiffer the rails and the better the track, the smaller are the undulations.

This is well illustrated on the diagrams, the 80 lb rails showing the least undulations.

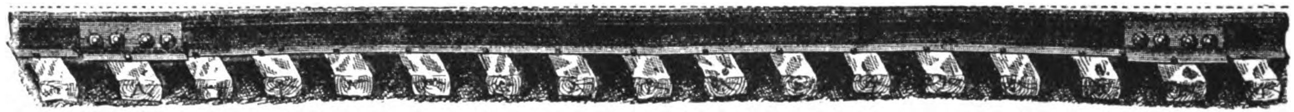
The strains of the metal in the rails under the wheels of the locomotives and cars are of two kinds, viz : compression in the head and tension in the base, while between the wheels the strains are reversed, the head being in tension and the base in compression — the strains reversing as each wheel passes over the rails.

These reversing strains tend to raise the rails between the wheels over each tie to be driven down the next instant by the passing wheel.

The joints, as a rule, being the weakest points in the rail, deflect more readily than the other

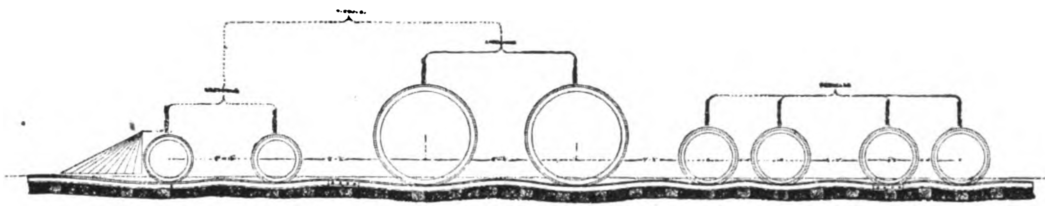


CUT No. 1. — Represents the First Form of Permanent Set in Rails, low at the joints and high in the centre; the receiving ends of the rails are also worn.

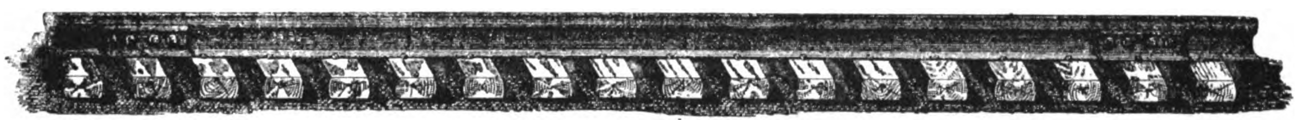


CUT No. 2. — Represents the Second Form of Permanent Set in Rails, low at the joints and centre and high at the quarters.

CUT No. 3. — Represents the Third Form of Permanent Set in Rails, a series of more or less irregular waves or bends.



CUT No. 4. — The depressions below the dotted line represent the deflections of the rail which take place in the best tracks under the wheels of the locomotives and cars.



CUT No. 7. — Fourth Form of Rails — represents the best condition of track, as the rails are in perfect surface to the eye. Under the trains the centres deflect more frequently than the joints.

portions, and are liable to take a set — much care being required to prevent development of forms similar to those of Nos. 2 and 1.

The deflection of rails increases with the age of service as their stiffness is decreasing by the loss of metal from the head and base.

From the above it will be readily understood that the undulations of the rails in the track may be due to one or a combination of several causes, to wit:—

1st *Short bends in the rails from the mills;*
2nd *Roughness of the rails from unequal wear;*
3rd *Long bends in the rails;*
4th *Low joints;*
5th *Deflection of loose rails, worn joints and ties;*
6th *Rails cutting into the ties.*

On the diagrams the "Condition of Track Line" for each inspection represents the average sum of *all* the various undulations of the rails per mile, and while relative as to the base line, also shows the comparison of one mile with another.

The average condition of each mile is indicated from the horizontal line crossed or touched by the condition of track line in the centre of the space for the mile.

Lines marked "Age of Steel" for each mile give its length of service, each horizontal space representing one year.

Lines marked "Percentage of Tangent and Curve" show the approximate alignment of both tracks per mile The percentage of tangent is marked on the left side of the space for the mile, and that of the curvature on the right side. Each horizontal space represents 10 p. c. for the mile.

Lines marked « Profile » show the gradients of the road, and are common to both tracks, though ascending grades on one track are descending upon the other, and *vice versa*.

Lines marked "Gauge of Track" read downward from the base, or 65th line, and show the amount the track is wide gauge, each horizontal space representing one-tenth (1-10) of one inch; a point projecting below the general average indicates that on some curves two or three rails are much wider than the rest, and usually will be found on the lower rails.

Lines marked "Side irregularities of the Rails", above the 65th line, represent the side irregularities of the rails, each horizontal space representing one-tenth (1-10) of one inch. This line reads from the highest point in the centre of the space for the mile.

Three spaces are about the best results which can be obtained.

DIAGRAM No. 1.

NEW YORK CENTRAL AND HUDSON RIVER RAILROAD

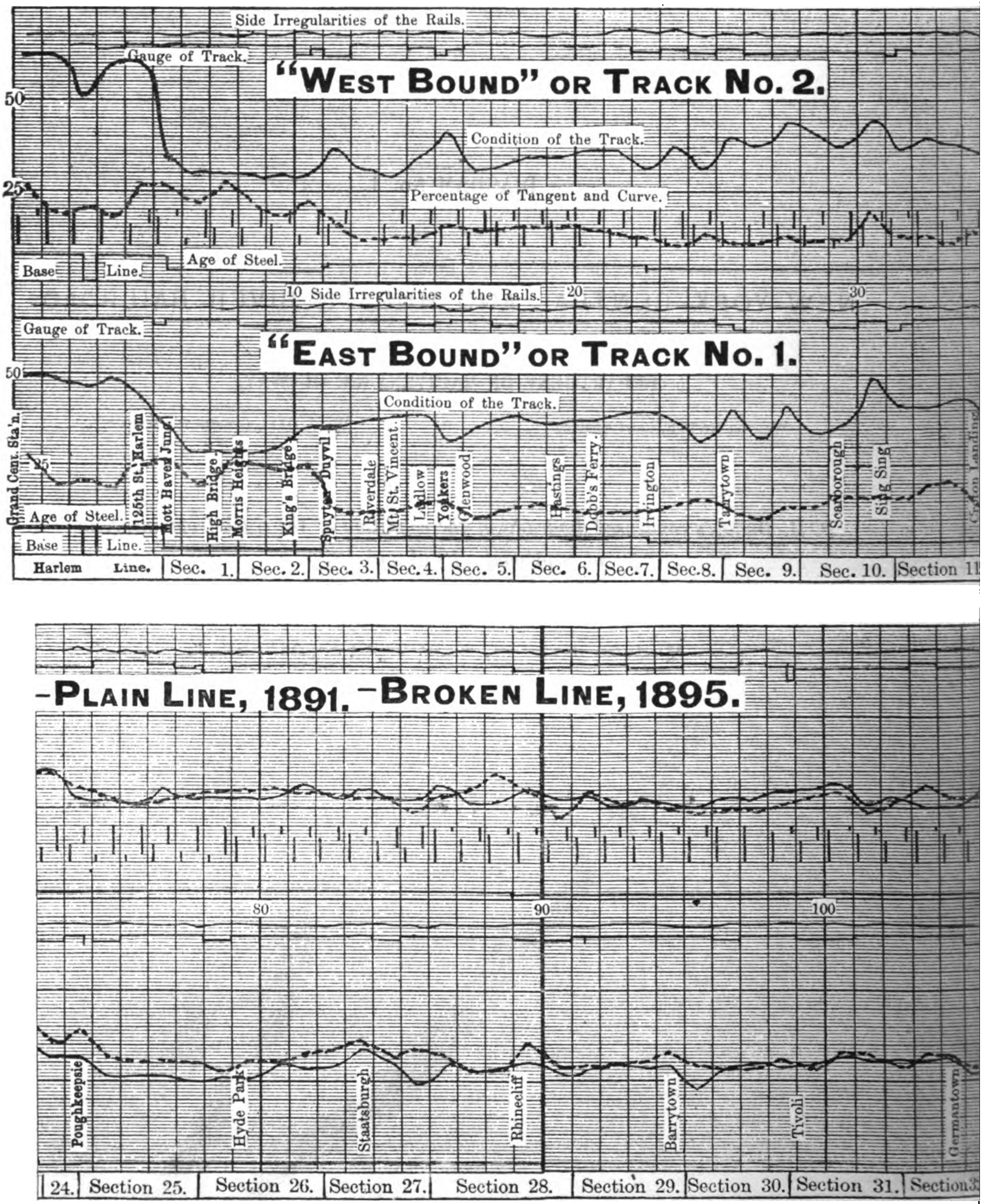
DEPARTMENT OF MAINTENANCE OF WAY.

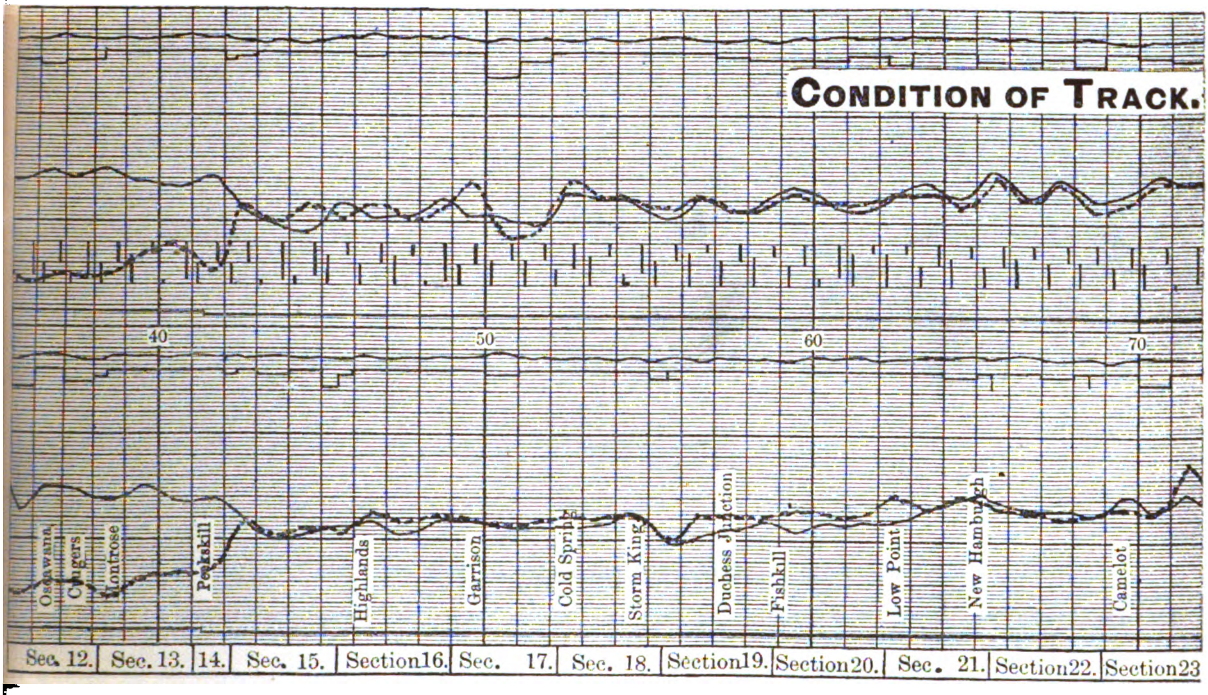
WALTER KATTE, Chief Engineer. W. D. OTIS, General Roadmaster.

P. H. Dudley's condensed diagrams of the condition of the track from inspection of September, 1891 and 1895.

80 lb steel rails, alternate joints, stone and gravel ballast, passenger and freight service.

Hudson division, New York to Albany.


Side Irregularities of the Rails.
Gauge of Track.
"West Bound" or Track No. 2.
Condition of the Track.
Percentage of Tangent and Curve.
Age of Steel.
Base Line.
10 Side Irregularities of the Rails.
20
30
Gauge of Track.
"East Bound" or Track No. 1.
Condition of the Track.
50
25
Grand Cent. Sta'n.
125th St. Harlem
Mott Haven Junc.
High Bridge
Morris Heights
King's Bridge
Spuyten Duyvil
Riverdale
Mt. St. Vincent.
Ludlow
Yonkers
Glenwood
Hastings
Dobb's Ferry.
Irvington
Tarrytown
Scarborough
Sing Sing
Age of Steel.
Base Line.
Harlem Line.
Sec. 1.
Sec. 2.
Sec. 3.
Sec. 4.
Sec. 5.
Sec. 6.
Sec. 7.
Sec. 8.
Sec. 9.
Sec. 10.
-Plain Line, 1891. -Broken Line, 1895.
80
90
100
Poughkeepsie
Hyde Park
Staatsburgh
Rhinecliff
Barrytown
Tivoli
Germantown
24.
Section 25.
Section 26.
Section 27.
Section 28.
Section 29.
Section 30.
Section 31.


CONDITION OF TRACK.
40
50
60
70
Highlands
Garrison
Cold Spring
Storm King
Duchess Junction
Fishkill
Low Point
New Hamburgh
Camelot
Peekskill
Montrose
Sec. 12.
Sec. 13.
14.
Sec. 15.
Section16.
Sec. 17.
Sec. 18.
Section19.
Section20.
Sec. 21.
Section22.
Section23

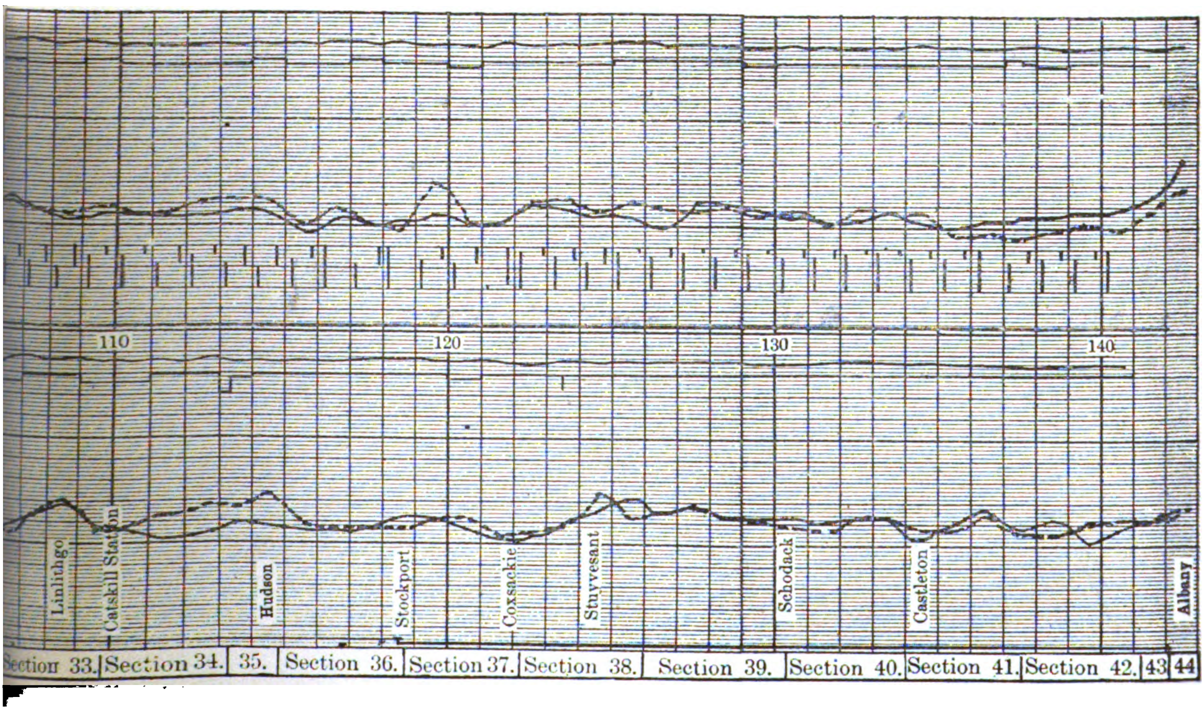

110
120
130
140
Linlithgo
Catskill Station
Hudson
Stockport
Coxsackie
Stuyvesant
Schodack
Castleton
Albany
Section 33.
Section 34.
35.
Section 36.
Section 37.
Section 38.
Section 39.
Section 40.
Section 41.
Section 42.
43
44

DIAGRAM No. 2.

BOSTON AND ALBANY RAILROAD COMPANY

DEPARTMENT OF MAINTENANCE OF WAY.

P. H. Dudley's diagrams of track inspections, of October, 1894, and October, 1895.

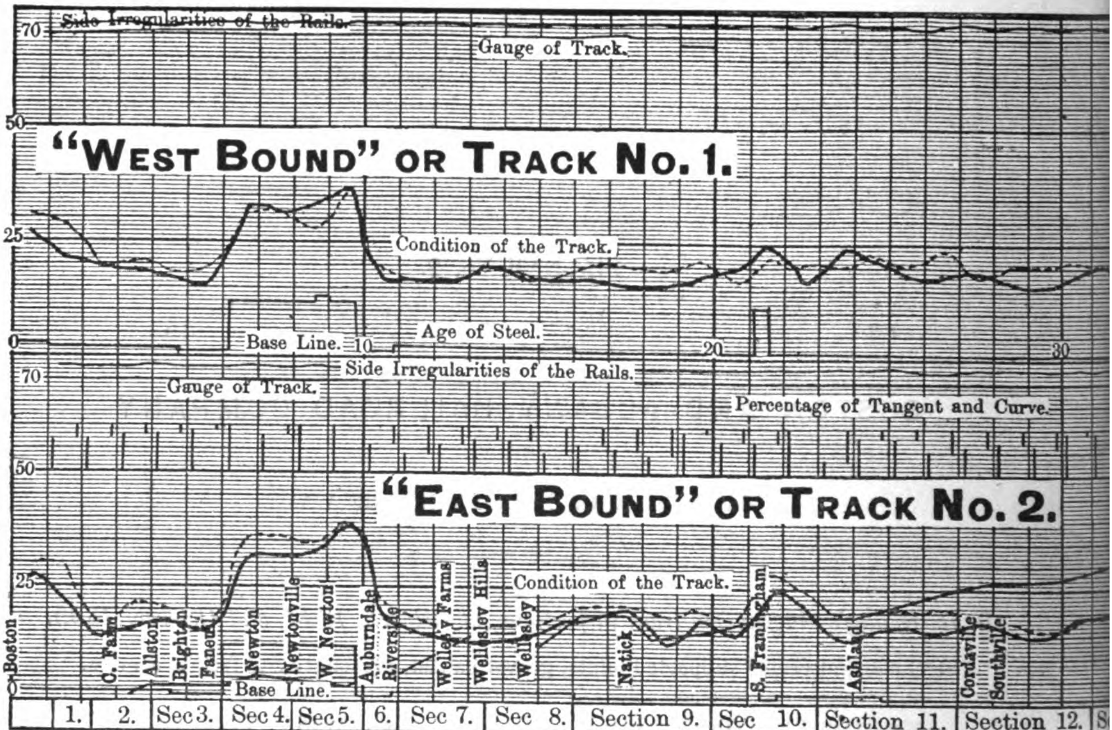
Steel rails, alternate supported joints, gravel ballast, passenger and freight service.

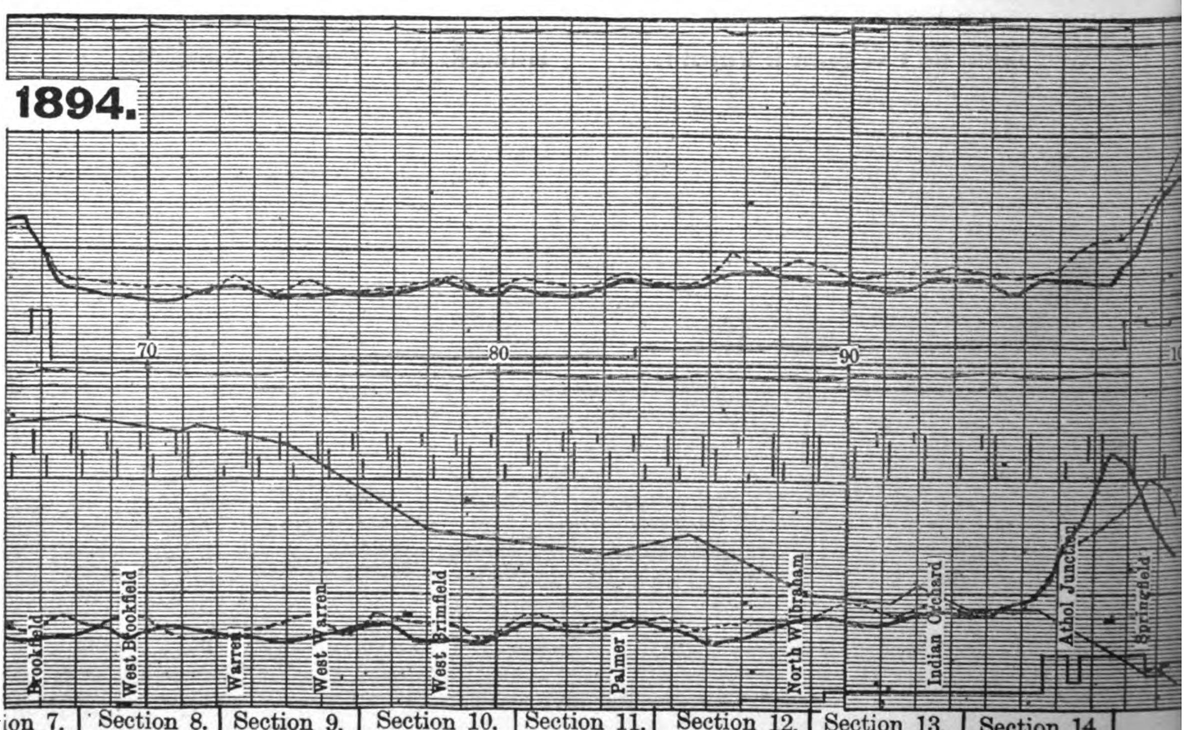
WALTER SHEPARD, Chief Engineer.
WILLIAM PARKER. Div. Engineer.
C. B. LENTELL, Roadmaster.

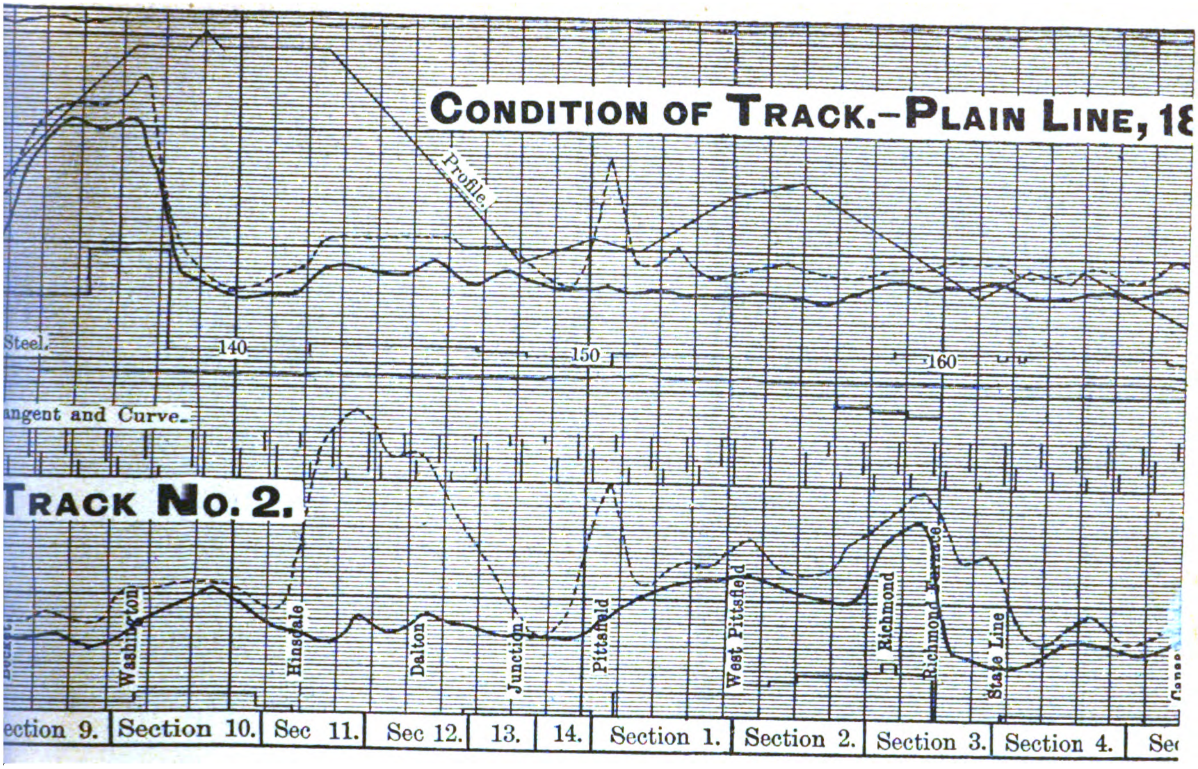
Division No. I. — Boston to Worcester.

E. E. STONE, Ass't Engineer.
E. A. HASKELL, Roadmaster.

Division No. II. — Worcester to Springfield.


Side Irregularities of the Rails.
Gauge of Track.
"WEST BOUND" OR TRACK No. 1.
Condition of the Track.
Base Line.
Age of Steel.
Side Irregularities of the Rails.
Gauge of Track.
Percentage of Tangent and Curve.
"EAST BOUND" OR TRACK No. 2.
Condition of the Track.
Base Line.
70
50
25
0
10
20
30
Boston
C. Farm
Allston
Brighton
Faneuil
Newton
Newtonville
W. Newton
Auburndale
Riverside
Wellesley Farms
Wellesley Hills
Wellesley
Natick
S. Framingham
Ashland
Cordaville
Southville
1.
2.
Sec 3.
Sec 4.
Sec 5.
6.
Sec 7.
Sec 8.
Section 9.
Sec 10.
Section 11.
Section 12.


1894.
70
80
90
Brookfield
West Brookfield
Warren
West Warren
West Brimfield
Palmer
North Wilbraham
Indian Orchard
Athol Junction
Springfield
Section 8.
Section 9.
Section 10.
Section 11.
Section 12.
Section 13.
Section 14.



CONDITION OF TRACK.—PLAIN LINE, 18
Profile.
Steel.
140
150
160
angent and Curve.
TRACK No. 2.
Washington
Hinsdale
Dalton
Junction
Pittsfield
West Pittsfield
Richmond
Richmond Furnace
State Line
ection 9.
Section 10.
Sec 11.
Sec 12.
13.
14.
Section 1.
Section 2.
Section 3.
Section 4.

DIAGRAM No. 3.

BOSTON AND ALBANY RAILROAD COMPANY

DEPARTMENT OF MAINTENANCE OF WAY.

P. H. Dudley's diagrams of track inspections, of October, 1894, and October, 1895.

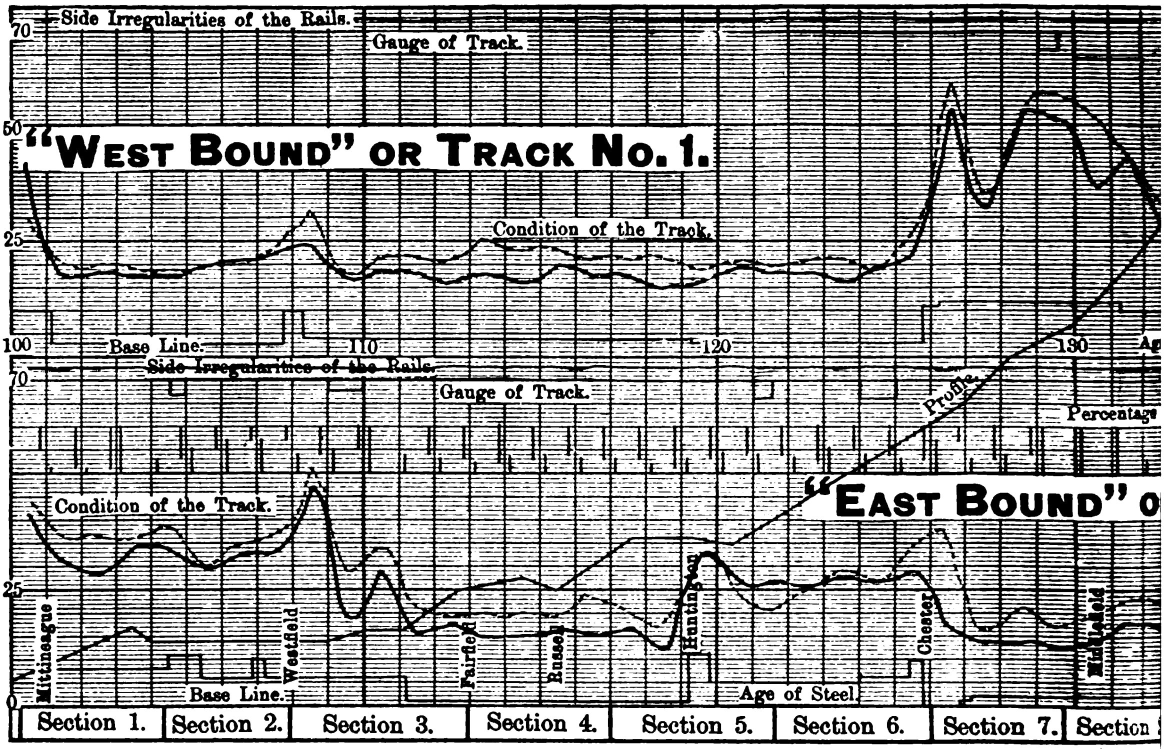
Steel rails, alternate supported joints, gravel ballast, passenger and freight service

WALTER SHEPARD, Chief Engineer.
T. J. SULLIVAN, Roadmaster.

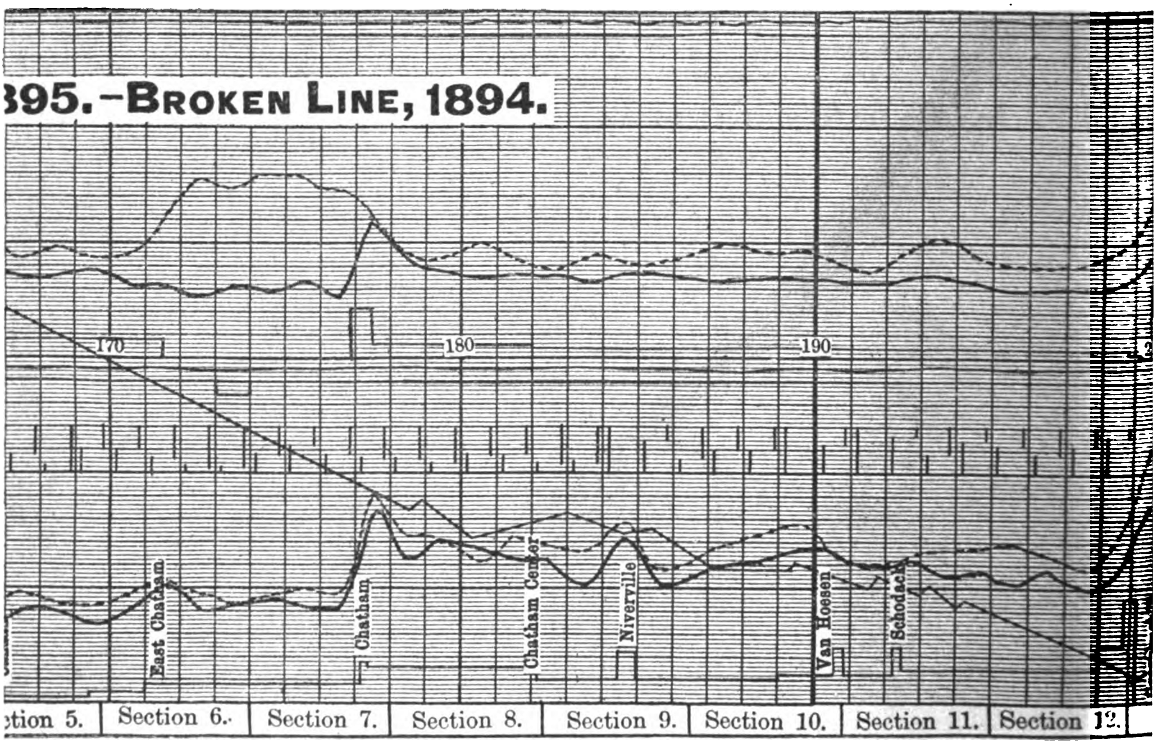
Division No. III. — Springfield to Pittsfield.

E. E. STONE, Ass't Engineer.
R. A. Mc QUAID, Roadmaster.

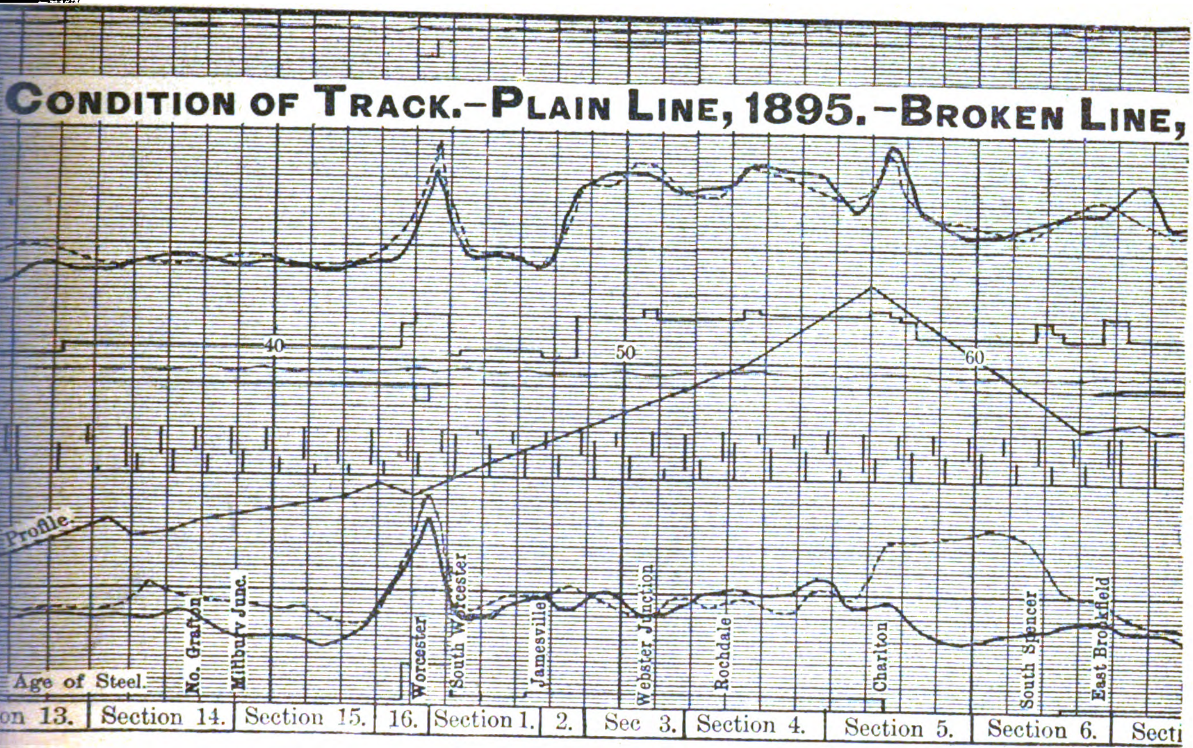
Division No IV. — Pittsfield to Albany.



Side Irregularities of the Rails.
Gauge of Track.
"WEST BOUND" OR TRACK No. 1.
Condition of the Track.
Base Line.
100
110
120
130
70
50
25
0
Side Irregularities of the Rails.
Gauge of Track.
Percentage
Profile.
"EAST BOUND" O
Condition of the Track.
Mittineague
Westfield
Fairfield
Russell
Huntington
Chester
Middlefield
Base Line.
Age of Steel.
Section 1.
Section 2.
Section 3.
Section 4.
Section 5.
Section 6.
Section 7.
Section



395.–BROKEN LINE, 1894.
170
180
190
East Chatham
Chatham
Chatham Center
Niverville
Van Hoesen
Schodack
ction 5.
Section 6.
Section 7.
Section 8.
Section 9.
Section 10.
Section 11.
Section 12.


CONDITION OF TRACK.—PLAIN LINE, 1895.—BROKEN LINE,
40
50
60
Profile.
Age of Steel.
No. Grafton
Millbury Junc.
Worcester
South Worcester
Jamesville
Webster Junction
Rochdale
Charlton
South Spencer
East Brookfield
on 13.
Section 14.
Section 15.
16.
Section 1.
2.
Sec 3.
Section 4.
Section 5.
Section 6.
Secti

1st SECTION. — WAY AND WORKS

QUESTION II

PLACES IN PERMANENT WAY

REQUIRING SPECIAL ATTENTION

Means to avoid the necessity of expresses slackening speed, and to prevent shocks in passing special points, such as sharp curves, long and steep gradients, facing points, rail-crossings, road-crossings, swing bridges, etc.

Reporter : Mr. Sabouret, engineer, Orleans Railway.

QUESTION II

CONTENTS

REPORT

By M. SABOURET

INGÉNIEUR DES PONTS ET CHAUSSÉES
PRINCIPAL PERMANENT WAY ENGINEER OF THE PARIS ORLEANS RAILWAY COMPANY

POSITION OF THE QUESTION.

To following observations preceded the detailled list of questions submitted to the Companies affiliated to the Congress.

« The avoid encroachments on the adjoining questions, reversions to questions previously discussed or even digressions on complex subjects which may be met with incidentally, we think it necessary to define at the outset the limits within which we shall be obliged to confine ourselves.

« We take it as agreed that Question II refers solely to the *trunk lines*, which are passed over each day by many trains at a running speed of at least 43 1/2 miles an hour (70 kilometres an hour).

« As far as *the road* is concerned, we shall only consider the *exceptional* curves and gradients for which the line has received a *local* strengthening and which are passed over without slackening speed.

« As far as the places requiring special attention are concerned which are protected by *administrative regulations*, such as the road-crossings and the small stations on single line, we only ask for that portion of the regulations the special object of which is to avoid the necessity of expresses slackening speed. »

The replies received have shown that in fixing 43 1/2 miles (70 kilometres) an hour as the minimum speed of a train, entitled to be called express, a too high

*

limit has not been assigned from the point of view in question. Indeed, from the numerous replies which have been received, it seems that, even on lines on which speeds of 43 1/2 miles (70 kilometres) an hour, and upwards, are allowed, no particular arrangement is used to do away with the slackening at the crossing of most of the special places which are enumerated in the headings of question II, if the passage over swing bridges and through single line stations is excepted.

And yet the arrangements adopted at single line stations are common to lines run over by trains, the speed of which does not exceed 37 miles (60 kilometres) an hour, and to those over which the fastest trains run.

Moreover a very clear conclusion is denoted in the replies received : the slackening at special points is never compulsory, it may be said, on account of the faulty resistance of these points, or of the insufficiency of the systems of signals. The methods which are applied in order to avoid the slackening are neither very new, nor very interesting. Considerations of a commercial nature, and even of a moral order, are found to have in the question quite another importance to considerations of a technical nature.

On lines where competition, the inclination of the public, or the spirit of progress, instigate an increase of train speed, slackening has been quickly abolished without contriving out-of-the-way methods to affect this. The temperament of the Administrations and the character of the populations do more to accelerate the speed of the trains than the little contrivances which are employed in order to strengthen the line at certain points. And it is thus that with lines equally strong, with similar appliances and signals, one Company allows its trains to travel everywhere at great speed, whilst another slackens the speed of its trains on every occasion.

It will be understood that to arrive at such a conclusion, question II cannot have called forth either very precise replies, or very instructive information. But it touched other interesting subjects, such as the form of regulations for level crossings, the method of working small stations, and the arrangement of important stations from the point of view of the passing through of expresses, the interlocking between signals and switches, etc. Must we approach some of these subjects from one side and wander from the question in point in order to make it attractive? It has not been thought so, considering that the principles of these adjacent questions especially affect traffic, and that they deserve separate treatment. I have therefore preferred to keep strictly to the question as it was defined in the programme of the Congress, at the risk of presenting less exhaustive a report.

SUBDIVISION OF THE REPORT.

Apart from junctions, the special points which may necessitate slachening are classed into three categories:

1° Special points of *the road*, that is to say, exceptional gradients and curves;

2° Special points of the *permanent way*, that is to say, the appliances of the way, points, acute and obtuse crossings and swing bridges;

3° Special points in the *running*, that is to say, level crossings, large and small stations, branches between stations.

I. — Special points of the road.

Exceptional gradients and curves.

Curves and gradients do not constitute in themselves special places on the line, and moreover the arrangements taken to give to the line the resistance, which the passage of express trains on curves and gradients exacts, form the object of question I.

We have therefore only to consider here *exceptional* gradients and curves. On the lines from Paris to Lyons and from Paris to Bordeaux for example, laid out with a maximum inclination of 1 in 200 (0.005), a gradient of 1 in 125 (0.008) is found exceptionally (at Blaisy and Etampes). On the other important lines with a minimum radius of 39.76 chains (800 metres) some curves will be found, the radius of which is as low as 24.85 chains (500 metres), that is to say, exceptional curves for these lines.

But these are quite comparatively unimportant exceptions, for express trains travel over lines, the normal inclination of which attains to 1 in 67 (0.015), and of which the radii are as low as 19.88 chains and 17.40 chains (400 and 350 metres).

The inclination alone, whether an up or down gradient, is not a cause of weakness on the line; on an up gradient, the speed is only limited by the power of the engine, and on a down gradient by the power of the brakes. On a long and quick down gradient run over by numerous trains descending with the brakes put on, rails with a raised head may perhaps be used in order to lengthen the life of the rails and to make the best use of the metal. But in any case the line is not strengthened in exceptional down or up gradients for the sole purpose of abolishing the slackening of speed.

Curvature, on the contrary, becomes a marked cause of weakness on the line as soon as the radius descends below a certain value. But this critical limit is essentially variable, since it depends on the constitution of the line, on the speed and load of the trains, and, above all on the flexibility and stability of the engines. It is impossible to assign it a determined value *a priori*. It can be affirmed nevertheless, that a sufficient resistance can never be successfully given to curves against badly balanced engines.

It has been rightly stated in the replies, that the line on curves is strengthened by increasing the number of sleepers, in using bedplates, more numerous and stronger screws or spikes with Vignoles rails, and heavier chairs with double headed rails. But these methods of strengthening are not confined to exceptional curves; they are employed on great lengths, and on a great number of curves. It may even be said that applied at first to sharp curves, their use is little by little being extended to all curves, and even to straight portions on lines with heavy traffic, because the small increase of capital which they entail is quickly compensated for by increased safety, diminution of the wear of material and of maintenance-labour..

Only two arrangements really special to exceptional curves have been pointed out, both in England; the addition of a guard rail (Midland, Manchester-Sheffield, and Lincolnshire, Glasgow and South Western, South Eastern, North British) and the connection of two parallel lines (Great Eastern).

The guard rail placed along the inner rail increases the transverse rigidity of the line and protects the outer rail against the tendency to tilting. But this is a costly solution and it is not proved that the groove between the rails in which hard stones or objects fallen from the trains may be wedged, does not increase, rather than diminish, the chances of derailment.

Connection by sleepers, or tie-roads, of two parallel-roads may be efficacious, but it causes great constraints in laying down and maintaining the road, and is not applicable to single lines on which, it must be recognised, sharp curves are ordinarily found.

To sum up, if the addition of a guard rail, and the tying together of two parallel lines employed on some systems in England be excepted, no other means of strengthening have been stated for the doing away with slackening of speed on exceptional curves and gradients than those which are usual on the running line and which form the object of question I.

II. — Special points of the permanent way.

1st. *Appliance of the way properly so called : switches acute and obtuse crossings.*

The only appliances of the permanent way which may be run over without slackening of speed are the switches and acute and obtuse crossings.

But these three kinds of appliances are necessarily encountered at double line junctions : their investigation, therefore, more properly belongs to question III, which is devoted specially to the abolition of the slackening of speed during the passage over junctions.

It is to be hoped moreover that the reporter of that question has obtained more explicit replies than have been sent to me.

The replies may almost be said to indicate that on the same system, the appliances used are the same on lines for ordinary speeds as on lines run over by expresses, and that a very careful maintenance is the only regulation applied to the latter.

Passengers cannot refrain from stating however that if these appliances are run over without slackening nearly everywhere, they experience much more serious shocks on one system than on another. Permanent way engineers also know that the wear of these appliances, principally that of the switches and of the noses of the acute and obtuse crossings, increases very rapidly with the speed of the trains. It is certain moreover that violent shocks are always accompanied by rapid wear, and that abolition of the shocks carries along with it diminution of wear.

The appliances best fitted for the passage of express trains will therefore be found where the least shock is experienced in running over them. It is certain that in its entirety this result is obtained in England better than anywhere else. Passing through large stations, encumbered with appliances and lines of way, at full speed, without oscillation, without shock, is certainly one of the facts which strikes the engineer most who travels for the first time in that country. The causes must then be sought which have yielded to the English railways this marked advance on the railways of the Continent.

Two principles are seen in them : the first concerns the formation of the permanent way itself, and the second a special organisation for the manufacture of the appliances (1).

The non-symmetrical double headed rail weighing from 80.6 to 90.7 lbs per yard

(1) M. De Busschere, chief engineer to the Belgian State Railways, has published on this subject some very complete and interesting information in the *Annales des écoles spéciales de Gand*.

(40 to 45 kilogrammes per metre) lends itself very easily by its form and great resistance, to the manufacture of the principal pieces of the appliances; point rails of switches, noses of acute and obtuse crossings, and wing rails. The cutting and putting together of these rails are easy and of little cost: an advantage is notably found of being able to give to each element, without supplementary expense, a great length and consequently great stability, without excessive rigidity, with a very good fishing.

In the ordinary chair which weighs from 35.3 to 52.9 lbs (16 to 24 kilogrammes an excellent model is obtained for the special large chairs which are used for the switches, crossings, etc., and which ensure to them a strong attachment to the sleepers.

Finally, the use of fir of strong scantling for the sleepers led to the placing under the appliances of very large blocks of timber, very broad and long and perfectly trimmed.

What the fittings, required for the running line, must have is a great vertical and tranverse resistance. But that is not enough, it is necessary further to give to these appliances a great perfection of form to avoid shocks at special points.

This perfection is the result of an organisation entirely peculiar to the English Companies. Each great Company possesses in fact, an engineering staff with office and workshops, fitted up solely for the investigation, manufacture, and erection of the permanent way appliances.

The examination of some English stations promptly shows the reason of the existence of this organisation. In the stations, always placed in the centre of the towns, every inch of space is utilized, and a strictly limited number of patterns cannot be made use of, according to the custom adopted on the continent. A special section practically entails the use of a special appliance; thence follows the necessity of very complicated working drawings and even of wooden models, the use of which is frequent.

If to this is added the fact that England is the country of the world where the Engineer frees himself most completely from the tyranny of the *invariable pattern*, it is easily understood that the English Companies have been induced to create for these permanent way appliances a special staff, and also that this organisation once created must necessarily tend to perfect the work to which it was specialized.

Is it advisable to follow this exampleon the continent? It is believed not. Generally, space is not limited in stations, and the form of the appliances does not need to be varied indefinitely. Also, very far from seeking a special solution for each case, most of the continental Companies consider it an improvement to reduce more and more the number of patterns of appliances. Moreover, if the existence of a special staff has been in England the means of improving the appliances, it is not the necessary cause of it. It may be understood even that the reduction of the number of types may allow a very great perfection to be given to each of them without the permanent assistance of a special staff.

It may be added also that the adoption, becoming more and more general on the systems of the continent, of a strengthened permanent way material, which will provide good materials and good models for the manufacture of the appliances of the way, will conduce necessarily to the improvement of these appliances.

To return to the subject of the report, it may be stated, that if the Companies do not possess all the appliances of the way of the same quality, nearly all however affirm that they can run over those which they use, without slowing down, at greatest speeds.

Nevertheless, a distinction must be made as far as the points are concerned, according as to whether they are taken facing or trailing. When taken trailing they are never in themselves a cause for slackening. On the contrary, on the lines where trains are allowed to pass over facing points at full speed, it is always compulsory to maintain these in their normal position by a plunger, provided or not, according to the circumstances, with a treadle bar working with the point lock.

The varied forms which have been given to these accessory appliances will not be described here, a great number of satisfactory patterns exist.

Some Companies still insist upon slackening at facing points, even when they are plunged. They do so, not because they think the resistance of these appliances insufficient, but because their presence always creates special constraints in working.

Every facing point becomes, in fact, a special point of the *running*, whether it is situated on the line between stations or in a station. This aspect of the question will be examined in the third part of the report.

To sum up, it is admitted almost generally, that the appliances, completed by a plunger to the facing points, do not constitute in themselves weak points of the line, and can be run over without slackening, especially where the safety of the running on the lines, which they connect, permits it.

2nd. *Swing bridges.*

From the point of view in question, swing bridges only offer a limited interest. In fact, only a very small number exist on the main lines.

In England, Belgium and Holland where a few of them are met with, none are run over without slackening.

On the French systems, the Northern Company alone possesses them.

Two Companies only have intimated that they have given up slowing down at the crossing of swing bridges; the Pennsylvania Railroad in the United States and the Northern of France.

The Pennsylvania states that it uses the Hackensack system of plungers and signals, but without describing it, or mentioning a publication where the information can be obtained.

The Northern of France has already abolished or is shortly about to abolish slackening at all its swing bridges situated on the main line, by providing them with an arrangement of locking and signals, which has been planned by its engineer, M. Forest, and of which a description is found in the *Revue générale des chemins de fer* (March 1888, note by M. Cossmann on the line from Noyelles to Saint-Valéry). In its normal position, the bridge does not bear on its pivot; it is fixed solidly and with great precision on resting blocks which receive it on the abutments. It is, further, maintained in this position by a bolt interlocked with the signals similar to those of a junction. An appliance, called *retardateur*, compels the keeper of the bridge to allow a certain period to elapse between the placing of the signals at « danger » and the opening of the bridge.

Locking and interlocking appliances with a « retardateur », fulfilling the same functions as the arrangement of the Northern of France, have been contrived by M. Bruneel, engineer to the railways of the Belgian State, and applied to the Duffel bridge, on the line from Antwerp to Brussels. (*Revue générale des chemins de fer*, September 1892.) But the slackening on passing over this bridge has been maintained.

III. — Special points on the road.

1st. *Level crossings.*

It has been pointed out in the replies that slackening is insisted upon at certain level crossings occurring where very busy streets in large towns meet the line; it has also been pointed out that certain level crossings are provided with protecting or warning signals, because of the defective view from the approaches, or because of the heavy traffic on one or other of the two roads. But all these measures are not special to express trains; slackening, when it is ordered is common to all trains and the signals of protection exist on secondary lines as well as on the lines most used.

In general, except on the Dutch railways [1], passing over a level crossing is not a reason for slackening.

The reply to this portion of question II is therefore entirely negative : nowhere need express trains slacken speed at level crossings, on account of the fact that they are express, and their speed never gives rise to special regulations.

2nd. *Stations run through without stopping.*

If slackening express trains is avoided on nearly all systems at special points of the line or permanent way and at level crossings, it is not the same for the passing of large or small stations. On many lines the trains are slackened on passing over facing points whether they are plunged or not. The maintenance or abolition of this slackening is particularly interesting on single lines, where one facing point at least is encountered at every station provided with a siding for passing purposes, that is to say at every 3 or 4 miles (5 or 6 kilometres).

The stations of small importance and the stations of average or great importance, will be considered successively, in distinguishing between the double and single line stations

a) Double line stations.

It is everywhere admitted that stations in double line can be run through without slackening by trains which do not stop there, whatever may be their speed, on the condition, clearly understood of not having turn tables on the running road.

All the switches are arranged to be trailing, and the slow trains which must be passed are shunted by pushing them backwards.

Direct shunting by a facing point is entirely exceptional in the small stations; it is only justified by the advantage of a more rapid shunting, and therefore is only met with on sections with exceptional traffic. The facing point which leads from the main line to a siding is in fact like a junction facing point not followed by an obtuse crossing. Slackening can therefore be abolished there, since it is abolished at complete junctions on certain systems.

(1) The following reply of the Dutch Railway Company to my question is particularly suggestive : « The law compels us to reduce speed on all curves leaving a radius lower than 50 chains (1,000 metres), on all gradients more severe than 1 in 200, on passing over facing points and obtuse crossings, level crossings, and swing bridges. »

In a recent paper, full of interest [1], M. Flamache has pointed out the best theoretical arrangements to be adopted in double line stations with the view of avoiding slackening speed in express trains. It is evidently useful on lines with very heavy traffic, to arrange the passing and shunting roads in passing stations in such a way as to increase the capacity of the traffic of the line, and to free the local service from the restraints which the passing of express trains entail. But that does not really affect the running of these trains, since it is everywhere admitted that small stations are run through at all speeds without slackening.

It may also be observed that the heaviest lines are nearly always the oldest and that now-a-days no new lines with heavy traffic are constructed. The question before us is, therefore, not to find out which is the best pattern of station to adopt from the point of view of the running of express trains on a projected line, but rather to consider how an old station, generally with very limited accommodation, can be adapted in the best possible way, its enlargement being obstructed by the arrangement of the approaches, and almost always by contiguous buildings. There remain then some special cases only, which belong to no special type, and in which the necessary expense plays the leading part.

In short it is the general rule in double line stations to avoid facing points and to sacrifice the road of the secondary lines to that of the main lines, which are arranged in plan and profile as the ordinary running line.

By means of these simple precautions the passage of the fastest trains may be allowed without slackening.

b) Single line Stations.

The method of passing stations is of the first importance on single lines on which express trains travel. Some examples will show this better than all argument.

On the Northern of France, the expresses from Paris to Tréport run over 59 miles (95 kilometres) of single line between Beauvais and Tréport. This distance is traversed with only one intermediate stop, at Eu, near Tréport. Fifteen small or large stations, of which three possess one or two junctions, are passed without a stop.

On the system from Paris to Orleans, the express No. 30 from Toulouse to Paris,

[1] *Bulletin de la Commission internationale du Congrès des chemins de fer.* Novembre 1894.

by Capdenac and Saint-Yrieix, travels on a single line from Toulouse to Nexon for 204 miles (328 kilometres) with a nominal speed varying from 34 to 43 1/2 miles (55 and 70 kilometres) an hour, according to the sections. In this course, it runs through twenty-five stations without stopping, and stops sixteen times. At twelve of these sixteen stops it crosses or passes other trains, and of the four stops without crossing two are situated at the summit of long up gradients where the engines are obliged to take water. The train only passess over one junction between stations; all the other junctions are situated in seven more or less important stations, where the train No. 30 meets others and makes important connections.

On other lines of the same system, the express No. 607 from Paris to Laqueuille (Mont-Dore Station) traverses a single line 119 miles (192 kilometres) in length between Saint-Florent, near Bourges, and Laqueuille. It passes seventeen stations without stopping and only stops nine times, of which eight are for crossing other trains. It only passes one junction between stations, the other junctions being situated in large stations.

From these instances, which could be multiplied, it clearly follows that the abolition of the slackening of speed at junctions is of very secondary importance on single lines and that the speed of trains on them depends especially on the regulations adopted for running through stations. It may even be said that an express train on these lines is only possible if all loss of time is avoided on passing most of the stations.

This question, it is true, presents little interest on many of the systems which have all their main lines served by double line of way : this is so with the English Companies, the Belgian State, the Eastern of France, the Lyons Company, etc. But it is not so everywhere; in hilly districts and in new countries lines connecting great centres are constructed as single lines, either to save money or because there is but little except through traffic. On these lines, however, express trains are really necessary.

Without doubt, the primary condition to fulfil, in order that trains may run at high speeds, is to provide the railways with permanent way material and engines adapted to the line. That alone is not sufficient : not only does the distance between stations generally average about 4 miles, but also many are situated at the bottom of long up gradients. High speed will never be obtained, if trains have to stop or even slacken at every station.

In the passing of a station by an express train two points have to be considered, according to whether it crosses or does not cross another train.

1st. *Passing and crossing another train.*

The regulations of most Companies prescribe the stopping of every train, when there is a crossing, whatever may be the direction of the two trains.

On certain Swiss lines, however, that of the Gothard in particular, the express trains are allowed to run through the crossing station at a very reduced speed, but without stopping, when the other train in an opposite direction has been shunted before its arrival.

On the Northern of France, stopping is compulsory for the crossing of trains travelling in opposite directions, whilst express trains can pass without stopping or slackening, slow trains travelling in the same direction and previously shunted. It is necessary to note besides that the passing of a slow train on a single line scarcely differs, from the safety point of view, from the passing on double line, which is nowhere considered as being a reason for slackening.

2nd. *Passing without crossing.*

It is everywhere admitted that certain stations can be run through without stopping, but on many systems slackening is compulsory either because the lines are not arranged for great speeds, or because the trains are made to slacken at all facing points.

The following Administrations have done away with slackening on certain of their lines, Belgian State, Danish State, Pennsylvania, Gothard, French State, Southern of France *(Midi)*, Northern of France, Orleans.

A speed of 43 1/2 miles (70 kilometres) is not attained on all these systems, but on all it is admitted that a single line station, conveniently arranged, can be run through without slackening by an express or fast train.

On the Gothard, however, a slight reduction of speed is prescribed, varying at different stations, according to the section.

In order to avoid slackening the first necessary condition is to establish in the station a direct line; in place of arranging two lines similar as to track and traversed, one by all trains in one direction and the other by trains in the opposite direction, one main line is established and one loop. The main, or direct line, is designed in plan and profile as the ordinary running line, and it is traversed by trains in both directions, stopping or not, every time that there is no crossing of trains. The straightness of the loop which is only used for trains crossing one another is sacrificed for the benefit of the through line.

In the stations for taking water, this plan is followed without alteration, if the trains in both directions can be supplied on the through line. It is necessary on the contrary, to allow a modification of the plan when the through line is provided only with one water appliance.

A second arrangement, equally general, consists in using a plunger at all facing points.

With regard to the other arrangements adopted, the greatest variety is presented. In one place the plunger of the facing points is kept in its place by a lever independent of the switches, without connection with the advance signals. (Northern and Southern of France, Orleans Company). The plunger is accompanied, or not, by auxiliary signals and the locking of its lever varies on different systems. At another place the switch is worked and plunged at a distance, by rigid connections, wire or hydraulic and by a single lever, or by two levers. Elsewhere, the switch, worked on the spot, is plunged at a distance, mechanically or electrically.

When the plunger is worked on the spot, it necessitates a pointsman for each switch for all the crossings. Staff is economised when the levers are concentrated in the centre of the station; but the connections are expensive and the distance of the appliances worked compels the switches to be interlocked with the signals.

These interlocking cabins at the centre of small stations are especially frequent in Austria and Switzerland.

Information too brief for description and classification has been received on all these arrangements. Their extreme variety is easily explained. The signals and interlockings are in fact merely a method of carrying out by mechanical means the working regulations (1), and these vary not only in different States, but on adjoining systems.

The conditions for accepting and allowing trains to pass in single line stations will certainly be a very interesting subject to investigate; but the appliances employed in each case only play an accessory part : the essential part belongs to the working regulations. This question will be taken up therefore in the 3rd section of the Congress.

c) IMPORTANT STATIONS.

In middling sized, or large stations facing points cannot be avoided, and the

(1) This aspect of the question has been specially brought forward by M. Brière, engineer in chief of the Orleans Company, in a note on the appliances employed for working at a distance, used by that Company. (*Revue générale des chemins de fer*, October, 1889.)

distruction between the single and double line loses its interest from the point of view under considerations.

Moreover, the conditions to be fulfilled, for avoiding the slackening of express trains in these stations are so intricate that no absolute rules can be applied.

On a given system no two stations are found, even secondary stations, which are really comparable. Much more do the divergencies increase when the system and country are changed.

It may well be said that lines intended for the running of expresses must be designed and laid down as between stations, and that too many permanent way appliances as well as signals must be avoided. But these conditions are both too obvious and too vague to be of any use whatever. Each station has its own physiognomy; the study of its handling exacts great experience in these kinds of projects, a profound knowledge of the regulations and routine of its working and a thorough understanding of local arrangements. The engineer who does not combine these qualities will come to grief in his undertaking, and he who possesses them is not in want of general principles.

3rd. *Private sidings.*

Only branches to manufactories, quarries, or work-yards, between stations, will be considered here.

On double lines connections are always made with trailing points and entry, or departure effected by backing.

On single lines the facing point is inevitable and is plunged.

The main lines are protected against the siding either by a scotch block, a signal, or a safety switch. Signals, scotch blocks, and switches are generally interlocked. In France the interlocking is compulsory.

Two conditions may be met with.

If trains are allowed to be shunted on to the siding, for the purpose of being passed by other trains, the working of the siding is entirely similar to that of a station arranged for shunting a train, and safety appliances for the passing and blocking which exist at other stations of the line, cannot be dispensed with. A permanent pointsman is also usually provided at these sidings.

If the service of the siding is carried out by through trains, which do not shunt there, it is sufficient to protect the working by signals. Most sidings of this kind are usually unattended except while shunting is going on, and, the signals and switch appliances remain locked.

Double line sidings are everywhere run over without slackening. Some Companies on the contrary, insist upon slackening at the passage of single line sidings; namely those which make trains slacken speed at all facing points whether they are plunged or not.

I have heard of an interesting arrangement in common use in England on staff-worked single lines. The switch at the siding is locked and the key is fixed to the staff. As in the Annett lock the key cannot be separated from the lock until the switch is fixed in its normal position.

CONCLUSIONS.

In conclusion, slackening at special points of the line is never caused by insufficiency of the appliances with which they are provided; the system adopted on each line depends especially on the administrative regulations, on the customs of the working Administration, and on the necessities of the traffic.

Thus, the Northern of France whilst only using wellknown arrangement, avoids slowing down at all permanent way fittings, including swing bridges, and the passage of single lines stations, even when an express train passes a slow train there; whilst on the Dutch lines whose road is as favourable as that of the Northern of France, whose permanent way is as strong, and whose safety appliances offer as much security the law requires trains to slacken on curves with radii lower than 50 chains (1,000 metres) on down gradients steeper than 1 in 200 (5 millimetres), at level crossings, at swing bridges, at facing points and at obtuse crossings.

I propose to draw up the conclusions of question II as follows :

« Gradients and exceptional curves where they are run over without slackening are not specially strengthened.

« Most Administrations allow express trains to pass at full speed permanent way appliances, level crossings, private sidings, and double line stations, without recourse to other means than those which are used for ordinary trains.

Passing through single line stations without slackening is allowed on a fairly large number of lines : very varied contrivances which are adopted for this purpose, depend essentially on the working regulations peculiar to each Administration, and numerous equally satisfactory technical arrangements are found suitable.

« Some Administrations allow trains to pass over swing bridges at full speed. »

Paris, 13th February 1895.

APPENDIX.

Detailed list of questions.

I. — PLACES ON THE LINE REQUIRING SPECIAL ATTENTION.

EXCEPTIONAL CURVES AND GRADIENTS.

1. — What is the least *normal* radius? What is the steepest *normal* gradient on the lines of your system which are passed over by expresses?

2. — What are the radii lower than the least normal? What are the gradients (and their length) steeper than the normal gradients which are met with exceptionally on these lines, and which are passed over without slackening speed?

3. — Describe the processes used to strengthen the line, or to protect the passage of the trains over exceptional places : local strengthening of the rails and fish-joints; strengthening of the attachments to the sleepers or longitudinals; increase of the number or the size of the sleepers; strengthening the line by small retaining walls, or by other means of obtaining lateral resistance; check rails.

4. — What is the weight, and what is the speed of expresses which pass over these exceptional places?

5. — What are the types of the engines and vehicles of which these trains are composed?

6. — On a line passed over without slackening speed, what rules are made to fix the greatest authorized speed, taking into account the composition of the trains and the profile of the line?

7. — Is the speed of the trains over exceptional curves and gradients registered by a fixed or portable apparatus placed on the line? By indicators fixed on the engines?

II. — POINTS AND RAIL-CROSSINGS.

A. — ARRANGEMENT OF THE APPLIANCES THEMSELVES.

(If the answers concerning these appliances have been given in reply to Question III. (Junctions), please sum them up in a few words.)

8. — Do you use a different arrangement for these appliances, according as they are, or are not, passed over by expresses without slackening speed? What are the differences? What systems, in particular, have you used or tested to avoid or diminish the shocks caused by passing over the points, crossing and rail crossings?

9. — What kind of safety appliances do you use for facing points which are passed over without slackening speed? Are these appliances always in conjunction with a point lock? Of what type are these locks?

B. — Accessory arrangements.

(In the description of the accessory arrangements, distinguish between those which are specified by government regulations and those which are due to the initiative of the working company.)

10. — What is the rule as to trailing points? Are they locked? How is their lever arranged?

11. — *Isolated facing points* to private branches, ballast pits, etc. — What is the rule as to the signals protecting these points? Are they considered as isolated obstacles or as a junction? Are they permanently watched? At what distance from the switch is the signal placed which calls for a stop or the slackening of speed when this switch is unlocked?

12. — *Passing Loops at Single-Line Stations.* — How is the line laid out from the points? What provisions are made for the looking of the points and the interlocking with the station signals? Is the train approaching the points in the facing direction without slackening speed warned by a special signal of the position of the points and their locking? At what distance is this signal from the points? What arrangements exist in view of preventing the breakage of the appliances by a train happening to travel wrong road, or to indicate this breakage if it occurs? Do you allow an express to pass in the stations without slackening speed a train going in the same or opposite direction which has been previously shunted clear of the line on which the express is travelling?

13. — Facing points and rail-crossings in *the large stations.* Have you special provisions other than the locking of the points and the interlocking with the signals?

III. — SWING BRIDGES.

14. — Have you any swing bridges passed over by expresses without slackening speed? How many trains pass over them, and how many times are they opened in 24 hours?

15. — Describe summarily these bridges and the special provisions taken to wedge them and to protect them by signals.

16. — What government regulations are specified for the protection of these works when they are passed over without slackening speed?

IV. — ROAD-CROSSINGS.

17. — Are the road-crossings on your system ever a cause of the trains slackening speed?

18. — Do special provisions exist in regard to the line, the gates, the systems of indication or protection, for the sole purpose of avoiding the necessity of expresses slackening speed at the road-crossings?

19. — Is the avoidance of this slackening made the object of special rules in the regulation of road-crossings? Is it required that the crossings be guarded by men, and by night as well as by day?

V. — MISCELLANEOUS.

20. — Beyond the places requiring special attention enumerated above, do others exist which have called for the use of exceptional means for avoiding the necessity of expresses slackening speed?

SECTIONAL DISCUSSION

July 2, 1895, 1.30 p. m.

Mr. JEITTELES, President, in the chair.

Mr. Sabouret, *reporter*. (In French.) — At first sight the question we have to discuss seems to be purely technical. One would naturally suppose that the Administrations which have abolished slackening at all these special points must have had recourse to more or less ingenious and effective expedients for giving to these weak points a strength equal to that of the ordinary running road. The facts however are not so. In reality the question is less technical than it appears.

There is one conclusion that forces itself on the mind of those who read the very numerous communications that have been kindly forwarded me from all quarters. It is this :— " The abolition of slackening at special points is rather the result of a determination to abolish it than of any measures taken to strengthen these points. " The abolition of slackening, like the increase of the speed of trains, has its origin in countries where energy is honoured, where the travelling public appreciates the value of time and the railways yield to a public demand. Fast expresses naturally imply passing over special points at high speed. There are no very new and complicated arrangements made for the abolition of slackenings. The machinery for strengthening and protecting the so-called special points is very much the same on the railway systems which abolish slackening as on the systems which maintain them.

The progressive temperament, the rashness if you choose so to call it, of the management, whether it be that it leads or that it follows public opinion, has much more to do with abolishing slacks than the most elaborate technical organisation in the world. People who choose to run fast are not likely to be stopped by the weakness of special points in the road and will easily get over the difficulty that they cause. Those on the other hand who think it wiser to hasten slowly, only half regret to be obliged to slacken. The railway — we will not call it timid but only prudent — which naturally dislikes high speed, calms its conscience by interspersing its staff regulations with wise counsels and placarding its road with notices to reduce speed. But for all that it no more neglects to strengthen the weak points in its road than its rasher neighbour.

We have got therefore a long way away from the technical character that

Question II seemed to bear at the outset. You will however forgive me for this possibly overlong preface, as it enables me to cut my report exceedingly short by taking all real interest out of the question of the various means employed in practice to avoid slacks at special points.

Let us examine the question in detail in the order adopted by the report. Apart from junctions at stations, the special points likely to cause slacks fall under three heads:—

1st Special points in the *profile* of the road, that is to say exceptional gradients and curves;

2nd Special points in the *permanent way*, that is to say switches, rail crossings and swing bridges;

3rd Special *traffic points*, that is to say road crossings, stations and station yards and junctions with private sidings.

I. — Special points in the profile.

Properly speaking, curves and gradients are not special points at all. One cannot conceive a line perfectly straight and level. But what is an exceptional curve or gradient? A curve or a gradient which is exceptional on one line occurs constantly on another. Accordingly the means of strengthening are the same for exceptional curves and gradients as for ordinary curves and gradients. But this is the subject of Question I.

As for gradients, a down gradient is in itself no obstacle to speed. If a train is run slow down a long bank, the real reason is the lack of sufficient brake power and the fear that a driver should lose control of his train. No one has ever suggested the idea that the road on a steep gradient must be strengthened to allow of fast running. I would mention here more particularly the reply sent by the Northern Railway of France which on a long bank of 1 in 74 (13·5 millimetres per metre) on the Tréport line has no limit of speed except that naturally imposed by the type of engine.

A sharp curve evidently checks speed more than gradients. Mr. Ast in his report on Question I mentions numerous methods suggested for strengthening the road round curves. It is not necessary to recall them here. But there are two methods described by English Companies which do not appear in Mr. Ast's report. The first consists in the employment of a guard rail, the second in fastening together the two parallel roads with cross-ties or transoms. That a guard rail on the inner side of a curve is constantly employed by the English Companies we have had frequent opportunities of observing in our recent excursions. Now it is very little in favour on the Continent. It would be interesting to learn from the English engineers what value they attach to this method of strengthening the road. One might object to it on the one hand that it is somewhat costly, on the other that hard stones and articles falling from the trains may wedge themselves in the intermediate space and so increase the chance of derailment. Presumably, however, this objection is only theoretical, as it does not deter the English.

To sum up, except for the addition of a guard rail and the tying together of two parallel roads which exist at certain points in England, we do not find any means for strengthening the road so as to prevent slacks on curves and steep gradients other than those made use of on ordinary open line and discussed under the head of Question I.

II. — Special points in permanent way.

Let us consider separately switches and other similar points belonging to the road proper and swing bridges.

a) *Points and crossings proper.* — Points and crossings are sometimes passed at full speed. But a double line junction is impossible without them. Their consideration therefore naturally belongs to Question III, which deals with the abolition of slacks at junctions. At the same time I should like here to make one remark of a general character. The replies of all Companies declare that they are satisfied with their arrangements under this head, and that these arrangements are the same on their express as on their ordinary lines. One cannot however fail to notice that in running over points and crossings at full speed one is very much worse shaken on one railway system than on another. It is clear that on the whole the best result is obtained in England. The running at full speed without oscillation or shock through great stations and yards crowded with points and sidings is, to an engineer who visits this country for the first time, a most remarkable experience. As I have stated in my report, this is due to two causes, the first, the construction of the running road itself, and the second, the special organisation for constructing and laying in the points.

The bull-headed rail weighing from 80 to 90 lbs a yard (40 to 45 kilograms per metre) lends itself admirably both by its shape and its rigidity to the construction of point rails, noses of acute and obtuse crossings and wing rails. On the other hand, the use of pine sleepers of large section enables these points to be laid on supports that are both long, broad and perfectly steady and true Finally, all the great systems have a special staff, with drawing office and shops, for designing, constructing and laying these special portions of road.

To sum up, one may say that it is pretty generally admitted that crossings where the facing points are locked, do not in themselves constitute any weakness in the road, and are run over at full speed unless the safety of the traffic on the roads connected by the crossing requires a slack.

b) *Swing-bridges.* — Swing-bridges are less interesting because they are less common. Two Companies report that they allow full speed over bridges, the Pennsylvania which uses the Hackensack apparatus and the Northern of France using the Forest apparatus. I have no information as to the Hackensack apparatus.

The Forest apparatus consists of a locking bolt and a mechanism called a "retardateur," so slotted with the signals as to oblige the bridge keeper to allow a certain interval to elapse between the placing of the signals at danger and the opening of the bridge. At the Duffel bridge, on the Belgian State Railways, there is a similar combination of locking bolts, signals and "retardateur", but the trains continue to slacken for all that. Here is a fresh instance of what I said at the commencement, that with precisely similar appliances one Company abolishes slacks and another does not.

III. — Special traffic points.

a) *Road crossings.* — As a general rule, — the railways of Holland, where the law compels a reduction of speed, are an exception, — level crossings never oblige express trains to slacken simply because they are express. At certain level crossings which are badly situated there are no doubt slacks, but in this case all trains alike slacken, express or ordinary.

b) *Roadside stations.* — I hesitate to touch on this point, for stations and station yards are not included as special points in the wording of Question II. Moreover the subject is one that concerns the traffic rather than the engineering department, and should naturally belong to the 3rd Section. Still a few words may be usefully said here. Roadside stations may be divided into :—

1st Unimportant stations on double road; 2nd Unimportant stations on single road; 3rd Important stations whether on single or double road.

1st *Unimportant stations on double road.* — One may say in general that these are passed at full speed, provided the through road has only trailing points.

The custom is to lay out the through road straight through the station, and for that purpose to make any necessary sacrifices in the curves and gradients of the connecting lines.

2nd *Unimportant stations on single road.* — This is a very interesting question. Stations are usually only 4 or 5 miles apart, and evidently no good inclusive speed can be attained if slacks at stations are insisted on. Many Companies accordingly dispense with slackening. Various methods are adopted. But we may say that the universal custom is to work the express on a through road which is the same for the non-stopping trains in each direction and has its curves no worse than the rest of the running road. The passing loop is sacrificed entirely to the through line and accordingly is entered by a sharp turn out at either end. Apart from this general rule, the means employed by the Companies to increase the safety of non-stopping trains through stations vary immensely.

Certain Companies lock all switches taken facing and the bolts are worked either from the ground or from a distance. In Switzerland and Austria, the point levers are concentrated in the middle of the station and are required to be interlocked with the signals.

When I spoke above of an express running through a station on a single line, I was considering the case where there was no train to be crossed at that station.

Few Companies permit an express on a single line to cross a second train, even though it has been placed in the loop beforehand, without slackening speed.

Usually the expresses when they either cross or overtake another train are required to stop. The Danish State Railways report that their expresses are not required to stop to cross a train already in the loop, but that they must run slow through the station. On the Northern of France, an express on a single line may run at full speed if the train which it has to pass is travelling in the same direction, but in the case of crossings proper slackening is compulsory.

Lastly the Midi allows an express to cross at full speed a train already placed in the loop whether meeting it or going in the same direction, and it permits this without feeling bound either to lock the facing points or to interlock the signals.

3rd *Important stations.* — For these it is impossible to formulate any general rule. One can only say that on most continental systems, trains are required to slacken through passenger stations of any importance. There are certainly exceptions to the rule, but the regulations laid down in these instances to avoid the necessity of expresses slackening are too complex for any generalisation to be possible.

It is however a clear principle that the roads along which the expresses run must be laid out as straight and as clear as possible from points and crossings and with as few signals as may be.

c) *Private sidings.* — When the siding is connected with a double road, the points are always arranged in the trailing direction, and trains are backed in and out. In this way, the necessity for slackening at the siding points is got rid of. Where the road is single and facing points are accordingly unavoidable they are locked. But even then some Companies require trains to slack in passing over them.

I may summarise by saying that slackening at special points is never the consequence of the inadequacy of the materials at command. The actual practice of each line depends upon idiosyncrasies of the individual Company, the necessities of its traffic and even more on the regulations laid down by the Government.

For example, on the Northern of France, with quite ordinary appliances there is no slackening at points or at swing bridges or in passing through stations in single line, not even where the fast train over-runs a slow one. On the other hand, on the Dutch lines with no worse curves and gradients, with an equally good permanent way and with points and crossings equally well made and maintained, the law requires trains to slack on curves of less than 50 chains (1,000 metres) radius, on gradients worse than 1 in 200 (5 millimetres), at road crossings, at swing-bridges, at facing points and at rail crossings.

It is therefore almost impossible to formulate conclusions which shall not be mere platitudes. Truth in railway matters is reached by so many different roads that one cannot describe any of them as the only direct road.

Here is what I suggest :—

" Gradients and exceptional curves where they are run over without slackening " are not specially strengthened.

" Most Administrations allow express trains to pass at full speed, points and

" crossings, road crossings, private sidings and double line stations, without " recourse to other means than those which are used for ordinary traffic.

" Passing through single line stations without slackening is allowed on a fairly " large number of lines. Very various methods are adopted; the matter is one " mainly of traffic regulation which each Administration must settle for itself, and " as for the mechanical and engineering appliances required to carry out the system " in force there are many, all equally satisfactory.

" Some Administrations allow trains to pass over swing-bridges at full speed. " (*Applause.*)

The President. — Gentlemen, it seems useless to begin a general discussion. The section can commence at once the consideration of the conclusions suggested by the reporter.

Mr. Bruneel, Belgian State Railways. (In French.) — The question on which Mr. Sabouret has reported is a child of my own, at least by adoption. It was on the programme of the Congress at St. Petersburg, and the late Sir George Findlay then reported on it. But as I pointed out at the time, the question which Sir George discussed was not exactly that set down for discussion, probably owing to an error in the translation of the text. Seeing that the question as it was proposed by the International Commission was in my judgement of very great interest, more particularly for the Belgian State lines, I ventured to suggest that it should be set down again for this present session and my suggestion was acted upon. You will therefore forgive me if I say a few words in defence of my child, and point out briefly that, contrary to what the reporter thinks, this question has for certain railways very great practical interest.

In Belgium there are on the State lines a large, — I may say too large a — number of points where slackening is obligatory. Now the question of increasing the speed of trains has been with us an exceedingly pressing one for some years past and we are making steady progress in this direction. Belgium you must remember is crossed by several main highways of international communication and competition, therefore has more force in compelling an increase of speed than on other continental systems. But the grounds for slackening speed are with us still very numerous and very seriously affect the running of our best trains.

A word first as to facing points. The reporter has stated that everywhere slackening has been abolished over facing points where the line is straight or on a curve of large radius. He should have said " almost everywhere " for the Belgian State is an exception to the rule. Even on our international lines, trains have to slack to 25 miles (40 kilometres) an hour over facing points in stations or at junctions.

The only exceptions made are in favour of royal specials, the international expresses and two or three local expresses which are allowed to run over facing points at 37 miles (60 kilometres) an hour, where the road is either straight or on a curve of at least 100 chains (2,000 metres) radius. But in every case the speed is limited to 37 miles (60 kilometres). I may add that precisely the same rules apply to points run over in the trailing direction. Is there really any obligation to maintain such a regulation, or ought we not rather to follow the example that so many Companies have set us? This is one of the points that I should like to hear discussed.

Swing-bridges are another cause of slackening. There is only one in England so far as I know, and in France also they are, I believe, exceedingly rare. In Belgium, on the contrary, in the flat districts of the country there are a number, even on the most important international lines. For example on the line between Brussels and Ostend there are still five, some of which however will shortly be got rid of. On the line between Brussels and the Dutch frontier viâ Antwerp, there are three. On the line between Brussels and the German frontier by Liége there is yet another — this time over a ship canal. Evidently the obligation to reduce speed on all trains, even the fastest expresses, to 25 miles (40 kilometres) an hour in passing over these bridges is a serious hindrance to our international traffic and one that it is highly desirable to get rid of.

The question accordingly is of very great interest for the Belgian State Railway system and I should be greatly obliged to delegates and especially those from Holland, who may be still plagued with a series of swing-bridges on their lines, if they would kindly state whether with them slackening is obligatory, and if not what are the methods and appliances adopted to render it unnecessary.

Mr. Werchovsky, Russian Ministry of Communications. (In French.) — It seems to me that there is a contradiction in Mr. Sabouret's report. At the opening, I find that he states :—

> One very distinct conclusion may be drawn from the answers received, slackening at special points is never, so to speak, necessitated by want of strength in the road at these points nor by the insufficiency of the signals.

It seems therefore that slackening is due rather to timidity than to any technical requirements. At the end of the report I find :—

> To sum up, slackening at special points is never the consequence of the insufficiency of engineering and mechanical appliances *available*.

The real question then is: " Is slackening justifiable with the appliances *actually in use?*" It may, I think, be said without contradiction that when the road is strong, trains fitted with continuous brakes may run down long banks at high speed without slackening. Further, they may pass even over very sharp curves without slackening when the fastenings of the rails are thoroughly good, the sleepers of large size and the ballast in perfect order. In a word, when the road is perfect there is no need to slack at special points. But are we justified in going so far as to say that slackening is caused merely by timidity and not by really practical necessity? I think not. When the road is laid with 56 and 60 lb (28 and 30 kilograms) rails...

Mr. Sabouret, *reporter*. (In French.) — That is not an express road at all.

Mr. Werchovsky. (In French.) — ...when the line is badly ballasted there must always be a certain danger in running down steep gradients even at low speeds. On a long bank, a train not fitted with continuous brakes may acquire a dangerous speed before reaching the bottom. Therefore to pass special points in the road at full speed it is essential that the road as well as the rolling stock be unexceptionable.

Mr. Michel, Algerian lines of the Paris Lyons and Mediterranean Ry. (In French.) — I should like to answer Mr. Bruneel's question. We have express trains, but our regulations still show great timidity and as in Belgium reduction of speed to 25 miles (40 kilometres) an hour at junctions is required. Not very long ago, the regulations required reduction to 12 $^1/_2$ miles (20 kilometres) but I am bound to say we are allowed full speed in passing over trailing points in stations. For my part, I think we might go further. It is worth while remembering that at the outset trains were required to come to a dead stop at junctions. After having successively permitted speeds of 12 $^1/_2$ and then 18 $^1/_2$ miles (20 and 30 kilometres) an hour we shall be allowed before long to run at speeds of 37 $^1/_2$ miles (60 kilometres) or even more.

The question of swing-bridges, raised by Mr. Bruneel, also interests us. In England, I only know of a single swing-bridge, situated near York. For the last 7 or 8 years trains run over it at full speed. I should be glad to learn from the officers of the Company concerned the following particulars :—

A swing-bridge necessarily implies a gap at the two ends. How do these two ends behave when a train runs over at full speed assuming that the rail employed is a 60 foot rail (18 metres), which requires $^3/_8$ of an inch (1 centimetre) play, and secondly, how does the rolling stock behave?

Mr. Berkley Wise, Belfast and Northern Counties Railway. — I think I can answer, not so far as the Great Northern Railway is concerned, but I can speak of another swing-bridge on a Railway with which I am connected in the North of Ireland, the Belfast and Northern Counties Railway. The traffic by the river is very small, consequently we are able, every time a ship passes, to take off the fish-plates. We have special-fish plates which unscrew very quickly and we undo the bridge every time. There is no slackening of speed, as far as the bridge is concerned, for the trains to pass over it, and there are 14 trains every day. There is a very sharp curve coming up to the bridge upon which we do slacken speed.

There is no mechanical arrangement for connecting the rails together. The opening of the bridge happens twice every day. Of course the bridge is interlocked with signals properly fixed at both sides.

There is one point in the Author's paper I should like to say a word about. On page 17 he came to this conclusion : that exceptional curves where they are run over without slackening are not specially strengthened.

I think the object of the paper was as to what means should be taken to avoid slackening on sharp curves. He has come to the conclusion that no strengthening takes place on exceptional curves where they are run over without slackening. I think the author of the paper must be wrong. There are several cases in my country, and also in England, where sharp curves are run over and the speed is slackened. I thought the question for discussion would be, what steps should be taken to enable the train to run round a sharp curve without slackening speed. I thought that was the matter we were to discuss.

The author of the paper suggests that we use double-headed rails universally in this country, on sharp curves from 12 chains downwards, while a guard rail or a check rail is placed on the inner rail. On the railway with which I am connected, we unfortunately have about 100 miles of flat bottomed rails, and about 150 miles of chair rails. As far as the chair rail is concerned, there is no difficulty whatever in putting a check rail there. The check rail is kept properly in its place by being fixed into the same chair — a special chair — in which the running rail is fixed, but there is a difficulty in fixing a check rail properly to the running rail on curves laid with a flat bottomed rail. I do not see any other means that we can adopt to make a sharp curve safe for high speed except by using the check rail. And the danger which the author suggests of stones and other hard substances going in between the check rail is not great, for, as far as the chair rail is concerned, there is such a deep space between the two rails that anything falls down. If a stone gets in, the wheel passes round and crushes it out. In a flange rail, where you may get a hard substance in between, there is some chance, but I have hundreds of curves checked in that way, and we never have the least trouble, and nothing has ever occurred. I do not think there is any other treatment we can possibly adopt for having a high speed round a sharp curve than by having it properly checked; in fact, the Board of Trade in this country compel us, round all curves of 10 chains and less, to have a check rail.

There is another very interesting point, to us in this country, which the author refers to, and that is, single line passing places. He suggests, or he states, that, on the Continent as well as in America, express trains when passing trains should run through stations on the straight road, while the stopping train goes into the siding. There are a great many advantages in that, but unfortunately in this country we are compelled to let every train go to the left hand, so that the train travelling in one direction must pass to the left, and the train coming from the opposite direction must pass to the left; therefore, in all cases we must run against the facing points in one direction or turn off from the straight line into the siding loop. On the railway I am connected with, we increased the speed of our trains lately, and we had to alter a large number of our passing places in order to allow the trains to pass going at full speed, which we do at about 40 miles an hour. We altered our stations so that the train approaching the station ran straight through the facing points. We put the whole of the curve from the siding to the main line at the other end of the loop.

Mr. Bruneel. (In French.) — Mr. Wise, if I understand him rightly, says that in the United Kingdom, when a single line is doubled to form a passing loop, trains always run on to the left-hand line.

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Mr. De Busschere, Belgian State Railways. (In French.) — Yes, that is what Mr. Wise said, but he also said that the facing points are so arranged that trains run straight in over them and that therefore the through road has had to be diverted either at the beginning or at the end of the station.

Mr. Sabouret. (In French.) — The trains run in straight. The sacrifice is made at the further end of the loop.

The President. — The reporter has told us that in stations on double road the regulations do not require slackening. This is not accurate, as in Belgium the regulations lay it down distinctly. It is the same in Austria, at least on the Company to which I belong.

I do not think that the section can accept the conclusion in its present form.

Mr. Sabouret. (In French.) — My conclusions do not say that all Administrations have abolished slacks, but that most of them have done so.

The President. (In French.) — I have carefully followed Mr. Sabouret's summary of his report and my impression is that the report is drawn up rather from a traffic than from a permanent way point of view. The reporter does not tell us what we have to do when there are regulations in force.

Mr. Michel. (In French.) — The result of Mr. Sabouret's report is that under present conditions both in England and on the Continent there are interlocked signals on all the dangerous points in the road. The question is whether this interlocking enables us to run through at a high rate of speed.

I spoke just now of the successive alterations in the rules of the Paris and Lyons Company.

The reform was very simply carried out, as our roads have all the interlocking that is necessary. All that had to be done was to insert in the regulations *25* instead of *12 $^1/_2$ miles* (40 and 20 kilometres) just as it will be sufficient to put *37 $^1/_2$* instead of *25 miles* (60 and 40 kilometres), when we get leave to increase our speed. There will be no need to make any change whatever in the road.

Mr. Sabouret. (In French.) — Still I have stated that certain Companies have taken to allowing full speed over facing points even without interlocking.

The President. — That is a traffic question.

Mr. Bruneel. (In French.) — Are those switches which are not interlocked provided with plungers?

Mr. Sabouret. (In French.) — The Midi of France which does not slacken speed at special points simply puts a padlock on the switches. I may add further that it actually allows an express to pass through stations on single line at full speed and to pass there a train, whether going in the same or opposite direction, which has been previously put into the loop, and all this without plunging the points.

Mr. Dufaux, Eastern of France Ry. (In French.) — On my line, we used to pass junctions with reduction of speed to 25 miles (40 kilometres) an hour for passenger trains and 9 miles (15 kilometres) for goods trains.

The disc signals were normally off, but we have just changed our junction locking so that the discs are normally closed, and now we pass all our interlocked junctions at full speed, except branches which lead off at a sharp curve. In their case a round slackening signal gives notice to the drivers to run at a reduced speed of 18 miles (30 kilometres) for passenger trains and 9 miles (15 kilometres) for goods trains. This new system of junction locking has led us to give notice to the junction signalmen of the approach of all trains, in order that if the line is clear the signals may be pulled right off and the train not checked.

Mr. d'Abramson, Russian State Railways. (In French.) — Will the reporter kindly tell me if there are any instances of express trains passing at full speed over facing points neither plunged nor padlocked?

Mr. Sabouret. (In French.) — I have not heard of any.

Mr. Bruneel. (In French.)— Before closing this discussion it would be exceedingly interesting if one of our American colleagues would kindly give us some information as to the manner in which these special matters that we have been considering are dealt with in their country.

The President. — We will see what can be done.

— The meeting adjourned at 4·30 p. m.

July, 3, 1895, 10. a. m.

Mr. Bruneel. (In French.) — I venture to repeat the request that I made yesterday that one of our American colleagues should give us some information as to their method of constructing and interlocking swing-bridges so as to avoid the reduction in speed of trains passing over them.

Mr. F. S. Curtis, New York, Newhaven and Hartford Railway. — There are a number of swing-bridges on the line of the road which I represent. They are contructed to allow running at full speed, but under the rules of the Company trains are not permitted to run on them to exceed 25 to 30 miles an hour.

Mr. Robinson, *secretary reporter*. — That is the general practice?

Mr. F. S. Curtis. — That is the general practice. There are some cases, in short swing-bridges, where trains are allowed to run at greater speed, but the general rule on swing-bridges is not to exceed 25 to 30 miles per hour.

The President. — What provision is made for speed when the swing-bridge is opened?

Mr. F. S. Curtis. — The trains cannot run to the open bridge without first disregarding the signals. They cannot run into the draw opening when the bridge is open or about to be opened, even if the signals are disregarded, as derailing switches are provided, locked up with the bridge in such a way that before the bridge can be moved the derailing switches must first be set. Therefore any attempt made to cross the bridge when the derail switches are set would result in derailing the train before it reached the bridge.

The President. — Would you have the kindness to make a sketch?

Mr. F. S. Curtis. — This sketch illustrates it. This represents the main line rail, and this shows the derailing switch being only on one rail, and this represents the draw-bridge. The draw is locked so that it cannot be opened or moved until you first open the derailing switch, and therefore a train disregarding the signals when the draw is open would by the derailing switch be run on the ground and could not get into the opening of the draw. It is believed that a good effect is produced on drivers and stokers by the knowledge that these derailing switches exist.

Mr. Demoulin, *secretary reporter.* — What is the distance between *these* two points of the sketch?

Mr. F. S. Curtis. — This refers to the distance that the derailing switch is placed away from the bridge? This is not a fixed distance, generally from 200 to 300 feet away.

Mr. Demoulin. — The trains run down off the rails?

Mr. F. S. Curtis. — If the train is derailed it runs on to the ground where the embankment is made wider, and a bulkhead is usually made of sand so that there will not be any possibility, if the train is derailed, of running over 20 or 30 feet at the most, even if it was running at a greater speed than 25 to 30 miles an hour. The material being sand the wheels would sink at once into it and therefore prevent going any distance.

Mr. Bruneel. (In French.) — Could not something be said about the Hackensack system employed on the Pennsylvania Railroad and how it acts, or give us the name of a publication where this is to be found?

The President. — No representative of the Pennsylvania Railroad is present in the room.

If you like we could add that it is usual to slacken speed when crossing swing-bridges.

Mr. Sabouret, *reporter.* (In French.) — But the Pennsylvania Company replied that it was doing away with slackening.

I think that the expression which says that " certain Administrations allow swing-bridges to be passed at full speed " describes the position quite accurately.

The information given yesterday as to guard rails shows that they are much more commonly used in England than I supposed. I propose therefore to add at the end of the first paragraph of my conclusions the following: —

" In England, however, there is frequently added a guard rail on the inner side of " very sharp curves. "

For the same reason it is necessary to say that " steep banks, etc., are not *as a rule* specially strengthened ".

I propose to add to the second paragraph after the words " most Administrations " the limitation " *chiefly in England and France* ".

It is evident from the statements that have been made that in Belgium and Austria it is the almost universal rule to slacken.

— The conclusions as modified were put to the vote and adopted.

DISCUSSION AT THE GENERAL MEETING

July 5, 1895, 2. p. m.

LORD STALBRIDGE, PRESIDENT, IN THE CHAIR

The President. — Mr. Richard Jeitteles, president of the 1st section, will read the French text of the report of his Section and then Mr. Leslie Robinson, secretary reporter, will read the English version.

Mr. Jeitteles. —

Mr. L. Robinson. —

Report of the 1st section.

" Le rapporteur a exposé comment, dans le questionnaire adressé aux Compagnies adhérentes, il avait cru devoir définir tout d'abord le cadre de son étude, en admettant que la question visait uniquement les grandes lignes parcourues chaque jour par plusieurs trains d'une vitesse de marche égale ou supérieure à 70 kilomètres (43 $^1/_2$ milles), qu'il fallait considérer seulement les courbes et pentes exceptionnelles ayant reçu une consolidation locale, de manière à pouvoir être franchies sans ralentissement, et enfin, en ce qui concerne les points spéciaux (tels que traversées de voies et petites stations sur lignes à simple voie), protégés par des règlements administratifs, en se bornant à la partie des règlements ayant pour but spécial de supprimer le ralentissement des trains rapides.

" The reporter first proceeded to call attention to the observations which preceded the detailed list of questions which he submitted to the Companies affiliated to the Congress, and he defined at the outset the limits within which he was obliged to confine his investigations. He took it as agreed that Question II refers solely to the trunk lines which are passed over by frequent trains at a speed of at least 43 $^1/_2$ miles (70 kilometres) an hour, and that he would only consider exceptional curves and gradients for which the line has received a local strengthening so as to be capable of being passed over without slackening speed. As far as the places requiring special attention are concerned, which are protected by administrative regulations, such as crossings and small stations on single lines, he limits his attention to that portion of the regulations the special object of which is to avoid the necessity of express trains slackening speed.

" Des réponses reçues, le rapporteur a dégagé cette conclusion, qui lui est apparue très nette : le ralentissement aux points spéciaux n'est, pour ainsi dire, jamais imposé par le défaut de résistance de ces points ou par l'insuffisance des systèmes de signaux. Les procédés auxquels on recourt pour éviter le ralentissement ne sont ni bien nouveaux, ni bien intéressants. Les considérations d'ordre commercial et même d'ordre moral se trouvent avoir dans la question une bien autre importance que les considérations d'ordre technique.

" Laissant de côté les bifurcations qui font l'objet de la Question III, le rapporteur a étudié successivement :

" 1° Les points spéciaux du tracé (pentes et courbes exceptionnelles);

" 2° Les points spéciaux de la voie (appareils de voie, aiguilles, croisements et traversées, ponts tournants);

" 3° Les points spéciaux de la circulation (passages à niveau, gares et stations, embranchements en pleine voie).

" En ce qui concerne les points spéciaux du tracé, Mr. Sabouret déclare que dans aucun cas on ne renforce la voie dans les pentes ni dans les rampes exceptionnelles dans le seul but de supprimer le ralentissement des trains.

" La courbure étant une cause marquée d'affaiblissement de la voie lorsque le rayon descend au-dessous d'une certaine valeur variable, dépendant de la constitution de la voie, de la vitesse et de la charge des trains, et surtout de la souplesse et de la stabilité des machines, on renforce souvent la voie dans les courbes, en augmentant le nombre des traverses, en employant des selles, des tirefonds ou des crampons plus nombreux et plus forts avec la voie Vignoles, des coussinets plus lourds avec la voie à coussinets.

" Deux dispositions seulement, vraiment

" A very clear conclusion seems to have been arrived at from the replies received. The slackening at special points is practically never caused by the weakness of these points, or by the insufficiency of signals. The methods which are applied in order to avoid slackening are neither very new nor very interesting. Considerations of a commercial nature, and even of a moral order, are found to have in the question much greater importance than considerations of a technical nature.

" Leaving aside junctions, dealt with in Question III, the reporter has investigated the following points :—

" 1st Special points in the profile of the road – that is to say, exceptional gradients and curves;

" 2nd Special points in the permanent way — that is to say, switches, rail-crossings, and swing-bridges;

" 3rd Special traffic points — that is to say, level crossings, stations and station-yards, and junctions with private sidings.

" As regards the special points in the profile of the road, the reporter said that the permanent way is never strengthened in exceptional gradients for the sole purpose of abolishing the necessity to slacken speed.

" Curvature, on the contrary, becomes a marked cause of weakness as soon as the radius descends below a certain value; but this critical limit is essentially variable, and depends on the nature of the line, on the speed and weight of the trains, and, above all, on the flexibility and stability of the locomotives. The permanent way is often strengthened in curves by increasing the number of sleepers, making use of saddle plates, more and larger screw-spikes or treenails in the case of a Vignoles road, and using heavier chairs on a chair road.

" Only two devices really special to curves spéciales aux courbes exceptionnelles, ont été signalées au rapporteur : l'admission d'un contre-rail et la liaison de deux voies parallèles.

" Le contre-rail placé le long de la file intérieure augmente la rigidité transversale de la voie et protège la file extérieure contre les efforts de renversement. Il a été établi par les déclarations faites en section lors de la discussion du rapport et reconnu dans les tournées faites depuis l'ouverture de la session, que l'emploi des contre-rails est très développé sur les voies anglaises, pour faciliter le passage des courbes ; nous ajouterons qu'on aurait pu, sans doute, constater que la voie anglaise laisse moins de jeu aux véhicules que les voies continentales.

" Mr. Sabouret avait fait une objection à l'emploi des contre-rails, à savoir que l'ornière dans laquelle peuvent se coincer des pierres dures ou des objets tombés des trains, pourrait augmenter, plus qu'elle ne les diminuerait, les chances de déraillement. D'après les déclarations faites à la section, cette objection du rapporteur ne serait pas fondée au moins pour la voie à double champignon généralement usitée sur les lignes anglaises de grande vitesse, les objets tombés dans l'ornière du rail et du contre-rail descendant facilement au niveau du ballast.

" En ce qui concerne les points spéciaux de la voie, le rapporteur a signalé, — ce qui a pu être reconnu par nombre de membres de la 1re section et du Congrès dans les tournées déjà faites, — les conditions spécialement bonnes de l'Angleterre où l'on traverse à toute vitesse sans oscillation, sans choc, des gares immenses, encombrées d'appareils et de voies. Ce résultat satisfaisant peut être attribué à deux causes : l'une tenant à la constitution de la voie en rails à double champignon dissymétrique de fort poids, la seconde à une organisation spéciale de la fabrication des appareils.

" Sur la question du passage des ponts tournants, qui présente un grand intérêt pour

have been pointed out, — the addition of a guard rail, and the connection of two parallel roads.

" The guard rail placed along the inner rail increases the transverse rigidity of the line and protects the outer rail against the tendency to tilting.

" From the statements made by the English members while discussing the paper, whose truth we have been able to see for ourselves in our recent excursions, it appears that guard rails are extensively used on English lines to improve the running over curves. It may be added that we have also seen that the English road allows less play to the wheels than the continental lines.

" Mr. Sabouret objected to the use of guard rails that the groove between the rails, in which hard stones or objects fallen from the trains may become wedged, might increase rather than diminish the chances of derailment. Statements made to the Section show that this objection has no weight as regards the double-headed rail used on English lines, as the objects that get between the rail and the guard rail have very little chance of being wedged, but fall through to the ballast.

" As regards the special points of the permanent way, the reporter has remarked that excellent results are obtained in England, where passing through large stations over a maze of crossings and points at full speed without shock is certainly one of the facts which struck the engineers belonging to the 1st Section of the Congress when travelling over English lines. These satisfactory results seem to be due to the construction of the permanent way itself, which is composed of heavy bull-headed rails, and the special organisation for the manufacture of the crossings and similar appliances.

" As regards swing bridges, which are of special interest to such countries as Belgium, certains pays, la Belgique notamment, le rapporteur n'a pu malheureusement obtenir des renseignements bien précis et complets.

" Au cours de la discussion, il a été signalé qu'en Amérique les ponts tournants sont construits de telle façon qu'il ne serait pas nécessaire de réduire la vitesse des trains à leur passage, mais on la réduit tout de même en pratique. En outre d'appareils d'enclenchement, on dispose souvent une voie de sécurité. Lorsque le pont est ouvert, celle-ci dirige le train sur une couche épaisse de sable fin où il amortit sa vitesse. Il y a lieu de penser que la voie de sécurité a surtout un effet moral sur les mécaniciens et chauffeurs qui peuvent conserver quelques craintes sur les risques d'un déraillement même préparé à l'avance.

" En ce qui concerne les points spéciaux de la circulation, passages à niveau, gares de passage, stations, embranchements, il s'agirait moins d'adopter des dispositions spéciales pour la constitution de la voie, que d'obtenir la réforme de règlements administratifs trop sévères dans certains pays du moins. Les exemples cités par Mr. Sabouret et divers membres de la section permettront peut-être aux ingénieurs intéressés d'obtenir le résultat qu'ils désirent.

" Les conclusions du rapport de Mr. Sabouret, légèrement modifiées par le rapporteur en vue de tenir compte des renseignements supplémentaires recueillis, soit au cours de tournées, soit lors de la discussion, ont été adoptées à l'unanimité par la section. "

the reporter was unfortunately not able to get together any definite or complete information.

" In America, we were told in the Section that the swing bridges are constructed so as to enable the trains to pass over them at full speed; but it appears that in practice they do slacken speed. These bridges are fitted with plungers and interlocking apparatus, but it is deemed expedient to place a « derailer » on the line at some distance from the bridge, with which it is connected and interlocked. If the bridge be open the point of the derailer is set in such a position that any train coming towards the bridge would run on to the ballast, which in those places is thick and sandy, so as to quickly check the speed. There is reason to think that the derailing switch has a good moral effect on the driver and fireman who know that they must run off the road if they pass their signals at danger.

" As regards special traffic points, such as level crossings, double and single line stations, private sidings, it is admitted that the question is rather of an administrative than of a technical character. No special arrangements need be adopted, but the too rigid regulations and laws in force in some countries might with advantage be mitigated. The examples mentioned by Mr. Sabouret and other members of the section will perhaps help the engineers concerned to effect the result they desire.

" The conclusions drafted by the reporter, slightly modified to allow for further information obtained either during the discussions or on the excursions, have been unanimously adopted by the section. "

CONCLUSIONS.

" Les pentes et les courbes exceptionnelles, " quand elles sont franchies sans ralentissement, ne reçoivent pas, en général, de renforcement spécial. Toutefois, en Angleterre,

" Gradients and exceptional curves, where " they are run over without slackening, are " not specially strengthened. In England, " however, there is frequently added a guard

" on ajoute fréquemment un contre-rail à la " file intérieure des courbes très raides.

"La plupart des Administrations, en Angleterre et en France principalement, acceptent " le passage en vitesse des trains rapides aux " appareils de voie, aux passages à niveau, " aux embranchements particuliers et aux " stations en double voie, sans recourir à " d'autres procédés que ceux qu'on emploie " avec les trains ordinaires.

" La traversée sans ralentissement des " stations en voie unique est admise sur un " assez grand nombre de lignes : les solu-" tions très variées qui sont adoptées dans ce " but dépendent essentiellement des règle-" ments d'exploitation propres à chaque " Administration et on trouve, pour les mettre " en application, de nombreuses dispositions " techniques également satisfaisantes.

" Le passage en vitesse sur les ponts tour-" nants est accepté par quelques Administra-" tions. "

" rail on the inner side of very sharp curves.

" Most Administrations, chiefly in France " and England, allow express trains to pass " points and crossings, road crossings, pri-" vate sidings, and double-line stations at " full speed, without recourse to other means " than those which are used for ordinary " traffic.

" Passing through single-line stations " without slackening is allowed on a fairly " large number of lines; very various me-" thods are adopted; the matter is one " mainly of traffic regulation which each " Administration must settle for itself and " as far as the mechanical and engineering " appliances required to carry out the system " in force there are many, all equally satis-" factory.

" Some Administrations allow trains to " pass over swing-bridges at full speed. "

— These conclusions were adopted by the General Meeting without discussion.

1st SECTION. — WAY AND WORKS

QUESTION III

JUNCTIONS

Best method of constructing junctions upon express lines so as absolutely to avoid slackening speed.

Best arrangements of points and crossings.

The most efficacious means of maintaining the speed of trains while abandoning super-elevation at junction-curves.

Reporter, Mr. Zanotta, Divisional Engineer, Mediterranean Railway of Italy, Milan.

QUESTION III

CONTENTS

REPORT

By M. A. ZANOTTA

ENGINEER, CHIEF PERMANENT WAY INSPECTOR OF THE MEDITERRANEAN RAILWAY, MILAN, ITALY

General considerations.

The ever increasing demands of the public, with regard to the rapidity of transport, and the difficulties of every kind which are opposed to an increase of the maximum speed of express trains, above the limit dependent upon the conditions of the line, and rolling stock, compel Railway Companies to study the best means of avoiding, as far as possible, slackening the speed of these trains at special points on the line, in order to increase their mean speed.

Among these special points, junctions, over which express trains are very often not allowed to run at full speed, ought to be taken into consideration.

On a system with few junctions, and with small traffic the loss of time due to this slackening is only of limited importance. But on a more crowded system where the junctions are more numerous, greater difficulty is experienced in working if they cannot be run over at full speed.

However, the slackening, such as the regulations on most systems prescribe, is not always observed by the engine-driver, especially in cases of delay, or when the junction is on a down gradient. It may be that the engine-driver benefits from the surplus of time which is allowed him, in view of the slackening at the junction, to slightly reduce the speed on a long run or at any special point, other than the junction. It is true that some Administrations control the slackening at junctions by special appliances such as speed-gauges (dromoscopes, dromopétards), etc., but the majority of Administrations have not these means of control.

*

It is therefore not only to increase the mean speed of express trains, but also as a measure of safety, that it would be of the greatest importance to construct junctions of such a kind that they may be run over in every direction at full speed.

The question, moreover, is not new to the Congress.

Question VII, B, submitted to the first session of Congress, in 1885, was expressed in this manner ;

« The most suitable arrangements and appliances to ensure the safety of running « in stations, at junctions, and over crossings. »

The conclusions which the Congress adopted on this subject were the following :

« It is desirable that the junctions should as far as possible, be in the stations « themselves. »

« When it is decided to place them between stations, it is necessary, as far as « possible, to avoid laying them in a cutting, on a sharp curve or gradient, to « endeavour to bring into use flying junctions, to lay out the converging lines « parallel to one another for a certain length, etc. In every case it is advisable to « provide the junction points with bolts and interlocking systems which enable « them to be run over at full speed if necessary. »

The general conditions most favourable for laying down junctions are indicated in these conclusions, especially in relation to their site, and the measures it is necessary to adopt to avoid any collision. The question of the protection of junctions was also discussed at the fourth session of Congress with regard to the question of the block and interlocking systems. (Article XVI. B.)

These points of the question will therefore not be reconsidered ; it is sufficient to observe that according to the information which various Administrations have supplied, many of the arrangements, described in the conclusions recalled above, are usually found applied to junctions run over by express trains.

Thus, for example, the bolting of the points, and the interlocking of the points with the signals are employed, it may be said, at all the junctions in question.

On some railways, in England for instance, the interlocking appliances are supplemented by the block system, and by strict local instructions which protect the trains against all danger of collision at the junctions.

There are cases where the branch line of the junctions, being on a sharp gradient, is provided with a safety road into which a train over-running its signal would be turned, instead of fouling the main line.

Other Administrations have sometimes adopted more radical means for avoiding collisions between trains, as pointed out by the first session of Congress, by replacing level crossings of junctions by the use of flying junctions.

Among these Administrations may be mentioned the Western of France, which made, in 1839, such an arrangement at Saint-Cloud (branch from the Fêtes Station); the Northern of France, which has brought them into use at many junctions, notably at the Épinay junction (lines from Paris to Pontoise and from Épinay to Monsoult), and at the Mennessis junction (lines from Creil to Saint-Quentin and from Amiens to Tergnier, etc.

Figure 1 represents the arrangement which has been planned by the Italian

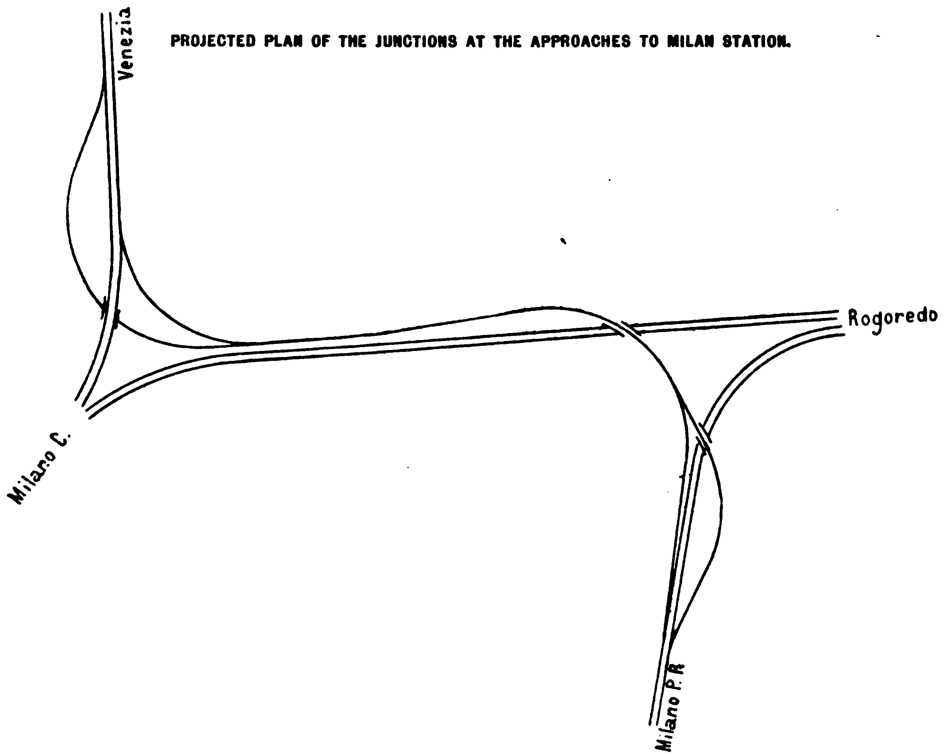


Fig. 1.

Administration of the Mediterranean lines, with a view to entirely avoiding the obtuse crossings of several junctions at the approaches to Milan station.

More stress need not be laid on this part of the subject but an examination will be made of the difficulties concerning the design, construction and laying down of a junction suitable for being run over at high speeds, difficulties which have only been submitted to a very summary investigation, in the preceding sessions of Congress, and which form the subject of this question.

Before passing to an investigation, however, it will not be useless to consider briefly the rules which regulate the running over junctions on some systems.

In order to get information on this subject, and on the modes of laying down junctions run over at high speed a detailed questionnaire (annexed) has been sent by means of the International Commission to several of the Compagnies affiliated to the Congress.

About thirty of the Companies have had the kindness to reply, and the reporter takes this opportunity of thanking them asmuch in the name of the International Commission as in his own.

The following are drawn from their replies, relative to the maximum speeds allowed for trains running over junctions :

Austria. — A Government order exists, according to which every train approaching facing points should reduce its speed to 31 or 18 1/2 miles (50 or 30 kilometres) an hour, dependent upon whether the points are plunged or not.

The limit of 31 miles (50 kilometres) is therefore not surpassed by any of the Austrian Companies who have responded to the questionnaire, and some Companies, such as the Austro-Hungarian State Railway Company do not exceed the limit of 18 1/2 miles (30 kilometres).

With regard to trains approaching trailing points some Administrations, such as the above mentioned State Railway Company, the South Austrian Railway Company, and the North Western administration do not prescribe, on any junctions, a reduction of speed on the main line, which is always straight; other Administrations on the contrary prescribe a limitation of speed for trains even on the main line; on the Northern system (Kaiser Ferdinand), for example, the speed of these trains is not allowed to exceed 37 miles (60 kilometres) an hour.

Further, an appreciable reduction of speed is compulsory for all trains running over the curved branch.

Belgium. — The State Railway has no junctions passed over at full speed. It is announced as very probable that, in the near future, trailing points will be run over at full speed; but at present the trains which approach trailing points, as also those approaching facing points, should not exceed the speed of 37 miles (60 kilometres) an hour on the main line of the junction (being straight or having a large radius), whilst on the diverging branch the greatest speed allowed is 25 miles (40 kilometres) an hour.

Denmark. — On the State system there are junctions run over, in every direction, even on a curve of 15 1/2 chains radius (315 metres), at a speed of 56 miles (90 kilometres) an hour.

France. — The Eastern and Northern Railway Companies, amongst the Administration who have responded to the questionnaire, are the only ones who allow trains to pass over their junctions on the main line at full speed. On the Eastern system, the maximum speed of the trains running over the main line is 56 miles (90 kilometres) an hour; on the Northern system the speed is fixed by the working time-table; and the engine-drivers are not permitted, when approaching à junction, to make use of the discretion which is allowed them on all other points of the system to increase their speed by half if behind time.

On the curved branch the speed is limited both on the Eastern and on the Northern systems to 25 miles (40 kilométres) an hour.

The rule laid down for the running of trains over junctions is invariably the same on the branch lines for both directions.

The Northern Company however are proceeding on some of the most important junctions of their system with the straightening of lines or the erection of necessary signals, to allow them to bring into force a new regulation, by which the running of trains at full speed will be permitted, in every direction, over these junctions. It is understood that this improvement will be realised in the course of the year (1894).

On the Midi system the engine-drivers of the trains on the main line at junctions must reduce their speed in such a manner that their trains can be brought to a stand-still before reaching the home signal of the junction, if circumstances demand it. Trains going to or returning from the branch line must always stop before reaching the junction points.

On the Paris-Lyons-Mediterranean system only the main line of the junction is run over at a maximum speed of 25 miles (40 kilometres) an hour; the branch lines are run over at a speed of 12 1/2 miles (20 kilometres) an hour.

The regulations of the Paris and Orleans Company limit the speed of passenger trains running over junctions to 18 1/2 miles (30 kilometres) an hour.

United Kingdom of Great Britain and Ireland and its Colonies. — On many of the systems the regulations for passing over some of the junctions do not impose any limitation of the speed of the trains in whatever direction they are running.

The Great Eastern, London and South Western, Manchester, Sheffield and Lincolnshire, Lancashire and Yorkshire, Caledonian, North Eastern, and London and North Western Railway Companies, for example, are in this position.

However, these same Companies generally limit the speed of trains on branch lines with curves of small radii. Thus, for example, on the Great Eastern Railway, the speed of the trains is limited to 15 miles (24 kilometres) an hour on branch lines having curves of 10 chains (201 metres) radius; on the London and South Western Railway the speed permitted on branch lines having sharp curves in 25 miles (40 kilometres) an hour; on the North Eastern Railway junctions having a radius of 15 chains (301 metres) are run over at a maximum speed of 30 miles (48 kilometres) an hour.

The London Brighton and South Coast Railway permits junctions to be run over at full speed in every direction, but the maximum speed is only 30 to 40 miles (48 to 64 kilometres) an hour. In the curves of junctions having a radius of 20 chains (402 metres) the maximum speed is 30 miles (48 kilometres) an hour.

Some other Companies, although allowing trains to run over the straight line of the junctions at full speed, even when approaching facing points, order the speed of the trains running over the curved branch to be reduced.

Such are, for example, the Great Northern Railway, — on which system the branch line of the junctions is run over at a speed of 10 to 20 miles (16 to 32 kilometres) an hour, — the Glasgow and South Western Railway, — who allow the straight line to the junction to be run over at a speed of 60 miles (96 kilometres) an hour whether the points are taken in a facing or trailing direction, whilst the curved branch is only run over at a speed of 15 miles (24 kilometres) an hour, although the radius of the curve may be as great as 20 1/2 chains (412 metres), — the Midland Railway, the Great Western Railway, etc.

Finally some other Companies, such as the South Eastern Railway, stipulate that the engine-driver must reduce the speed of his train at junctions, especially on approaching facing points, in which case the speed is not to be greater than 15 miles (24 kilometres) an hour.

On the systems of the Great Indian Peninsula Railway and the East Indian Railway the speed of the trains running over junctions is also limited, especially when approaching facing points.

United States of America. — On the Pennsylvania Railroad system, there are junctions which are run over at full speed in every direction. The maximum speed is about 50 miles (80 kilometres) an hour.

Italy. — On the Adriatic system, some of the junctions are run over at full speed, that is to say at 43 1/2 miles (70 kilometres) an hour, either on the straight or curved branch, and even when approaching points.

On the Mediterranean system, on the contrary, the regulations stipulate a slackening of speed for trains approaching every junction.

Holland. — On the Dutch Railway, the running over a junction at full speed is only allowed for trains passing over trailing points and running over the straight line of a non-symmetrical junction or the two curved branches of a symmetrical junction. The speed when passing over facing points should not exceed 28 miles (45 kilometres) an hour.

Portugal. — On the Portuguese Railways, trains running over junctions have not, in any case, a higher speed than 28 miles (45 kilometres) an hour.

Spain. — On the Madrid-Saragossa-Alicante, none of the junctions are run over at full speed by express trains.

Switzerland. — On the Gothard Railway there is only one junction leading to the Company's ballast pit. The switch used is that known as the « Blauel » apparatus.

The trains on the main line which, by the used of this switch, is not interrupted, have a maximum speed of 37 milles (60 kilometres) an hour.

It appears from the above that there is a great variety of regulations as to the speed of trains running over junctions; some Companies approve of the junctions being run over at full speed in every direction, without regard either to the curve of the diverging branch or as to the points or crossings; other Companies are not concerned about the crossings and facing points but consider it necessary to reduce speed on the curved line; others again see no danger in running over junctions at full speed except in the case of facing points and curved branches; finally, other Companies seem to think it necessary to reduce speed for all trains running over a junction in whatever direction it is approached.

It is very probable that some Administrations may have decided to limit the speed with a view to avoiding collisions rather than in consideration of the weak points such as switches, crossings and sharp curves referred to.

The slackening would then be necessitated so as to render the engine-driver absolutely master of his train and to enable him, consequently, to stop promptly if circumstances demanded it.

But the danger of collisions can be removed by the adoption of the arrangements which have been mentioned above. It will then only be necessary to consider the weak points of the junction properly so called, that is to say the switches, crossings and junction curves, under the three heads of design, construction and laying down.

Design.

Different arrangements of junctions. — There are three cases in the ordinary junction :

1° Where both branches of the junction are single line;

2° Where one is single and the other double;

3° Where both branches are double line.

The last case comprises, in relation to the design, all the difficulties which are encountered in the first, in addition to the difficulties which are peculiar to itself; the second case can generally be treated as the last, because the single line is, as a rule, doubled near the junction and then the same arrangements are employed as in the third case, as is indicated by the replies received (fig. 2).

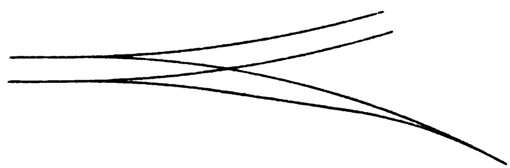


Fig. 2.

There are examples in which this arrangement is not followed; then in order to avoid the obtuse crossings the arrangement represented by figure 3 is adopted.

The Austro-Hungarian State Railway Company has adopted the arrangement shewn in figure 4 by which the facing points are avoided on the main double line.

Some other Administrations such as those of the Dutch, the Northern of France, the Pennsylvania, and the East Indian Railways, of those who have responded to the questionnaire, have sometimes adopted the arrangement shewn in figure 5.

But in all the arrangements shewn in figures 3, 4 and 5, the single line is always sacrificed; no Administration admits that it can be run over at full speed, except the Administration of the Southern Italian Railways, who allow their trains to run, even on the diverging branch of a junction arranged as in figure 3, at a speed of 43 1/2 miles (70 kilometres) an hour, and the Pennsylvania Railroad who allow their trains to run at full speed on the single line of the junction shewn in figure 5.

But at all events amongst the arrangements represented in figures 2, 3, 4 and 5, that of figure 2 appears to be the best arrangement for allowing trains to run at high speed even on the branch line.

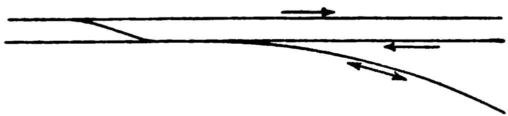


Fig. 3.

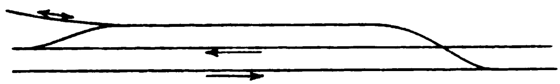


Fig. 4.

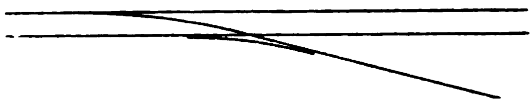


Fig. 5.

It will be sufficient then to consider the case of junctions of two double lines.

The arrangement most generally adopted for junctions of two double lines is that which has one of the branches in a straight line or on a curve of large radius; more rarely the symmetrical arrangement has been brought into use.

Junctions having one branch in a straight line. — In commencing then with the most general case it is evident that the design of the curved line depends upon the angles of the acute and obtuse crossings, on the gauge, and on the intermediate space between the two lines of the same road.

Let it be supposed, for the sake of simplicity that the branch diverging from the switches O (fig. 6) to the obtuse crossing B, is on a curve of a constant radius R, then the following relations exist between this radius and the angles A and B :

$$\sin^2 \frac{A}{2} = \frac{l}{2R} \qquad (a)$$

$$\sin^2 \frac{B}{2} = \frac{l + d}{2R} \qquad (b)$$

in which l is the gauge, and d the interval between the two lines of the same road.

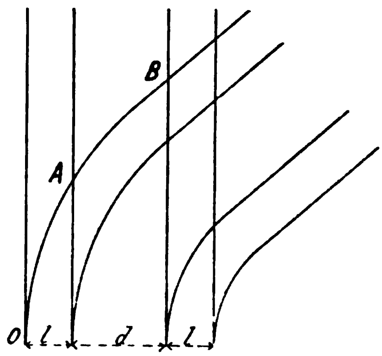


Fig. 6.

In order to have R as large as possible it is naturally necessary that A and B should be as small as possible.

To what limit can these angles be reduced?

Angle of the obtuse crossings. — The obtuse crossing B is limited by the fact that the flatter it is the greater will be the length of the gap between the nose and the knuckle, and if this angle descends below a certain limited value the wheel passing over the gap would be derailed. This wheel is in fact prevented from going out of its direction by the conjunct wheel (wheel on the same axle) which is guided by the guard rail of the crossing over which it is passing; but if the angle is too flat it may happen that this conjunct wheel ceases to be guided by the guard rail before the other wheel has arrived at the second nose of the crossing.

M. Schmid, in an article of Dr V. Roll's Encyclopædia (vol. V, p. 2166) finds that this limiting angle is about 9° for a crossing having the guard rail at the same level as the running rail. It is known, however, that with the object of being able to reduce this angle, a super-elevated guard rail has been used, for the purpose of prolonging the guidance of the wheel conjunct to that which is approaching towards the nose.

The same author has found for a super-elevation of 2 inches (50 millimetres) — a superelevation which is rarely surpassed on account of the clearance required for the rolling stock — that if the angle of the crossing was less than 7° 4', of which the tangent is about 1 to 8, there would be a certain length in the crossing where the wheel would be without guidance.

For the determination of these results, it has been supposed that the gauge is 4 feet 8 1/2 inches (1^m435), that the distance between the mathematical point of the crossing and the wing rail is 1.8 inches (45 millimetres), and between the actual point and the same wing rail 2 inches (49 millimetres); that 1 foot 8 inches (500 millimetres) is the radius of the wheel to be guided, and 0.4 inch (10 millimetres) the thickness of the actual point which has, moreover, been supposed to be at the same level as the bearing rail.

However these conditions and the results which are derived from them are not strictly valid for all systems.

It may be added that the theoretical condition, generally admitted in these investigations, that the axle is constantly at right angles to the axis of the line may sometimes not hold good, especially when there is not a certain length of straight at the crossing, or indeed when this condition being fulfilled, the axle considered has not a rigid connection with the next one or forms part of a truck with a very short wheel base.

The above result indicates nothing absolute; but it serves to give an approximate idea of the minimum angle of the obtuse crossing.

In fact nearly all the Administrations who have replied to the questionnaire employ obtuse crossings of which the tangents are equal to or higher than 1 to 8.

In France however, on the Northern system, obtuse crossings are employed of which the tangent is 1 to 9, with the guard rail super-elevated 2.4 inches (60 millimetres).

As will be seen the angle is a little less than that of 1 to 8 indicated above; but, on the other hand, the super-elevation of the guard rail is a little higher than that of 2 inches (50 millimetres) taken by M. Schmid.

On the Midi of France system, a crossing with an angle of 1 to 9 is about to be adopted with a guard rail super-elevated 2.2 inches (57 millimetres), which will then be in nearly the same conditions as those on the Northern.

The Western of France use crossings of which the tangent is 1 to 10.4, the guard rail having a super-elevation of 2.8 inches (70 millimetres).

The Lancashire and Yorkshire Railway which, as stated previously, permits junctions to be passed over at full speed in every direction, uses diamond crossings of which the tangent is as small as 1 to 10, and the guard rail is not super-elevated.

This signifies that practically, if the crossing is well laid down, it can be run over without danger even when its angle is below the usual limit and when the guard rail has no super-elevation.

The inertia of movement then enters into play and tends to maintain the travelling of the wheel in the initial direction; from this point of view, an increase of speed, which reduces the time during which any disturbing force can throw the wheel out of its direction, would be favourable to safety, as has already been observed by Sir H. Findlay in his *Report relative to the question of the lines for express trains* (*Bulletin du Congrès 1892*, p. 3031) (1), provided naturally that the conditions of the appliances be such that the train can travel smoothly over the crossing.

It is no less true however that if, by chance, any disturbing force whatsoever, a sudden application of the brakes for instance, should cause an oscillation, or a blow to the wheel, whilst it is running over this part of the crossing, where it is not guided, a derailment would very likely occur.

With the object of avoiding, or at least of lessening this danger, the adoption of a super-elevated guard rail and of an angle sufficiently open in order that the guidance of the wheel is not deficient, seems then to be very advisable.

The influence of the value of the angle upon the probability of derailments is shewn by the evidence of the table of derailments made for a period of four years on the system of the London and North Western Railway, which is inserted in the report of Sir H. Findlay above mentioned.

The relations between the number of derailments in the period indicated and the number of the crossings may be deduced as follows :

Number of obtuse crossings having the inclination of . .	**1/4**	**1/5**	**1/6**	**1/7**	**1/8**	**1/9**	**1/10**	**1/11**
Relation between the number of derailments and the number of the crossings	»	0.033	0.086	0:166	0.397	0.507	0.650	2.50

It will be seen, that the flatter the angle of the crossing is, the more numerous are these derailments.

(1) See also the *Compte rendu* of the fourth session, 1st vol., question VI.

Conclusion : it can therefore be affirmed that, from the results of calculation and from the rules practically followed by most of the Administrations, it is advisable not to adopt an angle appreciably less than 7°, or, what amounts to the same thing, an inclination less than 1 to 8.

Angle of the ordinary acute crossings. — With regard to the ordinary acute crossings values much lower than those indicated above for the obtuse crossings can be used without inconvenience.

Theoretically it may even be said that there is no limit for the angle of ordinary crossings, because however low it may be, the wheel passing over the gap of the crossing is continuously guided by its conjunct wheel, which can only be displaced to such an extent as the guard rail, always placed at the side of the rail carrying this wheel, permits it.

However, in practice it is impossible to descend below a certain value; the less the angle of the crossing is, the longer is the gap, which is always a weak point of the appliance, and the more accentuated becomes the action of shearing exerted by the tire of the wheel which, leaving the point, is carried on the wing rail.

A very low angle carries with it, further, the necessity of thinning the nose down excessively, which may then become too weak and bend or even break under the action of the lateral pressures and the shocks caused by the wheels. It is quite true that the guard rail should eliminate these pressures and shocks, but small alterations in the gauge of the line or wheels, little displacements of the guard rail, the wear of the tires and fixed pieces, etc., can though possibly only exceptionally, combine in such a manner that the wheel may strike the nose of the crossing.

It may be added that a very thin nose is not always easy to construct, especially if the crossing is made of steel in a single piece.

A very low angle of the common crossing would, further, increase excessively the length of the switch. With regard to this inconvenience certain special cases may be taken, such as junctions between stations. But in this case, at least when it is a question of a junction of two double lines, the minimum angle of the common crossing depends to a certain extent on the minimum angle of the obtuse crossing.

Thus, for example, if it is supposed that the angle B of the obtuse crossing (fig. 6) is 7° 7′ 3″ corresponding to the tangent 1 to 8, and if in the formulas (*a*) and (*b*) :

l = 4 feet 9 inches (1^m445) d = 6 feet 11 1/2 inches (2^m12),

which values are most frequently adopted, the following result is obtained :

A = 4°32′   tang. A = 0.08 (1 : 12.5).

Any lower angle than 4° 32′ would have the advantage of increasing the radius of the curve behind the switch, but would also have the inconvenience of lessening the radius of the curve between the ordinary crossing and the obtuse crossing.

This inclination of 0.80 = 1 to 12.5may, moreover, be considered as the minimum inclination actually adopted by the Administrations who have replied to the Questionnaire.

The Companies of the United Kingdom generally make use of angles greater than that of 0.08 (1 to 12.5). There are very few exceptions amongst those who have replied; thus, the Lancashire and Yorkshire Railway employ crossings of which the inclination is as low as 0.077 (1 to 13); on the London and Western Railway the minimum angle of the crossings is 0.067 (1 to 15); and the Great Northern Railway even have crossings of which the inclination is only 1 to 25, but this last inclination would probably only be found in entirely special cases.

In the United States, on the system of the Pennsylvania Railroad Company, the minimum angle of the crossings is 3° 49′, corresponding to a tangent of 0.067 (1 to 15).

But, with the exception of these cases, the value of the angle of the crossing is never lower than 0.80 (1 to 12.5), at least not in the junctions under consideration.

In Austria, for example, on the State Railway Company's system and on the Southern system, the minimum inclination is 0.085 (1 to 12), whilst on the North Western it is 0.095 (1 to 10.5).

On the system of the Belgian State Railways, it is 0.08 (1 to 12.5); on the Danish State system 0.083 (1 to 12).

In France, on the Northern, Paris-Lyons-Mediterraneaan and Midi 0.09 (1 to 11), on the Eastern 0.096 (1 to 10.4), on the Western 0.083 (1 to 12).

In Holland, on the Dutch Railway 0.10 (1 to 10), in Italy 0.09 (1 to 11), etc.

It may then be concluded that, with a few exceptions, the inclination of 0.08 (1 to 12.5) is the minimum one generally adopted for the acute crossings of junctions.

Design of the two branches of the crossings. — Another consideration relative to the design of the crossings remains to be considered.

In the non-symmetrical junction, which will be taken first, the diverging branch of the obtuse and acute crossings is sometimes laid down on a continuous curve, according to the theoretical design considered in figure 6.

At other times, on the contrary, short lengths of straight are introduced in the curve of the diverging line to the right of the crossings in order that the two legs of the crossings may be laid down in a straight line.

The second of these arrangements is that most usually adopted; it is necessary in the case where the crossings are made of steel cast in a single piece, and many Administrations think it is also usuful where the crossings are formed of rails, in order to avoid the danger of the wheel taking a false direction when passing over the gap of the crossings, a danger which is especially formidable in the curved setting out, because it is difficult and sometimes even impossible, in this case, to lay down the crossings with the super-elevation of the exterior rail.

The Northern and Eastern of France, for example, as well as many English Companies, always place the constituent parts of their crossings formed of rails in a straight line.

There are, however, some Companies who prefer to set out the diverging line in a continuous curve, even in the crossings.

Many English Companies and the Belgian State Administration, amongst others, follow this rule.

In the reply to question 16 (see appendix), the Belgian State Administration shows what it does in this matter; the acute or obtuse crossing is constructed straight and placed tangentially to the curve, but, in the course of laying it down, the legs on the diverging line are bent in such a manner as to obtain, as nearly as possible, a uniform curve.

Intervening rails. — The angles of the crossings being settled the radii of the connecting curves are then determined.

If, for example, in returning to the theoretical design of figure 6, it is supposed that an obtuse crossing having an angle of 7° 7′ 30″, of which the tangent is 1 to 8, is employed at B and if the following values are used in the formula (*b*).

l = 4 feet 9 inches (1^m445) $\qquad$ d = 6 feet 11 1/2 inches (2^m12)

then

$$R = 23 \text{ chains } (461^m66).$$

This is a radius which is very rarely exceeded for the non-symmetrical junctions under consideration. Sometimes however by the use of very acute crossings and by the adoption of widened intermediate spaces between the lines, greater curves may be obtained.

On the London and North Western Railway, for example, there are junctions where no curve is less than 30 chains (602 metres) in radius.

But the radius of the theoretical continuous curves would be reduced, if the crossings were set out with straight lengths.

This reduction which depends on the lengths of the straight portions which are inserted in the curve, is commonly very remarkable, the normal gauge and width of the interval between the lines of way being relatively small.

If, for example, it is desired to leave on either side of the crossings a straight portion 9 feet 10 inches (3 metres) in length, and if the acute crossing be taken under an angle of 4° 34′ 30″ (tangent 0.08) and the straight switch 19 feet 8 inches (6 metres) long, has a clearance of 4.33 inches (11 centimetres) at the heel, the intervening rails between the heel of the switch and the crossing can only be set out with a radius of about 18 chains (360 metres).

But even this radius of 18 chains (360 metres) cannot be attained for the intervening rails between the acute and obtuse crossings if the interval between the lines of way of the same road at the junction is within the limits ordinarily adopted.

In fact, if an obtuse crossing having an angle of 7° 7′ 30″ (tangent 0.125) is used, and if a straight portion 9 feet 10 inches (3 meters) in length on each side of the acute and obtuse crossings is always maintained, the width of the interval between the two lines of way of the same road necessary in order that the intervening rails indicated above can be set out with a radius of 18 chains (360 metres) is 9 feet 5 1/4 inches (2m88) at least, whilst practically the width of this interval is generally between 6 feet 6 3/4 inches (2 metres) and 8 feet 2 1/2 inches (2m50).

If it is desired to keep within these limits without reducing the angles of the crossings, it would be necessary to be content with sharper radii for the intervening rails, or with straight portions having a length so limited, that it would not only be worthless to employ them but it would be more useful to adopt a setting out in a continuous curve.

This will explain the reason why some Administrations, whilst using acute and obtuse crossings approaching in value the angles indicated above, have in their non-symmetrical junctions the intervening rails set out with a radius of only 15 chains (300 metres) and in some cases still less.

Switches. — There is an even more dangerous point in the design of junctions than in the curved intervening rails of small radius.

For the diverging switch the theoretical design of fig. 6 cannot be followed, even when using the curved switch, because of the limited length of the switch and of the necessity of preserving sufficient clearance at the heel of the switch for the free passage of the wheels on the stock rail.

The length of the switch should not exceed as a rule 19.68 feet (6 metres) and the clearance at the heel being generally more than 4.33 inches (11 centimetres), the radius of the curvature of the switch would be normally less than

$$\frac{(19.68)^2}{2 \times \frac{4.33}{12}} = 8 \text{ chains (163 meters).}$$

But the curved switch, the use of which is common enough in Germany, is not employed by the Administrations who have replied to the questionnaire, with the exception of those of the Southern of Austria, the New South Wales Government. and the Portuguese Railways.

The necessity of multiplying the number of switch types, and the facility with which the curvature of the switches can be modified during manipulation, or by atmospherical variations, are perhaps the principal reasons which have prevented the general use of curved switches.

In employing the straight switch, there is at the point an angle of deviation, which, for the values indicated above of the clearance at the heel and the length of the switch, would have a tangent

$$\frac{\frac{4.33}{12}}{19.68} = 0.0183.$$

In spite of the adoption of very acute crossings, by which curves of sufficiently large radii are obtained for the intervening rails, it is impossible to avoid in the design of the diverging line this weak feature of the switch; the existence of this is equivalent to the insertion of a small curve having a radius of 8 chains (163 metres) at the most, or to a sharp deviation at the point of the switch of which the effect would be still more dangerous than that of a curve of small radius.

It is perfectly true that some Administrations exceed, in the length of their switches, the length above indicated of 19.68 feet (6 metres). The Belgian State, for example, at the junctions of International lines, has adopted a switch 23.78 feet (7^m25) long. It is necessary however to add that the head of the rail of a special section, constituting the switch, has like the stock rail a width of 2.83 inches (72 millimetres) and that consequently the clearance at the heel is necessarily more than 4.33 inches (110 milimetres); it is as a matter of fact 4.803 inches (122 milimetres).

Another example may be cited, namely, that of the Glasgow and South Western Railway, type 1894 (annexed, fig. 69), which is 30 feet (9^m14) long.

But these are the exceptions, because most of the Administrations employ switches the length of which does not exceed the limit of 19.68 feet (6 metres) indicated, for the purpose, probably, of not causing the working of the switches to be too hard, and of not increasing excessively the length of that portion of the switch lying between the heel and the point where it commences to lean against the stock rail, as an excessive length of this portion would give place to dangerous flexures.

Speed attainable in relation to the design : In these conditions, can the slackening of the speed of express trains which run over the curved branch of a junction, the other arm of the junction being in a straight line, be dispensed with?

A curve of a radius of 22 1/2 chains (450 metres) is already made, by many Administrations, a reason for a limitation of speed, even if it is on the running line and when consequently all the super-elevation necessary can be applied, which is not always able to be done on the curves of junctions.

If the necessity of reducing this radius sensibly is added, when it is desired that the legs of the crossings shall be in a straight line, and also the still more serious circumstance of the sharp divergence at the point of the switch, it will be understood why most Administrations have found it until now prudent, if not necessary, to prescribe a reduction of the speed when passing over the diverging line of junctions having the other line straight.

This measure of safety has been adopted by some Administrations whose junctions possess curves which may be classed amongst the least sharp.

The Belgian State and the Glasgow and South Western Railways may be cited as an example, who have respectively at a few of their junctions curves of 22 1/2 chains (450 metres) and 20 1/2 chains (412 metres) radius and very long switches.

However, there are also, as has already been seen, Administrations who, although having curves of very low radii at their junctions, allow them to be passed over at full speed in every direction.

That of the Danish State Railway, for example, who allow junctions to be passed over with a speed of 56 miles (90 kilometres) an hour on curves of 15 1/2 chains (315 metres) radius and without super-elevation, is in this position.

From the replies of the English Companies, who do not limit the speed of trains passing over the curves of junctions, the Reporter has not always been able to discover the radii of these curves; but judging from the angles of the crossings he is led to believe that these radii are somewhat limited.

On the Italian Adriatic Railways a speed of 43 1/2 miles (70 kilometres) an hour is allowed on curved branches which at some points have a radius lower than 10 chains (200 metres).

It would appear then that with a rolling stock suitable for passing over very sharp curves, with special care in the laying down and in the maintenance of the appliances of the junction, and eventually by particular arrangements made with a view to strengthen the line in the curves without super-elevation, arrangements which will be noticed later, the speed of the trains can be maintained in every direction of the junctions, in spite of the difficulties of the design.

The possibility of running over very sharp curves, even without super-elevation at very considerable speeds, has besides been substantiated by the experiences at Noisy, which formed a subject of discussion during the fourth session of Congress.

Notwithstanding this being proved, it ought however to be repeated that up to the present most Administrations prescribe the slackening of the speed of trains on the diverging line.

Symmetrical Junctions. — If the two lines of the junction run over by express trains are of equal importance, it appears advantageous to employ the symmetrical junction, by which the two lines would divide between them the difficulties of the divergence and would also be in equal conditions even in relation to the design.

If the limiting angle of the acute crossings, having a tangent of 0.08, and the limiting angle of the obtuse crossings, having a tangent of 0.125, be maintained a theoretical design would be arrived at of which the two branches of the junction would have radii of about 44 1/2 chains (900 metres).

But it would be impossible even in this case to realise the theoretical design to the right of the switches.

For a curved switch, having a length of 19.68 feet (6 metres) and a clearance of 4.33 inches (11 centimetres) at the heel the radius of curvature of the switch could not be greater than 16 chains (327 metres); in adopting a straight switch, as is the usual custom, a sharp divergence would be encountered at the point, of which the effect would be still more disadvantageous than that of the small curve of 16 chains (327 metres) radius. Both lines would suffer this inconvenience, the improvement that could be given to the design of one branch by the symmetrical arrangement being to the detriment of the design of the other branch.

It is for this reason that many Administrations prefer to sacrifice one of the two lines in order that a completely correct design may be adopted for the other.

But when it is desired to allow both branches of the junction to be run over at full speed, it appears that the symmetrical design is the preferable one.

It is on symmetrical junctions where a curve of a lower radius than 30 chains (600 metres) does not exist, that the Northern of France Railway is about to allow trains to pass over in every direction at full speed, and further that the Administration of the Dutch Railway allows the two branchs of symmetrical junctions to be passed over at full speed by trains approaching trailling points, whilst it prescribes the slackening of speed of trains running over the curved branch of a non-symmetrical junction even when they approach trailing points.

Construction.

Without entering into all the details of the construction of the different parts of a junction, that is to say the switches, crossings and intervening rails, the Reporter proposes to consider a few of those, which appear to be the most important from the standpoint of the safety of express speeds.

Switches. — With regard to the switches, beyond their length and their straight or curved form which have been already noticed, their profile ought to be taken into consideration, on which depends :

1° The possibility of leaving the stock rail of the switch intact, or the necessity of enfeebling the section of this rail by planing the tables;

2° The possibility of giving a sufficient rigidity to the switch in order that it may resist the vertical and lateral forces transmitted by the rolling loads;

3° The possibility of obtaining easily a good connection between the switch and the adjoining rail.

With regard to the switches formed of rails, it is generally objected that they are less advantageous than those formed of special bars in relation to the circumstances mentioned in Nos. 1 and 2; and on the other hand switches formed of bars are objected to on account of the difficulty of making a satisfactory connection with the adjoining rail.

It is necessary, however, to observe that the necessity of planing the stock rail only occurs when Vignoles rails are used; it ceases generally if bull-headed rails are used

With regard to the rigidity of the switch it is quite true that by the use of a suitably profiled bar a switch can be obtained having a greater resistance, than ordinary switches formed of rails, to lateral forces exerted by the wheels on that portion of the switch which is not in contact with the stock rail.

The inferiority of switches formed of rails in this regard is especially notable in the case where they are formed of bull-headed rails.

But this inconvenience with switches formed of rails can be remedied, at least partially, by means of studs ordinarily formed by the prolongation of the heads of the bolts fastening the stock rails to the chairs.

And moreover the greatest danger of the flexures, sustained by the switch under the action of the forces above mentioned, would consist in that they would tend to force open the necessarily very weak point of the switch; but this danger is overcome if the point is well secured to the stock rail by a plunging appliance, an appliance which facing points are generally supplied with.

With regard to the resistance to vertical forces, the switch can always be constructed in such a manner that the point is effaced, for a certain length, close its origin, under the stock rail, and does not commence to carry the load until it has acquired sufficient strength.

In fact, in spite of the inconveniences encountered in switches formed of rails, they are usually employed in England, where there are most junctions run over at full speed. In England, the line being ordinarily laid with bull-headed rails, the switches do not necessitate the inconvenience of planing the stock rail.

But other Administrations, the Eastern of France for instance, use switches formed of ordinary Vignoles rails even at junctions run over at full speed.

One of the reasons why a great number of Administrations prefer these switches to be formed of ordinary rails is doubtless the facility of re-uniting them to the adjoining rails.

This connection can be made in fact by chairs and tie-bolts of a very simple form and by fish plates having the ordinary profile.

The joint with switches formed of rails has also been made a suspended one as on some English Railways (fig. 7).

The connection of the switch to the adjoining rail is much more difficult when the switch is formed of a bar of special profile, especially if with a view to planing the switch and stock rail as little as possible, wide and shallow bars are used for the construction of the switches.

Nevertheless, the problem of obtaining a good connection, even with switches formed of bars, has been studied and solved in many ways more or less simple.

On the system of the Danish State Railway, for example, the switch is forged at the heel, of which the profile is then similar to that of a Vignoles rail having the same height as the normal rail (see fig. 43, appendix).

The rotation of the switch is made around a pivot lodging in a circular cavity situated at the base of the heel of the switch; the vertical movement of this heel is prevented by the prolongation of the fish-plates, bolted to the adjoining rail.

In Austria, the Administrations who have replied to the questionnaire, that is to say the State Railway Company, the North Western and the Southern Railways,

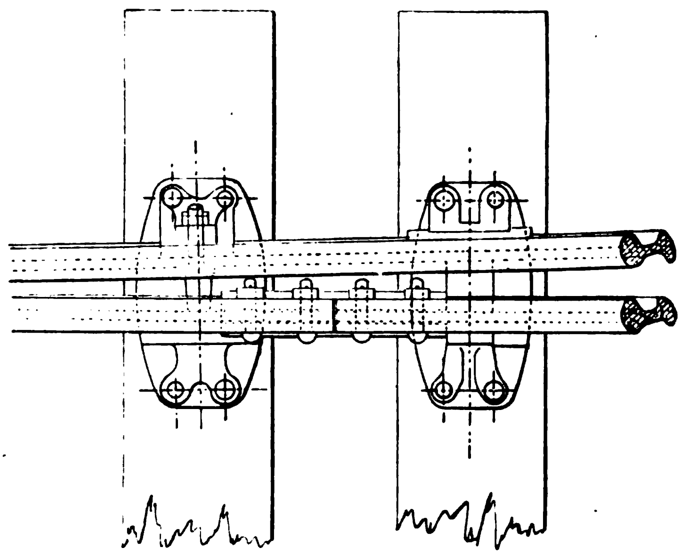


Fig. 7.

employ exclusively switches formed of bars shallower than the ordinary rail. In figure 14 (appendix) the profile of the switch used on the Austrian North Western Railway is shewn.

In Belgium, on the State system, switches formed of rails of a special profile are used, of which the form of the head and width of the bottom table are the same as in the normal rail, Goliath type weighing 105 lbs per yard (52 kilogrammes per metre), and of which the web is of less height but thicker than that of the normal rail. For the connection of this switch to the adjoining rail special iron chairs have been adopted provided with circular steel pivots around which the rotation of the switches is made.

The pivots prevent the sliding of the switch and adjoining rail, and iron tie-bolts between the chairs and stock rails prevent vertical movement (see fig. 23 to 25, appendix).

The Belgian State Railway Administration appears to be satisfied with this construction as, in reply to question 16, it states that the appliance has great solidity and more simplicity, owing to the suppression of accessory pieces.

Another solution which has been adopted by some Companies, those of the Italian Mediterranean and Adriatic Railways amongst others, is to construct the switches by means of bars of special profile the height of which is equal to that of the adjoining rail. This solution has some of the advantages and inconveniences of the two solutions considered up to the present.

The heel chair in use on the system of the Mediterranean Railway is represented by figures 8, 9 and 10.

It may be noted in passing that, in this case, the joint of the switch is on the same chair as the joint of the stock rail, whilst many other Administrations endeavour not to make these two points coincide, by prolonging the stock rail beyond the heel chair; the connection of this rail to the adjoining rail can then be made by suspended joint.

Nothing however need hinder the adoption of this arrangement in the case above cited, with the exception that it would be necessary to introduce some variation in the type of the chair.

It is also desirable that the joint, at the other end of the stock rail should be at a short distance beyond the point of the switch, in order not to expose this point to the shocks of the wheels passing over the joint, since the sleepers at this joint tend, more than at the intermediate sleepers, to lower themselves under the action of the rolling loads.

The Administration of the Western of France Railway whilst employing ordinary rails for the switches from bull-headed rails, makes use of bars deeper than the normal rail and having their base inclined at 1 to 20 to the axis of the web, for the switches from Vignoles rails.

On the Midi of France Railway a strengthened Vignoles profile is used weighing 124 lbs per yard (61·500 kilogrammes per metre).

On the Paris-Lyons-Mediterranean Railway a non-symmetrical Vignoles profile is used of which the web has an inclination of 1 to 20 when the base is horizontal.

On the Northern of France Railway also the switches are made by means of rails of special profile of which the web is inclined at 1 to 20 to the base, the sliding tables on the chairs being horizontal. These special rails have nearly the same depth as the adjoining rails but their width at the base is appreciably less.

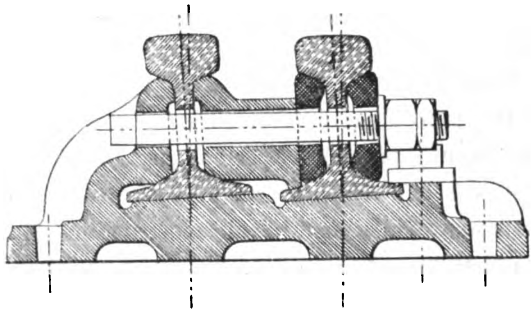


Fig. 8.

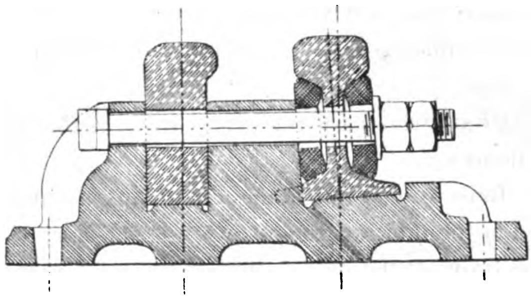


Fig. 9.

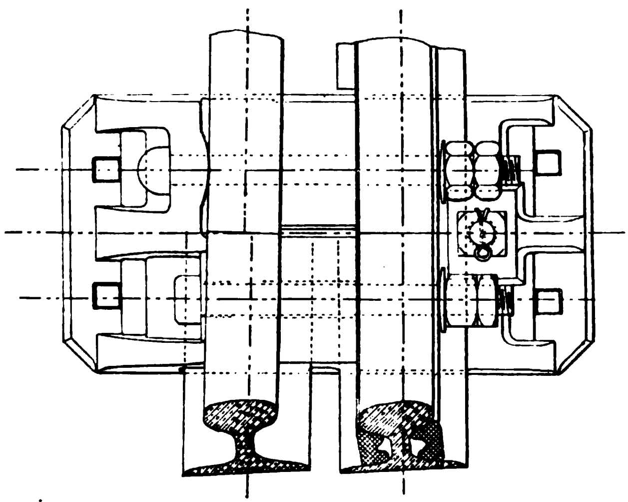


Fig. 10.

On the Dutch Railway, switches formed of bars of special profile having a height of 3 1/2 inches (9 centimetres) are being replaced by switches formed of rails having the same height as the normal rail.

It appears from the preceding that switches formed of rails are used for the appliances of junctions run over at full speed as largely as those formed of bars.

Either system appears then to lend itself to the construction of a switch sufficiently strong, of course provided that, in this construction, all the regulations have been observed that practice has designed with a view to avoiding or at least to diminishing the inconveniences from which neither system is exempt. The switch, nevertheless, not ceasing to constitute a weak point of the junction ought to be watched and maintained with all the special care which it exacts.

Before abandoning this subject it will be useful to make a few observations on the solutions which have been suggested with a view to leaving one of the lines of the junction absolutely intact.

Of the Administrations who have replied to the questionnaire two only have employed such appliances.

The Belgian State Railway has tested the « Williams » appliance, in which the switches, one placed at the interior, the other at the exterior, of the main line, are only run over by the trains of the branch line, which on leaving the points of the switches is elevated in such a manner as to permit the wheels to run over the rails of the main line.

But according to the replies given by this Administration the « Williams » appliance has given bad results.

In Switzerland on the Gothard system, as also on many German Railways, the « Blauel » appliance has been used, of which the principle is the same as that on which the « Williams » appliance is based.

In Switzerland, as in Germany, the « Blauel » appliance has given good results.

With this appliance moreover, as with the « Williams » appliance, the running is sacrificed on one of the lines of the junction, and, consequently, these special appliances cannot be used except where the traffic of the secondary line is incomparably less important than that of the main line.

On the Gothard system, in fact, the « Blauel » appliance has been utilized for a junction leading to a ballast pit.

Acute and obtuse angled crossings. — In describing the design of the junctions the minimum angles of the crossings in use on the systems of the Administrations, who have responded to the questionnaire, have already been indicated, and the part the super-elevated guard rail plays in the obtuse crossings has already been considered.

Many arrangements have been adopted for the construction of this super-elevated guard rails.

When the obtuse crossing is made of steel in a single piece and is not reversible the casting is made with a projection corresponding to the super-elevation of the guard rail.

An example of this construction is given in the new obtuse crossings of the Prussian State Railway (fig. 11).

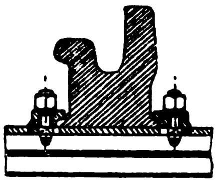


Fig. 11.

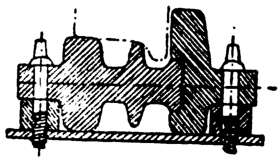


Fig. 12.

When the crossings are reversible a bar bearing on the cast guard rail has sometimes been used, and at other times a super-elevated guard rail forming a piece by itself and bolted to the reversible crossing.

Figure 12 represents an arrangement of this kind recently adopted on some Austrian systems.

The variety of the arrangements adopted in the case of crossings formed of rails is no less.

On some systems, especially in Germany, the super-elevated guard rail employed is formed of an angle iron; on the Eastern system guard rails formed of channel irons are made use of; and three wooden tie-rods binding the two guard rails of the crossing with mitres and bolts prevent them from drawing near to each other under the action of the shocks.

On the Paris-Lyons-Mediterranean system the guard rail is formed of an ordinary rail and the projection is obtained by raising it 2 inches (50 millimetres) to the right of the knuckle; the two guard rails of the obtuse crossing are tied together by means of a piece of ordinary rail.

On some systems the guard rail is only an ordinary rail laid on its side and bolted on special chairs to the desired height; the guidance of the wheels is then obtained by the base of the rail.

The Belgian State Railway employ a guard rail of a special profile (fig. 29 appendix) which by its similarity to the profile of the running rail, from which it differs only in the form of its head and in the width of the portion of the foot adjoining the nose offers a great facility in construction.

In acute crossings, the guard rail, which guides the wheel conjunct to that which is passing over the gap of the crossing, is generally an ordinary rail laid at the same level as the bearing rail.

However on some systems even this guard rail of acute crossings is laid at a higher level than that of the bearing rail; the object of this arrangement is evidently to increase the segment of the wheel bearing against the guard rail, the action of which is then more efficacious, and diminishes the wear of the guard rail, which causes the alteration of the clearance between the guard rail and the bearing rail to be slower.

It is not only necessary to guide the wheels running over the gap of the acute and obtuse crossings by the guard rails, but it is still further necessary to attenuate as far as possible the shocks, oscillations, and blows which are more or less produced at the extremities, knuckles and noses of the appliances, on account of their considerable length, of the special connections with the adjoining rails, of the change of level which the axle running over the gap experiences, etc.; more especially as the influence of the blows, endangering the safety and smoothness of travelling, increases with the speed of the trains.

The question whether to give the preference to crossings formed of steel of a single piece or to those formed of rails has been discussed for a long time, and even to-day it cannot be considered as solved; many Administrations only employ crossings formed of rails; others only employ steel crossings at the most important points of the line such as junctions; others, finally, use both systems.

It is of this question, as of many other questions concerning the line and consisting of a great quantity of elements, that it is not always easy to state precisely the relative importance.

The solidity of the crossing, the invariability of the relative position of its different parts, the elasticity which is necessary for the smoothness of travelling, the facility of obtaining exactitude of form, the possibility of giving to the wing rails and to the nose the relative level necessary for avoiding the vertical oscillations of the wheels running over the crossing (a possibility which besides exists only in acute crossings and which, even in these cases only borders upon an improvement more theoretical than real, for the deformations of the fixed pieces and of the tires alter immediately the relative level in question), the danger of unexpected ruptures, the facility of the construction and maintenance of the appliances, the facility of uniting them to the running line, etc., are the points which have been considered in the comparison of crossings formed of rails with those formed of steel in one piece, a comparison from which the advantages and disadvantages of each of the two systems result.

With regard to this question very interesting notices are found in the reports of the Union of German Railways (Verein) (1878-1884-1893). The conclusions inserted in these reports appear to prove that as far as the smoothness and safety of travelling is concerned the crossings formed of rails, *the weight and flexibility of which are in proportion to the rails to which they are fixed*, can be as and even more satisfactory than those formed of cast steel in one piece, provided that the rails are sufficiently long, well put together, and of good resisting power.

With regard to the arrangements adopted at junctions by the Administrations who have replied to the questionnaire, the following is a summary :

The English Companies employ exclusively crossings formed of rails; so also does the American Administration of the Pennsylvania Railroad.

Of the French Administrations the two who only allow junctions to be passed over at full speed, that is to say the Northern and the Eastern, employ crossings formed of rails. The Danish State Railway at junctions run over at full speed, make use of crossings formed of rails and having a nose of forged steel.

Crossings formed of rails are also used by the Belgian State Railway.

In Austria, on the contrary, the system ordinarily adopted by the Administrations of the State, North Western and Southern Railway Companies is that of crossings formed of steel in one piece.

The same system has been adopted on the junctions of the Dutch Railway.

In Italy, at junctions between stations, the crossings are generally formed of cast steel in one piece. However on the system of the Italian Railways of the Mediterranean the old obtuse crossings formed of a single piece, of which the ruptures were frequent, especially to the right of the nose, are replaced by crossings formed of rails supported on a bed-plate. With new obtuse crossings formed of rails they have found that the trains travel more smoothly and that the safety is increased, because they have no reason to fear sudden ruptures.

It would appear from the preceding that it may be concluded that the passage over junctions at full speed can be allowed as much on crossings formed of cast steel in one piece as on crossings formed of rails. It is necessary to add however that most of the Administrations who have replied to the questionnaire and who have junctions run over at full speed use acute and obtuse crossings formed of rails. With regard to the smoothness of the line the latter perhaps answer better than crossings formed of one piece, the considerable weight of which and their mode of connection to the adjoining rails give rise to greater shocks than those which are produced on crossings formed of rails, especially in the case of trains running over the crossings at great speeds. The crossing formed of rails cannot however give good results unless the rails are sufficiently long and well put together.

But whatever may be the system of the crossings used it is impossible to completely avoid shocks during the passage over the gap.

Special appliances have been tested in order to suppress this gap. Thus the same inventors of switches without interruption of the main line, which have been noticed above, have suggested appliances which maintain the continuity of the main line, even to the right of the crossing, the branch line passing above the main line.

The « Williams » appliance however did not give good results on the Belgian State system where it was tried on account of the difficult working of the appliance and of the facility with which the movable portion is displaced during the passage of trains.

The « Blauel » appliance, which has no movable parts at the crossing, appears to have given good results on the Gothard system and in Germany, but this appliance can only naturally be employed where the branch line is of an entirely limited importance as also in the case of a goods line branch, ballast pit turn-outs, etc.

It is known that in America, with a view of improving the passage over the two lines of the junction, they have used crossings having sometimes the nose and at other times the wing rails movable around pivots; in the first case the nose is held by a spring to the wing rail of the main line; in the second case the wings are held to the nose by springs.

In Austria, the « Hohenegger » appliance with movable points has been tested by which the gaps in the obtuse crossings are suppressed.

In the American arrangements, as in the « Hohenegger » appliance, endeavours have been made to ensure the exactitude of the position of the movable parts by means of treadles.

But all these arrangements, in spite of the incontestable advantage of the suppression of the gaps, have not yet reached a practical condition, because they exact on account of the multiplicity of the movable pieces an excessive watching which, moreover, does not always suffice to guarantee the regularity and safety of the working of the appliances. Of the Administrations who have replied to the questionnaire none have made use of them, at least at junctions passed over at full speed.

The intervening rails. — The construction of the intervening rails between a switch and a crossing, or between two crossings does not generally differ from the construction of the running rails.

However when these intervening rails are on the curve it is not always possible to give to the exterior rail, for the whole extent of the curve, the super-elevation necessary for the radius.

In junctions, when the intervening rails of the two branches are laid independently of each other, each on its own sleepers, it is possible in the ballasting to give a certain super-elevation to the exterior rail of the curved intervening rails, though it is not possible even in this case to obtain all the super-elevation desired on the whole extent of the curve.

In fact, on the side of the switches, the raising should be compensated for in the extent of the curve of the intervening rails, the heel of the switch being necessarily at the same level as the stock rail.

To the right of the crossings, as these are generally placed on frames formed of special sleepers or on ordinary sleepers with longitudinal girders, the super-elevation can only be obtained by notching the sleepers under the low rails or by the application of bed plates under the rails of great radius, which presents difficulties and inconveniences. It is quite true that the constituent parts of the crossing are most often formed in a straight line, but the straight portion that is inserted in the curve of the branch line has only a very limited length, of such a kind that the raising of the exterior rail of the intervening rail should be prolonged even to the right of the crossing, at least that the raising may be compensated for in the extent of the curve.

If it is a question of double line junctions the difficulties of obtaining the inclination of the exterior rail are increased; the application of the inclination is even impossible at the obtuse crossings.

When, in fact, one of the lines is straight the two obtuse crossings must necessarily be at the same level; when the two lines are on reverse curves the two obtuse crossings must still be at the same level, because if it is desired to give the inclination to one of the lines, the other line would have a contrary super-elevation.

The case of junctions having both lines in curves of the same sense is neglected, because it is evidently defective from the point of view of the passage over all the lines of the junction at full speed.

The obtuse crossings might be, and they very often are, laid in a straight line, but the necessity of having to lay them level does not allow all the inclination desired to be given to the exterior rails adjoining the obtuse crossings.

On account of all these difficulties the appliances are generally laid in one plane and, on many systems, even the intervening rails between the appliances are laid without inclination.

Amongst the Administrations consulted those of the Southern, State and North Western Austrian Railways, the Belgian State Railway, many French Administrations, such as the Western, Southern and Northern, and some English Companies such as the London Brighton and South Coast Railway, suppress all inclination at the junctions.

It is true that these Administrations do not allow the curved branches of junctions to be passed over at full speed.

But there are also Administrations who, whilst allowing the curves of junctions to be passed over at full speed, do not give any super-elevation to the exterior rail; the Danish State, the Lancashire and Yorkshire Railway, who alone give very rarely a slight raising to the exterior rail of the curves in question by means of the application of wooden soles under the chairs of this rail, and the Italian Adriatic Railway, may be cited as examples.

Other Administrations have endeavoured to obtain, where possible, the super-elevation corresponding to the radius of the curve, by the inclination of the sleepers : most of the English Companies, who allow the curved branches to be passed over at full speed, follow this procedure; the Great Eastern, London and South Western, Manchester Sheffield and Lincolnshire, and the Caledonian Railways may be cited as examples.

On the Great Eastern system, in cases where it is impossible to give the desired inclination to the sleepers, they have had resource to the sinking of the chairs of the interior rail by suitably notching the sleepers; and when special conditions compel them to give to the exterior rail an insufficient super-elevation the speed of the trains is reduced to an extent corresponding to the super-elevation which they have been able to obtain.

Some French systems, the Paris-Lyons-Mediterranean and the Eastern Railways for example, endeavour to obtain the desired super-elevation by the inclination of the sleepers, where however the curved branches are only run over at a reduced speed.

But, as has been seen, it is difficult, or rather impossible, to obtain at each point of the junction curves, all the super-elevation corresponding to the radius of the curve and to the speed of the trains, especially when it is supposed that these curves are run without slackening speed by express trains.

On the Danish State system, in order to make up in some manner for the absolute want of inclination, the spiking is made stronger and wedges are applied which rest against the exterior face of the rail of great radius.

On some of the English Railways where the rails, being laid in chairs, have generally stronger attachments than those of Vignoles rails, a guard rail placed at the side of the interior rail all the length of the curved branch starting from the heel of the switch is used.

A more radical means would consist, as has already been mentioned, in the suppression of the obtuse crossing which would then be replaced by a flying junction. The difficulties concerning the application of the inclination would then be limited to those due to the existence of switches and acute crossings.

The laying down.

Junctions are sometimes laid down on pieces of timber a great length.

This is the case, for example, on the junctions of the Belgian State Railways where this arrangement has been adopted with a view to avoiding the confusion of the extremities, and of permitting an easy packing of all the supports (annexed fig. 26).

Some other Administrations, on the contrary, only employ ordinary sleepers for their junctions, even to the right of the switches and acute and obtuse crossings. On the Eastern of France Railway, for instance, the sleepers destined for these appliances are chosen from amongst the most regular in form of the ordinary sleepers, and the sleepers of the ordinary crossings are tied together by longitudinals. This system has the advantage of discarding the use of special timber, which is very costly on account of its large dimensions, and of rendering the supply easier.

Yet other Companies employ special timber to the right and approaches of switches and crossings appliances, and limit the use of ordinary sleepers to the other parts of the junction.

Whatever may be the system of supports chosen for the sub-structure of junctions, it is evidently necessary that the perfect packing of these supports should be assured.

Such a packing necessary even for the running line has an absolutely particular importance for junctions; an importance increasing with the speed at which the junctions are run over.

Faulty packing would give place to unequal depressions under the action of the rolling loads, and these depressions would cause shocks, oscillations, and disturbances of movement extremely dangerous, especially on passing over switches and crossings.

With regard to the ballast on which the junctions ought to be laid, from the remarks of Sir G. Findlay, already cited on the « Question of the lines for express trains », the following definition may be borrowed : « An ideal ballast should be heavy, hard, tough, non-absorbent, and angular like durable road metalling, without admixture with earthy matter or allumina, free from dust, and uniform in size, a material through which water may pass freely without retaining it (1). »

This ballast should in its turn repose on a sub-structure well solidified and drained by drainage works exacted by the local conditions of the ground.

Summary.

In conclusion, it would without doubt be very useful to form junctions in such a manner that they could be run over at full speed in every direction; either with a view to increasing the rapidity of the journey or to the safety of the trains the engine-drivers of which for some reason have not respected the regulations for slackening.

The arrangements which have been used for this object are of two kinds : the first seek to protect the trains running over the junction in order to avoid collisions with converging trains; the others seek to improve the conditions of the appliances constituting the junction properly so called.

With regard to the arrangements of the first kind, the Congress has already discussed them during the first and fourth sessions.

With regard to the difficulties concerning the formation of the junction properly so called, and which are the object of the present question, the construction of the different parts of the junction, that is to say the switches, crossings and intervening rails, have been discriminated.

In examining the rules which regulate the passage over junctions on many systems, it has been seen that the passage at full speed on the straight branch of the junctions is admitted nearly always for trains which are not approaching facing points; less often the passage at full speed is admitted for the trains which run over the same branch but are approaching the facing points; and less often still the passage at full speed on the curved branches is admitted.

(1) See page VI-10 of Sir G. Findlay's report.

Further than the existence of the crossings and the switch, there are still the difficulties of the design which appear to oppose themselves to the passage at full speed on all the branches of the junction.

In order to render this design as correct as possible it is necessary to adopt acute and obtuse crossings having the least possible angles; but with a view to ensuring the guidance of the wheels running over the obtuse crossing the angles cannot decend below a certain value which according to the results of calculation and the regulations practically followed by the different Administrations ought to be about 7° corresponding to an inclination of 0.125. With regard to the ordinary crossing of the turn-outs it has been seen generally that the value of the tangent is not lower that 0.08. With these angles and the ordinary gauge of the line and interval between the two lines of way, it is possible to obtain for the diverging branch of the junction, having the other branch in a straight line, a continous curve of about 22 1/2 chains (450 metres) radius. This radius however necessarily sustains a sensible diminution if the constituent parts of the obtuse and acute crossings are maintained straight even after being laid down, as is exacted by most of the Administrations, and as is necessarily the case in crossings formed of steel in one piece.

With the object of being able to increase the radius of the intervening rails, it will be desirable not only to employ crossings as acute as possible, but perhaps further to adopt at junctions a wider interval between the two lines of way of the same road than the normal one.

Nevertheless the curves of the intervening rails would always be rather quick for the greatest speeds, especially because of the impossibility of giving to the exterior rail of these curves all the inclination corresponding to their radii. But further thes witch, which on account of its length being generally less than 19.68 feet (6 metres), presents, in the case of the curved switch, a curvature much more pronounced than that of the intervening rail, and in the more general case of the straight switch, a sharp divergence at the point the effect of which is certainly worse than that produced by the small radius of the intervening rail. In order to attenuate this inconvenience many Administrations tend to increase the length of the switch.

In spite of these difficulties, there are Administrations who, as has already been stated, allow the passage at full speed, even on the curved branch of junctions, having the other branch in a straight line.

In the use of the symmetrical arrangement the two lines would share the difficulties of the divergence. This arrangement appears to be the most rational one for the case where the lines of the junction are of equal importance and are run over by express trains having equal speeds

With regard to the construction of the different parts of the junction, it has been seen in commencing with the switches, that switches formed of rails can be employed as satisfactorily as those formed of special bars. The English Administrations, for instance, employ switches of rails exclusively.

A switch formed of rails may be obtained with sufficient resistance against the horizontal and vertical forces produced by the rolling loads, if the switch is properly constructed and is provided with a plunger. On the other hand solutions have been suggested sufficiently satisfactory for the union of switches formed of special bars to the adjoining rails, a union which has always been the weak point of such switches.

With regard to the crossings, it is not only necessary to guide the wheels running over the gaps, which is obtained by the guard rails, and which in the obtuse crossing have, on many systems, a super-elevation proportional to the angle of the crossing; but it is further necessary to endeavour to attenuate by suitable construction the shocks, oscillations and blows which are produced at the extremities, knuckles and noses of these appliances.

It appears that crossings formed of rails sufficiently long and well put together conduct themselves, as far as the smoothness of travelling is concerned, as well, and perhaps even better than those formed of steel in one piece.

In England, for example, crossings formed of rails are almost exclusively employed.

Finally, with regard to the construction of the intervening rails with a view to counteract to some extent the total or partial absence of the super-elevation of the exterior rail, resource has been had to the strengthening of the rail attachments, to the adoption of abutments which bear upon the outer face of the web of the exterior rail, to the employment of guard rails placed along the side of the interior rail on the whole length of the curved branch.

The difficulties will be lessened by laying the obtuse crossings in a straight line, and better still by obviating the necessity of obtuse crossings by the use of flying junctions.

It has been seen that the junctions are laid down sometimes on special timber, and at other times on ordinary sleepers. In every case it is necessary to take the greatest care by the use of excellant ballast to ensure the perfect packing of the supports.

APPENDIX.

DETAILED QUESTIONNAIRE.

1. — Are there on your system junctions passed at full speed by trains in each direction (i. e., passing to and from both lines at full speed), regardless of whether the points are taken in the facing or trailing direction?

2. — Are there junctions where full speed is maintained even when passing on the main line only, over facing points while on the contrary on entering the branch line the speed is reduced?

3. — Are there junctions passed at full speed only by trains coming off one of the two converging lines on to the main line, and so have only to pass trailing points?

4. — What is the greatest speed of the trains running over the facing points at the junctions mentioned in questions 1 and 2 above?

5. — In the junctions referred to in question 1, do the two diverging lines always form inverse curves, so that the junctions are symmetrical or nearly so?

6. — Or are there any cases of junctions passed in every direction at full speed, having one of the diverging lines straight, or with a very large radius ofcurve, and the other with a relatively sharp curve?

7. — In the case of the junctions that are symmetrical or nearly so, referred to in question 5, what is the minimum radius and the maximum speed allowed?

8. — In the case of the non-symmetrical junctions referred to in question 6, what is the minimum radius and the maximum speed allowed?

9. — What is the arrangement most frequently adopted for junctions where one of the diverging lines is single and the other double?

(a) When full speed is also allowed on the single line?

(b) When a reduced speed is enforced on it? (Give sketches.)

10. — Are curved point-rails used at junctions where full speed is allowed, even when entering a curved line?

11. — Are the point rails in use formed out of ordinary rails or of rails of a special section?

12. — In the latter case have the special rails the same height as the ordinary ones, or have they a wide bottom but less height than the ordinary rails?

13. — Are the crossings cast in one piece or formed of rails?

14. — What is the minimum angle of the crossings at junctions passed at full speed?

15. — Are super-elevated guard-rails used to guide the wheels during their passage over the gaps at the obtuse crossings? At what angle do you begin to use a super-elevated guard-rail, and how much is it super-elevated?

16. — Are the junctions always laid out so that the crossings are in a straight line or are the crossings on a curve?

17. — Have you made any attempts to get rid of obtuse crossings by using flying junctions?

18. — In the junctions where a curve is passed at full speed, is super-elevation given to the outside rail, and to what amount? To obtain this super-elevation is recourse had to notching the sleepers under the lower rail, or to the insertion of bed-plates under the outer rail, or to what other means?

19. — If it is found desirable or necessary to avoid the super-elevation of the outer rail are other means adopted to insure the safe passage of trains at full speed over junction curves? If so, please say what these means are and how far they are successful?

20. — Is the inside rail at junction curves fitted with a guard rail throughout its whole length or only at special places?

21. — Are the points at the junctions referred to in question 1 and 2 always plunged and fitted with locking-bars or treadles?

22. — Are the points interlocked with the signals?

23. — What is the normal arrangement of the junction signals?

24. — In the case of junctions where one of the diverging lines is entirely of secondary importance, are any special forms of points and crossings used, such as William's, Blauel's, etc., which permit the continuity of the main line to be maintained? If so, with what results?

25. — Are there any junctions where the branch-line is constructed with a safety siding?

26. — Has the rolling-stock of the trains which run over junction curves at full speed to conform to any special standard of construction (locomotives, carriages with radial axles, bogies or their equivalents, special under-frames, etc.)?

27. — Please give any further information not specifically asked for in the above questions.

Note. — Companies are particularly requested to have the goodness to send sketches or plans of some of the principal junctions passed by express trains, and of the special arrangements to which they have had recourse in laying them out so as to avoid slackening speed.

REPLIES.

SUMMARY.

Austria :

Southern of Austria.

Austro-Hungarian State Railway Company.

Austrian North-Western and South-North German Junction.

Belgium :

Belgian State.

Denmark :

Danish State.

United States of America :

Pennsylvania Railroad.

France :

Paris-Lyons-Mediterranean.

Western of France.

Eastern —

Northern —

Southern —

Great Britain and its Colonies :

North Eastern Railway.

Great Eastern Raiiway.

London and South-Western Railway.

Lancashire and Yorkshire Railway.

Great Northern Railway.

London Brighton and South Coast Railway.

Manchester Sheffield and Lincolnshire Railway.

Caledonian Railway.

Glasgow and South-Western Railway.

Great Indian Peninsula Railway.

Great Western Railway.

North British Railway.

Midland Railway.

New South Wales Government Railway.

London and North-Western Railway.

Holland :

Dutch Railway.

Portugal :

Royal Portuguese Railway Company.

Switzerland :

Gothard.

AUSTRIA-HUNGARY.

The Austro-Hungarian State Railway Company.

1. — No.

2. — According to a government order, every train, on approaching a facing point must, in Austria, reduce its speed to 31 or 18 1/2 miles (50 or 30 kilometres) an hour, according as to whether the points are plunged or not. Nevertheless, our Administration makes all trains without exception slacken their speed to 18 1/2 miles (30 kilometres).

3. — Trailing points are passed over without slackening.

4. — 18 1/2 miles (30 kilometres) an hour.

5. — The design of the junction is not symmetrical; it is composed of a straight line for one arm, and of a curve for the other; the main line is laid down straight.

6. — Only in some single line stations where the express train enters into the curve of the facing turn-out.

7. — On the main line there are not, outside stations, any symmetrical junctions.

8. — In the case of non symmetrical junctions, referred to in nº 6, the minimum radius is 15 chains (300 metres); with regard to the maximum speed, see replies to nºs 2 and 3.

9. — In junctions between a single line and a double line, we avoid as much as possible facing points on the double line. For that purpose we have adopted the following arrangement:

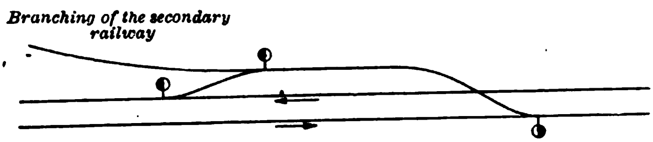


Fig. 13.

a) This case does not occur on our line.

b) The radius of the curve of the turn-out is more or less great, according to the speed of the trains running over the junction.

10. — We only use straight switches.

11. — Our point-rails are formed of rails of special section.

12. — The profile is that of an angle-iron with unequal sides, the horizontal side being wider than the base of our rails, the vertical side not being as high.

13. — Our crossings are formed of steel and cast in one piece. They are symmetrical and reversible.

14. — The minimum angle of the acute crossings is 4°52' (tangent 0.085) and that of the obtuse crossings is 7°14' (tangent 0.127).

15. — At obtuse crossings, we use guard rails having a superelevation of 1.20 inchs (30 millimetres).

16. — Curved crossings are only used in stations.

17. — Outside stations we avoid obtuse crossings, by constructing flying junctions.

18, 19. — No.

20. — The interior rail of junction curves is not fitted with a guard rail.

21. — The points of junctions referred to in nos 1 and 2 are always plunged, or connected with a central interlocking apparatus.

22. — See no 21.

23. — The normal position of the junction signals is « danger ».

24, 25, 26, 27. — No.

Austrian North-Western and South-North German Junction Railways.

1. — Yes, two; the junction of the Bohemia commercial line with our Tur-Titchin line and the Moravian frontier line with our Lichtenau-Mittelwalde line.

2. — Yes, the junctions on the Vienna-Tetschen main line, run over by express trains at speeds of from 40 to 46 1/2 miles (65 to 75 kilometres) an hour.

3. — No.

4. — The greatest speed of trains approaching facing points is :

In the case no 1 above. . . . . . . 18 1/2 miles (30 kilometres).
— no 2 — . . . . 31 — (50 —).

5, 6, 7. — In all the cases named, the main line is constructed straight.

8. — Minimum radius : 10 chains (200 metres); maximum speed allowed : 18 1/2 miles (30 kilometers).

9. — All the lines named above are single lines.

10. — Only straight switches are used.

11. — We use bars of special profile.

12. — The bars are of less height than the ordinary rail. (See fig. 14.)

13. — We use crossings of cast steel.

14. — Minimum : 5°25.

15. — No.

16. — The crossings of the junction are always laid down in a straight line, even if the main line is on a curve; the branch, for a minimum distance of 2 chains (40 metres), is laid down in a straight line.

17. — A main line is only crossed by another line by means of underneath or above bridges.

18. — In the case no 1, above, where the two junctions are run over at a speed of 18 1/2 miles (30 kilometres), there is no super-elevation on the exterior rail of the curve.

In the case no 2, speed : 31 miles (50 kilometres), the main line is always laid in a straight line, and the branch, which is always run over with a reduced speed, does not receive any super-elevation.

19. — In consequence of the principles mentioned in no 18 above, no other means are taken.

20. — A guard rail, 9 feet (2m75) long, is only provided on the interior rail opposite the crossing.

21. — Yes, plunged and provided with locking-bars.

22. — Yes.

23. — The signals are placed 25 chains (500 metres) in front of the junction, and the normal position indicated for the main line is : « all right »; for the branch : « danger ».

24. — On all the junction the switches, and acute and obtuse crossings are of the normal type.

25. — Yes, in all cases where the secondary line of the junction has such unfavourable gradients that fouling of the line may be feared.

26. — All the junctions can be run over in every direction by all the normal rolling stock.

27. — None.

Southern Railway.

1. — The junctions existing on our main lines are run over at full speed by the trains on the straight line of the junction, on approaching trailing points. With regard to running over facing points, the speed must be reduced and not exceed 18 1/2 miles (30 kilometres) an hour, when the points are not

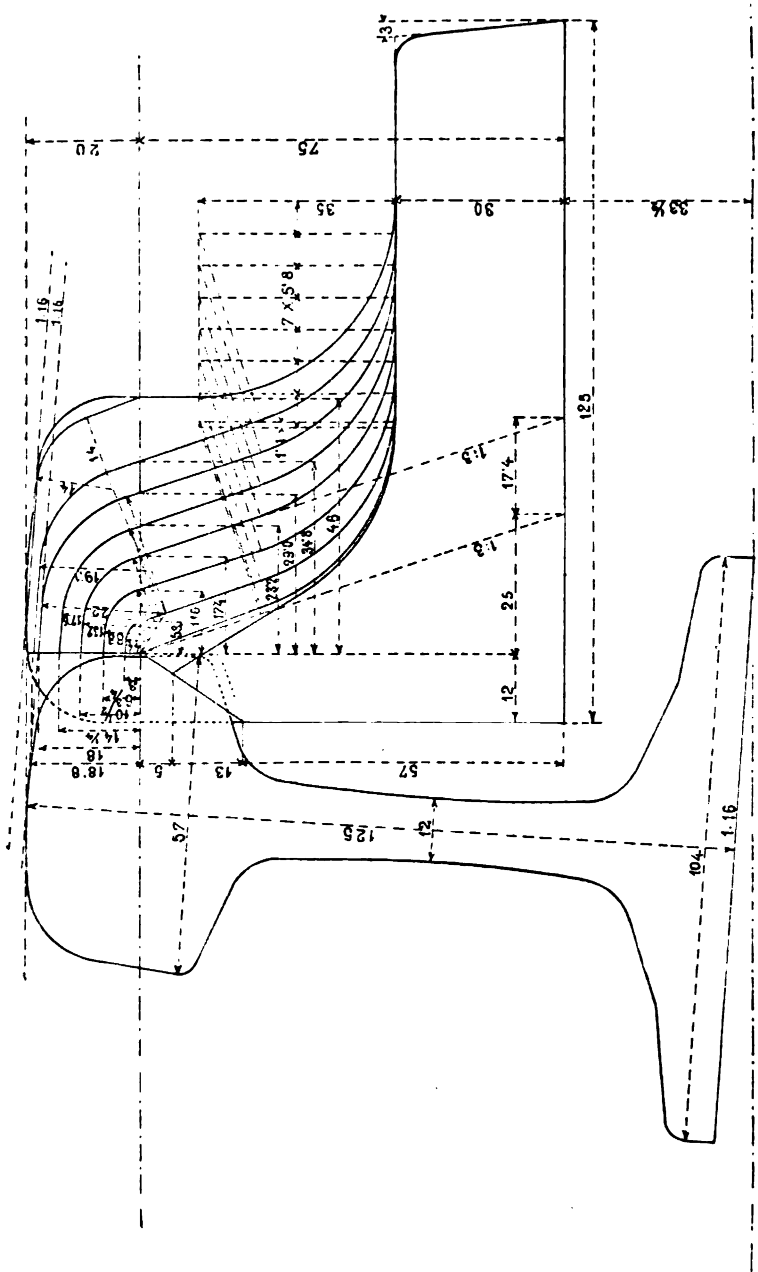


Fig. 14.

plunged, and 31 miles (51 kilometres) when they are plunged The curved branches of junctions must always be run over with a reduced speed.

2. — There are no junctions the main line of which is run over without slackening speed on approaching facing points.

3. — There are no junctions run over at full speed by trains coming from the two converging lines of the branch, because the passage over curves must always be made with a reduced speed.

4. — The maximum speed of trains approaching facing points is 18 1/2 or 31 miles (30 or 50 kilometres) as explained in No. 1 above.

5. — The junctions are laid in such a way that the main line is straight and the secondary line is on a curve.

6, 7. -- See No. 5.

8. — The minimum radius is 15 chains (300 metres), and the maximum speed is 31 or 18 1/2 miles (50 or 30 kilometres) an hour, as explained in No. 1.

9. — The junctions between a single line and a double line are always laid in stations, and are designed as follows.

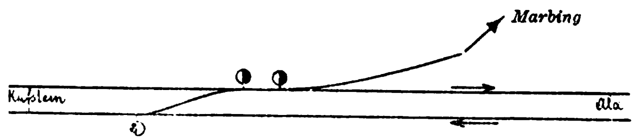


Fig. 15.

The junctions with goods lines are always made by means of trailing points. (See fig. 16) with regard to the speed, see No. 1.

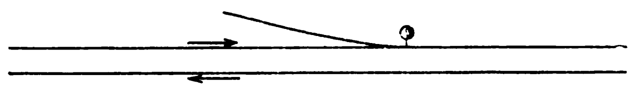


Fig. 16.

10. — At all junctions, we use curved point-rails.
11. — We use exclusively point-rails made of angle-irons.
12. — These point-rails have a less height than the ordinary rails and a wider base.
13. — We use crossings of cast steel (Martin).
14. — The minimum angle of the crossing is 4°54′.
15. — The guard rails have no super-elevation.
16. — The crossings are always laid in a straight line.
17. — No.
18. — The exterior rail of the curves is not super-elevated.
19. — Curves are not passed over at full speed.
20. — The interior rail of the curves is only provided with a guard rail to the right of the crossings.
21. — The switches of the junction are always plunged or manipulated by a central appliance. Treadles are not used.

22. — Where there are signals, they are always interlocked with the points.

23. — The signal is at least at a distance of 25 chains (500 metres) from the protected point and in such a position that it may be seen by the engine-driver at a distance of 10 chains (200 metres).

On lines on a steep ascent, this distance of 25 chains (500 metres) is reduced to 15 chains (300 metres).

24. — We do not use special switches or crossings which permit the continuity of the main line to be maintained.

25. — There are no safety roads at the junctions.

26. — For facilitating the running over curves, the engines of express trains are provided with bogies on two axles.

For vehicles of express trains on two axles, the wheel base is sometimes rigid (wheel base 15 feet 9 inches = 4m80); sometimes the axles have a certain amount of play (wheel base 18 feet 8 1/2 inches = 5m70); this wheel base secures the free passage over the curves of turn-outs.

The longer vehicles are provided with bogies on two axles.

BELGIUM.

The State Railway.

1, 2. — No.

3. — Not actually, but it is very probable that, in the near future, trailing points will be run over at full speed.

4. — 37 miles (60 kilometres) an hour.

5. — No.

6. — The speed of 37 miles (60 kilometres) an hour, named in No. 4, is only admitted on that branch of the junction vehicle which is straight or on a curve of large radius.

7. — Nil.

8. — The minimum radius is 22 1/2 chains (450 metres).

The greatest speed allowed is 37 miles (60 kilometres), on the straight line of the junction, as stated above.

On the diverging branch, it is 25 miles (40 kilometres) an hour.

9. — See figures 17 to 20.

a) This case does not occur.

b) See figure 21.

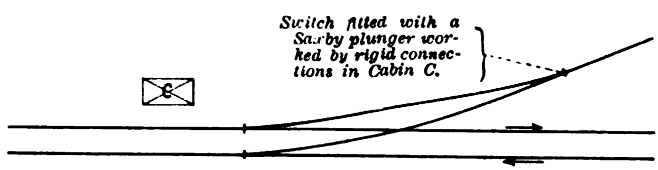
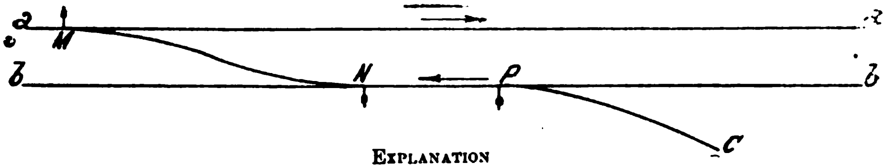


Fig. 21.

First case.

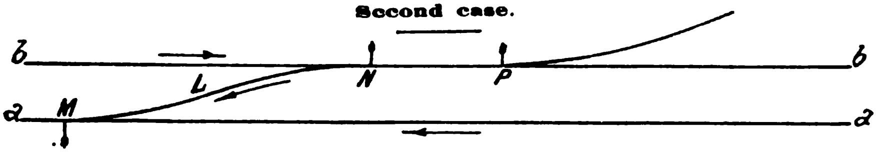


EXPLANATION

M. The switch stands for the left line *aa*
N. id. the line *bb*
P. id. the single line *C*.

Fig. 17.

Second case.

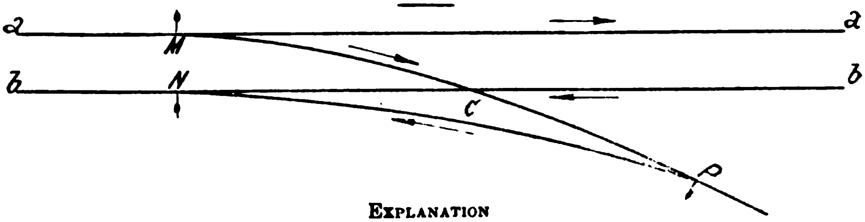


EXPLANATION

M. The Switch stands for the more frequented of the two lines
N. id. the junction of line *L*
P. id. the straight line *bb*

Fig. 18.

Third case

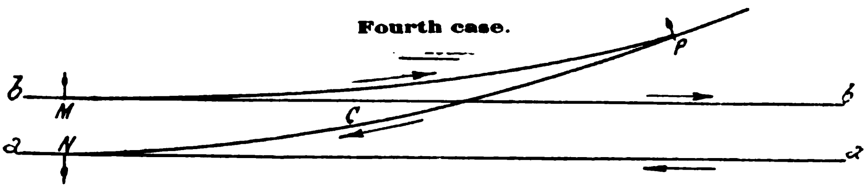


EXPLANATION

M. The switch stands for the line *aa*
N. id. the more frequented of the two lines
P. id. the line *C*

Fig. 19.

Fourth case.

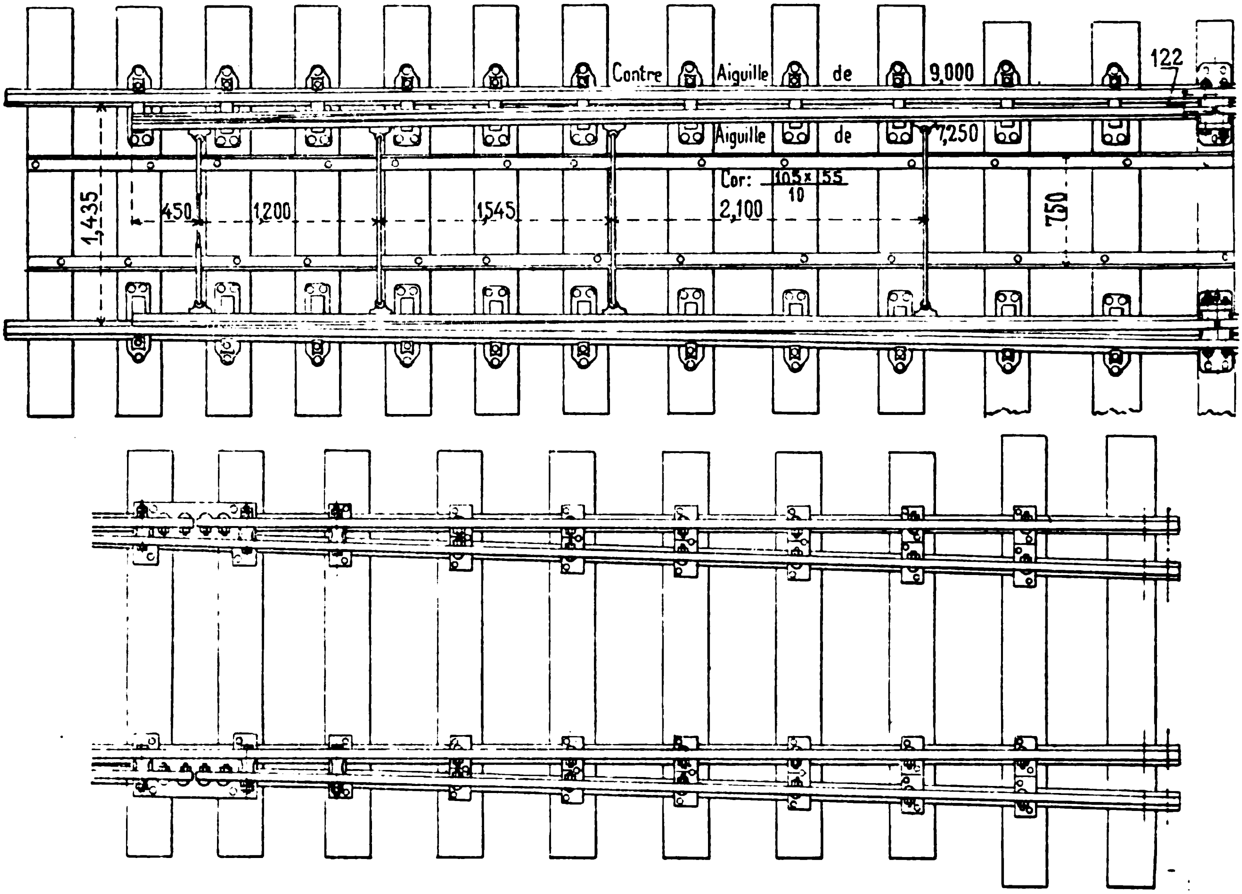


EXPLANATION

M. The switch stands for the straight line *bb*
N. id. the more frequented of two lines
P. id. the line C

Fig. 20.

10. — No. The switches for rails weighing 105 lbs per yard (52 kilograms per metre) remain straight, that is to say, the axis is rectilineal. But, they are practically bent and planed for a certain length (fig. 22).



Explanation of french termes : Contre-aiguille = Self-acting point; aiguille = point.
Fig. 22.

11. — The point-rail for turn-outs from rails weighing 105 lbs per yard (52 kilograms per metre) is of a special section (fig. 23, 24, 25).

12. — The special bar has a less height than the ordinary rail.

13. — Formed of rails.

14. — The minimum angle of acute crossings on lines run over with express speeds is 4° 35' 56" for the crossing C' (fig. 26 and 27).

For the obtuse crossings, the minimum angle is 7° 06' 14" (fig. 26 and 28).

15. — We make use of a super-elevated guard rail of special profile for all the obtuse crossings, on lines run over with express speeds.

The elevation of this guard rail above the level of the rail is 1·97 in. (0^m05) (fig. 29).

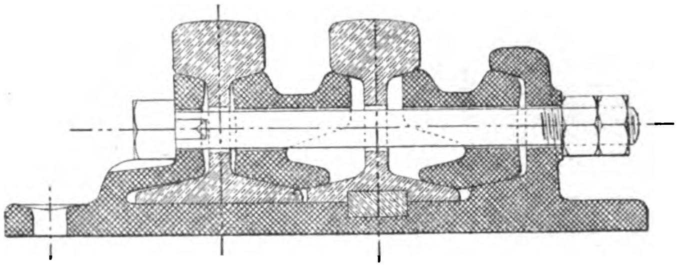


Fig. 23.

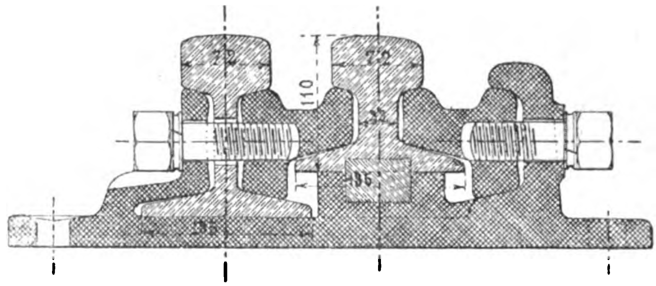


Fig. 24.

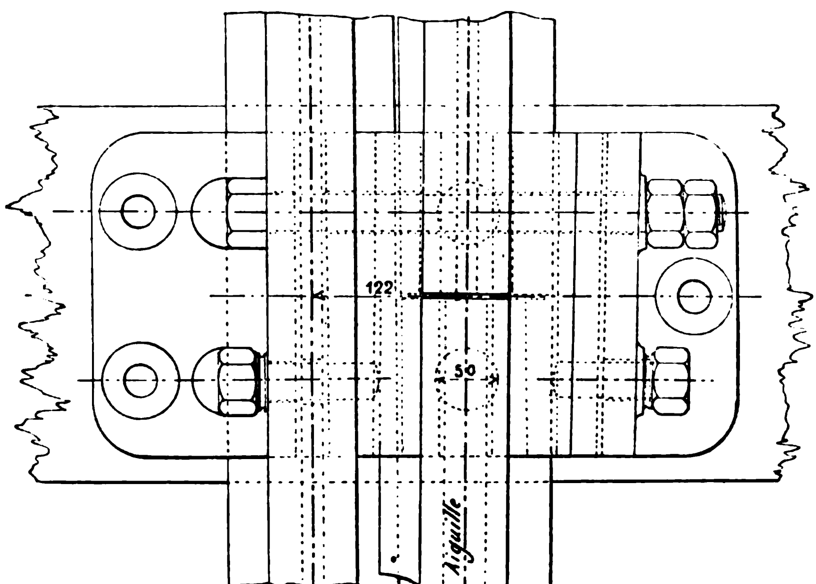


Fig. 25.

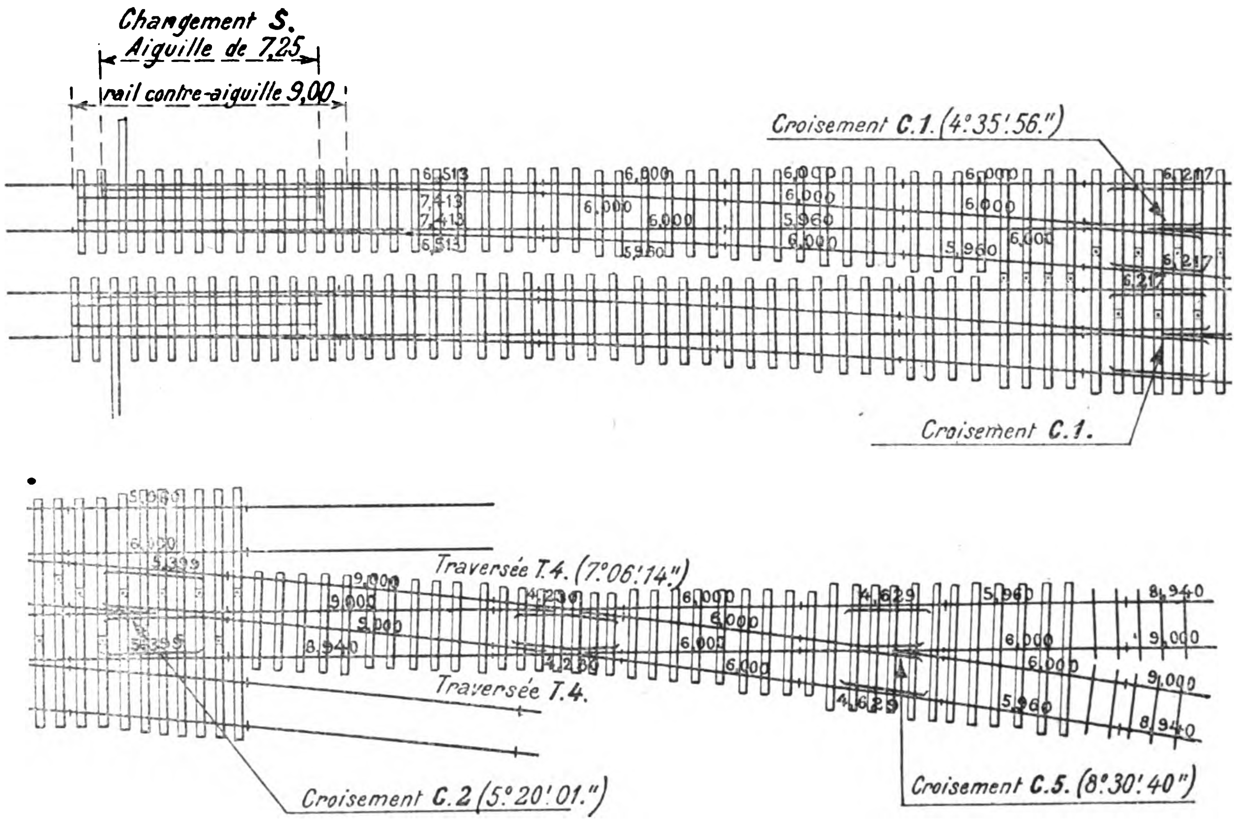


Fig. 26.

Explanations : Changement = Siding ; Croisement = Crossing ; Traversée = Diamond crossing; Aiguille = Point ; Rail contre-aiguille = Point rail.

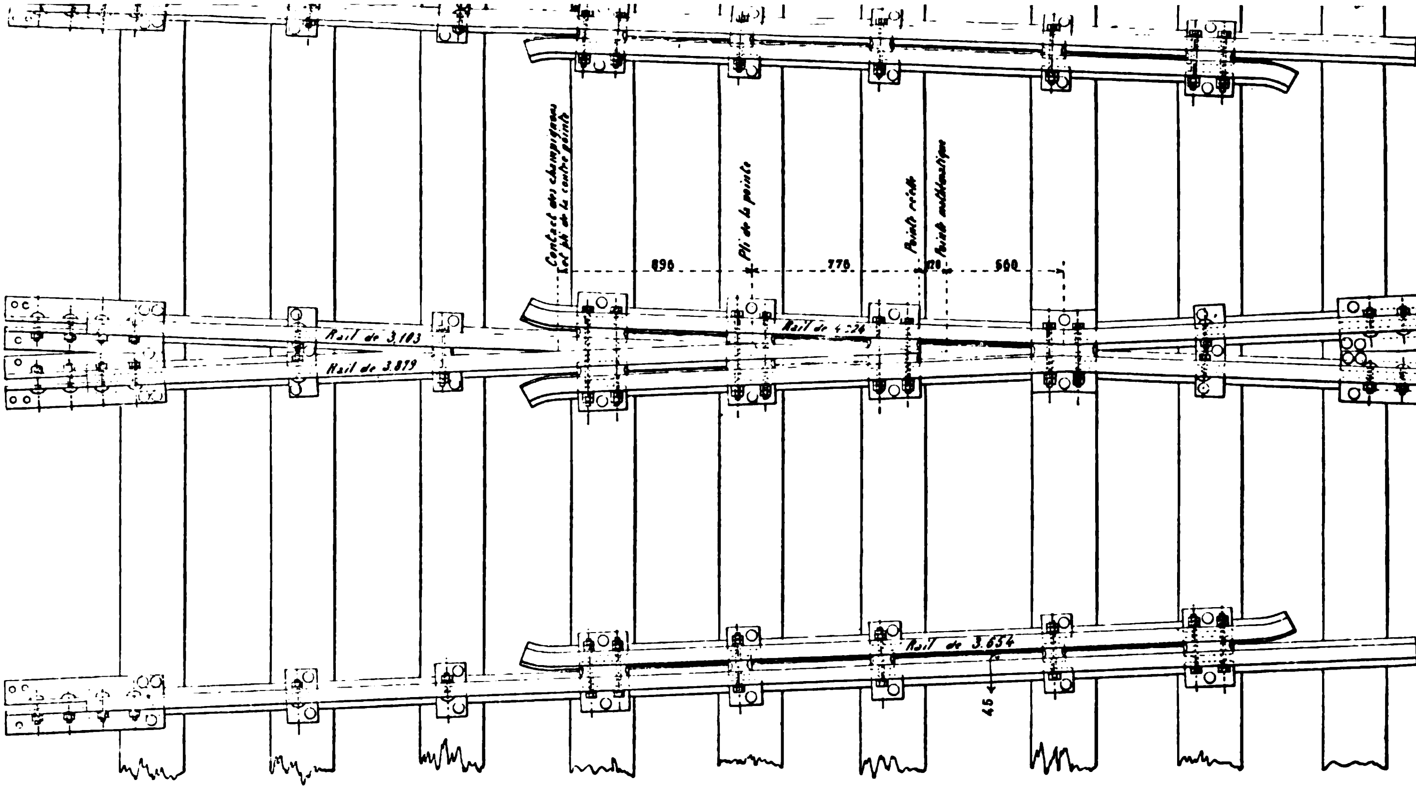


Fig. 27.

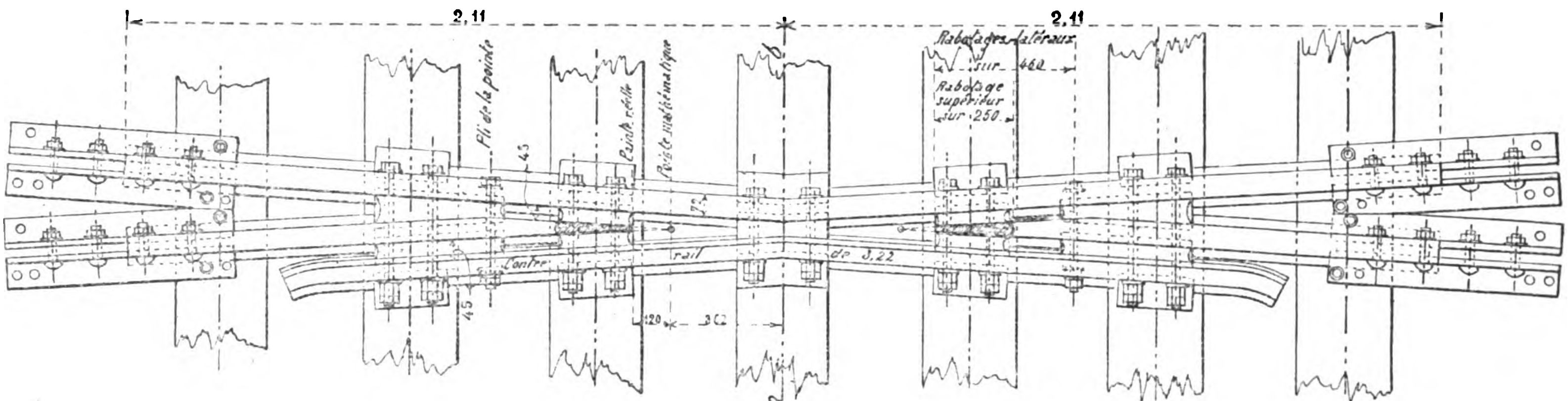


Fig. 28.

Explanation : Pli de la pointe = End of the second (or attached) rail ; Pointe réelle = Actual point ; Pointe mathématique = Mathematical point where the rail should end ; Rabotages latéraux = Planing down of the sides ; Rabotage su périeur = Planing down of the head.

Plan *ab.*

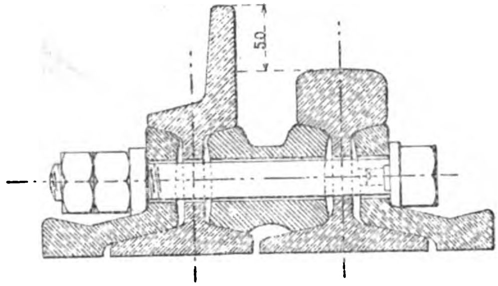


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Fig. 29.

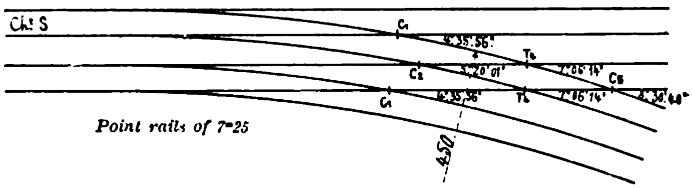


Fig. 30.

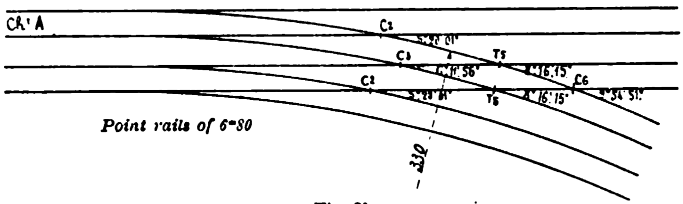


Fig. 31.

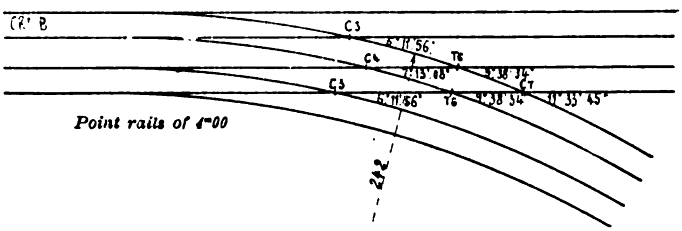


Fig. 32.

16. — The Belgian State Administration makes use of three types of switches, seven types of acute crossings, and three types of obtuse crossings, giving three complete junctions of 22.37 chains (450 metres), 16.44 chains (330m72), and 12 07 chains (242m76) exterior radius.

The first (fig. 30) is used for the junctions of two international lines, when trains travel quickly in both directions. It is not used in stations.

The second is used in junctions of an important line (in a straignt line or on a curve of large radius) with a secondary line.

It is used also for the direct entrance to stations leaving a local service (fig. 33), as well as in all cases where entire trains run in regular service on the diverging line.

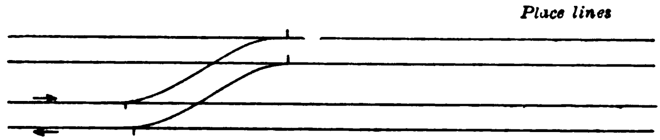


Fig. 33.

The third junction has been reserved for intermediate stations without a local service, where the diverging line is only run over by trains or engines shunting.

It has been noted that the angles of the crossings of this last junction were too open, thus bringing about a rapid wear of the appliances.

The third junction has therefore been replaced by a mixed junction as follows (fig. 34) :

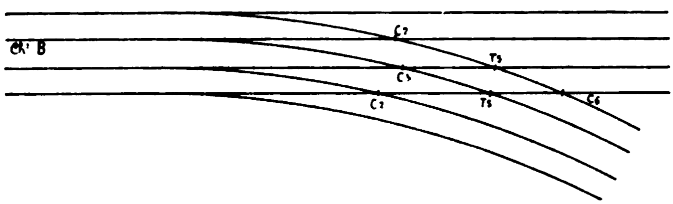


Fig. 34.

The short length of the blade of the switch B not having produced any bad effect, we have not thought it necessary to adopt the switch A.

However, our experience seems to indicate that with heavy rails, of which the metal is relatively little compressed by rolling, it is expedient to use small angles in the crossings and switches of great length.

The switches and crossings are constructed to the right or left, according as to whether the secondary line diverges to the right or left (fig. 35).

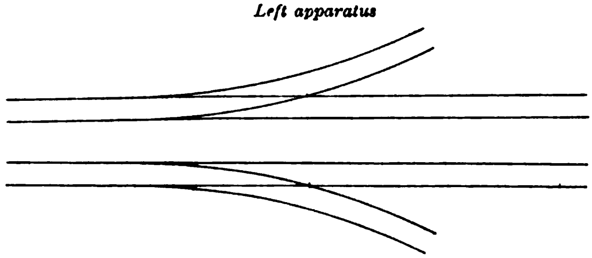


Fig. 35.

The stock-rail is bent as the plans indicate.

Three new features in the design, construction, and laying of these appliances are to be noted :

a) *Design.* — The curve of the junction is supposed to be continuous and tangent to the heel of the switch. The acute or obtuse crossing is laid tangentially to the curve, but it is constructed straight. The opposite rail is laid on the curve, as the following figure shows :

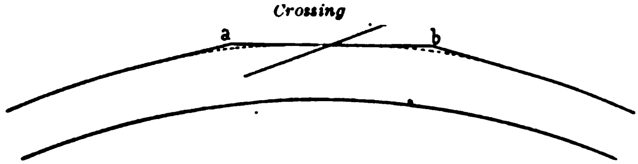


Fig. 36.

There remain then at *a* and *b* two small surplus widths which are made to disappear as much as possible in the course of laying the junction down.

The regularity of the curve and its centreing perfectly avoid the shocks due to variations of curvature.

b) *Construction.* — The point rail is made with a rail of special section which leaves the stock rail intact. A much greater solidity in the appliance is thus obtained, and also more simplicity on account of the suppression of accessory pieces. The difficulty of making a good heel to the switch in this arrangement has been solved by using a chair with steel pivots which has up to the present given good results.

The guard-rail of the obtuse crossing is also formed with a rail of special section giving great facility in construction.

c) *Laying down.* — The junction is laid down on special timbers of great length which avoid confusion of extremities and enable all the timbers to be easily packed. (See the plans of the laying down).

Results. — The results are, on the whole, satisfactory. We have only noted that the bent rails *a* and *b* (fig. 37) wear too rapidly.

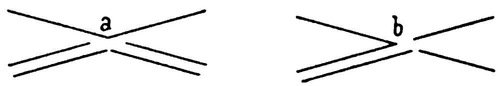


Fig. 37.

Their maintenance is as easy as that of the ordinary line.

17. — For the projected line from South Antwerp to Malines, it has been decided to make a flying junction at Neckerspoel at the junction with the existing line from Malines to Antwerp (fig. 38).

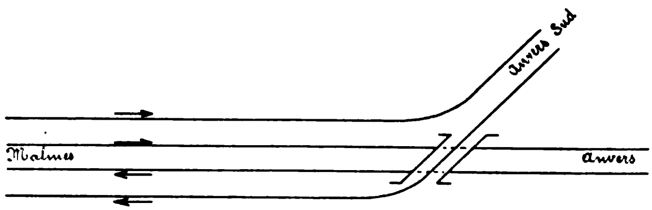


Fig. 38.

18. — No, since the main line of the junction is straight the two obtuse crossings must be at the same level.

19. — We content ourselves with slackening speed to 25 miles (40 kilometres) an hour on the curves of junctions.

This slackening in controlled by « Le Boulengé dromoscopes and dromopétards ».

20. — The interior rail of the curves of junctions is not provided with guard rails on the entire length. Guard rails are placed opposite the gaps of the acute and obtuse crossings. An arrangement for placing a guard rail in front of the switches has been tried, but was abandoned on account of want of efficacy.

21, 22. — Yes.

23. — « Danger. »

24. — The « Williams » appliance has been tested, but gave poor results.

The working of this appliance is difficult and the movable portion not being sufficiently secured is displaced during the passage of trains when the crossing is open or closed.

25. — Only one exists at Roux.

This arrangement is employed because the secondary line is on a steep down-gradient.

26. — No trains run over the curved lines of junctions at full speed.

27. — Nil.

DENMARK.

State Railway.

1, 2. — Yes.

3. — No

4. — 56 miles (90 kilometres) an hour.

5. — No.

6. — Yes.

7. — None.

8. — The minimum radius : 15 1/2 chains (315 metres); the greatest speed : about 56 miles (90 kilometres) an hour.

9. — There are no such junctions on our system.

10. — No.

11. — We use point rails formed of bars of special section. (See fig. 39 to 44.)

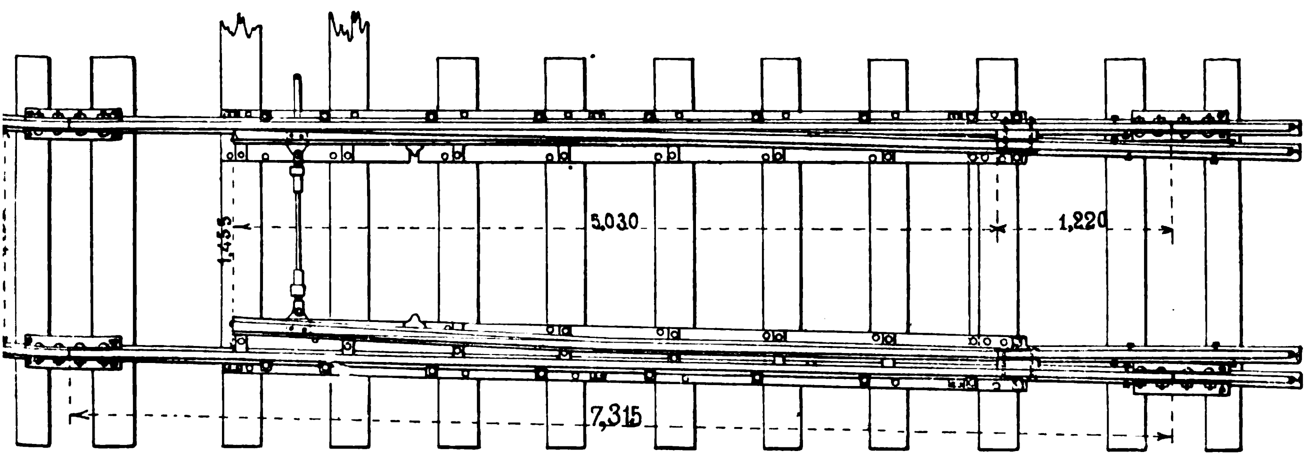


Fig. 39.

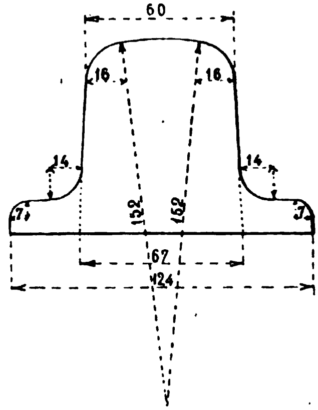


Fig. 40.

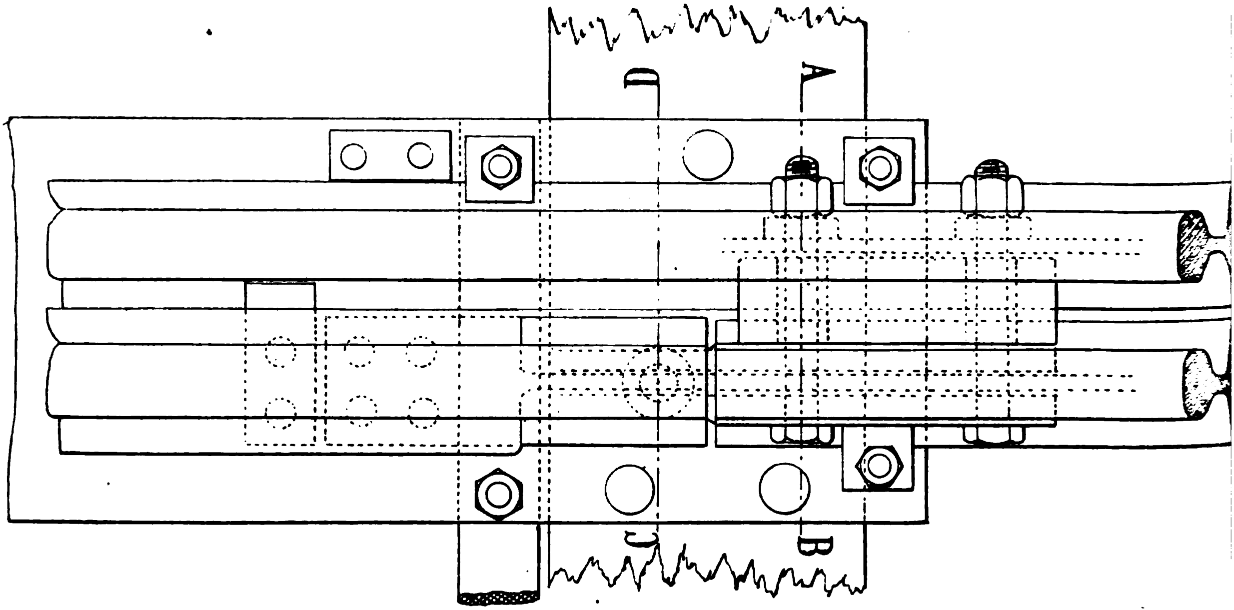


Fig. 41.

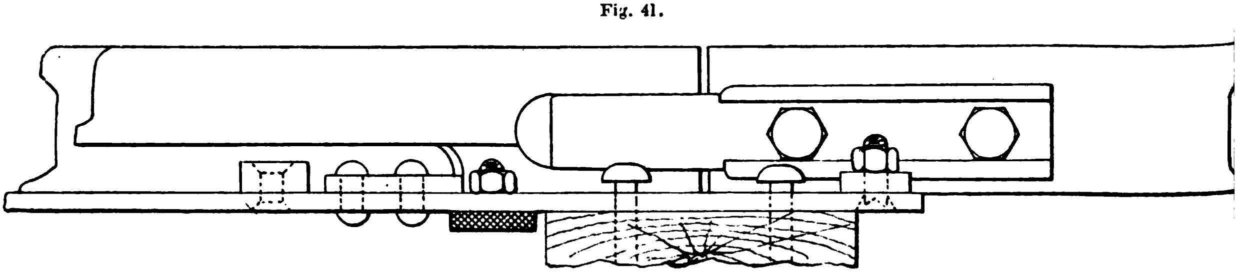


Fig. 42.

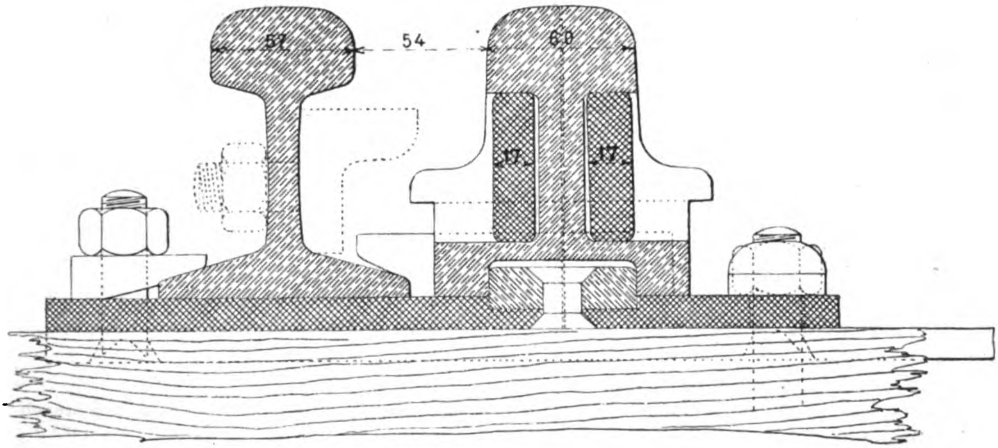


Fig. 43.

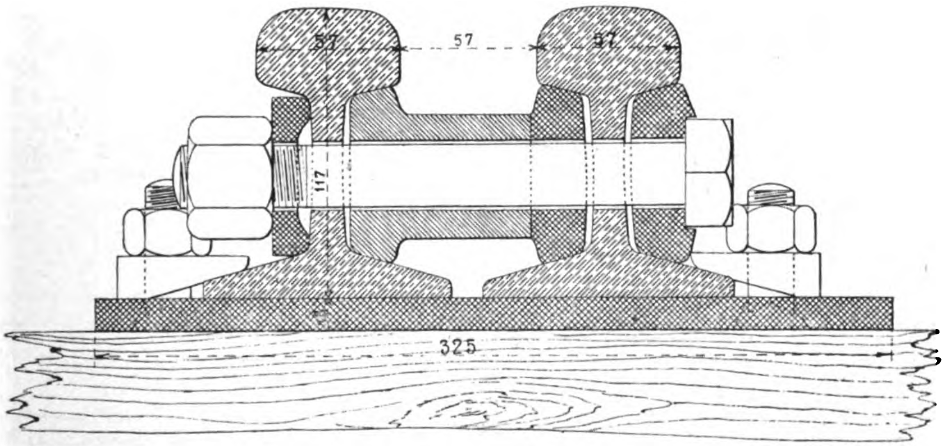


Fig. 44.

12. — We use bars having a wider base, but less height than the ordinary rail.
13. — Formed of rails and with a forged steel nose.
14. — The tangent of the angle = 1/12.
15. — No.
16. — They are always in a straight line.
17, 18. No.
19. — In the case in question, we make the spiking stronger and apply abutments supporting the exterior face of the rail.
20 — Only to the right of the centre of the crossing.
21. — They are always plunged.
22. — Yes.

23. — Danger.
24. — No.
25. — Yes.
26. — No.
27. — Nil.

UNITED STATES.

Pennsylvania Railroad Company.

1. — Yes. Harrison's on the New-York division is such a junction.

2, 3. — Yes.

4. — Probably 50 miles (80 kilometres) per hour.

5. — The junction at Harrisons is nearly symmetrical. Main line is a long easy curve, and branch is a straight line.

6. — No.

7. — About 2° [43 chains 8 ft (873 metres) curve]. Speed unlimited.

8. — None.

9. — *a*) See figure 45.
b) See figure 46.

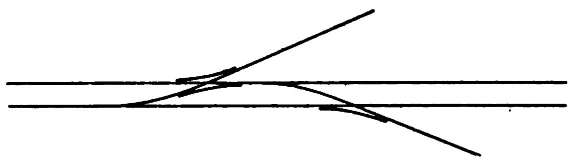


Fig. 45.

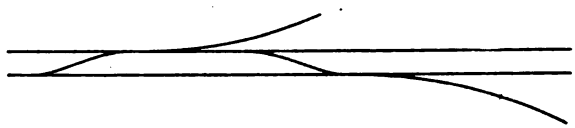


Fig. 46.

10. — No.
11. — Ordinary rails.
12. — No special rails.
13. — Formed of rails.
14. — 3° 49'.
15. — Top of guard rails is in the same plane as top of main rails.
16. — There are junctions on a curve.
17. — Yes.
18. — Do not superelevate curves through junction switches. On ordinary curves outside rail is elevated above the inner one. 1 inch for each degree of curvature (1) by raising the ties.

(1) As is well known by the expression « degree of curvature » is understood in the United States the angle at the centre, which in the curve under consideration is sub-tended by a line 100 feet (30m50) in length. (Reporter's note.)

19. — Guard rails are placed inside of the track next the inner rail and guard rail braces are used on outside of outer rail. Curves equipped thus are not considered safe for fast running.

20. — Only at special places.

21, 22. — Yes.

23. — Danger.

24. — No special devices are used.

25. — Yes, at several grade (level) crossings. The siding was not constructed for this purpose, but was an existing piece of track and was utilised as a safety road.

26. — Our standard rolling stock is expected to pass safely at all points on the running tracks.

FRANCE.

Paris, Lyons, Mediterranean Railway.

1. — No.

2. — Yes.

3. — No.

4. — For the main line. In other directions 12 1/2 miles (20 kilometres).

5, 6, 7, 8. — Nil.

9. — *a*) See figures 47 and 48.
b) See figures 47 and 48.

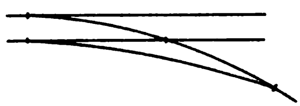


Fig. 47.

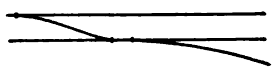


Fig. 48.

10. — No.

11. — Special section.

12. — The same height.

13. — Formed of rails.

14. — 0.09.

15. — Yes. Crossing 0.013. Extent 0.05.

16. — Generally on a curve.

17. — Seldom.

18. — Superelevation according to speed.

19, 20. — No.

21, 22. — Yes.

23. — Danger.

24, 25, 26. — No.

27. — Nil.

The Western Railway.

1. — There does not exist on our system a junction run over at full speed, in any direction whatsoever.

The engine-drivers are informed, on the contrary, that in consequence of article 37 of the order of 1846 : « At 24 3/4 chains (500 metres) at least before arriving at the point where a branch line crosses the main line, the engine-driver must reduce his speed in such a manner that the train can be brought to a stand still before reaching this crossing, if circumstances demand it. »

This measure must be rigorously observed on rising and falling lines, whether on the main line when approaching the junction, or on each of the two lines of which the junction is composed.

2. — The recommendation made to our engine-drivers, and named above, is absolute.

There does not exist, consequently, on our system any junction of which the main line is run over without slackening speed.

3. — The recommendations above are equally applicable to trains which, coming from one of the lines of the branch towards the main line, do not pass over facing points.

4. — The speed of trains and engines must not exceed, when passing over facing points : 18 1/2 miles (30 kilometres) an hour, for passenger trains and light engines; 12 1/2 miles (20 kilometres) an hour, for goods trains.

Nevertheless, this speed may be increased to 31 miles (50 kilometres) an hour under special authority, (in the circumstances determined in article 36 of the 70th appendix of the General Order, No. 4). But, up to the present, any speed higher than 25 miles (40 kilometres) has not been authorised.

5. — Most of our junctions are formed according to the type shown in figure 49.

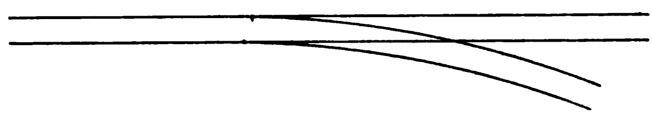


Fig. 49.

With one line straight, and the other curved; the radius of the rails between the heel of the switch and the crossing is about 15 chains (300 metres).

6. — Some junctions placed in special situations, on account of local arrangements, are laid with symmetrical curves; the curves are then about 24 3/4 chains (500 metres) radius.

In either cases, the speed of the train is as stated in No. 1.

7. — In this case, the radius of the curves is about 24 3/4 chains (500 metres). The maximum speed allowed is that indicated above in No. 4.

8. — According as stated above in reply to No. 5. The minimum radius of the curves in non-symmetrical junctions is about 15 chains (300 metres). With regard to the maximum speed, it is always fixed as stated above in No. 4.

9. — The arrangements most frequently adopted for junctions are those represented by the plan below.

In every case the speed allowed is as stated above in No. 1.

The arrangements represented by figures 50 and 51 are generally adopted. When trains on the single line pass one another near the junction we use the arrangement shown in figure 51.

Figure 52 indicates an arrangement adopted more rarely; in this case the switches of the junction of line preceding that for the branch are trailing switches for the trains running on the double line.

10. — We do not use any curved point-rails in our turn-outs, whether the line is straight or curved.

11. — The profile of our point-rails in turn-outs from bull-headed rails is the same as that of ordinary rails; we use, on the contrary, a special section for point-rails in turn-outs from Vignoles rails.

12. — In switches for Vignoles rails, the special rails are 5·11 inches (130 millimetres) in height, the ordinary rails having a height of only 4·92 inches (125 millimetres). The thickness of the web is 0·55 inches (14 millimetres) in place of 0·47 inches (12 millimetres) in the ordinary rails; the base of the point-rail of special section is inclined at 1 to 20 to the axis of the web.

13. — The acute and obtuse crossings used on our system are nearly all made of forged and planed steel.

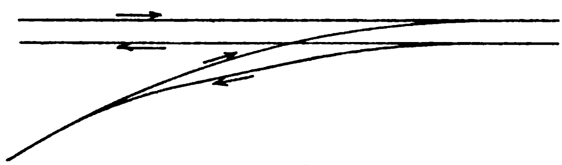


Fig. 50.

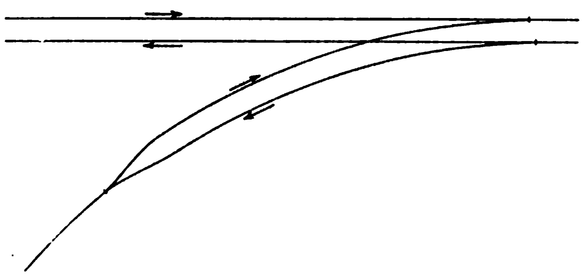


Fig. 51.

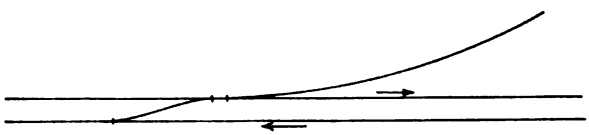


Fig. 52.

14. — The minimum angle of the acute crossings is 4°45' and of the obtuse crossings 5°30' both for junctions and station shunts.

15. — We only make use of a super-elevated guard rail in obtuse crossings of 5°30' which are more especially utilized for crossings leading to slip points.

In this case, the guard rail is 2·76 inches (70 millimetres) above the rail and is 18 1/2 inches (470 millimetres) long.

16. — The crossings are sometimes straight, and sometimes curved.

17. — This arrangement has been brought into use at different points, notably at Saint-Cloud (branch from the Fêtes Station), where it was projected and constructed in 1839, and at the branch of the line from Saint-Cloud to Etang-la-Ville.

18. — The speed of trains at junctions being reduced, as stated in No. 1, we do not give any super-elevation to the exterior rail of junction curves.

19. — We have not had recourse to any special means for ensuring the safety of trains running over the curves of junctions, the speed being reduced as indicated in No. 1.

20. — In our junctions, the interior rail is never provided with a guard rail.

21. — At certain junctions denoted by special orders and indicated in the working time-table (V), facing points, as far as the normal direction of running is concerned, are provided with a plunger fixed to a treadle or locking-bar which keeps them in an invariable position during the passage of trains and engines.

The use of this plunger, combined with the interlocking between the signals and switches, allows trains, provided with an effective continuous brake, and light engines, to run over these junctions in every direction, at a speed which may amount to 25 miles (40 kilometres) an hour, if other circumstances permit.

22. — The switches of facing points at junctions are always interlocked with the signals.

23. — The plans beneath indicate the arrangements generally adopted for the signals of junctions.

1st. *Junction of two single lines.*

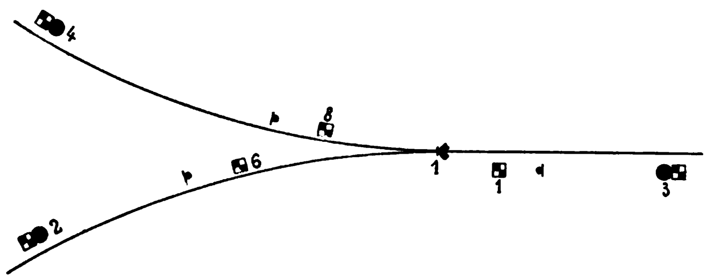


Fig. 53.

The switch 1 (fig. 53) stands normally for the most frequented line.

The signals 6, 8 and 1 are normally at « danger ».

The signals 2, 4 and 3 are normally at « all right ».

The signals 2 and 6 are interlocked in such a manner that to put 6 at « all right », it is necessary to put 2 at « danger ».

The signals 4 and 8 are interlocked in such a manner that to put 8 at « all right », it is necessary to put 4 at « danger ».

The signals 1 and 3 are interlocked in such a manner that to put 1 at « all right », it is necessary to put 3 at « danger ».

The signals 6, 8 and 1 are interlocked in such a manner that only one of these signals can be at « all right » at one time.

2nd. *Junction of a single line with a double line.*

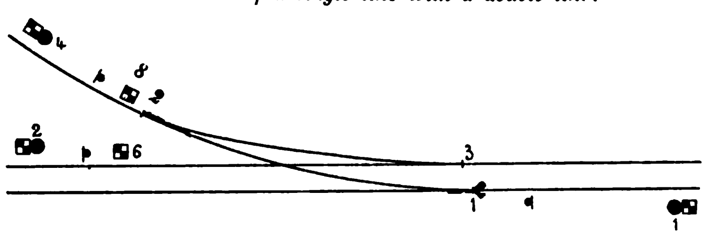


Fig. 54.

The switches 1 and 2 (fig. 54) between which the obtuse crossing lies, are worked by the same lever, and their normal position is against the crossing.

The normal position of signal 8 is « danger ».

The normal position of the other signals is « all right ».

The signals 4 and 8 are interlocked in such a manner that to put 8 at « all right » it is necessary to put 4 at « danger ».

The signals 2 and 6 are interlocked is such a manner that it is necessary to put the signal 2 at « danger » before signal 6.

The signals 8 and 6 are interlocked in such a manner that they cannot be at « all right » simultaneously.

The lever of the switches 1 and 2, is interlocked with the signals 6 and 8, in such a manner that the latter must be at « danger » before the switches can be set for the obtuse crossing.

3nd. *Junction of two double lines.*

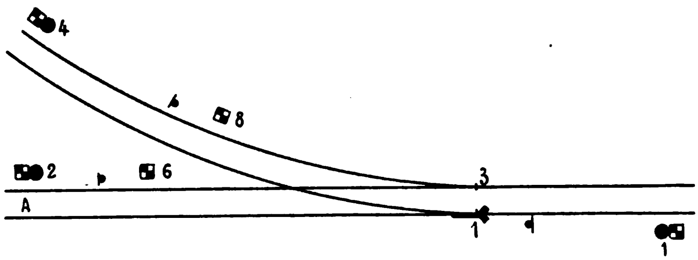


Fig. 55.

The switch 1 (fig. 55) is plunged, and stands normally for the most frequented direction *A*.

The switch 3 stands for the most frequented direction.

The normal position of signal 8 is « danger ».

The normal positions of the other signals is « all right ».

The signals 4 and 8 are interlocked in such a manner that to put 8 at « all right », it is necessary to put 4 at « danger ».

The signals 2 and 6 are interlocked in such a manner that it is necessary to put signal 2 at « danger » before signal 6.

The signals 8 and 6 are interlocked in such a manner that they cannot be at « all right » simultaneously.

The switch 1 is interlocked with signal 6, in such a manner that the latter must be at « danger » before setting the switch for the crossing road.

24. — We do not make use of any special appliances for permitting the continuity of the main lines to be maintained.

25. — The secondary lines of a small number of junctions are provided with a safety road; the switch giving access to this road and that giving access from the secondary to the main line are then manipulated by the same lever.

26. — Concerns engines department.

27. — The facing points of our junctions not being preceded by a home signal, it has not been possible to obtain, by interlocking, the certainty that the plunging is effective during the passage of trains. The have therefore provided the independent levers of the plungers of a certain number of these switches with a balance-weight sufficient to always bring these levers back into the position of « plunger locked »; a treadle with a cam permits the pointsman to maintain the plunger lever in the position « plunger clear » during the working of the switch.

For controlling the maximum speeds prescribed by our regulations and indicated in the replies to questions 4 and 21, we use near certain junctions appliances called « dromo-pétards ».

The Eastern Railway.

1. — No.
2. — Yes.
3. — No.
4. — About 56 miles (90 kilometres) an hour.
5. — This case does not occur.
6. — This case does not occur.
7. — Radius : 30 chains (600 metres).
8. — The speed is limited to 25 miles (40 kilometres) on curved lines.
9 — *a*) This case does not occur.
b) See figure 56.

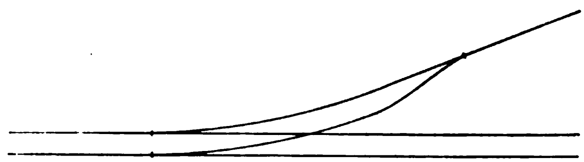


Fig. 56.

10. — No.
11. — Ordinary rails.
12. — Rails having the same height as the ordinary rail.
13. — The acute and obtuse crossings are formed of rails.
14. — 5° 30'.
15. — Yes. — For angles lower than 11°. — The guard rail is formed of iron and is super-elevated 1·46 inches (37 millimetres).
16. — Both the acute and obtuse crossings are always straight.
17. — Yes, at some points.
18. — Yes, the same super-elevation as on curves between stations. The super-elevation is obtained by inclining the sleepers.
19. — No.
20. — Generally, the guard rail is of ordinary length, but the tendency is to prolong them in order to diminish the shocks at the entrance to the appliance.
21. — These switches are always plunged and provided with treadles.
22. — Yes.
23. — Actually, the home signal is alone normally at « danger », the advance signal is normally at « all right ».

In the future the two signals will be normally at « danger ».

24, 25, 26, 27. — No.

Northern Railway.

1. — This case does not yet occur on the Northern system, but will occur very shortly The regulation for junctions has been prepared with a view to allow this acceleration to be realized during the passage of all junctions which are in convenient conditions of curvature or gradient. We are finishing, on some points of the system, straightening of lines or erection of signals necessary in order to allow us to put this regulation into force, and there is reason to think that this improvement will be realized in the course of the year for the most important junctions of the Northern system.

2. — Yes, this case is connected with the preceding one, the signals for the main line being arranged.

in accordance with the regulation, in such a manner that they can be taken « off » in time to avoid all slackening of speed of trains running on the main line.

3 — No, the rule applying to the passage of trains at junctions is invariably the same for both directions of each of the branch lines.

4. — That fixed by the working time-tables, and, in virtue of the regulation, engine drivers on approaching a junction are not permitted to use the discretion allowed them, on all the other points of the system, to increase by half if behind time, the speed fixed by the working time-tables.

5. — Both symmetrical and non-symmetrical junctions are used on the Northern system, depending upon local considerations.

6. — No.

7. — The minimum radius of the curves is, in this case, 30 chains (600 metres), and the maximum speed allowed is that fixed by the working time-table.

8. — The minimum radius is about 15 chains (300 metres), and the greatest speeds are 25 miles (40 kilometres) for passenger trains and 12 1/2 miles (20 kilometres) for goods trains.

9. — The figures below (figs. 57 and 58) indicate the arrangements made on the Northern system for unctions of a single line with a double line.

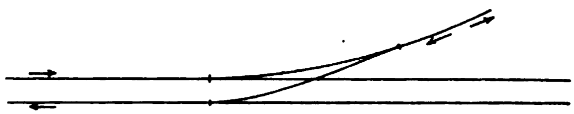


Fig. 57.

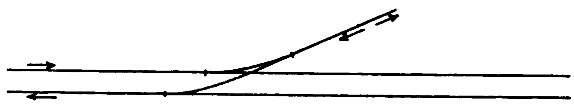


Fig. 58.

In all these junctions, the single line deviates by a curve from the double line, and, consequently, the trains on the single line do not run over the junction at full speed.

10. — We only use curved switches for slip points which occur very rarely in our junctions.

11. — The point rails are formed by means of rails, weighing 91 lbs. per yard (45 kilogrammes per metre), of special profile the webs of which are inclined at 1 in 20 to the base, the sliding tables on the chairs being horizontal.

12. — These special rails have nearly the same height as the ordinary rails, but their width at the base is considerably less.

13. — We only employ acute and obtuse crossings formed of rails.

14. — The minimum inclination of acute crossings is 1 to 11. The minimum inclination of obtuse crossings is 1 to 9.

15. — All our obtuse crossings are provided with super-elevated guard rails to guide the wheels during their passage over the gaps.

The super-elevation adopted is 2.36 inches (60 millimetres) for crossings having an inclination of 1 to 9, and 1 inch (25 millimetres), for crossings having an inclination of 1 to 7.7 and upwards.

16. — We have not always been able to design our junctions in these conditions and generally the angle of the obtuse crossings differs from that of the acute crossings, but the crossings themselves are always straight.

17. — This arrangement has been brought into use at many of our junctions, notably at the Épinay junction (lines from Paris to Pontoise and from Épinay to Montsoult), and at the Menessis junction (lines from Creil to St.-Quentin and from Amiens to Tergnier).

18. — There is no super-elevation in the constituent parts of a junction.

An answer to the general question may be expected in question 1.

19. — We have no arrangements designed to make up for the absence of super-elevation in the curves of junctions, but when the curves are too sharp in relation to the speed of the trains, we place sign posts in advance of them indicating to the engine-drivers the limit of speed which they must observe.

20. — In junctions, guard rails are only used to the right of the gaps of the crossings.

21, 22. — Yes.

23. — With the exception of some cases — on account of local circumstances — the interlocked junctions are preceded, in each of the directions, by signals as follows:

1. *A junction signal*, which consists of a post bearing a plate, on which is inscribed the word « *junction* » (« *Bifur* ») in black letters on a transparent back-ground, placed at a distance of 10 chains (200 metres) at least in advance of the distant signal, hereafter described.

At night, this signal is illuminated by a transparency and gives, consequently, the same appearance as in the daytime.

2. *A red distant signal*, at a sufficient distance from the home signal, hereafter described, to cover a train stopping in front of it.

3. *A signal with a green and white board*, fixed or turning, placed at a distance of 39 3/4 to 44 3/4 chains (800 to 900 metres) from the home signal hereafter described.

4. *A home signal with a red and white board*, provided, but only on the lines run over in one direction, with a fog signal which is automatically placed on the rail when the signal is at « danger ». This signal is placed at a distance of 6 chains (120 metres) from the point it has to cover which is either the point where the interval beteveen the two lines of way is reduced to 5 feet 9 inches (1 in 75) or the facing point. This distance can, in certain cases, be reduced.

In addition, a *signal of direction*, worked with the same lever as the facing point, indicates to the engine-drivers the direction given by the switch.

. . . .

. . . .

On each of the branches of a junction and on the line common to both, the distant signals are normally set at « all right », the home signals are normally at « danger », and the signals with green and white boards, even when they are movable, are normally at « danger ». (Extract from regulations for the passage of trains at junctions and swing bridges.)

24. — No test of this kind has been made on the Northern system.

25. — On the lines which the Northern Company works itself, there is no example of this arrangement. But it exists on some secondary lines, either of normal or narrow gauge, abutting on to the Northern lines, either by a junction or level crossing, in certain cases, for example, where either on account of the gradient of the secondary lines towards the Northern lines, or on account of the angle of the crossing, this precaution is rendered indispensable.

We may cite, as examples of this arrangement, for junctions with foreign lines, St. Quentin [line from Vélu to St. Quentin on a gradient of 1 in 100 (10 millimetres)]; Dercy-Mortiers (the Serre Valley line); Monchecourt (the Azincourt mines crossing); Ham, Rosières, Nesles, Montreuil, the Fontinettes (for oblique crossings of narrow gauge); finally, the Blense-Borne, the Madeleine, etc. (for tramways cutting the main lines at nearly right angles).

26. — No.

Southern Railway and Garonne Canal.

1. — No.

2. — At junctions which exist on the Southern system, the engine-drivers of the trains of the main line must reduce their speed to such an extent that their train can be stopped before reaching the home signal of the junction, if circumstances demand it. With regard to those who are going to or coming from the branch line, they must always stop before reaching the points.

3. — No.

4. — In the Southern system, there is no special limitation of speed for trains passing over a junction.

5. — We have no junctions run over in the conditions of No 1.

6. — We have no junctions run over in every direction at full speed.

7. — On all junctions, the trains stop before going to or coming from the branch; their speed on the diverging line is consequently very low : The minimum radius is 13 1/2 chains ($270^{m}81$).

8. — Main line : radius infinite.

Branch line : radius 13 1/2 chains ($270^{m}81$).

The latter is run over at a very low speed.

9. — *a*) This case does not occur on our system.

b) See figures 59, 60, 61 and 62.

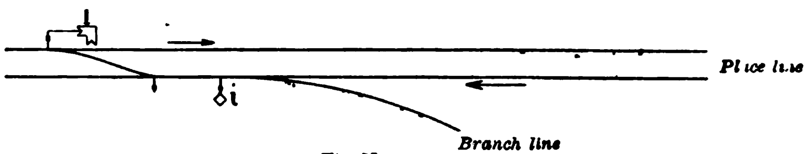


Fig. 59.

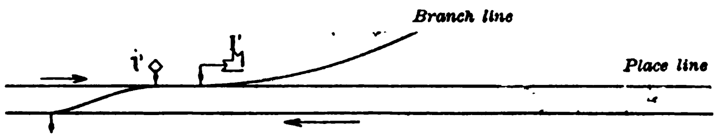


Fig. 60.

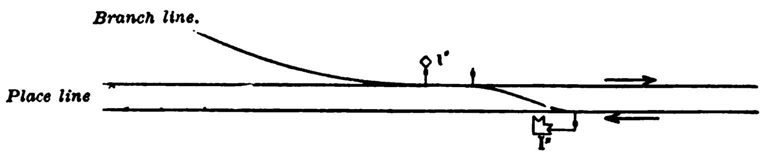


Fig. 61.

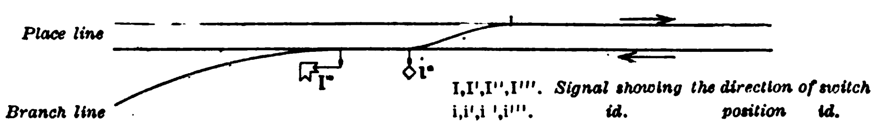


Fig. 62.

10. — We do not make use of curved point-rails in any case.

11. — The Southern Company use, at junctions, point-rails formed of strengthened Vignoles rails weighing 124 lbs. per yard (61.500 kilograms per metre).

12. — The special rails for switches have the same height as the ordinary rail.

13. — The Company uses only acute and obtuse crossings cast in one piece.

14. — The minimum angles adopted up to the present on the Southern system are 5° 9' 11" for the acute crossings and 7° 26' 11" for the obtuse crossings. The company is about to use obtuse crossings with an angle of 6° 17' 46".

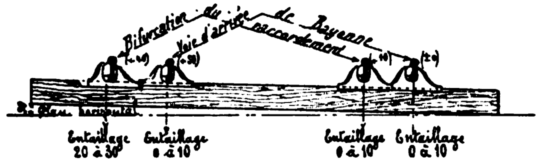
15. — The Southern Company has only, up to the present, tested super-elevated guard rails for the obtuse crossings; but the new type adopted with an angle of 6° 17' 47" has guard rails super-elevated 2.24 inches (57 millimetres).

16. — The junctions are designed so that the crossings are straight; no curved acute or obtuse crossings exist on the system.

17. — Yes. In Cette station for the crossing of the Montbazin line by goods lines.

At Beautiran, Pezenas, Montbazin, Beziers and Montpellier for junctions of local lines with the Southern lines.

18. — The junction of the outer circle of Bordeaux with the Bayonne line is an instance of this kind. The main line is on a curve of 46 chains (930 metres) radius, the super-elevation is 1·96 inches (50 millimetres) and the diverging line of the junction has, consequently, a contrary super-elevation. On the main line, the super-elevation of 1·96 inches (50 millimetres) is obtained by the inclination of the sleepers and, in order to diminish the contrary super-elevation of the diverging line, the sleepers are notched on the side of the small radius. This arrangement is shown on the section below (fig. 63).



Explanation : Bifurcation du raccordement = Junction ; Entaillage = Notching ;
Voie d'arrivée de Bayonne = Line from Bayonne.

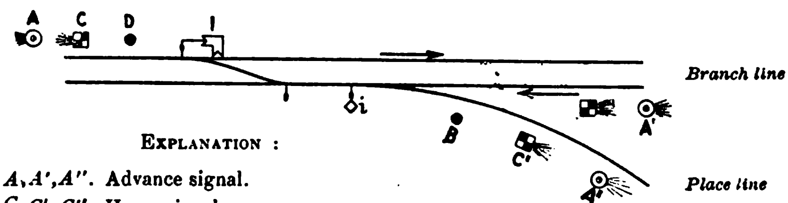
Fig. 63.

19. — No super-elevation on our junctions.

20. — Guard rails are only used to the right of the acute and obtuse crossings.

21. — In a general manner, at junction points, we use locking cams provided with treadles.

22. — At junctions on the Southern system, the switch levers are interlocked with the signals, in such a manner that, when the signals are at « all right », the switches stand for the main line (fig. 64).



Explanation :

A, *A'*, *A''*. Advance signal.
C, *C'*, *C''*, Home signal.
B. Stopping point for all trains coming from the branch line.
D. Stopping point for all trains going to the branch.
I. Signal showing direction of switch.
i. Signal showing position of switch.

Fig. 64.

24. — Up to the present, no special forms of switches and crossings Williams, Blauel, etc., which permit the continuity of the main line to be maintained, have been made use of on the Southern system.

25. — No.

26. — No trains run over the curves of junctions at full speed.

Trains coming from or going to the branch stop at the junction.

As regards the trains on the main line, the engine-drivers are instructed to reduce their speed to such an extent that they can stop their trains at the home signal of the junction if circumstances demand it. (Art. 37 of the order of 1846.)

27. — Ordinary arrangements of our junctions. See figure 65.

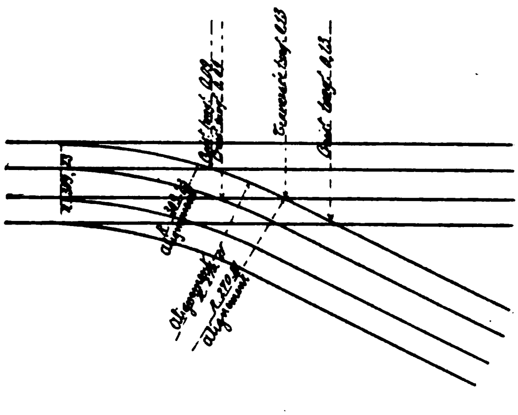


Fig. 65

UNITED KINGDOM OF GREAT BRITAIN AND IRELAND AND ITS COLONIES.

Great Eastern Railway.

1, 2, 3. — Yes.

4. — There is no limitation in speed at junctions generally. At certain junctions, however, owing to exceptional circumstances, a speed restriction is imposed, and in the case mentioned in clause 2 the maximum speed is 15 miles per hour.

5. — No.

6. — Yes. Many cases exist.

7. — Have no such case.

8. — About 10 chains (201 metres). The maximum speed allowed is 15 miles (24 kilometres) per hour.

9. — Nil.

10. — No, the point rails are straight in all cases.

11. — The point rails are formed out of ordinary sections.

12. — Nil.

13. — The crossings are built up of rails of the same section as the running rails.
14. — About 8° to 9°.
15. — All crossings are guarded by check rails, which in most cases are 12 feet (3m65) long. No guard rails outside the running rails are used.
16. — Junctions are always laid out so that the diamond crossings are on the straight. Circumstances may occur to necessitate them being on a curve, but it is very undesirable.
17. — No.
18. — The largest amount of superelevation possible, subject of course to its not being in excess of the calculated amount, is always given at junctions; generally it is difficult to get the full amount of superelevation desirable. The timbers are generally canted where possible or the lower chairs are let into the timber by « jagging ».
19. — If it is impossible to give the full superelevation required and circumstances necessitate only a very little superelevation the speed of trains should be reduced so as to bring it in accordance with the superelevation which can be given.
20. — Only at special places.
21, 22. — Yes.
23. — In places where junction block working exists the junction signals are kept normally at danger.
24. — No.
25. — Yes, there are places where a branch junction line connects with another road, and the points leading into this road may be set so as to form a trap when a converging train is signalled on the other road.
26. — No.

London and South Western Railway.

1, 2. — Yes.
3. — No.
4. — 50 miles (80 kilometres) an hour.
5, 6. — No.
7. — See No. 5.
8. — Minimum radius 7 chains.
9. — Reduced speed is enjoined at all single with « double » junctions (vide figure 66).

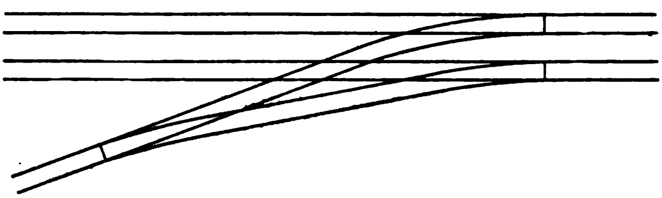


Fig. 66.

10. — No.
11. — Ordinary rails.
12. — See No. 11.
13. — Formed of rails.
14. — One in 8.
15. — Not used.
16. — Generally on a curve.
17. — Yes.

18. — Superelevation to the outer rail of a curve is given as soon as the junction will allow. Superelevation would be obtained by lifting and packing with ballast the outer rail.

19. — A check or guard rail is sometimes provided within the inner rail of a curve leading from a junction.

20. — At special points only.

21. — Yes, all facing points.

22. — Yes.

23. — On.

24, 25, 26. — No.

Lancashire and Yorkshire Bailway.

1, 2. — Yes.

3. — No.

4. — Nil.

5. — No.

6. — Yes.

7, 8. — Nil.

9. — See figure 67.

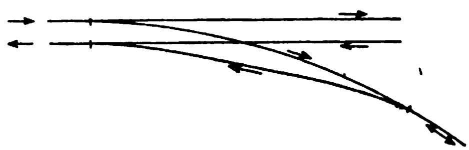


Fig. 67.

10. — No.

11. — Formed of ordinary rails.

12. — Nil.

13. — Formed of rails.

14. — Down and crossing 1 in 10, and crossing 1 in 13.

15. — No.

16. — On a curve,

17. — Yes.

18. — Slight superelevation is sometimes given by placing wood packing under the chairs of the outer rail of the curve, but this is exceptional.

19. — Nil.

20. — Only at special places except on very sharp curves.

21. — All facing points are fitted with plunger and locking bar.

22. — Yes.

23. — At danger.

24, 25, 26. — No.

Great Northern Railway.

1. — The general rule is that main line trains passing a junction do not reduce speed, but trains from branch lines reduce speed from 10 to 20 miles (16 to 32 kilometres) an hour.

2. — Yes.

3. — At all junctions trains passing on to or off branch lines are required to reduce speed.

4. — 50 miles (80 kilometres) per hour.
5. — No.
6. — There are no cases in which junctions are passed in every direction at full speed.
7. — No.
8. — Minimum radius 10 chains (201 metres). Maximum speed for radius of 10 chains (201 metres) 10 miles (16 kilometres) an hour.
9. — Junctions are always laid in for double lines.
10. — No.
11. — Ordinary rails.
12. — The same height as ordinary rails.
13. — Formed of steel rails.
14. — 1 in 25.
15. — Check rails not superelevated are laid to the outer rail opposite the gap in the crossing in all cases.
16. — Both.
17. — Yes, in many instances.
18. — Superelevation is given to the outside rail in accordance with a table regulated by the speed allowed. The sleepers are packed.
19. — Yes, a check or guard rail is fixed next the inner rail.
20. — Yes, through the whole length.
21, 22. — Yes.
23. — At danger.
24. — No.
25. — Never in the case of passenger lines.
26. — No.

London, Brighton and South Coast Railway.

1. — Yes.
2, 3. — No.
4. — From 30 to 40 miles (48 to 64 kilometres) an hour.
5, 6. — Yes.
7. — 20 chains (402 metres). 30 miles (48 kilometres an hour.
8. — Nil.
9. — No special arrangement.
10. — Nil.
11. — Ordinary rails.
12. — Nil.
13. — Formed of ordinary rails.
14. — 1 in 8.
15. — No.
16. — Straight.
17. — Yes.
18. — No superelevation .
19. — Nil.
20. — Throughout its whole length.
21, 22. — Yes.
23. — At danger.
24, 25, 26. — No.

Manchester, Sheffield and Lincolnshire Railway.

1, 2, 3. — Yes.
4. — 50 miles (80 kilometres) an hour.
5. — Nearly always so — not in every case.
6. — No.
7. — Sharpest curve 20 chains (402 metres). No restriction of speed.
8. — Minimum radius 20 chains (402 metres). No restriction of speed.
9. — All double junctions.
10. — No.
11. — Ordinary rails.
12. — No special rails.
13. — Formed of rails.
14. — Minimum angle 1 in 8.
15. — Yes, angle 1 in 8 and continue on in places to the end of the switch rail.
16. — Both.
17. — No.
18. — As much superelevation is given as crossings will admit and is effected by packing the sleepers or timbers.
19. — The further means used is the adaption of check or guard rails.
20. — Yes, depending on the curve.
21, 22. — Yes.
23. — Danger.
24, 25. — No.

North Eastern Bailway.

1, 2. — Yes
3. — Nil.
4. — 50 miles (80 kilometres) per hour.
5, 6. — No.
7. — 15 chains (301 metres) radius — 38 miles (48 kilometres) per hour.
8. — Same as No. 7.
9. — All junctions of main line are double.
10. — No.
11. — Ordinary rails.
12. — Nil.
13. — Formed of rails.
14. — 1 in 9.
15. — Yes in all cases 5 to 6 feet (1^m53 to 1^m83) on each side of the gap.
16. — No, many are on curves.
17. — No.
18. — Superelevation is given as far as possible, but cannot be applied to crossings by packing the sleepers.
19 — Nil.
20. — Only at special places.
21, 22. — Yes.
23. — At danger.
24. — No.
25. — Yes.
26. — No.

Caledonian Railway.

1, 2. — Yes.
3. — No.
4. — No limit, but say 50 miles (80 kilometres) an hour.
5, 6. — No.
7. — Half a mile (800 metres) radius, and say 50 miles (80 kilometres) an hour.
8. — We do not go at full speed through such junctions.
9. — The arrangement we adopt is to make a double junction and this applies whether the speed is fast or slow.
10. — No.
11. — Ordinary rails.
12. — We have none.
13. — Formed of rails.
14. — 1 in 8.
15. — We use guard rails, but they are not superelevated.
16. — The junctions are not always laid out so that the crossings are in a straight line, but some of them are on a curve.
17. — No.
18. — Yes, and to the extent which the radius of the curve requires and the other rails of the junction admit of.
No, we pack up the sleepers with ballast.
19. — We provide check rails through the crossing in all cases, wether the outer rail is elevated or not, and have found this arrangement satisfactory.
20. — Throughout the whole length if the radius of the curve is 10 chains (201 metres) or under.
21, 22. — Yes.
23. — Danger.
24. — No.
25. — Yes.
26. — No.
27. — Nothing to add.

Glasgow and South Western Railway.

1. — No.
2. — Yes.
3. — No.
4. — 15 miles (24 kilometres) an hour going through the junction, and 60 miles (96 kilometres) an hour for trains going straight on.
5, 6. — No.
7. — 15 chains (301 metres) radius, 15 miles (24 kilometres) an hour.
8. — 20 1/2 chains (412 metres) radius, 15 miles (24 kilometres) an hour going through the junction.
9. — Double junction (see figure 68).
10. — No.
11. — Ordinary rails.
12. — Nil.
13. — Formed of ordinary rails.

14. — See sketch annexed (figure 69).
15. — No.
16. — The junctions are laid out both curved and straight.
17. — No.
18, 19. — Nil.
20. — Its whole length (see figure 69).
21, 22. — Yes.
23. — Danger.
24, 25. — No.

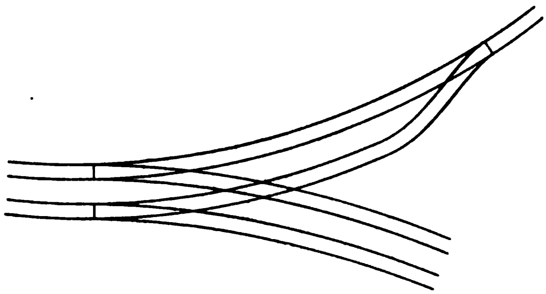


Fig. 68.

Great Indian Peninsula Railway.

1. — No, not in each direction; the speed depends on whether points are facing or trailing.

2. — No, by our rules the speed over all facing points is reduced to 10 miles (16 kilometres) an hour.

3. — At all junctions where there are facing points the 10 miles (16 kilometres) an hour rule is in force, but it does not refer to trains taking the points trailing.

4. — 10 miles (16 kilometres) an hour.

5. — Not always.

6. — No.

7. — About 1,200 feet (394 metres) radius. No maximum speed is laid down as such junctions are so situated as to necessarily cause the speed not to exceed about 20 miles (32 kilometres) an hour.

8. — The reply to the last question applies here also.

9. — We have no such junctions.

10. — No.

11. — They are formed out of ordinary rails.

12. — Nil.

13. — As a rule they are formed of rails.

14. — No diamond crossing is flatter than 1 in 8. Our flattest ordinary crossing is 1 in 12.

15. — No, the guard rails are not superelevated.

16. — With one exception the crossings are on the straight.

17. — No.

18. — Superelevation is not given, the speed of trains not calling for it.

19. — As trains do not pass junctions as full speed no special means have been adopted.

20. — Only at special places.

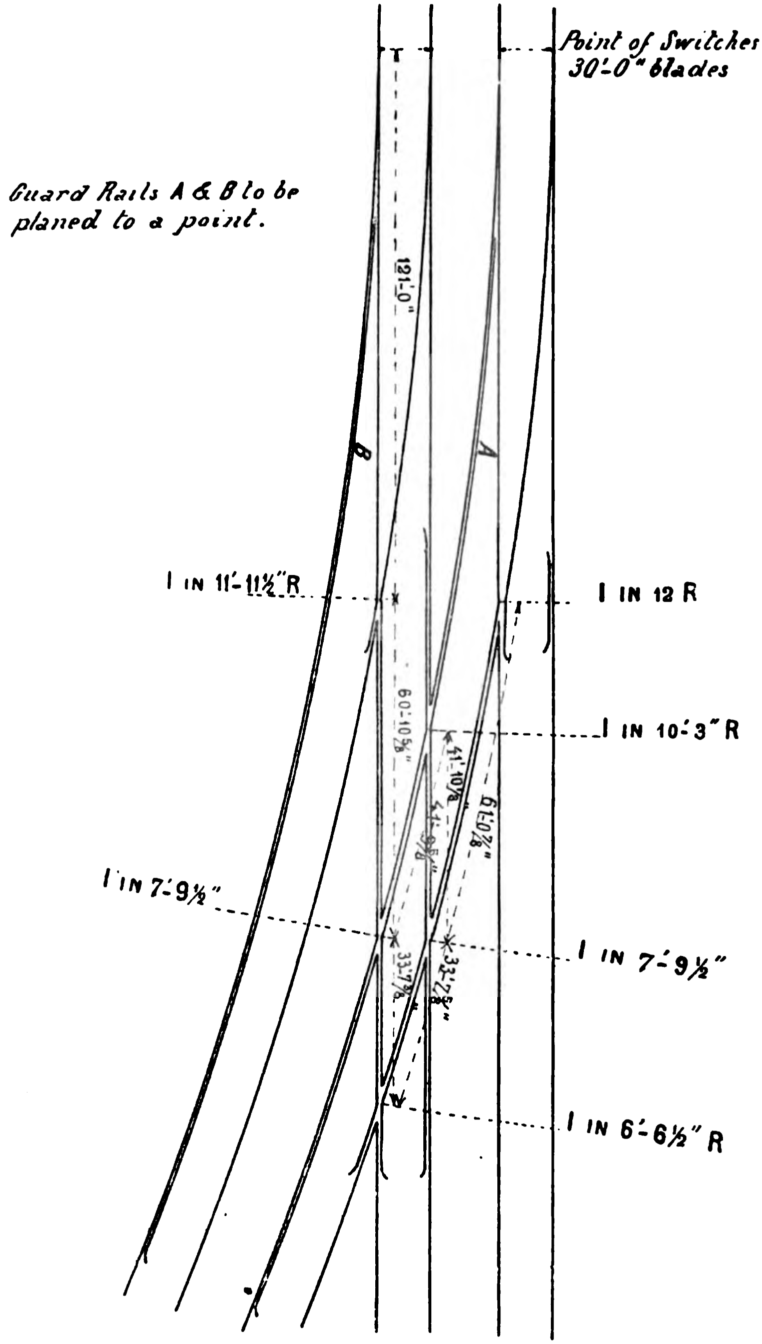

Point of Switches
30'-0" blades
Guard Rails A & B to be
planed to a point.
121'-0"
B
A
1 IN 11'-11½"R
1 IN 12 R
60'-10⅝"
1 IN 10'-3"R
41'-10⅞"
61'-0⅞"
1 IN 7'-9½"
1 IN 7'-9½"
33'-7⅞"
32'-7⅝"
1 IN 6'-6½"R

Fig. 69.

21, 22. — Yes.
23. — Danger.
24, 25. 26. — No.

Great Western Railway.

1. — No, full speed is only maintained upon the lines which are straight or have a comparatively easy curve.
2. — Yes, but only in a few cases.
3. — No, we make no difference between trailing and facing points.
4. — 60 miles (96 kilometres) an hour.
5, 6. — No.
7. — We have no such curve.
8. — We have such cases in which on sharp curve road we allow a curve of about 10 chains (201 metres) radius, and a speed of about 15 miles (24 kilometres) an hour.
9. — If one line can be laid out straight or nearly so and the other at a comparatively sharpe curve, full speed is allowed over the straight line and reduced speed enforced over the sharp curve. If both lines are sharply curved speed is reduced on both lines in both directions.
10. — No.
11. — Formed out of ordinary rails.
12. — Nil.
13. — Crossings are formed of rails.
14. — About 1 in 8.
15. — Only ordinary guard rails about the same height as the running rail are used, and they are used for all angles and extend about 9 feet (2^m74).
16. — If the curves require it the crossings are curved.
17. — Yes, the subway for Metropolitan trains to Westbourne Park.
18. — Superelevation is given to the outside rail according to the radius of the curve by means of packings underneath the outside rail. This can only be done satisfactorily when the elevation is slight.
19. — We have never tried any method of avoiding the necessity for superelevation if passing at a high rate of speed.
20. — Only at places opposite crossings.
21. — The facing points are fitted with locking bars and treadles and are plunged but not the trailing points.
22. — Yes.
23. — At danger.
24. — None are used.
25. — Not if a passenger train travels over unimportant lines but on some mineral branches a short sidings is so used to protect the main line.
26. — We have many different kinds of rolling stock passing such junctions.

North British Railway.

1, 2, 3, 4. — The speed of trains through junctions is regulated by rule as follows : — « Engine « drivers of trains when running through junctions to or from lines diverging from the straight road, « must so reduce their speed as to ensure a steady passage for the whole train through the junction points « and crossings. Where special rates of speed to be observed in running over certain junctions and other « portions of the line are fixed they will be found in the notices or appendices. »
5. — No.

6. — See answer to questions nos 1, 2, 3 and 4.
7, 8. — Nil.
9. — We have no uniform practice.
10. — Nil.
11. — Ordinary rails.
12. — Nil.
13. — Formed of rails.
14. — Cannot give this information.
15. — No.
16. — We have junctions of both descriptions.
17. — No.
18. — This depends on what the junction is.
19. — Guard rails are used where necessary.
20. — We have no uniform practice.
21, 22. — Yes.
23. — Danger.
24. — We do not use any special forms of points.
25. — No.

Midland Railway (England).

1. — No.
2. — Most of our junctions are of this description.
3 — Yes.
4. — No specified speed.
5, 6, 7, 8. — Nil.
9. — See fig. 70.

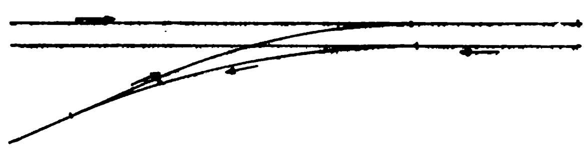


Fig. 70.

11. — Planed out of ordinary rails.
12. — Nil.
13. — Formed of rails.
14. — Diamond crossings are as far as possible kept about 1 in 8.
15. — Nil.
16. — Not always.
17. — Yes.
18. — The surfaces of the rails of both roads are kept in one plane so as to give the requisite super-elevation in the fast line.
19. — Nil.
20. — Only at special places.
21, 22. — Yes.
23. — At danger.
24, 25. — No.
26. — Nil.

New South Wales Government Railway.

1. — No.

2. — Yes; speed is not limited when passing over facing-points in the straight road, but in all cases it is reduced on curves to branch lines.

3. — No.

4. — In the case referred to in question No. 2, 40 miles (64 kilometres) per hour is allowed on the straight road, and 15 miles (24 kilometres) per hour is allowed on the branch.

5. — See answer to question No. 1.

6. — There are no such cases.

7. — See reply to question 1 and 5.

8. — Radius, 10 chains (201 metres); speed, 10 miles (16 kilometres) per hour.

9. — (a) None.

(b) See sketch below (No. 71). Speed in all cases reduced on branch lines; full speed on main lines.

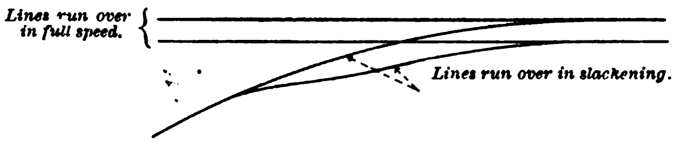


Fig. 71.

10. — Yes; point-rails 15 feet (4m5) in length are curved 3/8" (10 mm.) in the whole length.

11, 12. — They are formed out of ordinary rails.

13. — Formerly cast-steel reversible crossings were used, but these have not been found satisfactory and crossings built up of ordinary rails are now the standard.

14. — At all junctions on main lines ordinary crossings are limited to 1 in 9, and diamond crossings 1 in 8.

15. — Check-rails are laid on the same level as the running rail.

16. — The crossings are always laid in a straight line, except in special cases.

17. — There are no flying junctions in this Colony.

18. — No superelevation is given to the outer rail of the curves at junctions on straight roads. In the case of junctions where the roads curve in opposite directions superelevation is given by packing the ballast and cutting out the timbers where necessary.

19. — No.

20. — No guard-rails are used except at the crossings, which are now made 21 feet (6m40) long in all cases.

21. — Yes, in all cases with locking-bars.

22. — Yes.

23. — At « danger ».

24. — No.

25. — One case only exists, viz : on the Redhead Line (private line) at its junction with the main Northern Line at Adamstown, near Newcastle.

26. — No special rolling-stock is reserved for this purpose.

London and North Western Railway.

1, 2. — Yes.

3. — No.

4. — The ordinary speed of the train at the discretion of the driver. Not limited by any regulation.

5. — No.
6. — Yes.
7. — (See answer to question 5.)
8. — 30 chains (603 metres), ordinary speed of the trains. No limitation.
9. — The junctions are always double with the double line.
10. — No.
11. — Out of ordinary rails.
13. — Formed of rails.
14. — Standard maximum angle for diamond crossings 1 in 8, other crossings 1 in 15.
15. — No.
16. — Curved or straight as may be wanted.
17. — Yes, in some cases.
18. — Where superelevation can be given, the chair seat (if on the same timber or sleeper) is jagged out under the lower rail.
19. — Only a high standard of maintenance.
20. — Occasionally the whole length, generally only at special places.
21, 22. — Yes.
23. — At danger.
24. — None such are used.
25. — No.
26. — No, but obviously carriages of the most recent construction are put in the most important and swiftest trains.
27. — See fig. 72, 73, 74, 75, 76, for junctions over which engine drivers are not required to slacken the speed of trains; and diagrams Nos. 77, 78, 79, for junctions over which trains slacken speed.

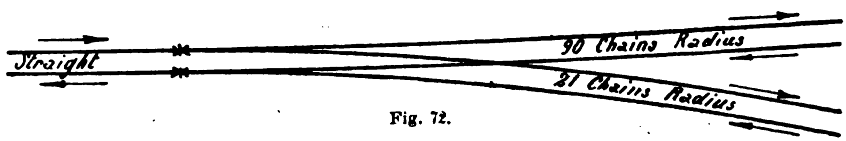


Fig. 72.

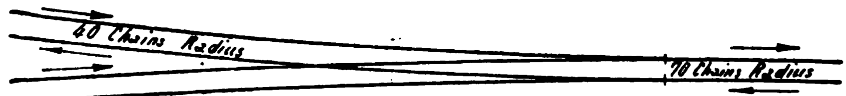


Fig. 73.

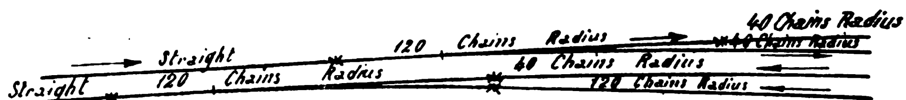


Fig. 74.

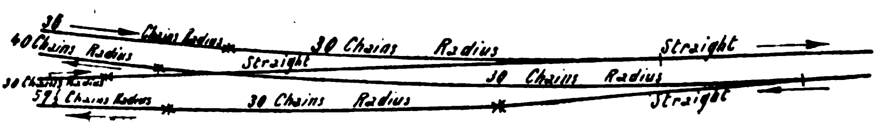


Fig. 75.

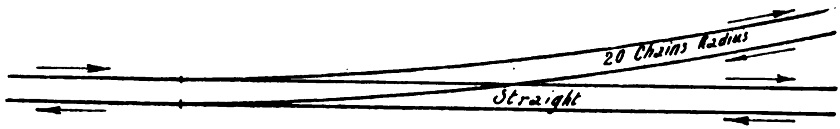


Fig. 76.

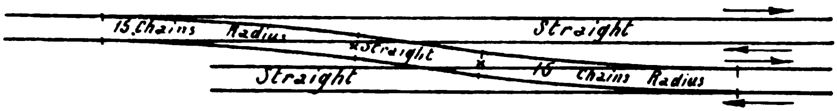


Fig. 77.

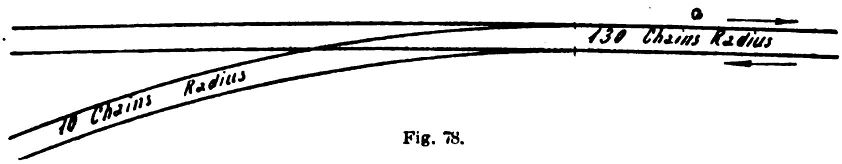


Fig. 78.

Fig. 79.

HOLLAND

Dutch Railway.

1-2. — No.

3. — Yes.

4. — 28 miles (45 kilometres) an hour.

5. — Many junctions are symetrical in order that they may be run over without slackening speed by trains coming from the two branches.

6. — No.

7. — Radius, 25 chains (500 metres); speed, 28 miles (45 kilometres).

8. — The maximum speed for trains approaching facing points is 28 miles (45 kilometres); the minimum radius, 10 chains (200 metres).

9. — The case *a* does not exist.

10. — No.

11. — Point-rails formed of rails of special profile are being replaced by those formed of ordinary rails.

12. — The height of the rail of special profile is 3·5 inches (9 centimetres), that of the ordinary rail 5·06 inches (13 centimetres).

13. — As a general rule, the crossings are made of cast steel; exceptionally, for extraordinary angles we make use of crossings formed of rails.

14. — See Nos. 1 and 2.

The normal inclination for crossings of junctions between stations is 1 to 10, sometimes 1 to 9.

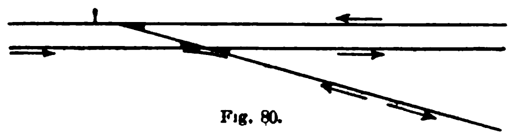


Fig. 80.

15. — Yes, always for obtuse crossings. The guard rail is superelevated 2 inches (5 centimetres).

16. — The acute and obtuse crossings are always straight.

17. — No.

18. — In the curves of junctions, super-elevation is never given to the exterior rail.

19. — See Nos. 1 and 2.

20. — Only to the right of the crossings.

21. — Switch plungers worked separately are only used very exceptionally; our appliance for working switches at a distance, serves at the same time to plunge them.

Locking bars are adopted in single line stations wherever the switches are worked at a great distance

22. — Yes.

23. — See figure 81.

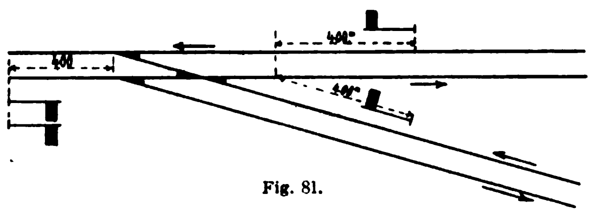


Fig. 81.

24. — No.

25. — Yes, for junctions of which the secondary line is of very little importance, such as junctions with works.

26. — No.

PORTUGAL.

Royal Portuguese Railway Company.

1. — We have four junctions passed over at full speed by all trains; these are the Bemfica and Chellas junctions, on the branch from Santa-Apolonia to Bemfica, and the Lares and Verride junctions on the connecting line, which joins the Lisbon to Figueira line to the Alfarellos branch. There are further two other junctions, namely, the Campolide and Sette-Rios on the metropolitan line which are passed over at a low speed on account of their special conditions.

2 3. — No.

4. — The average speed of trains approaching facing or trailing points is, on the Bemfica junction, 19 miles (31 kilometres); on the Chellas junction, 23 3/4 miles (38 kilometres); on the Lares junction, 22 1/2 miles (36 kilometres), and on the Verride junction, 22 1/2 miles (36 kilometres). These numbers may be increased by 3 miles (5 kilometres) to represent the maximum speeds.

5. — No.

6. — In all the junctions indicated, the main line is straight and the branch is on a curve of 20 chains (400 metres) radius.

7, 8. — Answered.

9. — We have none.

10. — Generally, point-rails at junctions are straight. We also employ curved switches.

11. — Our point-rails are formed of bars of special profile, according to the patterns most used.

12. — The bars have the same height as the ordinary rail.

13. — We use crossings of steel cast in one piece.

We have no obtuse crossings.

14. — The minimum angle of the crossings is 5° 10' (tangent 0·09).

We also have crossings having an angle of 4° 30' (tangent 0·08) for curves of a lesser radius than 20 chains (400 metres).

15. — No.

16. — In all the junctions indicated the crossings are on a curve.

17. — No.

18 — We do not give any superelevation to the exterior rail of the curves of junctions.

19. — No.

20. — We only use a guard rail for the crossings.

21. — No.

22. — Yes. At Bemfica, Chellas, Lares and Verride we use the Viguier system. At Campolide and Sette-Rios we are going to apply the Saxby and Farmer system.

23. — We use an « advance » disc for each of the directions, interlocked with the switches, and lamps placed on a rod connected with the lever for the switches.

24, 25. — No.

26. — Our rolling stock is, generally, provided with convenient arrangements to facilitate the passage over the curves of 15 and 17 1/2 chains (300 and 350 metres) radius of our lines, and passes easily over the junctions (1).

SWITZERLAND.

Gothard Railway.

1. — No.
2. — Yes.
3. — No.
4. — 37 miles (60 kilometres) an hour.

(1) The locomotives used for our trains which run over curves of small radius at great speeds, are provided with bogies or simply with a radial axle, according to the case.

The carriages composing these trains are also provided with bogies.

We have also carriages on three axles, of which the extreme ones are radial and the intermediate one has a certain amount of play.

5, 6, 7, 8. — Nil, the reply to question 1 being negative.

9. — Our system has no junction of this kind.

10. — Nil, the reply to question 1 being negative.

11. — On our system we have only one junction, which leads to a ballast pit belonging to the company. The switch that we use is that known as the « Blauel » apparatus; the point rails are formed of bars of special profile.

12. — The bars have a wider base, but less height than the ordinary rail.

13. — At the crossing, the rails of the main line have no gap, whilst those of the diverging line are interrupted by a piece of cast iron.

14. — The angle of the crossing is 7°.

15. — The maine line not being interrupted, it is superfluous to adopt guard rails; the guard rails of the diverging line are not superelevated.

16. — The turn-out of our junction is straight.

17. — No.

18, 19, 20. — Nil, the reply to question 1 being negative.

21, 22. — Normally, that is to say when the line is free for the trains of the main line, the « Blauel » switch is electrically plunged by the two adjacent stations; in case of the ballast pit not being used for a length of time sufficiently prolonged, the switches of the turn-out are taken away and the electric current is interrupted. The switches are not provided with locking bars or treadles.

23. — When the switches stand for the secondary direction, the two signals protecting the junction indicate « danger », at all other times « all right ».

24. — See reply to question II. Up to the present, that is to say for seven years, the « Blauel » apparatus has given good results.

25. — The junction is provided with a safety road.

26. — Nil, the reply to question 1 being negative.

27. — No.

DISCUSSION BY THE FIRST SECTION

Meeting held on July, 3 (morning sitting).

MR. JEITTELES, PRESIDENT, IN THE CHAIR.

Mr. Zanotta, *reporter.* (In French.) — The circumstances which may influence railway Companies in requiring fast trains to slacken at junctions arise from :—

1st The possibility of converging trains coming into collision;

2nd The weakness naturally inherent in a junction both from its profile and from its construction.

As for collisions, we try to prevent them by correct methods of signalling, interlocking and block system which have already several times occupied the attention of this Congress.

Question III, now under consideration, deals especially with difficulties of the second kind, that is with those that concern the actual laying out of the junction proper.

I find from the replies sent in by Companies who have been questioned that full speed is almost universally allowed on the straight roads of junctions where points are not taken facing; this is also allowed, though not quite so universally where points are taken facing. Full speed is less often allowed if the line curves.

So then the main factors militating against trains running fast at junctions would seem to be the difficulties of laying them out, that is, the sharpness of the curve at which lines come in and the divergence at the switch, rather than the weakness of the road due to the presence of the actual points and crossings.

It would however be difficult, from the regulations enforced by different Companies, to arrive at any very definite idea of the importance that should be attached to this difficulty in profile, for while one Company allows full speed, even on junction curves with a radius of 15 chains (300 metres) and even less, another Company does not allow it when the radius is 22 $^1/_2$ chains (450 metres). Still it cannot be said that this difference between Companies is always due to any appreciable difference in the actual roads or their constituent parts, for we find instances in which companies with similarly built roads and equally good arrangements allow quite different speeds in running through junctions.

In his paper on special points of the road Mr. Sabouret remarks that " considerations of commercial and even general expediency are of even greater importance in this question than considerations of a technical nature, " and I cannot help agreeing with him so far as the special question of junctions is concerned.

As to the arrangements adopted or to be recommended for junctions run over at speed, I have tried to include in my report those of them which appeared to me of most importance from the points of view of profile, construction and laying down.

I will summarise them briefly and in so doing keep to the same order as was followed in wording the question on which I was called upon to report.

Best methods of constructing. — Amongst these I may mention first the arrangements recommended for junctions in general by the Congress at its first session in its conclusions upon Question VII-B, namely : to avoid junctions in cuttings, at sharp curves or on gradients, to endeavour to replace level crossings by overhead or underground crossings, to carry converging roads parallel to one another for some distance, etc. We may add that, if converging lines are equally important so far as speed of trains using them is concerned, the best plan to avoid slackening seems to be to build them symmetrically. If this cannot be done we ought to try to build the line going off from the straight with a curve of as great radius as possible.

A road with great vertical and lateral resistance is also one of the most important requisites where junctions are to be run over at high speed. This class of road has, be it said, already been adopted or is in course of being adopted by almost all the Companies running fast trains.

Finally there is no gainsaying that these junctions must be very carefully laid and maintained; special stress must be laid on the need of suitably spaced sleepers of strong scantling, and ballast of good quality lying on firm and well drained subsoil.

Points. — Points are usually locked. Apart from this arrangement which is also adopted for points taken facing, even when run over after slackening, I know of no arrangements really special to points run over at high speed. We can only state that under these circumstances Companies use point-rails as long as possible to make the angle they form with the stock-rail as small as may be.

When the ordinary rails are very stiff they make very good point-rails.

The Pennsylvania Railroad, the English Companies in general, and the Eastern of France use nothing but ordinary rails for points.

On the other hand, on lines where special steel bars are made into points, various more or less simple but satisfactory enough devices have been invented for joining the points to the running road.

Crossings. — In the same way as Companies try to make point-rails as long as possible they also endeavour to make the openings of diamond and obtuse crossings as small as possible so as to lessen the curve of the divergence.

The openings of diamond crossings are as low as $^1/_{12\cdot5}$ and in the case of the English Companies even as low as $^1/_{15}$.

For obtuse crossings the minimum angle is generally about $^1/_8$; there are however instances where the opening is as small as $^1/_{10}$.

On the Continent when the opening of obtuse crossings is very small, a slight amount of superelevation is given to the guard rail of the crossings. The English Companies do not seem to regard this superelevation as necessary.

Full speed is allowed over crossings made of steel cast in one piece as well as over crossings made of ordinary rails.

It even seems that crossings of the latter kind afford smoother running provided that the rails of which they are made are sufficiently stiff and long and fit together well.

All the Companies in the United Kingdom, the Pennsylvania Railroad and the two French Companies which allow full speed over their junctions, namely the Northern and the Eastern, use ordinary rails for their crossings.

The intervening rails between a switch and a crossing. — If one branch of a junction is straight, the other on a gradual curve, the curve can be given a radius of about 22 $^1/_2$ or 30 chains (450 or 600 metres) if ordinary and obtuse crossings with the minimum angles already mentioned are used.

These radii may, however, be considerably less if the constituent parts of the diamond and obtuse crossings are kept straight, even after being laid down, as is required by most Companies and as must necessarily be done if the crossings are made of steel cast in one piece. If the symmetrical arrangement be adopted the radii would be nearly double those just mentioned.

To make up for the entire or partial absence of superelevation of the outer rail in some measure, reliance is placed, especially in the case of Vignoles rails, on strengthening the rail fastenings by the use of stays bearing upon the outer side of the rail and sometimes by the use of a check rail placed along the inner rail all along the curve.

This, gentlemen, is the information I have collected which has induced me to draw up the following conclusions :—

" The Congress finds that a large number of Administrations allow trains to pass junctions at full speed, especially trains running on the straight line or on lines with curves of large radius.

" A permanent way with stiffness to resist vertical and horizontal strains, curves not too sharp (an arrangement which can be arrived at either by adopting a symmetrical design for the two lines or by employing very acute crossings), sleepers of large section suitably spaced and good ballast resting on a solid and well-drained formation, may be considered, in conjunction with the arrangements suggested in the conclusions arrived at on Question VII-B at the first session of the Congress, to embody the most favourable conditions for the construction of junctions which are run over by express trains in all directions at full speed. "

Mr. Gordiéenko, Russian Ministry of Ways of Communication. (In French.) — If we examine the replies of railway Administrations to the detailed list of questions on junctions, we see in the first place that in most cases it is neither the conditions of working nor the profile of their line which oblige them to slacken speed at junctions. The main reasons are those connected with construction, that is the necessity of using points, switches and crossings, and the impossibility of superelevating the outer rail sufficiently on junction curves of small radius. Out of 29 railway Administrations only two, the Western and the Midi of France, require the driver to slacken speed before reaching the junction, no matter from which side he may be coming, to such an extent that he can bring his train quite to a standstill before reaching the stop signal.

All other railways either allow trains to go through junctions in both directions without slackening, or if this is required it is only for trains taking the points facing, and then speed has only to be reduced for trains entering the divergent line.

Evidently with a view to safety it would be wiser to slacken when coming from the branch on to the main line, that is when taking the points trailing. But exactly the contrary is done.

It is then, I repeat, conditions of construction which lead railway Administrations to require trains to slacken speed in going over points and crossings.

If it is at times desirable not to have to slacken at junctions, we need only see how the points and crossings ought to be constructed so as to enable trains to run at full speed in all directions.

The construction of points and crossings was to have been one of the questions for discussion at the fourth session of the Congress, but as no paper was written on the subject there was no discussion.

Having been asked to write a report on this subject for the recent annual meeting of the Russian permanent way engineers, and it being my duty to suggest a new pattern of points for the Nicolas railway, I have paid special attention to this question. I have become convinced that most of the patterns of points used on the Russian and other railways are often far from perfect.

Considering the importance of this subject I first beg to be allowed to suggest that you should express a wish to have put down for discussion at the next meeting of the Congress the question of constructing points and crossings in such a way that they may be taken at a high rate of speed.

To return now to the replies sent in by the Administrations : we find that out of 29 only 4 allow their junctions to be run through *without slackening*, namely : 1st, The State Railways of Denmark [maximum speed 56 miles (90 kilometres), minimum radius of junction curve, 15 3/4 chains (315 metres)]; 2nd, Manchester, Sheffield and Lincolnshire [maximum speed 50 miles (80 kilometres), minimum radius 20 chains (400 metres)]; 3rd, London and North Western curves of from 30 to 20 chain (600 to 400 metres) radius, and 4th, Great Eastern. It must further be noticed that the London North Western, though it does not limit speed by its regulations, leaves the matter to the judgement of the driver, but in the case of curves of less than 20 chain radius reduction of speed is obligatory, that the Great Eastern occasionally under exceptional circumstances limits speed, and in these cases the maximum speed allowed on the curve (minimum radius 10 chains [200 metres]) is only 15 miles (24 kilometres) an hour.

The Caledonian and Pennsylvania cannot be reckoned among this group because these two lines only deal with symmetrical junctions with curves of very large radius (40-43 chains 8 feet [800 to 873 metres]) and of still greater importance symmetrical points, wherein the angle the points make with the axis of the road is only half the angle of the point belonging to the branch road in an ordinary non-symmetrical junction.

Accordingly there are only four railways on which the driver can run over facing point junctions, even on to the divergent line, without slackening. But even though he is authorised to run at full speed there is nothing to show that he always does so.

It would be of interest to have information on this point. I therefore beg the delegates from the Danish State Railways, the London and North Western, the Great Eastern and the Manchester and Sheffield, to tell me whether they are certain that the drivers really do at times run at full speed over the facing points of junctions towards a divergent line on a curve.

Mr. F. E. Robertson, East Indian Ry. — I represent the East Indian Railway. As no gentleman appears to answer for the London and North Western Railway, perhaps I might say a word. I wish to remark that my railway has always, as far as I know, used No. 10 obtuse crossings without inconvenience.

Mr. Robinson, *secretary-reporter*. — What does No. 10 mean?

Mr. Robertson. — One in ten. The tendency seems to be to limit the angle of these crossings to 1 in 8, but we have never found any trouble with 1 in 10 crossings and the check rail.

Mr. Gordiéenko. — I ask if the speed is reduced.

Mr. Robertson. — I cannot answer for the London and North Western Railway.

Mr. Gordiéenko. — Are crossings with an angle of 1 in 10 used very often?

Mr. Robertson. — Yes. On the East Indian Railways.

Mr. Gordiéenko. — You have spoken about the possibility of passing the switches at full speed even with facing points on to the divergent road. What I want to know is, would an engine pass in such conditions at full speed?

Mr. Robertson. — I believe they do in England.

Mr. Gordiéenko. — To have permission to do it is one thing, but actually to do it is quite another.

Mr. Robinson. — I think the information Mr. Gordiéenko is endeavouring to obtain is this; in the answers sent by the Companies they say they give their engine-drivers carte blanche to run at full speed: Mr. Gordiéenko wants to know whether the engine drivers do it or not. In your own Company do you give carte blanche and do they run at full speed or slacken?

Mr. Robertson. — My own experience is that they run at full speed when they have not carte blanche. The inclination is always to drive faster than the rules permit. I do not think a driver ever slackens if he has carte blanche.

Mr. Gordiéenko. (In French.) — As regards running over the curved lines of junctions towards the main line, that is over trailing points, this is permitted not only on the four railways mentioned and on the Pennsylvania and the Caledonian, but also on the Dutch Railway Company, the Midland, Great Indian, and on the Austro-Hungarian State Railways, that is on ten railway systems altogether. Then again 19 railways allow full speed over facing points if the trains are running on the straight road; only two, the Midi and Western of France, as I have just said, make their trains slacken in going over junction points even when taken trailing and on the straight road.

This seems to me to demonstrate clearly :—

1st, That most Railway Administrations regard it as dangerous to run over junctions at full speed or simply over facing points on to a divergent road;

2nd, That everywhere most railways think speed should be limited in going over points on the divergent road even when they are taken trailing;

3rd, That on the contrary most railways think it quite right to run at full speed over facing points if the train is going on the straight road and if the points are properly locked or bolted.

If we now turn to what might constitute a greater danger for trains running over points and crossings than when they are going on the straight road or on a curve, we can, I think, come to the following conclusions :—

A. If the points are carefully constructed, carefully worked and bolted or locked and if they are towards the straight road, there is no danger in running over them at full speed. The only risk is in running over facing points, especially if the angle is very acute, and the only way to avoid the risk is to have a check rail firmly fixed in such position as to allow of the flange passing through the crossings and to prevent its striking against the nose.

I may say that this is not always the case and that sometimes the slight differences in the distances between tires are not allowed for;

B. In going over points on the straight road when they are taken trailing shocks are sometimes felt. When the point rail is short and consequently the angle of the crossing large and the spread of the road at the beginning of the points noticeable we run the risk of the wheel which strikes the facing point of the diverging road dropping inside the rail. Such accidents have occurred on the Russian railways.

So it may happen, owing to certain peculiarities in construction, that running over points in the trailing direction on the straight road is more dangerous than when taken facing.

In both these cases, therefore, assuming that the points are well made and well fixed, they may always be run through at the speed authorised on the ordinary running road;

C. All other conditions are those of running over points on the divergent road. When the trains take points facing, the shock of the flange is felt by the nose of the points and by the heel when the points are taken trailing. There is the same deviation and the same shock in the two cases. But the train taking the points facing is more likely to be thrown off the rails, because where the shock arises the point-rail is about an inch (2 or 3 centimetres) lower than the stock-rail and the result is the flange can easily mount over the point.

The violence of the shock increases in proportion as the square of the speed and the square of the sine of the angle of the point. I am a little surprised to find that very few railways have curved points. This used to be the case in Russia, but now several lines are beginning to use curved points and find them better than straight ones.

The shape of the cross section of the points may also sometimes tend to derailment. On the South Western of Russia it has been noticed that this is the case if the inner surface is not vertical.

Be this as it may, it is not so much upon the radius of the points' curve or of the junction curve that the speed to be authorised depends, but on the angle at which the shock comes, which, in the case of straight points, is the angle of the point-rail.

I suggest for your consideration, gentlemen, the following conclusions :—

" 1st, Trains can be run in both directions on the straight line over points at the same speed as on the straight line without points, if points are of good construction and locked in the direction of the main line.

" 2nd, For trains passing in the direction of the branch line over points either facing or trailing, it is desirable to slacken speed, whether the points are locked or not. "

Mr. Brière, Paris and Orleans Ry. (In French.) — Gentlemen, I think Mr. Zanotta's report has been particularly ably written, that it is as it should be and is confined within the bounds of what should be stated in a Congress, and I hope you will accept the reporter's conclusions just as they are. Mr. Gordiéenko asks to have the question of the construction of points put on the agenda for next Congress. I am of opinion — and several of my friends are of the same opinion — that this is too special a question to fall within the scope of the Congress.

If we were to accede to Mr. Gordiéenko's request some one would be justified in asking the Congress to take up quite special subjects, such as the manufacture of bolts for instance. I think the Congress ought not to go in this direction, but deal only with general questions.

Mr. Gordiéenko. (In French.) — The question of the construction of points was on the agenda for the St. Petersburg session and so it was not thought too special a subject.

The President. — I think the section wishes to vote upon Mr. Zanotta's conclusions at once. (*Hear! Hear! on all sides.*)

Mr. Gordiéenko. (In French.) — The first paragraph of Mr. Zanotta's conclusions simply states facts; I think nothing would be lost in adding thereto an expression of opinion and this is what my conclusions do.

The President. — Mr. Gordiéenko states an opinion and he would like the Congress to recognise its truth.

Mr. Gordiéenko. (In French.) — I simply ask you not to confine yourselves to stating facts.

Mr. Brière. (In French.) — It is just exactly our business to state facts. We must show great caution and not advance theories which may be found faulty in practice. Moreover our Constitution shows that the line we ought to take is the one I have just drawn. As we cannot vote we ought to confine ourselves to statements of fact.

Mr. Debray, *Principal Secretary.* (In French.) — It is a mistake to say we cannot vote. The Sections give their opinions on the reporters' conclusions and the result is submitted to the general meeting.

The President. — It is profitless to continue this discussion; the general meeting will either accept or not accept our suggestions.

I declare the discussion closed and I now put the first paragraph of Mr. Zanotta's conclusions.

— This paragraph was adopted.

The President. — This means that the first paragraph of Mr. Gordiéenko's conclusions is rejected.

I now put Mr. Zanotta's second paragraph.

— The second paragraph was adopted.

The President. — Does Mr. Gordiéenko wish his second conclusion to be put to the vote?

Mr. Gordiéenko. (In French.) — My conclusion concerning running over points towards the diverging road is as follows :—

" For trains passing in the direction of the branch line over points either facing or trailing, it is desirable to slacken speed whether the points are locked or not. "

Mr. Zanotta, *Reporter*. (In French.) — This is just the opposite of what I suggested.

Mr. Gordiéenko. (In French.) — I do not press the point.

The President. — Gentlemen, I am pleased at the outcome of our discussion.

I think I am expressing your feelings by congratulating the reporter on his very valuable paper. (*Hear! Hear!*)

— The meeting adjourned at 12 o'clock.

Meeting held on July 4, 1895, at 10 a. m.

MR. RICHARD JEITTELES IN THE CHAIR

The President. — At yesterday's meeting, Mr. Gordiéenko asked us to propose that the question of the *construction of points* should be included in the programme for discussion at the 6th session of the Congress.

Mr. Brière has given us his opinion upon the subject. If no one else wishes to speak I shall put the matter to the vote.

Mr. Gordiéenko, Russian Ministry of Ways of Communication. (In French.) — Mr. Brière has said that the question is too special a one. But as I have said this question was on the programme before (at St. Petersburg), and the only reason why it was not discussed was because the report upon it was not ready in time. In view of the importance of the question I must press my motion that the subject may be brought before the Congress at its next session.

— Mr. Gordiéenko's proposal was put to the vote and adopted.

The President. — The resolution will be reported to the general meeting.

DISCUSSION AT THE GENERAL MEETING

July 5, 1895 (afternoon).

LORD STALBRIDGE, PRESIDENT, IN THE CHAIR.

The President. — I call upon Mr. Richard Jeitteles, President of the 1st Section, to read the French text of the Report. Mr. Leslie Robinson, Secretary Reporter, will subsequently read the English version.

Report of the 1st Section.

Mr. Jeitteles. —

" Cette question a fait l'objet d'un très remarquable rapport dont les conclusions ont été adoptées par la section à une grande majorité.

" Dans l'exposé qu'il a présenté à la section, Mr. Zanotta a rappelé l'observation faite par Mr. Sabouret, rapporteur de la question nº II, que les considérations d'ordre commercial et même d'ordre moral se trouvent avoir dans la question une bien autre importance que les considérations d'ordre technique.

" Il en est pour la Question III comme pour la Question II.

" Comme conditions les plus favorables de construction, Mr. Zanotta cite les dispositifs conseillés lors de la première session du Congrès dans les conclusions de la question VII, littéra B, c'est-à-dire éviter d'établir les bifurcations en tranchée forte courbe ou pente, chercher à remplacer la traversée à niveau par le passage au-dessus et au-dessous, tracer

Mr. Leslie Robinson. —

" This question was the subject of a very interesting report, the conclusions of which were adopted by a large majority in the Section.

" Mr. Zanotta called attention to the observations made by Mr. Sabouret, the reporter of Question II : « That considerations of commercial and general expediency are of greater importance in this question than considerations of a technical nature. »

" Question III is similar in this respect to Question II.

" Mr. Zanotta stated that the most favourable conditions of construction, according to the conclusions arrived at on Question VII-B, at the first session of the Congress, were : " To avoid junctions in cuttings, at sharp curves and on gradients, and to endeavour to substitute other means of communication either below or above the line, to lay out the les voies convergentes parallèlement l'une à l'autre sur une certaine longueur, etc."

"Mr. Zanotta recommande, pour le cas où les deux lignes convergentes sont parcourues par des trains rapides ayant la même vitesse et également importantes, la disposition symétrique, et si cette combinaison n'est pas possible, de donner à la voie déviée le plus grand rayon de courbure possible par l'adoption de croisements assez aigus et d'une entrevoie assez large.

"Il faut naturellement que les voies des bifurcations soient fortement constituées; la pose de ces voies exige des soins particuliers, et l'on peut y recommander l'emploi des supports de fort équarrissage, convenablement espacés, d'un ballast de bonne qualité reposant sur une plate-forme solide et bien asséchée.

"En ce qui concerne les aiguilles, Mr. Zanotta constate qu'elles sont généralement verrouillées, qu'il y a une tendance à employer des aiguilles aussi longues que possible; ces aiguilles peuvent être souvent constituées avec des rails de la voie ordinaire.

"Pour les croisements de changement et de traversée, on leur donne la plus faible ouverture possible en descendant jusqu'à $^1/_{12.5}$ ou $^1/_{15}$ pour les croisements de changement et jusqu'à $^1/_8$ pour les croisements de traversées, et quelquefois même $^1/_{10}$.

"Les Administrations anglaises ne paraissent pas reconnaître la nécessité de la surélévation donnée généralement sur le continent au contre-rail de la traversée.

"Les croisements constitués avec des rails ordinaires de la voie seraient peut-être plus favorables au point de vue de la douceur de la marche que les croisements d'une seule pièce.

"Mr. Zanotta constate que la disposition symétrique présente des conditions plus favorables pour le tracé des raccords; on arrive ainsi à des rayons presque doubles de ceux obtenus quand l'une des branches est maintenue en ligne droite.

converging lines parallel to one another for a certain length, etc."

"Mr. Zanotta recommended for the case of converging lines run over by express trains with equal speed and of equal importance that both lines shall converge equally and if this cannot be effected, that the converging line shall have as flat a curve as possible, and the angle of intersection at crossings be very acute with plenty of width between the up and down lines.

"The junctions must be strongly made; the laying out must receive special attention; substantial supports, suitably spaced out, must be used, and also ballast of good quality, resting on a solid and well drained formation.

"As regards the points, Mr. Zanotta said they are generally bolted, and that there is a tendency to use switches, as long as possible, which can often be made with ordinary rails.

"For single and diamond crossings the smallest possible opening should be given down to $^1/_{12.5}$ or $^1/_{15}$ for the former and $^1/_8$ or even $^1/_{10}$ for the latter.

"English Companies, as a rule, do not recognise the necessity of giving any super-elevation to the guard rail in crossings, as is done on the Continent.

"The crossings made with ordinary rails tend perhaps to smoother running than those made in one piece.

"Mr. Zanotta maintained that the symmetrical convergence of the two lines is preferable for junctions, as the radii of the curves are then nearly double what they would be if one branch ran straight.

" Afin de remédier en quelque manière à l'absence totale ou partielle de surélévation du rail extérieur, on a recours, surtout dans le cas de voies Vignoles, au renforcement des attaches de ce rail, à l'adoption de contre-fiches qui s'appuient sur la face extérieure du même rail et en quelques cas à l'emploi d'un contre-rail placé latéralement au rail intérieur tout le long de la branche en courbe.

" Diverses observations ont été présentées par Mr. Gordiéenko (Russie), d'après qui le ralentissement des trains au passage des bifurcations serait motivé par des conditions de construction qui ont fait l'objet d'études spéciales en Russie. Mr. Gordiéenko avait présenté à la section les conclusions suivantes, qui n'ont pas été adoptées, la section ayant estimé qu'il suffisait de ratifier les constatations consignées dans les conclusions de Mr. Zanotta sans formuler de règle :

" 1° Les aiguilles solidement construites " dans tous leurs détails, verrouillées ou calées " dans la direction de la voie droite, peuvent " être franchies par les trains dans les deux " directions de la voie droite, avec les vitesses " qu'on admet pour la voie droite;

" 2° Pour le passage des aiguilles, dans la " direction de la voie déviée, il est toujours " à recommander de modérer la vitesse, que " l'aiguille soit verrouillée ou non, qu'elle " soit prise par la pointe ou par le talon. "

" Mr. Gordiéenko avait également proposé de demander à la Commission internationale de reprendre pour la sixième session du Congrès la question de la constitution des aiguilles qui a figuré à l'ordre du jour de la quatrième session, mais qui n'a pu être traitée à Saint-Pétersbourg.

" Cette proposition a été combattue par Mr. Brière (Paris-Orléans), par la considération que le Congrès doit se tenir dans l'étude des questions générales, on ne saurait s'engager dans les détails. La section est d'avis de soumettre la proposition de Mr. Gordiéenko à la séance plénière.

" In order to counteract to some extent the total or partial absence of superelevation of the outer rail, the attachments, and this is particularly the case with the Vignoles rail, are strengthened by abutments which bear upon the outer face of the rail, and sometimes also guard rails are placed along the side of the inner rail on the whole length of the curved branch.

" Several remarks were made by Mr. Gordiéenko (Russia), to the effect that the slackening of trains at junctions depended upon the conditions of construction, and that these conditions had been the subject of special study in Russia. Mr. Gordiéenko made the following proposals to the Section which were not adopted, the Section being of opinion that the conclusions arrived at by Mr. Zanotta should be adopted and that it was not necessary to draw up fixed rules :—

" 1st Trains can be run in both directions " on the straight line over points at the same " speed as on the straight line without points, " if points are of good construction and locked " in the direction of the main line;

" 2nd For trains passing in the direction of " the diverging line over points either facing " or trailing, it is always advisable to slacken " speed whether the points are locked or " otherwise. "

" Mr. Gordiéenko also wished the International Commission to be asked to put down the question of the construction of points for discussion at the sixth session of the Congress, as it was on the programme for the fourth session at St. Petersburg, but was not discussed.

" This proposal was objected to by Mr. Brière (Orleans Railway) as he considered that the Congress should confine itself to general questions, and not enter into details. The Section decided to submit Mr. Gordiéenko's proposal to the general meeting.

" La section présente à l'approbation du Congrès les conclusions suivantes :

" The Section presents for the approval of the Congress the following conclusions : —

CONCLUSIONS

" Le Congrès constate qu'un grand nombre " d'Administrations admettent le passage en " vitesse sur les bifurcations, surtout pour " les trains parcourant les branches en lignes " droites ou en courbes de grand rayon.

" Une voie très résistante aux efforts verti- " caux et horizontaux, un tracé qui ne com- " porte pas de courbes ayant des rayons trop " faibles (tracé auquel on peut arriver en " adoptant une disposition symétrique pour " les deux branches de la bifurcation ou en " employant des croisements de changement " et de traversée très aigus), l'emploi de sup- " ports de fort équarrissage convenablement " espacés et d'un ballast de bonne qualité " reposant sur une plate-forme solide et bien " asséchée, peuvent être considérés con- " curremment aux dispositifs conseillés dans " les conclusions relatives à la question VII, " littéra B, de la première session du Congrès " parmi les conditions les plus favorables à " l'établissement des bifurcations parcourues " en tous sens à toute vitesse. "

" The Congress finds that a large number " of Administrations allow trains to pass over " junctions at full speed, especially trains " running on the straight line, or on lines " with curves of large radius.

" A permanent way with stiffness to resist " the horizontal and vertical strains, curves " not too sharp (an arrangement which can be " arrived at either by adopting a symmetri- " cal design for the two lines or by employing " very acute crossings), sleepers of large sec- " tion suitably spaced, and good ballast, " resting on a solid and well- drained forma- " tion, may be considered, in conjunction " with the arrangements suggested in the " conclusions arrived at on Question VII-B, " at the first session of the Congress, to em- " body the most favourable conditions for the " construction of junctions which are run over " by express trains in all directions at full " speed. "

The President. (In French.) — Gentlemen, I have to submit to you the following proposition by Mr. Gordiéenko. This proposition has not been printed.

" It is advisable to ask the International Commission of the Congress to put the question of the construction of points on the agenda of the 6th session. This question was on the agenda of the 4th session but was not dealt with. "

There is no need, I think, to vote upon Mr. Gordiéenko's proposition. All we can do is to refer it to the International Commission of the Congress within whose province it comes.

— Agreed.

— The conclusions arrived at by the Section on Question III were adopted by the general meeting without comment.

Corrigendum in Mr. Zanotta's Report.

Page III/57, on line 17, *after* : " For the main line ", *insert* : " 25 miles (40 kilometres) ".

1st SECTION. — WAY AND WORKS

QUESTION IV

CONSTRUCTION AND TESTS OF METALLIC BRIDGES

A. ***What are the quantities of metal used and required to be used in railway bridges, according to the regulations in force in different countries?***

B. ***What are the nature and value of the methods adopted by the different railway administrations for the original and the subsequent periodical testing of metal bridges?***

C. ***What is the real value of these tests, and can they be regarded as practical means of settling the actual state of repair and the margin of safety of the above-mentioned structures?***

***Reporter* : Mr. Max Edler von Leber, Principal Inspector of the Railway Control Department, Ministry of Commerce, Vienna.**

QUESTION IV

CONTENTS

REPORT

By M. Max Edler von LEBER

CHIEF-INSPECTOR FOR THE IMPERIAL ROYAL GENERAL SURVEY OF AUSTRIAN RAILWAYS
AT THE I. R. MINISTRY OF TRADE

In order to leave no doubt as to the manner in which he would treat question IV, the reporter had expressed his personal opinion as to the relative importance of questions A and B at the time when the International Commission of the Congress did him the honour to entrust him with the drawing up op this report. This opinion was merely an argument in favour of the suppression of question B, which is really not one that concerns constructors; it is moreover an opinion that has been since fully confirmed by the study of the subject for all countries.

The primary tests are absolutely necessary; they constitute a guarantee of safety that we owe to the public, and the mere fact that certain bridges did give way under these tests (1) is sufficient to show that they are indispensable. In the same way, the

(1) These were road bridges in various countries, for which local authorities without experience contracted by tender and which incapable or unscrupulous contractors constructed at an absurdly low cost. We do not think it necessary to quote examples.

periodical tests to be made every five or six years, when the bridges are painted, are necessary for engineers. The small deflections observed show the stability and state of preservation of the framework as well as the resistance of the entire structure when subjected to dynamic forces, etc. But we do not think that any engineer living, who is a specialist in iron bridges, would pretend to deduce from the results obtained by such tests « the effective conditions for obtaining stability and the degree of safety » in each of the many various parts of the structure. These conditions are arrived at by tests made of the materials used in construction, calculations of resistance, arrangement of pieces, etc.

We will therefore merely glance at these difficulties in order to arrive at the main point which is clause A of question IV. This question, as it is expressed, contains all that is really of interest with regard to iron bridges (1) and, in order to treat it in all its aspects, we have divided our report under six heads as follows :

I. — *Iron bridges up to 1870;*

II. — *Live loads to be considered due to rolling stock;*

III. — *Regulations concerning the live loads to be taken for iron in calculations for iron bridges;*

IV. — *Manufacture of iron and steel to be used in bridges;*

V. — *Limits of internal strains in the material of the bridges;*

VI — *Quantities of material to be used for bridges, under various conditions of span and height.*

We will afterwards sum up, presenting our conclusions to the Congress.

We have received about 60 valuable reports from all parts of the world, many of which contain very fully detailed information, which we shall be able to use even after the session. Fresh reports keep arriving. Lastly, our former eminent Vice-President at the Congress of Brussels in 1885, His Excellency M. Thielen, Minister of Public Works, at Berlin, has just decided, upon our initiative that the Administrations of the grand system of the Prussian State are authorised to furnish us with the information relating to question IV; we hope even yet to obtain communications from Bavaria and Saxony, which we shall make use of at the last moment.

While thanking our eminent colleagues for the courteous attention paid to our interrogatory, we must at the same time excuse ourselves for not having, owing to want of time, turned it to the best account for the London session.

(1) Including the questions of stability and safety mentioned above.

I. — Iron bridges up to 1870.

When we wish to follow the history of iron structures in the Old World, we must turn to England and to English engineers. In the traditional home of metallurgical industries, we can note the principal stages in the manufacture of iron and steel in large masses and their employment for the girders of bridges, of which the increasing span and the ever-improving mode of construction have commanded the admiration of all Europe.

The large plate girders of the Conway and Britannia Bridges constructed about the middle of the century were no doubt, to our fathers, a marvel of technical skill (1), just as the Forth Bridge, that giant of modern bridges, with its spans of 1,710 feet (521 metres), has just shown the present generation what the genius of English engineers is capable of producing. In fact the employment of iron structures for railway bridges has advanced with the improvement of metallurgical processes and with the development of railways. It would be useless to give a detailed history of these industries here. We will merely draw attention to the fact that in 1845 when it was proposed seriously to span long distances by means of iron structures, plate-girders for smaller spans were already in general use. Their dimensions were determined either by direct tests or by considerations of similitude connected with these experiments, when larger spans were being considered. It was by methods of this kind that the plans of the first large tubular structures of the Conway and Britannia Bridges were arrived at; at this time the calculations for determining

(1) *In England :* 1847 to 1848, the Conway Bridge, with a span of 400 feet (122 metres); 1847 to 1850, the Britannia Bridge with a span of 460 feet (140 metres).

In Germany : 1850 to 1856, a bridge over the Vistula, near Dirschau, with a span of 397 feet (121 metres).

In France : 1852, a bridge over the Seine, near Asnières, with a span of 95 feet 5 inches (30 mètres); 1855, a bridge over the Garonne, near Langon, with a span of 242 feet 9 inches (74 metres).

Almost as soon as plate-girders for large spans were adopted, they were replaced by lattice-girders and truss-girders, which were much more economical.

In England : 1849, the Windsor bridge, with a span of 190 feet (58 metres); 1850 to 1852, the Chepstow bridge, with a span of 295 feet (90 metres) (of open lattice-work); 1854 to 1858, Saltash bridge, with a span of 456 feet (139 metres) (curved booms).

theoretically what section should be adopted for the various parts were unknown(1). But from 1885 new theories respecting the resistance of materials such as are now admitted commenced to develop themselves.

The comparison of the « Britannia » plate-girders with the « Saltash » truss-girders showed in the case of the latter a considerable saving of material and greatly helped to encourage constructors in the pursuit of those researches that Stephenson, Brunel and other great engineers had so brilliantly inaugurated in England.

To the French engineers Navier, Bresse (2) and Clapeyron (3) must be given the credit of having really established the fundamental bases of our theories as to the resistance of materials, in the form that they have since been applied universally. Important improvements have been made in them by eminent mathematicians from all parts of the word, and if it can be affirmed that since about 1860, iron bridges have been constructed on the basis of exact theoretical calculations, it is no less true that at the present day the members of the Congress taking part in the session of 1895, and having occasion to contemplate the immense trusses of the Forth Bridge can admire not only the enormous span of 1,710 feet (521 metres), but yet more the sagacity of the engineers in knowing how to turn to account all the refinements of the modern theoretical calculations and processes of construction, so as to reduce the cost to a minimum, and at the same time give to the structure a sufficient resistance to withstand all possible contingencies.

(1) See the publications of the time on this subject :

1° Eaton Hodgkinson, F. R. S., *Experimental researches on the strength and other properties of cast iron*. London, J. Weale, High Holborn, 1846;

2° G.-H. Love, *Mémoire sur la résistance du fer et de la fonte*. Paris, 1852; a criticism on the English experiments;

3° Stokes, *Transactions of the Cambridge philosophical Society*, 1849, of which we find an analysis in the *Annales des ponts et chaussées*, 1851 ;

4° Phillips, *Annales des mines*, vol. VII, 1855, and *Comptes rendus de l'Académie des sciences*, december, 3rd, 1866, on the relations of similitude to be observed in making experiments on a small scale;

5° Fairbairn, *Civil engin. and archit. Journal*, 1860. Experiments on the repetition of strains.

(2) L. Bresse, *Cours de mécanique appliquée, professé à l'École des ponts et chaussées*. Paris, 1859.

(3) Report for 1857, presented to the *Académie des sciences*, Paris, establishing the theory of continuous girders by means of bending moments on the supports.

It must however be remarked that in the thousands of railway bridges of ordinary span, the constructors have not followed in the paths of the marvellous progress characterised by the exceptional structures that we have just quoted. The engineers charged to draw up the plans were obliged to take into account the processes of manufacture of the metal and various parts of the structure, and the methods of arrangement at their disposal, the cost of labour and other local influences.

Thus in Europe, since 1860, and after the invention of foundations sunk to a great depth by means of compressed air cylinders, an invention which dates from the same period (1), we have seen a large number of bridges spring up with straight girders continued over a certain number of spans and supported on piers resting on caissons. For the solid web was substituted a close lattice-work of flat bars strengthened by rigid uprights so as to prevent buckling. The large railways then in course of construction all over Europe, many of which have become main arteries of circulation, include many structures of this kind; their construction was generally effected by launching them from the support lengthwise (*lançage longitudinal*) and this appreciably diminished the cost of scaffolding. The main girders of the bridges constructed at Kehl and Cologne, on the Rhine, constitute historical monuments of this system of construction which was abandoned about 1867 in favor of lattice girders with rigid cross-bars, the lattice work being very open. The idea conceived by Clapeyron in 1857, of profiting by the continuity of the girders through several spans so as better to utilise the metal without affecting the rigidity was not the only one in view in endeavoring to abandon the arrangement of independent girders for each span, in order to gain additional resistance from the supports. Girders with anchored ends, with funicular suspensions, with strut-beams, etc., were ideas that remained unfruitful, whereas the idea of the iron arch being substituted for the stone one and of utilising the supports as abutments has given rise to a series of very practical iron bridges distinguished for their elegance of construction and offering as much resistance as bridges constructed on other systems. The theory of these arches was originated by Bresse (2) in 1859, and improved by Albaret,

(1) In 1859, a bridge was built across the Rhine, near Kehl, the first with large pneumatic cylinders sunk 64 feet (19.50 metres) below low-water mark.

In 1858, a bridge was built over the Gironde, at Bordeaux; with pneumatic piers sunk 69 feet (21 metres) below low-water mark. Caissons have generally been substituted for piers. In India, for the bridge of Benares on the Ganges, tubular cylinders have been sunk by dredging to 140 feet (42.6 metres) below low-water mark. (London, 1881, W. F. Batho, consulting engineer.)

(2) *Cours de mécanique appliquée*. Paris, 1859, already quoted, with tables for the arches.

in 1862 (1). It was at once put in practice and this was the origin of that type of construction to which belong the great arches of more than 525 feet (160 metres) span, constructed much later over the Mississippi at Saint Louis over the Douro at Oporto and over the Garabit ravine in France.

In short we may say that in the Old World, about 1870, iron bridges took the general forms that have to all intents been preserved since and that the methods of calculation were those in use at the present day. We shall discuss later the improvements not very apparent but of considerable importance which Governments and great Railway Administrations have since been led to introduce in the metallic parts of more recent bridges. We may remark that long before 1870 or even 1867 iron bridges in the New World were constructed with truss-girders of open triangular lattice-work, as soon as spans exceeding those for which plate-girders were used were in contemplation. This is especially true of the framework connected by pins at the points of intersection, which the American engineers adopt in preference for their bridges (pin-connected bridges) in order to lessen the cost of putting them together, in consideration of the high price of labour of the place of erection. The European engineers use riveted connections exclusively, and the few bridges that had been constructed with pin-connections (2) have had to be replaced by more stable structures. Moreover, convinced as we are in Europe of the superiority of riveted over pin-connected bridges, we do not fail to render homage to the cleverness with which the American engineers have solved the most difficult problems; we find also that they prefer riveting wherever it seems compatible with the conditions necessitated by local circumstances.

II. — Live loads to be considered due to rolling stock.

One of the most essential elements to be considered in determining the quantity of metal to be used in iron bridges is of course the moving load to be reckoned in calculations of resistance which mainly consists of the weight of the locomotives and

(1) *Annales des ponts et chaussées*, 1862, 2nd half-year, p. 305, for arches properly so-called, and 1870, n° 271, p. 463 to 573 for arches with rigid spandrels. Several arched bridges, thus calculated, have been constructed on the Algerian railways.

(2) In Austria, in particular, the Schnirch, Neville and Schiffkorn systems, for the two latter of which both wrought and cast iron were used simultaneously. In America, composite structures of iron and wood formerly rather numerous, have likewise been eliminated.

tenders to be taken into account. The « Sharp and Roberts » locomotives in 1840 weighed, when empty, 12 tons only; the « Stephenson » locomotives in 1845 weighed 18 tons at most ([1]). These very modest weights were soon exceeded. The few types of engines used at first for trains of all kinds were replaced by special types according to the kind of train. In 1850, the Crampton locomotive used specially for express trains, passed from England to France and was at once adopted by three great Companies (Northern, Eastern and Lyons Railways). It weighed 28 tons when loaded, 10 tons of which were borne by the driving axle. As soon as it was decided to let such a weight be borne by a single axle, the others were equally heavily loaded. The locomotives of mixed trains and goods trains with two or three axles coupled and loads distributed over them as equally as possible, became heavier and heavier. After the railway over the Semmering in Austria was finished, a competition was organised for arriving at the best locomotives capable of drawing goods trains up gradients of 1 in 40, up to then unknown in railway engineering. In this competition which has remained famous, the Engerth locomotive, which obtained the first prize, gained only a temporary success; it had to be modified and it was by placing the leading axle of the tender on the frame-work of the locomotive that the 4 coupled type was arrived at, which type up to the present day constitutes the engine *par excellence* for mountain lines. Such engines have always been considered by bridge engineers as constituting the heaviest load to be taken into account in the calculations of the resistance of iron bridges, this being mainly due to the little distance between the axles. About 1864 an attempt was made to increase the number of axles. The « Petiet » locomotives of the French Northern Company, had four cylinders working two systems of two or three axles each. The goods locomotive of this system had when loaded a total weight of 57.6 tons equally distributed over six axles; making

Engine with 3 axles.	*Sharp and Roberts, 1840.*	*Stephenson, 1845.*
([1]) Diameter of driving wheels	5 feet 59 inches (1.66 metre).	5 feet 7 inches (1.70 metre).
Total heating surface	600 sq. feet (55.80 sq. metres) (with 162 tubes).	743 sq. feet (69 sq. metres) (with 139 tubes).
Diameter of piston	13 inches (33 centimetres).	13 3/4 inches (35 centim.).
Stroke of the piston	18 inches (46 centimetres).	20 inches (51 centimetres).
Weight of engine when empty .	12 tons.	18 tons.
Position of fire-box.	Between the hind axle and the driving axle.	Projecting behind the last axle.

The two locomotives were registered at 5 atmospheres; the Stephenson locomotives with the driving wheels in the middle of the engine were subject to a marked oscillatory movement.

9.6 tons to each axle (1). At the Paris Universal Exhibition 1867, were exhibited various other similar monster locomotives, since given up (2); they strained the permanent way and bridges far too much, without there being an excessive load on the axles, this load being then generally limited to 12 tons at the most. This limit was then quite sufficient for engines of goods trains; it was only exceeded for express trains. Locomotive engineers were persuaded, at any rate until 1865, that coupling-rods were incompatible with great speed; hence the necessity of increasing the adhesion on the single driving axle, in order to render it capable of drawing an express train of 15 to 18 carriages at a speed of 43 1/2 miles (70 kilometres) an hour. The initiative in this direction was taken by the English railways (3), where the load on the axle was raised from 12.5 to 14.5 tons. It would certainly have exceeded this, if fresh trials, made with coupling rods fixed with extreme care had not, in 1868, furnished complete proofs of the admissibility of these rods for express locomotives. The Sturrock type, of the Great Northern Railway, was the first to be adopted on the continent, and was introduced, with some modifications, on the French Northern Lines. Between 1874 and 1876, nearly all the principal European Railway Companies had come to adopt types of locomotives with coupled axles for express trains, and it seemed as if this innovation would result in a proportionate lightening of the load borne by one single axle, and also of the strain brought to bear on iron structures by such an axle. Subsequent experience, however, proved the contrary, at least as far as the continent was concerned. At the Paris Universal

(1) *Annales des mines*, 6th series, vol. V, p. 137, 145, 149 and 153. Twelve wheels of 3 feet 6 inches (1.065 metre) in diameter. Total length between axles = 19 feet 8 inches (6 metres). Heating surface = 1,293 square feet (213 square metres). Diameter of pistons = 16 1/2 inches (42 centimetres). Piston stroke = 17 1/4 inches (44 centimetres).

(2) We shall see further on, that subsequently engines quite as heavy although differently constructed were again allowed.

(3) The *Mac-Connell locomotive* of the London and North Western Railway with free driving axle, driving wheels 7 feet 6 inches (2.30 metres) in diameter, 861 square feet (80 square metres) of heating surface, adhesion load 12.5 tons.

The *Ramsbottom locomotive* of the same Company, with free driving axle, driving wheels 7 feet 6 inches (2.30 metres) in diameter, 1,022 1/2 square feet (95 square metres) of heating surface. adhesion load 12.5 tons.

The *Nelson locomotive*, of the Caledonian Railway, with free driving axle, 1,152 square feet (107 square metres) of heating surface, adhesion load 14.5 tons.

Exhibition, 1878, it was remarked that nearly all the French Administrations [1] had considerably increased the weight of their locomotives for express trains and goods trains; viz (in tons):

(1) . . . . Heavy locomotives in France about 1878.

COMPANIES		Lyons.	Orleans.	Western.	Eastern.	Southern.	Northern.
Express trains. .	Number of axles	4	4	3	3	3	4
	Axle loads	12 9	12 9	12·5	13 5	13·0	13·5
	Tractive force	25·2	25·0	24·9	27·0	26·0	27·0
	Total weight.	44·8	41·8	36·0	35·7	37·5	41·6
3 axles coupled .	Axle loads	11 8	13·4	12·5	11·5	12·8	9·5
	Total weight.	34·7	38 0	36·5	33·0	37·0	28·3
4 axles coupled .	Axle loads	13·7	13·0	»	11·6	13·8	12·2
	Total weight.	51·7	48·8	»	46·2	54·0	43·4

The locomotive with four axles coupled of the Southern-Company, which figures as the heaviest in this table, has remained up to the present time the one that has occasioned the greatest strains on French iron bridges. The English engines of the same period did not weigh 54 tons, for the type with 4 axles coupled had not penetrated into England; but on the other hand the axle load in England exceeded 14 tons for engines of express trains. In Austria, the engine known as the « Semmering », which formerly constituted the prototype of locomotives with 4 axles coupled, has about 1878 attained to the weight of 51 tons, and although the load on the axle did not exceed 13 tons the « Semmering » train strained the bridges nearly as much as the French Southern locomotive.

The last Universal Exhibition at Paris in 1889 and the accompanying third session of the Congress again showed a slight increase in the weight of the engines and the maximum axle load, as is shown by the following table of locomotives with 4 axles coupled and their tenders, in which we arrange the Companies as before according to the extent of their lines.

(1) The reader can find full details and very complete drawings summing up all the technical data of railway industries, up to this period, in the great work *Das Eisenbahnwesen in Frankreich*, Vienna, 1 vol. in-folio. Carl Gerold's Sohn. Copies of this work were distributed among members of the Congress, at Brussels, at the time of the first session in 1885.

(2). Heavy locomotives with four axles coupled in France about 1889.

NAME OF RAILWAY.	LENGTH FROM BUFFER TO BUFFER of the engine.	LENGTH FROM BUFFER TO BUFFER of the tender.	DISTANCE BETWEEN THE EXTREME AXLES of the engine.	DISTANCE BETWEEN THE EXTREME AXLES of the tender.	WEIGHT OF THE ENGINE. Total.	WEIGHT OF THE ENGINE. Heaviest axle load.	WEIGHT of the TENDER.
					Tons.	Tons.	Tons.
Paris-Lyons-Mediterranean	32' 3 1/2" (9m840)	20' 1 3/8" (6m130)	13' 3 1/2" (4m050)	8' 2 3/8" (2m500)	53·77	14·10	24·90
Orleans	32' 0 5/8" (9m769)	19' 6" (5m940)	13' 4 5/8" (4m080)	8' 6 3/8" (2m600)	50·18	13·50	21·45
Eastern	30' 10 1/2" (9m410)	19' 3" (5m870)	12' 11 1/2" (3m950)	8' 2 3/8" (2m500)	49·20	12·87	23·37
	35' 6" (10m820)	Loc. T. (Loc. T.)	16' 6 7/8" (5m050)	Loc. T. (Loc. T.)	55·60	14 88	Loc. T.
Southern	30' 10 3/4" (9m420)	20' 4 5/8" (6m215)	12' 8 3/8" (3m870)	8' 2 3/8" (2m500)	54·00	14·22	20·00
Northern	29' 30 3/4" (9m115)	18' 5 7/8" (5m635)	13' 11 1/4" (4m250)	8' 2 3/8" (2m500)	44·10	12·00	21·60
State	32' 9 1/2" (9m995)	18' 5 1/4" (5m620)	13' 3 1/2" (4m050)	8' 8 1/4" (2m650)	53·30	13·55	23·10

N. B. — Loc. T. means Tank-engine.

These engines were such as were in general use in France about 1889. The exceptional types that figured at the exhibition exceeded these as regards loads; thus we get the compound locomotives with four axles coupled exhibited by the Paris-Lyons-Mediterranean and the Northern Companies :

(3). Compound-Locomotives (1) with four axles coupled, Paris 1889.

NAME OF COMPANY.	LENGTH FROM BUFFER TO TENDER.	DISTANCE BETWEEN EXTREME AXLES.	WEIGHT total.	WEIGHT heaviest axle load.
			Tons.	Tons.
Paris-Lyons-Mediterranean	32' 3 3/8" (9m840)	13' 3 1/2" (4m050)	57·10	16·00
Northern	31' 7 1/2" (9m640)	13' 9 3/4" (4m200)	51·70	13·00

It is certain that at the same time the compound express locomotives, used in England on the main lines, carried still heavier axle-loads; we shall discuss this

(1) System inaugurated in France by M.-A. Mallet on the little line from Bayonne to Biarritz. See : *Étude sur l'utilisation de la vapeur dans les locomotives*. Paris, 1878, Capiomont and Renault.

later. From the very complete lists made in 1892 and 1893 of all the locomotives in use throughout the German Empire (1), it is seen that the axle load is there generally limited to 14 tons (2), and does not exceed 15 tons in the heaviest engines constituting an exception to this rule. We will quote the following instances : —

(4) . . . . Heavy locomotives used in Germany about 1893.

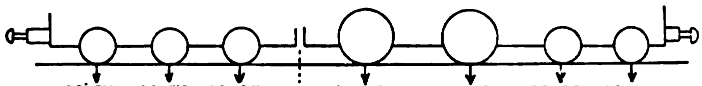
NAME OF ADMINISTRATION.	Number of axles.	LENGTH OF ENGINE AND TENDER		DISTANCE BETWEEN THE EXTREME AXLES		WEIGHT OF THE ENGINE		WEIGHT OF THE TENDER.
		between the buffers.	between the extreme axles.	of the engine.	of the tender.	total.	heaviest axle load.	
						Tons.	Tons.	Tons.
I. — *Goods engines.*		Types with as a rule 4 axles coupled.						
Altona Railway	4	51' 6 1/4" (15m710)	36' 7 1/2" (11m165)	11' 9 3/4" (3m600)	10' 4 3/8" (3m160)	46·00	11·5	32·4
Berlin Railway	4	52' 11 3/8" (16m140)	41' 4 1/8" (12m610)	20' 8" (6m300)	10' 10" (3m300)	49·32	13·4	30·6
Wurtemberg State Railway . .	5	55' 11" 1/8 (17m049)	40' 10 1/8" (12m450)	19' 8 1/4" (6m000)	9' 10 1/8" (3m000)	68·50	13·7	27·7
Louis of Hesse Railway. . . .	4	49' 3 3/8" (15m021)	34' 5 3/8" (10m500)	11' 5 1/8" (3m483)	9' 10 1/8" (3m000)	45·00	11·3	24·0
Baden State Railway	4	51' 1" (15m570)	36' 2 1/4" (11m030)	12' 10 1/2" (3m925)	8' 10 1/4" (2m700)	50·25	12·6	27·0
Palatinat Railway	4	52' 5 7/8" (16m000)	38' 6 5/8" (11m750)	15' 5" (4m699)	9' 6" (2m896)	51·60	12·9	25·2
II. — *Express engines.*		Types with as a rule 2 axles coupled.						
Altona Railway	4	51' 2 3/4" (15m615)	40' 11 1/4" (12m480)	21' 6 7/8" (6m575)	11' 0" (3m350)	49·80	14·1	37·0
Berlin Railway	4	51' 2 3/4" (15m615)	40' 11 1/4" (12m480)	21' 6 7/8" (6m575)	11' 0" (3m350)	49·10	14·1	36·4
Bromberg Railway	4	51' 2 3/4" (15m615)	40' 11 1/4" (12m480)	21' 6 7/8" (6m575)	11' 0" (3m350)	49·05	14·4	35·9
Elberfeld Railway	4	51' 2 3/4" (15m615)	40' 11 1/4" (12m480)	21' 6 7/8" (6m575)	11' 0" (3m350)	48·92	13·8	37·5
Erfurt Railway	4	51' 2 1/4" (15m602)	34' 4 1/8" (10m467)	21' 6 7/8" (6m575)	11' 0" (3m350)	49·38	14·2	36·2
Francfort Railway	4	51' 2 3/4" (15m615)	37' 7" (11m455)	18' 2 1/2" (5m550)	11' 0" (3m350)	48·65	13·8	38·2
Hanoverian Railway.	4	51' 2 3/4" (15m615)	40' 11 1/4" (12m480)	21' 6 7/8" 6m575)	11' 0" (3m350)	49·32	14·1	36·4
Cologne left bank Railway. . .	4	51' 3 3/8" (15m630)	40' 9 3/4" (12m440)	21' 5 7/8" (6m550)	11' 0" (3m350)	51·50	15·0	37·4
Bavarian State Railway . . .	4	50' 6 1/4" (15m400)	40' 8 1/8" (12m400)	21' 10 5/8" (6m670)	10' 10" (3m300)	50·00	13·8	32·0
Saxony State Railway	4	49' 11 5/8" (15m230)	40' 0 3/8" (12m200)	22' 1 3/4" (6m750)	11' 7 3/4" (3m550)	49·40	14·0	29·2
Wurtemberg State Railway . .	4	52' 9 1/4" (16m084)	39' 0 1/2" (11m900)	19' 0 3/8" (5m800)	9' 10 1/8" (3m000)	54·20	13·8	27·7

(1) *Statistik der im Betriebe befindlichen Eisenbahnen Deutschlands bearbeitet im Reichseisenbahnamte.* This fine work quotes all the engines, with their numbers, dates of construction and details of all kinds.

(2) A condition up to now compulsory on all Administrations belonging to the « Verein deutscher Eisenbahnverwaltungen ».

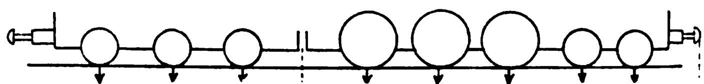
(5) . . . Heavy locomotives (and tenders) in Austria and Hungary about 1894.

British measures. | **Tender.** | **Locomotive.**



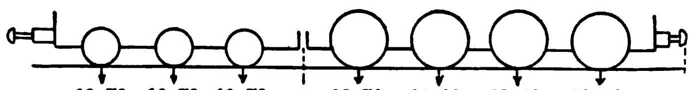
No.	Railway	Tender.	Locomotive.	Distances
1	K.K. Austrian State Railway. (Express.)	13·71 11·78 13·27	14·41 14·40 13·83 12·74	< 6' 1 3/4" × 4' 11" × 5' 7" × 4' 2 7/8" :< 3' 10 7/8" × 9' 2 1/4" × 5' 10 3/4" × 8' 10 1/4" × 5' 0 3/4" >
2	Hungarian State Railway. (Express.)	11·40 11·30 11·30	14·15 14·15 10·25 10·25	< 5' 10 5/8" × 5' 2 1/8" × 5' 2 1/8" × 4' 11 1/4" × 5' 1 1/8" × 8' 2 3/8" × 5' 7" × 5' 7" × 6' 0 5/8" >
3	Austrian North Western Railway. (Express.)	11·20 10.70 10·70	14·00 14·00 10·00 10·00	< 5' 6 5/8" × 4' 11" × 4' 11" × 4' 1 1/4" × 4' 0 5/8" × 7' 2 3/8' × 6' 6 3/4" × 5' 7" × 4' 7 3/4" >
4	Hungarian State Railway. (Express.)	13·43 13·47 13·63	14·00 14·00 13·35 13·35	< 6' 5 1/8" × 5' 3" × 5' 3" × 4' 11 3/8" × 5' 4 7/8 × 7' 10 1/2" × 6' 10 5/8" × 5' 10 3/4" × 6' 7 5/8" >
5	Austrian State Railway. (Express.)	10·80 10·50 11·00	13·90 14·00 9·40 9·40	< 5' 11" × 4' 9 7/8" × 5' 9 3/4" × 4' 2 3/8" × 4' 7 7/8 × 8' 2 3/8" × 5' 7" × 5' 7" × 5' 0 1/4" >
6	Austrian Southern Railway. (Express.)	10.37 10·37 10·36	13·99 14·00 9·89 9·89	< 5' 9 1/4" × 4' 4 3/8" × 4' 9 7/8" × 4' 4 1/8" × 4' 9 1/4" × 7' 10 1/2" × 7' 0 5/8" × 5' 8 7/8" × 4' 2 3/8" >
7	Austrian Northern Railway. (Express.)	8·33 8·33 8·33	13·80 13·80 9·70 9·70	< 5' 7 5/8" × 5' 1 3/4" × 5' 4 1/8 × 4' 9" × 6' 3 5/8" × 8' 6 3/8" × 6' 0 7/8" × 5' 7" × 5' 0 1/2" >

Tender. | **Locomotive.**



No.	Railway	Tender.	Locomotive.	Distances
8	Hungarian State Railway. (Passenger trains.)	11·40 11·30 11·30	13·90 13·90 13·80 7·80 7·80	< 5' 10 5/8" × 5' 2 1/8" × 5' 2 1/8" × 4' 11 1/4" × 6' 10 5/8" × 5' 8 7/8" × 5' 7" × 4' 6 1/2" × 5' 10 3/4" × 4' 6 7/8" >

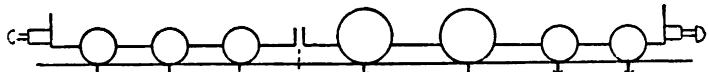
Tender. | **Locomotive.**



No.	Railway	Tender.	Locomotive.	Distances
9	Austrian State Railway. (Goods.)	10·70 10·70 10·70	13·70 14·00 13·40 13·40	< 5' 11" × 4' 9 7/8" × 5' 9 3/4" × 4' 2" × 10' 7" × 4' 5 1/8" × 3' 11 1/4" × 4' 5 1/8" × 9' 8 5/8" >
10	Austrian Southern Railway. (Goods.)	12·20 12·20 12·10	13·00 13·40 13·00 13·00	< 5' 5 1/8" × 4' 11" × 5' 7" × 4' 9 1/4" × 10' 3 3/8" × 3' 11 1/4" × 3' 11 1/4" × 4' 5 1/8" × 9' 2 3/8" >
11	Austrian Company. (Goods.)	10·70 10·35 10·75	13·30 14·00 13·90 13·90	< 5' 5" × 5' 0 1/8" × 5' 4 1/4" × 4' 9 3/8" × 7' 3 5/8" × 6' 9 1/8" × 4' 2" × 4' 2" × 9' 4 5/8" >
12	Austrian State Railway. (Goods.)	10·00 10·00 10·00	13·00 14·00 13·30 13·20	< 5' 11" × 4' 9 7/8" × 5' 9 3/4" × 4' 2" × 8' 4 7/8" × 4' 7 1/8" × 4' 7 1/8" × 4' 7 1/8" × 8' 10 1/4" >
13	Austrian Southern Railway. (Goods.)	9·20 9·20 9·10	13·21 13·57 12·16 12·16	< 5' 9 1/2" × 4' 5" × 5' 5 3/8" × 4' 7 1/8" × 10' 6 3/8" × 3' 10 1/2" × 3' 10 1/2" × 3' 11 1/4" × 9' 8 3/4" >
14	Austrian Company. (Goods.)	10·70 10·35 10·75	12.65 13·50 13·00 12·90	< 5' 5" × 5' 0 1/8" × 5' 4 1/4" × 4' 9 3/8" × 7' 3 1/8" × 6' 9 1/8" × 4' 2" × 4' 2" × 9' 4 5/8" >
15	Austrian State Railway. (Goods.)	11·60 10·60 9·30	13·00 13·00 13·00 13·00	< 5' 9 5/8" × 5' 3" × 5' 3" × 4' 0 3/8" × 9' 10 7/8" × 3' 9 1/4" × 3' 9 1/4" × 3' 11 1/4" × 9' 7 1/4" >
16	Hungarian State Railway (Goods.)	11·40 11·30 11·30	12·42 11·83 11·25 11·58	< 5' 9 1/2" × 5' 2 1/4" × 5' 2 1/4" × 4' 11 1/4" × 9' 6 1/4" × 3' 9 1/4" × 3' 9 1/4" × 4' 3 1/8" × 8' 7 3/4" >
17	Austrian State Railway. The heaviest locomotive.	Locomotive-tender Tank-engine	14·50 14·50 14·50 13·10	< 10' 3 1/4" × 4' 5 1/2" × 4' 5 1/8" × 3' 10 3/4" × 8' 9" >

Metric measures.

Tender. **Locomotive.**



1 K. K. Austrian State Railway. (Express.)
13·71 11·78 13·27 : 14·41 14·40 13·83 12·74
< 1·875 × 1·500 × 1·700 × 1·292 × 1 192 × 2·800 × 1·800 × 2·700 × 1·542 >

2 Hungarian State Railway. (Express.)
11·40 11·30 11·30 : 14·15 14·15 10·25 10·25
< 1·795 × 1·580 × 1·580 × 1·505 × 1·552 × 2·500 × 1 700 × 1·700 × 1·844 >

3 Austrian North Western Railway. (Express.)
11·20 10.70 10·70 : 14·00 14·00 10·00 10·00
< 1·692 × 1·500 × 1.500 × 1·250 × 1·235 × 2.200 × 2·000 × 1·700 × 1·418 >

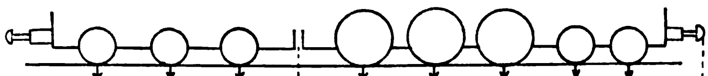
4 Hungarian State Railway. (Express.)
13·43 13·47 13·63 : 14·00 14·00 13·35 13·35
< 1·900 × 1·600 × 1·600 × 1.510 × 1.650 × 2·400 × 2·100 × 1·800 × 2 022 >

5 Austrian State Railway. (Express.)
10·80 10 50 11·00 : 13·90 14·00 9·40 9·40
< 1·805 × 1·470 × 1·770 × 1·281 × 1·419 × 2·500 × 1·700 × 1.700 × 1·530 >

6 Austrian Southern Railway. (Express.)
10.37 10·37 10·36 : 13·99 14·00 9·89 9·89
< 1·760 × 1·330 × 1·470 × 1·325 × 1·455 × 2 400 × 2·150 × 1·750 × 1.280 >

7 Austrian Northern Railway. (Express)
8·33 8·33 8·33 : 13·80 13·80 9·70 9·70
< 1.719 × 1·570 × 1·630 × 1·447 × 1·922 × 2·600 × 1·850 × 1·700 × 1 537 >

Tender. **Locomotive.**



8 Hungarian State Railway. (Passenger trains.)
11·40 11·30 11 30 : 13·90 13·90 13·80 7·80 7·80
< .·795 × 1·580 × 1·580 × 1·505 × 2·100 × 1·750 × 1·700 × 1·385 × 1·800 × 1·394 >

Tender. **Locomotive.**

9 Austrian State Railway. (Goods.)
10·70 10 70 10·70 : 13·70 14·00 13·40 13·40
< 1·805 × 1·470 × 1.770 × 1.270 × 3·225 × 1·350 × 1·200 × 1·350 × 2·962 >

10 Austrian Southern Railway. (Goods.)
12·20 12·20 12·10 : 13·00 13·40 13·00 13·00
< 1·655 × 1 500 × 1·700 × 1·455 × 3·135 × 1·200 × 1·200 × 1·350 × 2·805 >

11 Austrian Company. (Goods.)
10·70 10·35 10·75 : 13·30 14·00 13·90 13·90
< 1·654 × 1·528 × 1·633 × 1·458 × 2·227 × 2·060 × 1·270 × 1·270 × 2.862 >

12 Austrian State Railway. (Goods.)
10·00 10·00 10·00 : 13·00 14·00 13·30 13·20
< 1·805 × 1·470 × 1·770 × 1·270 × 2.563 × 1·400 × 1·400 × 1.400 × 2.700 >

13 Austrian Southern Railway. (Goods.)
9·20 9·20 9·10 : 13·21 13·57 12·16 12·16
< 1·765 × 1 340 × 1·660 × 1·400 × 3·210 × 1·180 × 1·180 × 1·200 × 2.965 >

14 Austrian Company. (Goods.)
10·70 10·35 10 75 : 12.65 13·50 13 00 12 90
< 1·654 × 1·528 × 1·633 × 1·458 × 2·212 × 2·060 × 1.270 × 1·270 × 2·862 >

15 Austrian State Railway. (Goods.)
11·60 10·60 9·30 : 13·00 13·00 13·00 13·00
< 1·767 × 1·600 × 1·600 × 1·230 × 3·025 × 1·150 × 1·150 × 1·200 × 2.925 >

16 Hungarian State Railway (Goods.)
11·40 11·30 11·30 : 12·42 11·83 11·25 11·58
< 1·765 × 1·580 × 1·580 × 1·505 × 2·903 × 1·150 × 1.150 × 1·300 × 2·635 >

17 Austrian State Railway. The heaviest locomotive.
Locomotive-tender Tank-engine : 14·50 14·50 14·50 13·10
< 3.182 × 1·360 × 1·350 × 1·190 × 2 668 >

(6) . . . . . . Heavy locomotives (and tenders) in Europe about 1894.

British measures.

1 North Eastern Railway. (Express.) Worsdell and Borrie system.

2 Manchester Sheffield and Lincolnshire Railway (Express).

3 Manchester Sh. & Lincolnre Ry Standard. (Express.)

4 West Highland Railway. (Express.)

5 London & South Western Ry Adams. (Express.)

6 Winby's Express Compd Loc. Hawthorn & Leslie, Newc. on Tyne

7 London & North Western Ry. Webbs Comp. Express Locom. Standard, Crewe 1893.

8 Mersey Railway Kitson & Co. Leeds. (Goods.)

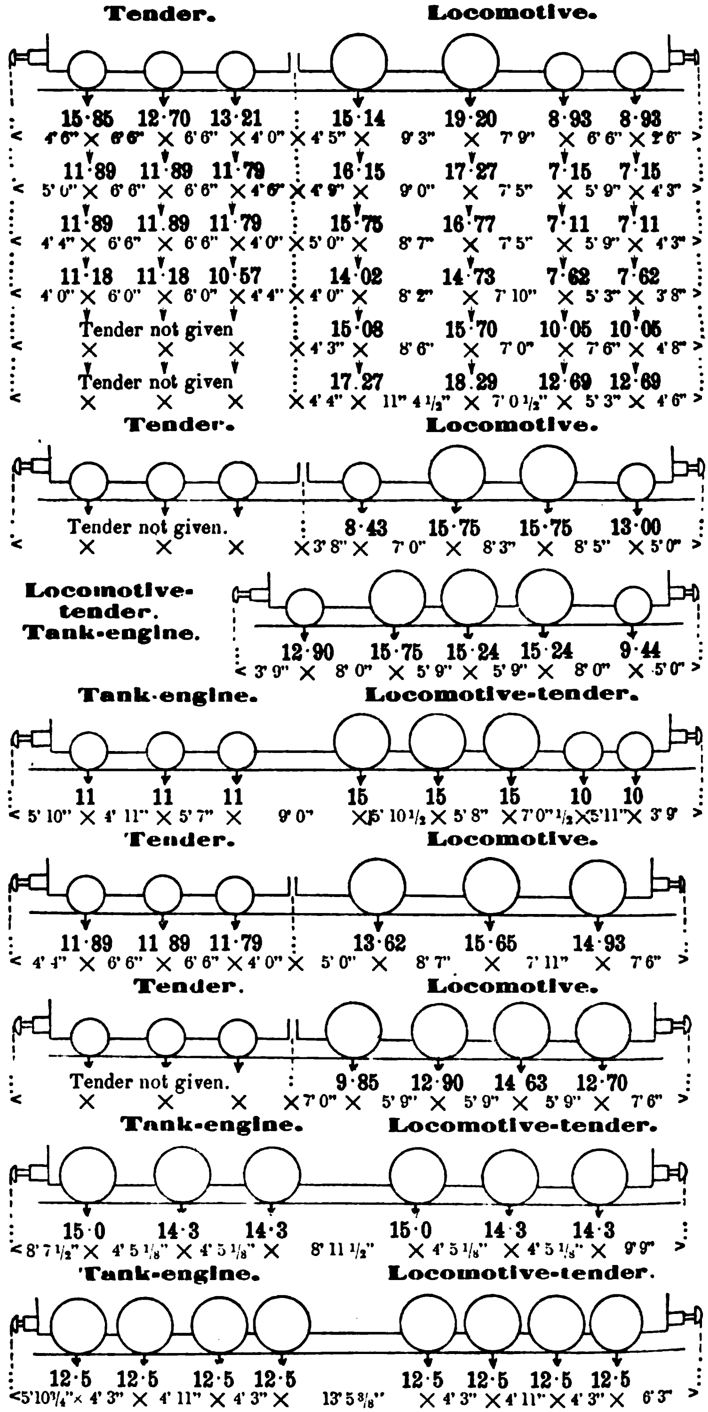
9 St-Gothard Railway. Mallet Compound Express. (Passengers.)

10 Manchester Sh. & Lincolnre Ry. Standard Loc. for Goods. (Goods.)

11 London & North Westhern Ry. Webbs Comp. Loc. Crewe 1893. (Goods.)

12 St-Gothard Railway. Mallet Compound Duplex. (Goods.)

13 French State Railway. Heilmann Electric Locomotive. (Dyn. : 410 kilow.) Experimental.



Metric measures.

1 North Eastern Railway. (Express) Worsdell and Borrie system.

2 Manchester Sheffield and Lincolnshire Railway (Express).

3 Manchester Sh. & Lincolnre Ry Standard. (Express.)

4 West Highland Railway. (Express.)

5 London & South Western Ry Adams. (Express.)

6 Winby's Express Compd Loc. Hawthorn & Leslie, Newc. on Tyne

7 London & North Western Ry. Webbs Comp. Express Locom. Standard, Crewe 1893.

8 Mersey Railway Kitson & Co. Leeds. (Goods.)

9 St-Gothard Railway. Mallet Compound Express. (Passengers.)

10 Manchester Sh. & Lincolnre Ry. Standard Loc. for Goods. (Goods.)

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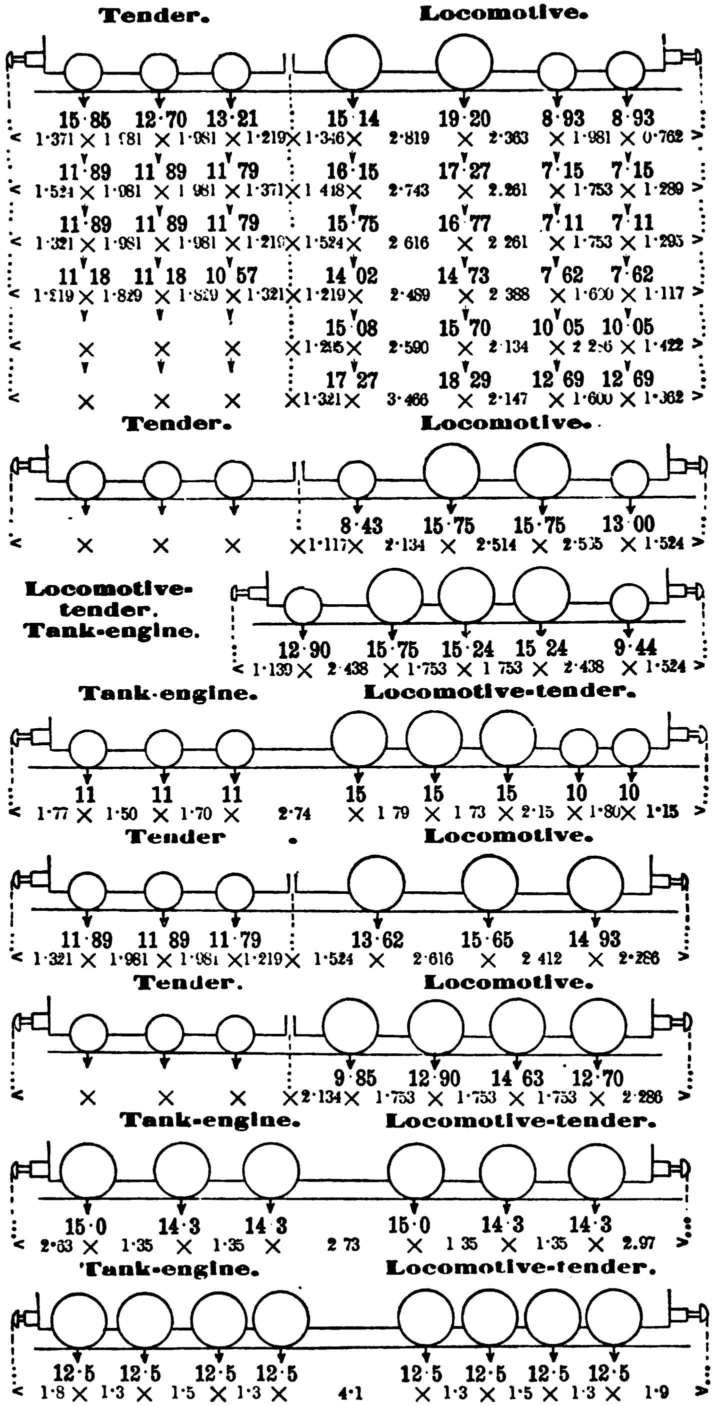


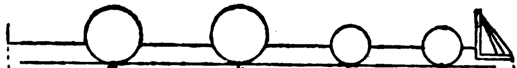
(7). . . Heavy locomotives in use in the United States of America about 1894.

British measures.

Express, 2 axles coupled.

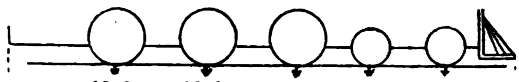
No.	Railway / Builder	Axle loads	Distances
1	Philadelphia & Reading Railway, compound, 4 cylinders. Baldwin, Locomotive Works, Philadelphia.	14·6 — 18·9 — 18·9 — 14·0	6' 6" × 7' 0" × 6' 10" × 9' 6" × 8' 2"
2	Machine-type Baldwin L. W., comp., 4 cyl. Burnham Williams & C°, Philadelphia.	10·4 — 18·9 — 18·8 — 9·5	5' 10½" × 6' 11½" × 7' 4" × 10' 4" × 11' 6"

Express and passenger trains, 2 axles coupled.



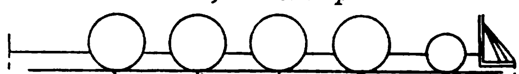
No.	Railway / Builder	Axle loads	Distances
3	Erie Railway, drivers engine. Cooke Patterson Locomotive Works.	20·1 — 20·3 — 10·4 — 10·4	5' 9" × 8' 6" × 9' 1" × 6' 0" × 6' 7½"
4	New York Central & Hudson River Railway. West Albany N. Y.	19·1 — 19·1 — 9·2 — 9·2	5' 3" × 8' 6" × 8' 9" × 6' 8" × 7' 6"
5	Central Ry of New Jersey, compound, 4 cyl. Baldwin Locomotive Works, Philadelphia.	19·0 — 19·0 — 8·4 — 8·4	6' 8" × 7' 6" × 7' 11½" × 6' 10" × 6' 7½"

Express and passenger trains, 3 axles coupled.



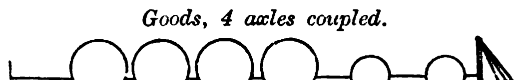
No.	Railway / Builder	Axle loads	Distances
6	Terre Haute & Indianapolis Railway. Pittsburgh Locomotive Works, Pittsburgh.	16·6 — 16·6 — 16·6 — 6·4 — 6·4	6' 7½" × 7' 0" × 6' 4" × 4' 8" × 5' 7" × 6' 6"
7	Great Northern Railway. Brooks Locomotive Works, Dunkirk.	15·8 — 15·8 — 15·8 — 6·1 — 6·1	8' 0" × 7' 9" × 6' 9" × 4' 10" × 5' 10" × 6' 8"
8	Charleston & Savannah Railway. Rogers Locomotive Works, Paterson.	14·9 — 14·9 — 14·9 — 8·0 — 8·0	5' 4½" × 7' 0" × 6' 6" × 5' 0" × 6' 2" × 6' 8"

Goods, 4 axles coupled



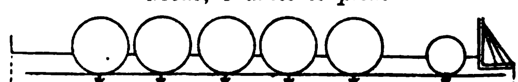
No.	Railway / Builder	Axle loads	Distances
9	Mohawk & Malvue Railway, comp. 2 cyl. Schenectady Locomotive Works, Schenectady.	15·0 — 15·0 — 15·0 — 14·9 — 7·7	6' 9½" × 4' 10" × 4' 1½" × 4' 10" × 7' 7" × 6' 10"
10	Great Northern Railway, compound, 4 cyl. Players Patent, Brooks, Dunkirk.	14·7 — 14·7 — 14·7 — 14·7 — 7·7	7' 8" × 4' 10" × 4' 10" × 5' 10" × 7' 6" × 7' 7"
11	Norfolk & Western Railway, compound, 4 cyl. Baldwin Locomotive Works, Philadelphia.	13·7 — 13·7 — 13·7 — 13·7 — 7·9	6' 11" × 4' 11" × 4' 9" × 5' 2" × 7' 11" × 5' 4"
12	Illinois Central Railway. Rogers Locomotive Works, Paterson.	13·4 — 13·4 — 13·4 — 13·4 — 8·5	4' 11" × 5' 0" × 5' 0" × 6' 9" × 7' 8" × 6' 11"

Goods, 4 axles coupled.



No.	Railway / Builder	Axle loads	Distances
13	Duluth & Iron Range Railway. Schenectady Locomotive Works, Schenectady.	15·8 — 15·8 — 15·8 — 15·8 — 6·8 — 6·8	8' 4" × 4' 11" × 4' 8" × 5' 11" × 3' 10" × 6' 0" × 5' 10"
14	Great Northern Railway. Brooks Locomotive Works, Dunkirk.	15·4 — 15·4 — 15·4 — 15·4 — 4·6 — 4·6	7' 6" × 4' 10" × 4' 10" × 5' 10" × 3' 11" × 5' 10" × 6' 6"

Goods, 5 axles coupled.



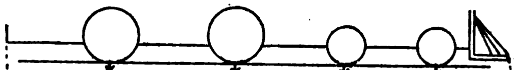
No.	Railway / Builder	Axle loads	Distances
15	New York, Lake Erie & Western Railway, Compound, 4 cylinders. Baldwin Locomotive Works, Philadelphia.	15·6 — 15·6 — 15·6 — 15·6 — 15·6 — 10·4	5' 8½" × 4' 8" × 4' 5" × 4' 11" × 4' 10" × 8' 5" × 6' 0½"

Metric measures.

Express, 2 axles coupled.

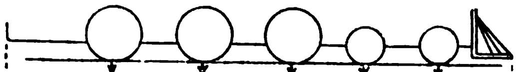
1	Philadelphia & Reading Railway, compound, 4 cylinders. Baldwin, Locomotive Works, Philadelphia.		14·6	18·9	18 9	14 0	
		1·932	2·135	2·084	2 808	2.490	
2	Machine-type Baldwin L. W., comp., 4 cyl. Burnham Williams & C°, Philadelphia.		10·4	18·9	18·8	9·5	
		1·795	2·119	2·236	3·143	2·500	

Express and passenger trains, 2 axles coupled.



3	Erie Railway, drivers engine. Cooke Patterson Locomotive Works.	20·1	20·3	10 4	10·4	
		1·746	2.592	2 765	1·830	2·020
4	New York Central & Hudson River Railway. West Albany N. Y.	19·1	19·1	9·2	9·2	
		1 601	2·592	2·668	2·034	2·203
5	Central Ry of New Jersey, compound, 4 cyl. Baldwin Locomotive Works, Philadelphia.	19·0	19·0	8·4	8·4	
		2.033	2·287	2·427	2·084	2 025

Express and passenger trains, 3 axles coupled.

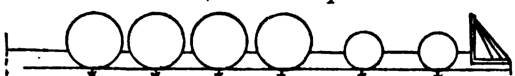


6	Terre Haute & Indianapolis Railway. Pittsburgh Locomotive Works, Pittsburgh.	16·6	16·6	16·6	6·4	6·4	
		2 016	2·133	1 930	1·422	1·727	1·595
7	Great Northern Railway. Brooks Locomotive Works, Dunkirk.	15·8	15·8	15 8	6 1	6 1	
		2·440	2 363	2·058	1·474	1·780	2·033
8	Charleston & Savannah Railway. Rogers Locomotive Works, Paterson.	14 9	14.9	14 9	8·0	8 0	
		1·640	2·135	1·982	1·525	1·880	2·038

Goods, 4 axles coupled.

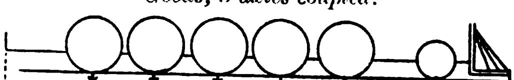
9	Mohawk & Malvue Railway, comp. 2 cyl. Schenectady Locomotive Works, Schenectady.	15·0	15·0	15·0	14·9	7·7	
		2·074	1.474	1.322	1·474	2·312	2·084
10	Great Northern Railway, compound, 4 cyl. Players Patent, Brooks, Dunkirk.	14·7	14·7	14·7	14·7	7·7	
		2·340	1·474	1·474	1·779	2·287	2·319
11	Norfolk & Western Railway, compound, 4 cyl. Baldwin Locomotive Works, Philadelphia.	13·7	13·7	13·7	13·7	7·9	
		2 110	1 500	1·448	1 576	2·410	1·620
12	Illinois Central Railway. Rogers Locomotive Works, Paterson.	13·4	13·4	13·4	13·4	8.5	
		1·500	1·525	1·525	2·056	2·330	2·109

Goods, 4 axles coupled.



13	Duluth & Iron Range Railway. Schenectady Locomotive Works, Schenectady.	15·8	15·8	15·8	15·8	6·8	6·8	
		2·542	1 500	1·423	1.804	1·170	1·830	1·780
14	Great Northern Railway. Brooks Locomotive Works, Dunkirk.	15·4	15·4	15·4	15·4	4·6	4·6	
		2·287	1·474	1·474	1·779	1·194	1·780	1·970

Goods, 5 axles coupled.



15	New York, Lake Erie & Western Railway, Compound, 4 cylinders. Baldwin Locomotive Works, Philadelphia.	15·6	15·6	15·6	15·6	15·6	10·4	
		1·741	1·423	1·348	1·495	1·474	2·566	1·840

*

Besides these heavy engines in daily use, there are a certain number of tank engines quite as heavy, in which the axle load amounts to 15 tons, and a certain number of old engines with three and even two axles where we sometimes find a still heavier load; but these anomalies need not be taken into account when considering the question of the strain exerted on the iron bridges of the principal lines.

We have endeavoured to enumerate the heaviest engines at present in service on the railroads of both worlds. We have drawn up three tables (5), (6), (7), one for Austria and Hungary, one for Europe and particularly England [1], and one for the United States of America [2] in which we have shown the engines and tenders that we consider should be taken into account when considering the greatest strains brought to bear on the bridges. In order to simplify the description of similar types we have represented them by one and the same diagram giving underneath the loads and distances of the axles, and also the length of projection of the buffers beyond the extreme axles. From these can be deduced if required the lengths, or loads, total or mean, belonging to each case.

III. — Regulations concerning the live loads to be taken into calculation for iron bridges.

After giving the above summary of the increasing loads that railway engineers have thought fit to impose upon permanent way and bridges, we will now proceed to explain how and to what extent it has been possible and should be considered expedient to construct and strengthen iron bridges so as to meet the present requirements. We may remark here that it is impossible to reconstruct the permanent way and bridges for every new invention brought out by locomotive engineers, that such reconstructions which are extremely costly, especially on lines of great magnitude, can only be performed from time to time, after mature consideration of the circumstances necessitating them. It ought to be considered whether the amount

(1) See the technical journals : *Engineering and Engineer*, for 1894 and 1893; the particulars given are often insufficient.

(2) See, for American engines, the two works :

1° Bute and Borries, *Die Nordamerikanischen Eisenbahnen* (particularly p. 36). Kreidel, Wiesbaden, 1892.

2° H. von Littrow, « Uebersicht der in Chicago 1893 ausgestellten Locomotiven » (*Organ für den F. der E.*, 1894, XXXI. Bd., 5. Heft). This excellent summary furnished us with the dimensions and weights given in our table in metrical measurements.

of capital invested in the permanent way and the bridges is compensated for by the benefits obtained as regards the locomotive department. We do not think that this has ever been seriously considered owing to the complete separation which exists between the different departments almost everywhere. At any rate, within the portions to be reconstructed locomotive engineers and permanent way engineers should combine to avoid all excessive strains. This is what the writer endeavoured to bring before the Congress, during the first session of 1885, when the majority or members were not willing that this ticklish question should be raised. It was not until fresh accidents had happened to bridges overstrained beyond measure, and the question was taken up by the public, the directors, and governments that an understanding was arrived at between the two departments in the principal countries of both worlds; and at the fourth session at St. Petersburg in 1892, the writer had the satisfaction of obtaining from the Congress an affirmative vote at any rate partially solving this important question, a vote to which we will refer again later, in order to state it more accurately and expand it if necessary so as to take into account the circumstances of the present day.

1. — *Regulations as to loads previously published.*

When we have to draw up regulations as to loads on railway bridges, we must first ascertain what is the weight of the heaviest rolling stock and what is the composition of the most unfavourable trains *to be provided against.* The loads to be allowed being once fixed and all the bridges being calculated accordingly, the running of heavy trains should be compulsorily restricted within the limits corresponding to the hypotheses assumed at first, as, if these limits are exceeded, the bridges in service might be subjected to unforeseen strains.

In the regulations issued formerly, these two sides of the question were unfortunately not always taken into account and the history of the construction of bridges, in all countries and under all governments, shows that if governments and directors of great railway Companies have been led to adopt more solid structures and stricter regulations, they have been influenced rather by accidents that have really happened than by scientific deductions.

In England, questions of this nature, which were suggested by the important bridge-work executed by Stephenson and Brunel from 1847 to 1850 were at first left exclusively to the talent and experience of engineers; it was not until after the Tay bridge accident that the Board of Trade in July 1881 published a kind of general specification somewhat more detailed containing a certain number of principles to be observed in the construction and management of railroads and fixing some rules for iron bridges without however laying down any precise limit of live load (1).

On the continent, the need for stating more exactly what loads were to be assumed in the calculations for bridges was soon felt; the first regulations, however, show too plainly the very laudable object of the compiler to be clear and brief. The weight of the locomotives was simply estimated per metre of the total length, choosing the heaviest amongst those in use at the time and the weight per metre thus obtained, and considered as an equally distributed load, was given as the lowest limit of the live load to be allowed for in the calculations.

It was thus that in France circulars were published by the Public Works department, dated the 26th of February 1858, and the 15th of June 1869 (2), fixing quite insufficient limits of load for short spans; engineers however have had the sense not to keep to these limits.

The Austrian regulations for the construction of bridges published August 30th 1870, drawn up in consequence of the breaking down of a bridge over the Pruth, near Czernowitz, which happened in 1868, show a genuine advance as regards regulations concerning loading; here the bending moments produced by locomotives on short-

(1) *Memorandum of important requirements* signed : Board of Trade (railway Department). July, 1881, Henry G. Calcraft. We read :

§ 17. — The breaking weight of a cast iron bridge must be equal to at least 3 times the dead load + 6 times the live load. For bridges of iron and steel the load imposed consisting of dead and live loads should not strain the material more than 5 tons per square inch (787 kilograms per square centimetre) in the case of iron and 6 1/2 tons per square inch (1,024 kilograms) in the case of steel.

§ 18. — We shall take for the live load, in these calculations, the heaviest locomotives in use on railways.

§ 19. — For the construction of bridges of large span a wind pressure of 56 lbs per square feet (273 kilograms per square metre) must be taken into account in the calculations.

These very liberal regulations, expressed in very general terms, at least contain nothing inaccurate and might be considered sufficient from the English point of view if we did not know with what indifference railway administrations often treat questions relating to calculations of resistance. The new regulations published by the Board of Trade in August 1892 were besides quite as liberal, and do not stipulate for anything exact as to live loads.

(2) These circulars are quite insufficient for bridges of less than 49'3" (15 metres) span. In them the regulations for the test load were prescribed as follows :

1° A dead load of about 1 1/2 ton per foot run (5,000 kilograms per metre) of track for spans up to 20 metres, and of about 1 1/5 ton per foot run (4,000 kilograms per metre) for longer spans, this load to remain in position for eight hours;

2° A live load consisting of at least two locomotives weighing with their tender 60 tons each and of loaded trucks weighing 12 tons each sufficient in number to cover the whole of the span, the speed being from 12 1/2 to 22 miles (20 to 35 kilometres) an hour.

span bridges are taken into account, and the moving load, then fixed by means of a single scale, would be almost sufficient even at the present day for spans not exceeding 49'3" (15 metres) (1).

The French circular of the 9th of July 1877, which was still in force up to August 1891, also contains one scale only for moving loads (2), this is calculated

(1) At that time equivalent loads were not taken into account so much as regards shearing strains. We must not forget that our first calculations of resistance of any accuracy based on the theory of bending moments only date from 1860. Navier and Bresse disregarded shearing strains and declared, with reference no doubt to plate-girders, that there was no need to take them into account. Side by side with this we quote the proposals of the Association of Austrian engineers and architects, presented to the Commerce Department before the publication of the regulations.

(8) . . . Comparative table of the loads proposed and prescribed in 1870

SPAN.	MOVING LOAD.		SPAN.	MOVING LOAD.		SPAN.	MOVING LOAD.	
	Proposal of the association.	Regulations of 30th Aug. 1870		Proposal of the association.	Regulations of 30th Aug. 1870		Proposal of the association.	Regulations of 30th Aug. 1870
Metres.	Tons.	Tons.	F. I.	Tons.	Tons.	F. I.	Tons.	Tons.
3'3" (1 m.)	26·0	26·0*	16'5" (5 m.)	11·0	10·0	98'5" (30 m.)	5·4	4·0
4'11" (1·5)	17·3	17·5	32'10" (10 m.)	7·7	8·3	131'0" (40 m.)	5·0	4·0
6'7" (2 m.)	13·5	15·0	49'3" (15 m.)	6·2	6·7	164'0" (50 m.)	4·6	4·0
8'2" (2·5)	13·0	14·2	65'7" (20 m.)	5·8	5·0	196'10" (60 m.)	4·3	4·0

* Completed by means of the consideration of 13 tons on an axle capable of being used everywhere.

As may be seen by comparing with the loads of scale **a** of the Austrian regulations of 15th September 1887, it is to be regretted that the proposals of the Association were not adopted in 1869; they were well suited to a train of two « Semmering » locomotives of 56 tons each and loaded trucks of 15.6 tons each; it would have enabled the dimensions of many bridges with spans of 66 to 197 feet (20 to 60 metres) to be calculated much better than has been done.

(2) This scale may be compared with that of the Austrian regulation of 1870 as follows :

(9) . . . . Comparative Table of loads prescribed in 1877 and 1870 in France and in Austria.

SPAN.	MOVING LOADS.		SPAN.	MOVING LOAD.		SPAN.	MOVING LOAD.	
	The circular of 1877.	The regulations of 1870.		The circular of 1877.	The regulations of 1870.		The circular of 1877.	The regulations of 1870.
	Tons.	Tons.	F. I.	Tons.	Tons.	F. I.	Tons.	Tons.
3' 3" (1 m.)	24·0*	26·0	16' 5" (5 m.)	9·8	10·0	98' 5" (30 m.)	4·3	4·0
4' 11" (1·5)	16·0*	17·5	32' 10" (10 m.)	7·3	8·3	131' 3" (40 m.)	4·1	4·0
6' 7" (2 m.)	12·0	15·0	49' 3" (15 m.)	5·7	6.7	(164' 0") (50 m.)	3·9	4·0
8' 2" (2·5)	11·0	14·2	65' 7" (20 m.)	4·9	5·0	196' 10" (60 m.)	3·7	4.0

* Completed for an axle load of 12 tons.

The French circular is really much more rigorous than the regulations of 1870, as the internal strain on the iron is limited in it to 8,535 lbs per square inch (600 kilograms per square centiaccording to the bending strains produced at the middle of the bridge, by trains drawn by a single locomotive with four axles, weighing with its tender 72 tons or by two locomotives with three axles weighing with their tender 60 tons each. The strains produced by these loads are at certain points of the bridge, considerably below those corresponding to the engines with 4 axles in service at the present day; the adoption of a single scale of loads determined by the consideration of the bending strains (strains on the booms) leads moreover of necessity to quite incorrect results in calculating the sherring strains (strains on the web-bracing) (1).

The French circular of 1877 contains a regulation which although incomplete constitutes an important innovation : Article V (A) forbids the employment, without the previous sanction of the Minister of Public Works, of engines weighing more than 72 tons. These prohibitive rules may be considered as the indispensable complement of all regulations as to loads, for they alone can prevent them from becoming illusory.

The Russian circular of the 5th (17) of January 1884, N° 60, published in the « Journal of the Ministry for ways and roads of the 10th of February 1884, addressed

metre), whereas the regulations allowed a limit of 11,378 lbs per square inch (800 kilograms per square centimetre).

(1) In his work published in 1880 (*Eisenbahnwesen in Frankreich*, Vienna, C. Gerold's Sohn), circulated amongst the members of Congress 1885, the writer discussing (p. 81 to 99) this circular, showed, by means of exact calculation, the necessity of adopting for all regulations of this kind, two distinct scales of loads. The loads then proposed (p. 94 and 97, and pl. V) were sufficient for a train consisting of three locomotives (nos 1021 to 1040) of the Southern Company of France, each weighing 74 tons with its tender, and of a train of trucks weighing 15.4 tons each.

(10) . . . Table representing the loads proposed by the writer in 1880.

SPAN.	MOVING LOADS FOR THE		SPAN.	MOVING LOADS FOR THE		SPAN.	MOVING LOADS FOR THE		SPAN.	MOVING LOADS FOR THE	
	bending strains **a**	shearing strains **b**		bending strains **a**	shearing strains **b**		bending strains **a**	shearing strains **b**		bending strains **a**	shearing strains **b**
	Tons.	Tons.		Tons.	Tons.		Tons.	Tons.		Tons.	Tons.
3'3" (1 m.)	27·6	27·6	16'5" (5 m.)	10·7	13·3	98' (30m)	5·5	6 6	262' (80m)	4·3	4·6
4'11" (1m5)	18·4	20·6	33' (10m)	8·0	9·0	131' (40m)	5·3	6·1	328' (100m)	4·0	4·2
6'7" (2 m.)	13·5	18·0	49' (15m)	6·3	8·0	164' (50m)	5·1	5·6	394' (120m)	3·8	4·0
8'2" (2m5)	12 5	16·0	66' (20m)	6·0	7·3	197' (60m)	4·9	5·2	525' (160m)	3·4	3·5

The Austrian regulations of the 15th of September 1887 assumed these figures without any modification for large spans, and figures rather above these for shorter spans, so as to take into account the Arlberg locomotives.

to inspectors, directors and managers of railways » concerning « the technical conditions to be observed in iron structures for railway bridges », contains the most *complete* regulations about live loads, amongst all similar rules previously published. In it are fixed *the equivalent loads, for the bending and shearing strains, for those parts of the bridge near the supports and for those near the middle of the span,* with directions to proceed by interpolation for the intermediate parts of the bridge (1).

We ought, on the other hand, as for all the preceding regulations of loading, to make all the necessary interpolations as regards the span of the bridge, when it comes between two spans of the prescribed scale. The resulting complication of the practical application of these carefully studied regulations causes their scientific value to be forgotten, for constructors generally prefer to make their calculations directly by means of equivalent train loads which are also indicated by the Russian

(1) The Russian engineers chose the rolling loads exactly as the writer had done in 1880 (p. 95 of *Eisenbahnwesen in Frankreich*), defining them as *Gurtbelastungszug* and *Strebenbelastungszug* which we will translate as *bending train* and *shearing train*, each consisting of three locomotives with four axles coupled, their tenders and a train of trucks.

(11) . . . Comparative table of loads prescribed in Russia according to three scales.

SPAN.	MOVING LOAD **a**	**b**		SPAN.	MOVING LOAD **a**	**b**	
	for M_x if $x = \frac{l}{2}$	for M_x and V_x if $x < 2^m$	for V_x if $x = \frac{l}{2}$		for M_x if $x = \frac{l}{2}$	for M_x and V_x if $x < 2^m$	for V_x if $x = \frac{l}{2}$
	Tons.	Tons.	Tons.		Tons	Tons.	Tons.
3'3" (1 m.)	30·0*	30·0*	60 0*	98' (30 m.)	5·5	6·3	7·3
4'11" (1m5)	20·0*	22·5*	40·0*	131' (40 m.)	5·3	5 9	6·6
6'7" (2m.)	15·0	20·0	30·0	164' (50 m.)	5·2	5·6	6·3
8'2" (2m5)	13 7	18·7	26·7	197' (60 m.)	5·0	5·3	6·1
16'5" (5 m.)	12·0	14·5	18·6	262' (80 m.)	4·6	4·8	5·8
33' (10 m.)	7·5	8·5	12·4	328' (100 m.)	4·3	4·5	5·6
49' (15 m.)	6·0	7·3	9·8	394' (120 m.)	4·0	4·2	5 4
66' (20 m.)	5·6	6·8	8·4	525' (160 m.)	3·7	3·8	4·9

* Values added in accordance with the axle load of 15 tons prescribed by article II and with the distance between the axles of 4' 4" (1m32) both for Mx and the middle of the span and for Vx in the two last columns.

The first two columns of loads correspond within a little to scales **a** and **b** of the Austrian regulations of 1887. We must besides mention particularly that the scales of moving loads quoted here and previously should in no wise be considered as reproducing the actual figures of the original documents, but rather as giving the polygonal contours which, when formed with the abscisses of entry of the Austrian regulations, best replace the similar contours which are obtained as graphic expressions of the regulations quoted; we can thus easily compare them with the scales **a** and **b** prescribed in Austria.

circular [1] rather than have recourse to all the interpolations that we have just mentioned.

2. — *Form to be given to regulations of loads.*

When drawing up the Austrian regulations as to loads, it was desired above all that they should be *easy of practical application* and at the same time as accurate as possible. It was represented that the moving loads might be fixed in all cases under the form of *typical rolling loads* indicated by the distances between the axles and the loads on the axles (or even only by the locomotives, tenders and trucks composing them, without any order being previously fixed) or under the form of *equivalent loads equally distributed.*

At first sight the first system would seem to be preferable; a single sketch of the « typical trains » or of the locomotives, tenders and trucks to be considered is sufficient in such cases for all the bridges and their component parts, and the list of regulations or the circular to be drawn up is thus all prepared in a satisfactory manner.

On examining matters a little closer, however, we soon see that such a system would merely put aside the difficulty without solving it. The regulations to be drawn up as regards loads should have for their basis a system of moving loads sufficient in all cases to represent the straining effects of all the rolling stock in service on the railways of a country, with all the usual combinations of trains. Now this cannot be represented by a single « typical train load » or even by the indications of a typical locomotive, tender, or truck, although, in the latter hypothesis, that of vehicles defined singly, we can really form a certain number of typical trains. In every special case where with this system it is necessary to decide whether a given train may or may or may not run on a given line, we must always go back and calculate afresh the strains produced both by the given train and the typical train on all the bridges with different spans of the line in question, as well as on all their component parts, and then examine whether the strains produced by the given train exceed those of the typical train or not. If then it is proved that the given train is admis-

(1) The total distance between the axles of the locomotives = 3 × 4 feet 4 inches = 13 feet (3 × 1.32 = 3.96 metres), their total length = 31 feet 5 inches (9.58 metres). The axle load is 15 tons up to $\lambda = 21$ feet (6.40 metres), 13.75 tons up to $\lambda = 28$ feet (8.54 metres) and 12.5 tons for $\lambda > 8.54$. The length of a tender = 21 feet 7 inches (6.58 metres), its weight = 3 × 10.67 tons = 32.01 tons. The length of a truck = 24 feet 8 inches (7.52 metres), its weight = 16.40 tons.

sible for one span, it is not necessarily proved for another; if it is proved for the booms, it is not for the web-bracing, lastly even — to follow the Russian engineers — a given train that would be equivalent to the typical train for the boom or web-bracing of one single panel in a bay, would not perhaps be so for those of the next panels and so on.

When carrying out in figures all these researches and comparisons, we must continually go back and examine afresh, for each detail of construction of each bridge, what is the most disadvantageous position of each of the trains to be compared, etc.

These insurmountable difficulties and objections incurred by the application of the system of typical trains have led for the Austrian Regulations of the 15th September 1887 as well as for all previous regulations or circulars, to the adoption of the *system of prescriptions by equivalent loads uniformly distributed;* thus we have, once for all, to make a minute study of the bending and shearing strains resulting in all possible cases of the running of rolling stock.

The conception of loads uniformly distributed furnishes the simplest method of estimating moving loads. If we wish, for instance, to compare the effects of two trains on any detail of construction, we have only to set down the equivalent loads per metre in order to obtain at once a clear result for the whole, from which we can at once deduce if necessary the excess of load estimated in hundredths.

3. — *General remarks on the loads prescribed in Austria.*

After very close study of the subject, the Austrian regulations of loads have been able to be set forth in the very simple form of two scales of moving loads each containing 12 numbers. The typical train, considered at first, consists of three locomotives with four axles with their tenders and the required number of trucks, as indicated in § 3, *d*, of the regulations. The scales of load obtained by means of this train (1) were slightly modified afterwards; they had to be adapted to other requirements for small spans, and their indications had to be moderated for large ones. The system of specifying by equivalent uniform loads facilitated corrections of this kind. By extending these calculations to all the sections of the bridges under consideration, not only was scale a for the booms (2) considerably improved *to*

(1) That is, the two polygons obtained with the « bending train » and the « shearing train » derived from it.

(2) The apices of the polygon recorded in the scales have their coordinates expressed in round numbers, and the rectilinear sides with simple inclinations being also expressed in round numbers,

scale **b** *for the web-bracing an entirely new form was given in which the length loaded within the span, is admitted as value of entrance to the scale prescribed,* which constitutes an exact mathematical solution for representing the shearing strains produced by the trains. For local lines the mode of procedure was at first the same as that employed for main lines, but the lighter trains indicated in § 3 *h* of the regulations were taken as the starting point. By comparing all the results thus obtained all the scales of load have been able to be arranged according to the system finally adopted.

The scales **a** and **b** of loads allowed should really be, considered as polygonal diagrams, as simple as possible (¹), including nearly all the diagrams representing the bending and shearing strains resulting from all the trains allowed on the railway, so that the differences between these diagrams and the actual curve do not generally exceed 3 to 6 per cent, and in the exceptional cases of a number of unfavourable circumstances, about 10 per cent.

Altogether more than 40 trains were considered, and the various comparative calculations relating to them showed that the difference of tolerance above-mentioned could not be diminished without uselessly restricting the composition of the trains in service or rendering the construction of bridges costly beyond measure. By contenting ourselves with the accuracy defined by the limits of allowance above-mentioned, we have been able, on the other hand, to extend the use of the scales **a** and **b** to the calculations concerning bridges for lines of local interest (by means of co-efficients of reduction of 80 p. c. and 60 p. c.) and even to use these scales of load for the circulation of the cross-girders and longitudinal girders of any bridge whatever. In this manner, the Austrian regulations have again been able to be considerably simplified without losing their capability of general application.

The writer, who at the time of the first sitting of the Congress, made every effort to draw the attention of the Congress to the necessity of bringing about an agreement between the conditions of resistance of bridges and the increasing loads imposed upon them by the rolling stock, has thought it worth while to enter some-

the interpolations are greatly facilitated never involving recurring decimals. The regulations quoted before are expressed in the same manner.

(¹) We find that for spans varying between 33 and 98 feet (10 and 30 metres) we must slightly raise scale **a** in order to take into account the sections situated between the support and the middle of the span; the sections dividing the span into two unequal parts, forming respectively 1/6 and 5/6 of the entire span, are best suited to this purpose.

what into detail here as to the manner in which the question has been completely regulated in Austria.

4. — *The exact definition of the equivalent uniform loads for a given part of the structure.*

When we have to determine the dimensions of any particular part of a bridge, in view of a given load, we must ascertain which, amongst all possible positions of the train, imposes on the part considered, the greatest possible strain. We then designate as *equivalent uniform load* (or load uniformly distributed) that which, as compared with the rolling load, covers about the same length of the track and produces the same strain in the part considered.

However, as the load uniformly distributed, which covers a part of the bridge, may vary in extent and in value per square metre or running metre, it seems to follow that for every train we should substitute a number of equivalent uniform loads answering to the definition given. It has been decided to limit the extent of the uniform load to all those parts of the section of the track covered, where it has the effect of increasing the strain borne by the part considered. In this way, for each bridge and each part of a bridge that part of the track on which the load is to be imposed is so to say, fixed beforehand, according to the system of construction adopted, and the *definition given of the equivalent load only concerns the load per square metre or per running metre taken into consideration.*

We know, for instance, that for a bridge with independent spans with plate-girders, we determine the dimensions of the chords by supposing that the load extends all over the span, that for a similar arched bridge on the contrary, it must be supposed that only one or two parts of the span are subjected to the load, according to the portion of the chords considered (1). In the same way, for the bridges that we have just mentioned, the solid web or a close lattice-work instead may be determined by supposing that the load covers a part of the bridge known beforehand.

Even in the case of our modern structures with open lattice-work or trusses, which are calculated, as we know, according to the theory of jointed systems, i. e. supposing that all the weights and loads are concentrated in the joints or apices, *the idea of equivalent uniform loads* can always be very clearly ascertained; it is

(1) See M. Albaret's theory (*Annales des ponts et chaussées*, 1862, 2nd half-year, p. 305, and 1870, p. 463 to 573 for rigid spandrels).

sufficient to assume that each joint takes all the loads from centre to centre of the adjacent panels, and moreover to consider each part of the structure in connection with the joints known beforehand as being loaded or at the centres of the panels which should accordingly form the limitis of the uniform equivalent load. Consequently when it is required *to determine the dimensions of any part of the structure in view of a train of a given load or of the uniform equivalent load to be assumed for calculations, it must be clearly understood that the extent of the part of the track on which the load is to be imposed is determined beforehand by the system of construction adopted, whereas the equivalent load per metre is really the unknown quantity depending solely on the train that it has to replace.*

This load, which we will call p in this explanation (per running metre of the track) is generally designated, in ordinary technical language, as the equivalent load to be found; this is all the more customary as for the types of bridges most used with independent or continuous girders, the extent of the uniform loads to be assumed is in each case determined by simple well-known rules, which at the commencement render unnecessary any subsequent researches.

For parts that may be alternately in tension and compression, we have *a uniform equivalent load for the tension and a uniform equivalent load for the compression; these are, in all possible cases, two complementary loads*, which together, would cover the whole section of the bridge floor. The two values of the two separate loads per metre are not however equal as a rule.

5. — *Equivalent load in regard to bending moments and to sharing strains.*

We are accustomed, in the practical calculations of bridges to collect all the external forces acting upon a section of the bridge (including the reactions of the supports) into a single couple representing the *bending moment* and a single force representing *the shearing strain*. These resulting forces being supposed to be applied to the section, can be substituted for the sum total of the reactions exercised on one of the two parts of the structures by the other part, looked upon as suppressed.

For bridges free at the ends [1] (with girders resting on the supports) the bending

[1] For all structures free at the ends or girders resting freely on two supports, the shearing force acts vertically. For arched bridges, on the other hand, the single force replacing it takes a special direction for each section, so that each of these strains is resolved into a force normal to the section (compressive strain) and a force normal to the arch, i. e. withstood by the section (shearing strain properly so-called).

moments are used for the calculation of the chords and the shearing strains for that of the web-bracing. In such a case, the equivalent loads for a part of the chord or a diagonal are confused with those that give the corresponding bending moment or shearing strain and we say, *uniform equivalent load as to bending moment or shearing strain* for we are always brought back to these two static quantities in all researches of this kind.

The equivalent loads in regard to the bending moments or to shearing strains have really a special value for each part of the chord or web-bracing; it had however previously been the custom amongst engineers to accept *for the calculation of the entire chords the equivalent load for the bending strains at the middle of the span, and for the calculation of all the web-bracing, the equivalent load for the shearing strain near a support* (1). In the Austrian regulations, the loads have been so well determined as to bending strains that they adopt themselves in the best possible manner to strains of all sections, and the loads for shearing strains, so that they adapt themselves perfectly theoretically to all shearing strains. We however expressly remark here that *all calculations past and present, made in order to determine the uniform equivalent loads replacing a train of a given load only relate to bridges with girders resting freely on two supports placed at their extremities* (2). But these two scales **a** and **b** of the Austrian regulations being once established for independent spans, it has been easy to extend their application to girders continued over several spans, this being an excellent mode of construction and one very much used in both hemispheres. We have reproduced these regulations as an appendix to our report (3).

(1) For calculating the chords this custom has been adopted almost exclusively. For the calculation of the web bracing, on the other hand, the train load itself is often used by employing methods (often graphic) leading to a more exact estimate of the strains to which the bracing is subjected.

(2) See on this subject the following publication : *Annales des ponts et chaussées*, n° 3, Jan, 1877, « Second note on the calculations of stability of longitudinal girders », by C.-H. Kleitz, 13th May, 1876. (The first note of October 15th, 1855, had only appeared in manuscript). The writer only considers bending strains and in conclusion arrives at propositions in which one can hardly find a complete expression of his very careful and instructive work.

(3) All the details of these calculations and the Austrian regulations are to be found in the works : *Die neue Brückenverordnung des österreichischen k. k. Handelsministeriums*. Vienna, 1888, W. Braumuller, and *Calculs des ponts métalliques à une ou plusieurs travées*, Paris, 1889, Baudry et Cie. These works contain a number of numerical tables and diagrams facilitating the calculations in general, whatever loads are assumed.

6. — *The most recent regulations as to load.*

The regulations as to load established since 1887 and which at least partially exceed in severity those we have just mentioned, are as follows :

France.	29th August 1891, ministerial circular.
Switzerland	19th August 1892, federal government.
England	August 1892, Board of Trade.
Hungary	14th April 1893, State Railways.

It is with regret that we remark that the form in which these regulations are drawn up is not one which we approve; the authorities have confined themselves to assuming certain types of locomotives and heavy tenders and to stipulating that all calculations of resistance should be deduced from them. Also it must be observed that the Board of Trade does not mention any particular types but leaves it to each Administration to choose them under the most unfavourable conditions, so that, theoretically at least this very open regulation can always be made to suit. The following is a description of the typical trains for the other three countries:

France, 1891. — The typical train consists of two engines with four axles, their tenders and loaded trucks; the engines with their tenders are both placed in front of the train. We must, besides take into account the force exerted by an independent axle carrying 20 tons [1].

Switzerland, 1892. — The typical train consists of three locomotives with four axles and their tenders, placed most unfavourably, at the head of the train, all the trucks being coupled behind.

For main-girders of small bridges with less than 49 feet 3 inches (15 metres) span, and also for the longitudinal and transverse girders, we must increase the loads resulting from the typical train by $2 \times (15 - l)$ p. c., l representing the theoretical span of the parts considered.

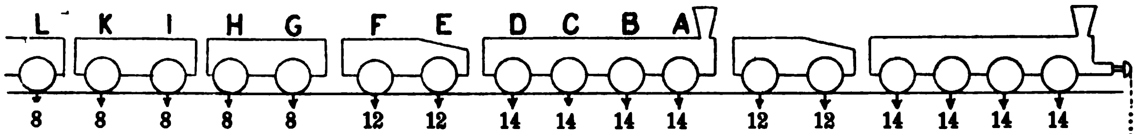
Hungary, 1893. —The typical train consists of two locomotives with 4 axles and their tenders with trucks capable of being placed either in front or behind and representing an equivalent uniformly distributed load of 0.15 ton per foot run

(1) We understand that this condition concerns the main girders of small bridges quite as much as longitudinals and transverse girders in general. (The circular seems to imply the contrary.)

(2.8 tons per running metre) of track [1]. We use, besides, the formula 2 (15 — *l*) p. c., as above.

The three lists of regulations as to loads define the typical trains by means of diagrams showing the axle-loads and distances between the axles; we represen these trains in the following manner :

(12). . . . . . **France 1891.** — 2 locomotives, 2 tenders and trucks behind.
With single axle of 20 tons.



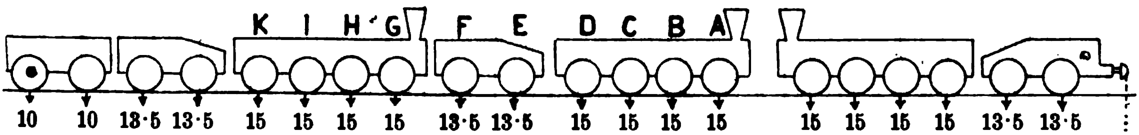
British measures.

9'10 1/8 × 9' 10 1/8 × 9' 10 1/8 × 9' 10 1/8 × 9' 10 1/8 × 11' 5 3/4 × 8' 2 3/8 × 15' 1 1/8 × 3' 11 1/4 × 3' 11 1/4 × 3' 11 1/4 × 15' 1 1/8 × 8' 2 3/8 × 15' 1 1/8 × 3' 11 1/4 × 3' 11 1/4 × 3' 11 1/4 × 8' 6 3/8 >

Metric measures.

3·0 × 3·0 × 3 0 × 3.0 × 3.0 × 3·5 × 2·5 × 4·6 × 1·2 × 1·2 × 1·2 × 4·6 × 2·5 × 4·6 × 1·2 × 1·2 × 1·2 × 2 6

(13). . . . . . **Switzerland 1892.** — 3 locomotives, 2 tenders and trucks behind.
With 2 (15—*l*) p. c. in addition.



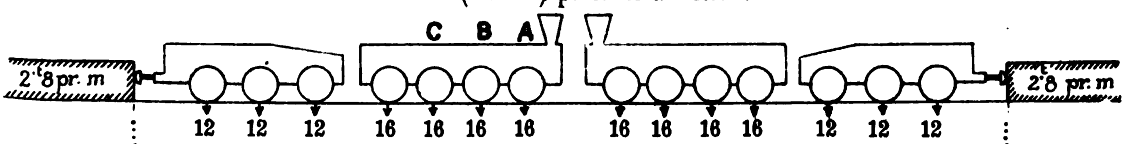
British measures.

13'1 1/2 × 11'5 3/4 × 11'9 3/4 × 9' 2 1/4 × 14' 5 1/8 × 4'3 1/8 × 4'3 1/8 × 4'3 1/8 × 14' 5 1/8 × 9' 2 1/4 × 14' 5 1/8 × 4'3 1/8 × 4'3 1/8 × 4'3 1/8 × 18' 4 1/2 × 4'3 1/8 × 4'3 1/8 × 4'3 1/8 × 14' 5 1/8 × 9' 2 1/4 × 5'3 >

Metric measures.

4·0 × 3·5 × 3·6 × 2·8 × 4·4 × 1 3 × 1·3 × 1·3 × 4·4 × 2·8 × 4·4 × 1·3 × 1·3 × 1·3 × 5·6 × 1·3 × 1·3 × 1·3 × 4·4 × 2·8 × 1·6

(14) . . **Hungary 1893.** — 2 locomotives, 2 tenders and a uniform load of 2.8 tons per metre.
With 2 (15—*l*) p. c. in addition.



British measures.

< 6'6 3/4 × 4' 11 × 4' 11 × 13' 9 3/8 × 3'11 1/4 × 3'11 1/4 × 3'11 1/4 × 19' 8 1/4 × 3'11 1/4 × 3'11 1/4 × 3'11 1/4 × 13' 9 3/8 × 4' 11 × 4' 11 × 6' 6 3/4 >

Metric measures.

2·0 × 1·5 × 1·5 × 4 2 × 1·2 × 1·2 × 1·2 × 6·0 × 1·2 × 1·2 × 1·2 × 4·2 × 1·5 × 1·5 × 2·0

[1] We understand that, for shearing strains, the trucks are all supposed to be placed in the rear of the train, whereas the text which is not very clear seems to imply the contrary. Moreover, the enormous loads resulting from these regulations only concern new bridges.

We must assume that the writers of the above regulations have previously studied their influence on the calculations of resistance for iron bridges. However, this may be, we have taken the trouble to compare them with the Austrian regulations, at least as regards the bending strains by calculating very scrupulously the equivalent loads per metre of track for spans of 3'3 to 5·30' (1 to 160 metres), it being understood that in each case we place on the middle of the bridge that of the axles A, B, C, shown in the corresponding diagram which gives the maximum [1]. We have collected in one table all be results found, viz :

(15) Comparative table of the loads p per metre of track, representing as regards bending strains, the prescribed loads, caused by typical trains.

SPAN.	Austria 1887.	France 1891.		Switzerland 1892.		Hungary 1893.	
		Middle.	p	Middle.	p	Middle.	p
	Tonnes.		Tonnes.		Tonnes.		Tonnes.
3' 3" (1 m.)	30·00	B	40·000	B	38·400	C	40·960
4' 11" (1·5)	20·00	B	26·667	B	25·400	C	27·093
6' 7" (2 m.)	15·00	B	20·000	B	18·900	C	20·160
8' 2" (2·5)	13·50	B	12·096	B	15·000	C	17·279
16' 5" (5 m.)	11·50	B	11·648	B	14·112	C	15 979
33' (10 m.)	8·50	B	8·512	B	9·768	C	10·701
49' (15 m.)	7·00	B	6·742	B	6 893	C	7·744
66' (20 m.)	6·50	B	6·056	A	6·529	B	7·084
98' (30 m.)	6·05	A	5·274	A	6·169	A	6·089
131' (40 m.)	5·60	A	5·112	C	6·068	A	6·436
164' (50 m.)	5·30	B	4·773	C	5·859	A	6·020

SPAN.	Austria 1887.	France 1891.		Switzerland 1892.		Hungary 1893.	
		Middle.	p	Middle.	p	Middle.	p
	Tonnes.		Tonnes.		Tonnes.		Tonnes.
197' (60 m.)	5·00	B	4·442	D	5·558	A	5·655
230' (70 m.)	4·70	C	4 153	E	5·246	A	5·353
266' (80 m.)	4·40	C	3·907	E	4·960	A	5·103
299' (90 m.)	4·25	D	3·700	F	4·740	A	4 895
332' (100 m)	4·10	E	3·528	G	4·537	A	4·720
365' (110m.)	3·95	F	3·393	G	4·355	A	4·571
398' (120 m)	3·80	F	3·279	H	4·193	A	4·443
431' (130 m)	3·70	H	3·188	H	4·042	A	4·332
464' (140 m)	3·60	K	3·116	I	3·907	A	4·235
497' (150 m)	3·50	M	3·058	I	3·784	A	4·149
530' (160 m)	3·40	M	3·009	K	3·672	A	4·073

In this table we must carefully distinguish the figures relating to short bridges of less than 50 feet (15 metres) span; for these, there is an excess of load in the Swiss

(1) For the details of these calculations, which are somewhat intricate, consult the theory and methods of the writer in the work : *Calculs des ponts métalliques à une ou plusieurs travées*, p. 35. Paris, Baudry, 1889. To make a similar comparison, as regards shearing strain, we should require first to elucidate certain points in the regulations. We doubt whether every bridge constructor has time to make these researches; it would be better that those who draw up the regulations should make them once for all. Moreover on this subject we call attention to the typical calculation which we give further on as an example in an appendix to chapter III.

and Hungarian regulations. In the French regulations there is an excess of load only for much smaller spans, in consideration of the single axle of 20 tons. This is the object of the considerations that particularly concern the maximum axle-load admitted (in Austro-Hungary and Germany, 14 tons), we shall refer to this again later on.

As to the loads prescribed in Switzerland and Hungary for large spans, we can but feel convinced that at present they seem exaggerated beyond measure for those countries.

The loads prescribed in Austria as we have shown in chapter II of our report, at present cover the strains imposed by all the trains running in Germany and Austro-Hungary. We have found also that the somewhat lighter loads prescribed in France are amply sufficient in that country and the difference at least as far as Austria is concerned, is easily explained by the comparison of the tenders which are lighter in France. Another comparison made with the loads prescribed in Russia, which were studied with the greatest care (II) and which are at the present day quite sufficient to meet the requirements of the rolling stock in use brings us to the same conclusions.

To sum up, then, we are, in principle, opposed to typical trains; we think, moreover, that when they are used, we should at any rate try *to keep, as far as possible, to the rolling stock actually running on the lines considered* (1). Without

(1) It seems that in the United States of America no formal regulations have so far been made either by the Central Government, individual States, or the Railway Commissioners, concerning the rolling loads to be taken into consideration as standards for the various railway lines. However, in that country managers, consulting engineers, and manufacturers, have been led, simply owing to the enquiries instituted when bridges have given way under trains in motion, or when similar disasters have occurred, to adopt more solid structures. They now find it cheaper in the end to enforce stricter regulations on their own account. We have received the specifications which the following consulting engineers intend to adopt: Theodore Cooper, New York, 35, Broadway, 1890 (new and revised edition). G. Bouscaren, Cincinnati, O., 99, West 4th Street, 1890 (second edition revised). J.-A.-L. Waddell, Kansas City, Mo., 1893.

Several classes (3 to 7) of railway lines are taken into account, and in each case a typical loaded train forms the basis for calculation. This is usually formed of two 10-wheeled engines (called « consolidation engines » and of the type 9 to 12 in table 7). The four main axle loads in some typical trains of the first class rise as high as 20 tons, no wheel base greater than 5 feet (1.52 metre) being taken into consideration. We think that, as explained further on, it is hardly possible to really construct such engines, and in order to show the greatest rolling loads that such typical wishing to dwell further on the regulations at present in force, we propose to try to reconcile the interests of all our railway colleagues, by submitting to the Congress a system of loads representing all the engines quoted in chapter II.

7. — *Project for international regulations to be submitted to the Congress.*

In order to render our proposition both comprehensible and acceptable, we present it at first in the form of typical vehicles, giving afterwards the scales **a** and **b** of uniform loads per metre of the track, for calculations.

If we study generally all the trains, we may state that the carriages and trucks composing them have only a secondary influence on the majority of bridges, an influence which is only taken into consideration for spans of more than 131 feet (40 metres), since the total length of two locomotives with their tenders, which constitute the essential basis of all typical trains, is already more than 98 feet (30 metres). Calculation shows that we can take carriages and trucks into consideration with all the accuracy desirable by representing them as a load uniformly distributed behind the locomotives and tenders as in the Hungarian regulations (1).

Now the usual trucks of 16 tons, which are about 23 feet (7 metres) long, represent a load of 0·70 ton per feet (2·3 tons per running metre) of track. We may say that the great majority of carriages and trucks come within this limit. We have

trains could provide, we give the following tabular comparison between the above mentioned regulations and those proposed by us as given farther on :

SPAN.		Proposed by the American regulations. In pounds per foot track.				Proposed by the American regulations. In tons per metre track.				Proposed by the reporter in tons per m. tr.	
Metre.	Feet.	Cl. 1.	Cl. 2.	Cl. 5.	Cl. 7.	Cl. 1.	Cl. 2.	Cl. 5.	Cl. 7.	Ext. heavy.	Heavy
5	16	9300	8680	6730	5400	13·8	12·9	10·0	8 0	12·5	11 5
10	33	7580	7070	5500	4470	11·3	10·5	8 2	6.7	9 5	8 5
15	49	6680	6240	4920	40 0	9·9	9 3	7.3	6·0	8 5	7·0
20	66	6070	5670	4530	3770	9·0	8·4	6·7	5 6	8·0	6·5
40	131	...	5175	4184	3530	...	7 7	6 2	5·2	6·8	5·6
80	262	...	4775	3906	3322	..	7·1	5·8	4·9	5 3	4·4
120	394	...	4558	3770	3240	...	6·8	5·6	4·8	4.3	3.8

(1) This is what the writer proposed in 1888 and 1889, page 121, of his work : « *Calculs des ponts métalliques.* »

next to consider the reservoir-vans for molasses or petroleum which have led engineers to establish the higher limit of 0·85 ton per feet (2·8 tons per running metre). This constitutes in Austro-Hungary a maximum in a certain sense, for heavier trucks cannot be placed directly after the engines and tenders. Lastly on certain main lines exceptionally heavy waggons are being used for conveying coal, stone, limestone, etc.; and for these a load of about 1 ton per feet (3·3 tons per metre) has been arrived at. These waggons are excluded from a large number of lines; they constitute a load that has not as yet been exceeded. In Austria, for instance, any transport proposed beyond this limit is subjected to a special inquiry concerning the permanent way and the bridges. We must remark that the limits we quote comprise all the vehicles often mentioned such as the American trucks of 30 tons and others which, on account of their length are less to be feared. We may also say that the carriages in general use never exceed the limit of 0·7 ton per feet (2·3 tons per metre) and that the exceptional carriages *de luxe* in both worlds, including the kitchens, the accumulators for electric lighting, etc., never attain the limit of 0·85 ton per foot (2·8 tons per metre).

We have then three types of heavy trucks weighing 1 ton (3·3), 0·85 ton (2·8) and 0·70 ton per foot run (2·3 tons per metre). We will represent them by trucks with 2 axles weighing 24, 20 and 16 tons and measuring 23 feet 11 1/2 inches (7·3 metre), 23 feet 7 1/2 inches (7·2 metre) and 22 feet 11 1/2 inches (7·0 metre) metres respectively. For the sake of convenience, we will call these trucks W_1, W_2 and W_3.

To come now to typical load trains representing the whole of the trains running, according to the facts supplied to us and which we have summed up in chapter II, as far as the principal international lines are concerned (1), we have thought it best to distinguish two cases, or more correctly two groups of railways.

The first group comprises the main arteries of circulation in the United States of America, where the exceptionally heavy rolling stock that we have mentioned is used; it also includes a certain number of main lines in the Old World, where the traffic is quite as great, where the permanent way is even rather stronger than in America, but where the rolling stock is not as yet so fully developed. We must assume that what has been realised in America will soon be done here. Already, in England, the axle load of express engines amounts to 18 and 19 tons; in America it amounts to 20 tons for the ordinary locomotives with 2 axles coupled for express

(1) We evidently cannot here discuss branch lines or local lines which in each country are subject to special regulations.

trains. But express engines have now been constructed with 3 axles coupled; these are types 6, 7, 8 of our table (7) which have now become general in America. Their axle load now amounts to nearly 17 tons, but the history of the development of the locomotive summed up above obliges us to provide for an axle-load amounting to 20 tons (1). The tenders for such trains must be made accordingly. They are generally made with 4 axles in America and weigh up to 40 tons, rarely more.

The second group comprises all the principal international lines that have not reached this stage of developement and on which such loads will not be allowed for a long time. We think we may say that the great majority of railways in the Old World and a considerable number of those in the New will remain in this second group, so that the limits as to load that we assign to it, as summing up the actual requirements of the present traffic, are of more special interest to us.

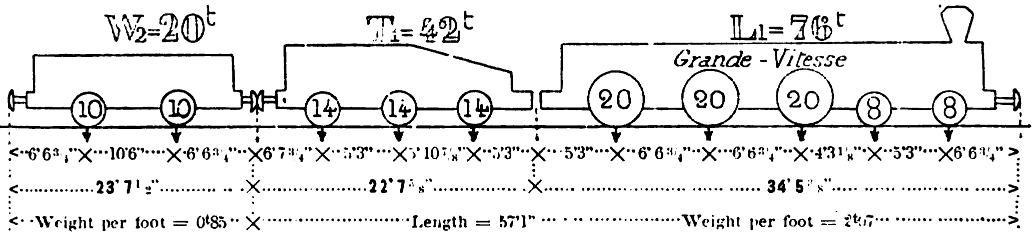
For the sake of clearness we shall designate as *extra heavy trains* those of the first group, and as *heavy trains* those of the second. For each of these groups, it is absolutely impossible (2) to represent the effects of strains caused by all the trains in circulation by a single typical train; we must at least have two trains which will of course be the fastest passenger train and the heaviest goods train, thus representing to a certain extent the two extremes of the traffic. We thus arrive at four typical trains which together give the strains required :

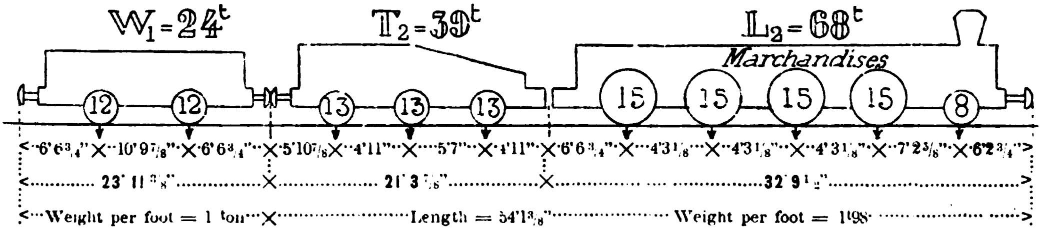
(1) This limit once being admitted by locomotive engineers, it will become general and the construction with three axles coupled constituted only a temporary solution of the problem. At least this is what we have learnt from the history of engines with two axles coupled.

(2) We demonstrate this in our graphic table, pl. I; this shows more generally all the inconveniences of regulations by typical trains, and the advantages of regulations by loads uniformly distributed..

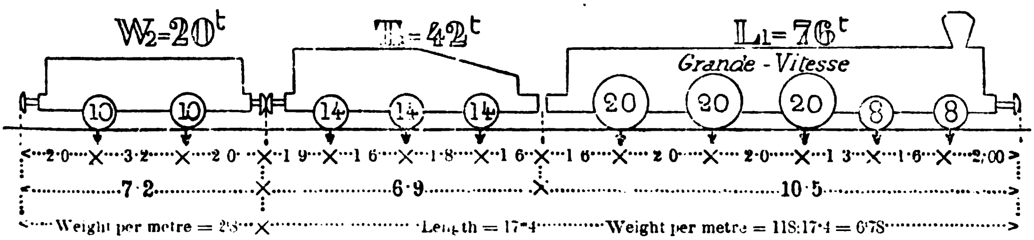
(16). . . . . 1st Group : Extra-heavy typical trains.

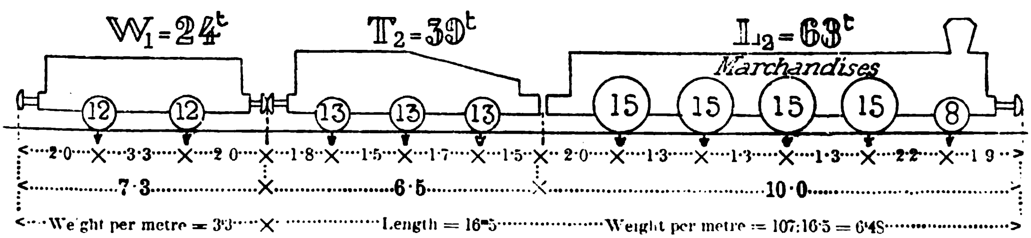
British measures.





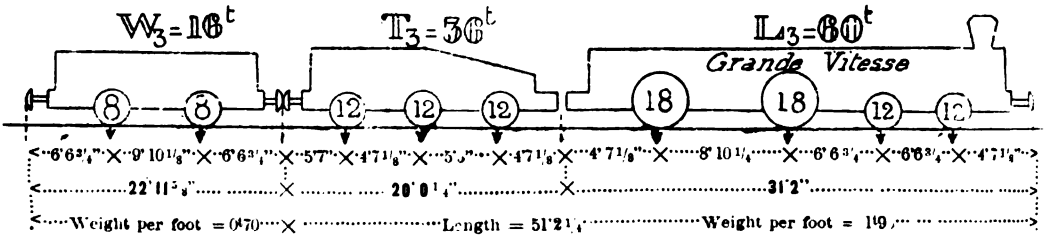
Metric measures.

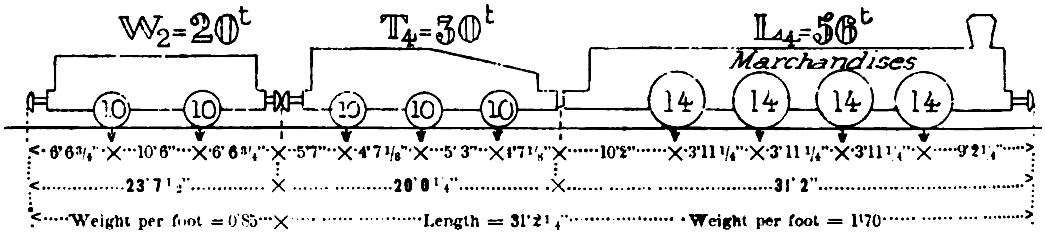




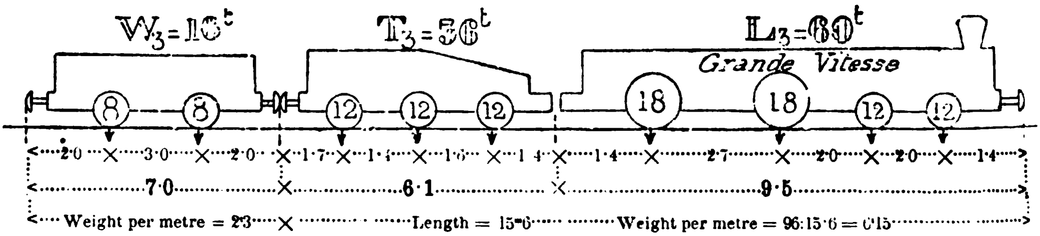
(17) . . . . 2nd Group : Heavy typical trains.

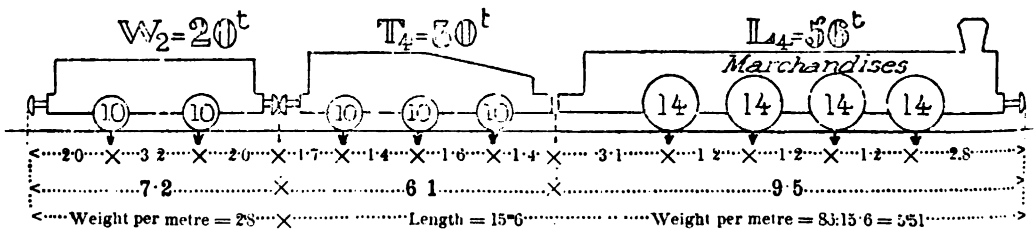
British measures.





Metric measures.





It was only after a careful study of all the rolling stock quoted in chapter II and after very laborious calculations made for the purpose of finding well graduated vehicles, which should satisfy the requirements of the rolling stock at present in use and of the regulations in force, that we were in a position to submit these types to the Congress. We submit : 4 typical locomotives : L_1, L_2, L_3, L_4, weighing 76, 68, 60 and 56 tons and typical tenders T_1, T_2, T_3, T_4, weighing 42, 39, 36 and 30 tons respectively.

The type L_1 is derived from the American locomotives, L_2 combines in itself the American engines nos 9 and 12 of our table (7) and the typical locomotives of the Swiss regulations. L_3 and L_4 represent types well-known in both hemispheres. L_4, moreover, is directly in accordance with the French and Austrian regulations and also with the vote sanctioned by the Congress during the fourth session at St-Petersburg (1) in 1892 (2).

As regards tenders, the distances between the axles and the axle-loads allowed have only an indirect influence on the strain exercised by the whole train, for in this respect the locomotives outdo the tenders so that, with the latter, it is mainly the weight per metre of track that is taken into account. In Europe we had mainly to consider tenders with two and three axles which, for the *heavy trains* of the second group weigh 27 and 36 tons or 24 and 30 tons according to whether we are considering express trains or goods trains. As to the tenders of the *extra heavy trains* of the first group, they are not so well defined ; they have 3 axles in Europe, 4 in America. Their weight always exceeds 36 tons, rarely 40 ; we have admitted types of 42 and 39 tons according to whether we were dealing with express trains or goods trains. Lastly, in order to have a set of well graduated typical tenders, we have supposed them all to be constructed with 3 axles, leaving out those that weigh less than 30 tons. As regards the carriages and trucks, it will be seen that we use the types W_2 and W_1 for the *extra heavy trains* and the types W_3 and W_2 *for heavy trains*, of course always assuming that the carriages are not so heavy as the trucks.

(1) « It seems desirable that the permanent way and the bridges on the great international lines should be sufficiently strong to allow of the passage of a couple of vehicles each having four axles of 14 tons with 3 feet 11 1/4 inches (1.20 metre) distance between them. » To be exact, we must add that the total wheel-base of the whole should be about 42 feet (12.80 metres), the wheel-base of two engines L_4, placed facing one another.

(2) We have not thought it necessary to take into account the American types 13, 14, 15 of our table (7), as we consider them exceptional.

With all the above mentioned vehicles, we generally make up our four typical trains in the usual manner, i. e. with two engines accompanied by their tenders at the head of the train and all the trucks behind. This arrangement is also the one adopted in the French regulations; it really gives rise to somewhat intricate calculations as to the bending strains, since for each span preliminary researches are necessary as to the axle of the train to be placed on the middle of the bridge in order to obtain the maximum. But the straining effects thus obtained are such as we really meet with in actual working and we think at least for the *extra heavy trains*, there is no plausible motive for going beyond this.

For the *heavy trains* of the second group, which are much more familiar to us, we have not sought to increase the loads obtained as has just been explained; but it seemed to us practical, for large spans, to take into account to a certain extent the goods trains which may be formed by combining in another way lighter vehicles than those which serve as types.

On the basis of the conditions thus assumed, we have calculated for our four typical trains, the scales of load uniformly distributed per metre of track, which we shall therefore be able to adopt, both for bending and shearing strains.

When large spans are concerned, we can for each of our two groups (16), (17) identify (to within a few hundredths) (1) the loads given by the two trains that compose it. For short spans [we will say of less than 33 feet (10 metres)], the loads imposed by the trains present such irregularities that it is best to replace them by a regular law as to load, and, there again, we can identify what concerns the two trains of one group. For this part of our work, we have thought it would be interesting to record all the results of our calculations on one diagram which the reader will find subjoined (plate I). This table furnishes us with almost irrefutable arguments against typical trains (2); we will refer to this later on. In short for each pair of trains constituting a group, we establish a scale **a** of equivalent loads per metre of track serving for the calculation of the bending strains, and another similar scale **b** serving for the calculation of the shearing strains.

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(1) Can the peculiar curve which really represents the effects of all regulations of this kind be seriously accepted as including all the similar effects obtained in working a large railway system?

(2) The greatest discrepancy is found in the third train, which for 130 feet (40 metres span, gives, with the extreme axle-loads of 18 tons, about 5 per cent more than we get with the fourth train.

(18) Table of loads uniformly distributed per metre of track equivalent to the loads of the typical trains.

SPAN OR LENGTH LOADED.	EXTRA HEAVY TRAINS.		HEAVY TRAINS.	
	a. Bending strains. — Load per metre of span.	**b**. Shearing strains. — Load per metre of length loaded.	**a**. Bending strains. — Load per metre of span.	**b**. Shearing strains. — Load per metre of length loaded.
	Tons.	Tons.	Tons.	Tons.
3'3" (1 m.)	40	40	36	36
4'11" (1m5)	27	28	24	26
6'7" (2 m.)	20	23	18	21 5
8'2" (2m5)	16	19·5	15	19
16'5" (5 m.)	12·5	15	11·5	14
32'10" (10 m.)	9·5	11	8·5	10
49'2" (15 m.)	8·5	9·6	7·0	8·5
65'7" (20 m.)	8·0	8·7	6·5	7·6
131'3" (40 m.)	6.8	7·3	5·6	6·2
262'6" (80 m.)	5·3	5·8	4·4	4·8
393'8" (120 m.)	4·3	4·8	3·8	4·0
525'11" (160 m.)	3·8	4·3	3·4	3·5

N. B. — For intermediate spans or lengths of track loaded we shall proceed by rectilinear interpolation.

These scales of loads are subject to slight modifications for short spans, when the maximum axle-load allowed for a system does not reach one of the limits of 20 or 18 tons [1] which we have introduced into our two groups, the locomotives moreover keeping to all intents the weights allowed in our types. This has been specially studied. In fact, up to about 8 feet 2 inches (2m5) of span, the load per metre depends almost entirely on the maximum axle-load admitted, whatever may be the types of vehicles considered. It is almost the same up to spans of 16 1/2 feet (5 metres), in a certain sense, i. e. for a given system, so that these short-span bridges can be calculated without taking into account the type of vehicle. To explain this, we may remark that between the load and the minimum distance between the axles, there exists a certain practical relation. Thus, we have found that for axe-loads of 14, 15 and 20 tons, the minimum distance between axles is

[1] The case in which the Hungarian regulations allow axle-loads of 16 tons to a 4 feet (1m20) wheel-base, is not practically illustrated by any engine constructed.

about 4 feet, 4 feet 3 inches and 6 1/2 feet (1m20, 1m30 and 2 metres) [1]. We can thus establish approximately the following practical relation :

(19)	Axle-loads	12 t.	13 t.	14 t.	15 t.	16 t.	17 t.	18 t.	19 t.	20 t.
	Minimum distance .	3'3" (1m00)	3'7" (1m10)	3'11" (1m20)	4'3" (1m30)	4'7" (1m40)	5'1" (1m55)	5'7" (1m70)	6'1" (1m85)	6'7" (2m00)

For each of our spans : 3 feet 3 inches, 4 feet 11 inches, 6 feet 7 inches, 8 feet 2 inches and 16 1/2 feet (1m00, 1m50, 2m00, 2m50 and 5m00) we have calculated the effects of each of these systems of axles with their corresponding spacing; we then recorded on a similar table, for each system the greatest equivalent loads **a** and **b**, chosen from among those that we have found for this system and all the preceding ones. For axle-loads above 14 tons, we have, moreover, taken into consideration the combination of a driving axle and an axle bearing 8 tons placed 4 feet 3 inches (1m30) from the former; we have thus again increased our values, where necessary. Lastly, we found it convenient to graduate to a certain extent all the loads obtained into a single continuous table, the values being expressed roughly as tons and half-tons. The result of all these researches is that, up to 8 feet 2 inches (2m50), there is no occasion to establish any vehicle as a type, whereas towards 16 1/2 feet (5 metres) about the same values are found for all the systems (19) so that for such a span, it matters very little whether we are considering *heavy trains* or *extra heavy trains* as far as the loads to be allowed are concerned. We have both for the values **a** and the values **b** expressed the difference roughly by adding a ton more for the *extra heavy trains*. We therefore get :

(20) Table of loads uniformly distributed per metre of track equivalent to the loads of the typical vehicles, according to the maximum axle-load allowed.

Span or length loaded.	TRAINS.	14 tons.		15 tons.		16 tons.		17 tons.		18 tons.		19 tons.		20 tons.	
		a	**b**	**a**	**b**	**a**	**b**	**a**	**b**	**a**	**b**	**a**	**b**	**a**	**b**
3' 3 3/8" (1m0)	Extra heavy, heavy or various.	28	28	30	30	32	32	34	34	36	36	38	38	40	40
4' 11" (1m5)	Extra heavy, heavy or various.	19	24	20	25	21	25	22·5	26	24	26	25·5	27	27	28
6' 7" (2m0)	Extra heavy, heavy or various.	14	19·5	15	20	16	20·5	17	21	18	21·5	19	22	20	23
8' 2" (2m5)	Extra heavy, heavy or various.	13 5	18	13·5	18	14	18·5	14·5	18·5	15	19	15·5	19·5	16	19·5
16' 5" (5m0)	Extra-heavy,	...	...	...	...	12·5	15	12·5	15	12·5	15	12·5	15	12·5	15
	heavy.	11·5	14	11·5	14	11·5	14	11·5	14	11 5	14	...	...	...	...

N. B. For intermediate spans or lengths loaded we must proceed by rectilinear interpolation making a distinction between 8 feet 2 inches and 16 1/2 feet (2·5 and 5 metres) as to which of the two groups is being considered.

[1] 1 ton English equals 2,240 lbs, and 1 ton kilometric equals 2,207 lbs. Therefore for the purposes of this report it has not seemed necessary to differentiate between English and metric tons.

This single table for short span bridges is connected directly with our tables (18) drawn up from the two groups of typical trains; the relations between them are shown graphically by means of straight lines as far as the spans comprised between 8 feet 2 inches and 16 1/2 feet (2^m50 and 5 metres) are concerned; these lines for the span of 16 1/2 feet (5 metres) converge towards the points representing the four values indicated in our tables (18). Our graphic table (plate I) shows the *ensemble* of all these loads that we propose, for spans comprised between 6 1/2 and 33 feet (2 and 10 metres). In our graphic table (plate III) will be found also, for spans of from 16 1/2 to 525 feet (5 to 160 metres), the diagrams representing our scales of loads. We have now to explain a special point in our propositions concerning large spans.

It will be observed that the extremities of the two curves **a** and **b** representing the *extra heavy trains* are separated by half a ton, whilst the two similar lower curves **a'** and **b'** representing the *heavy trains* seem to tend to converge, to within about one tenth of a ton (1).

The reason is that for the *extra heavy trains* we have thought it best to keep strictly to the typical trains defined (16) allowing trucks behind only, whereas for the *heavy trains* which comprise the great majority of trains adopted in both hemispheres, we felt compelled to take into account the practice now followed by many bridge engineers consisting in also taking into account goods trains with trucks in front and behind, or trains composed of more than two locomotives, somewhat less heavy than those represented by our types, etc (2).

These variations in the hypotheses of loads do not to any extent affect scale **b'**, relating to the shearing strain for which the original hypotheses are the most unfavourable. But for scale **a'**, which concerns the bending strains they lead us to increase the loads somewhat, for large spans. It seemed impossible not to take

(1) The same convergence is observable in the Russian scales of 1884, which we quote.

(2) We may quote in reference to regulations allowing trucks both in the front and rear of the train, those of Russia in 1884, of Austria in 1887, of Hungary in 1893 and in Germany, for instance, those of the Breslau, Bromberg and Hanover Directorates, all belonging to the Prussian State Railways, in 1894. In the same way for the load trains prescribed with more than two locomotives we shall quote those of Russia in 1884, of Austria in 1887; then in Germany, for instance, those of the Bromberg Administration in 1891 and of the Hanoverian Administration in 1894, lastly in Roumania those of the General Railway Administration concerning the work for the large bridge over the Danube, near Cernawoda.

into account these hypotheses of load which are recognised by numbers of distinguished European engineers (1).

We have therefore left the extremities of the curves **a** and **b** where they were fixed in Austria after a very profound study of more than 40 different trains. Moreover the mere comparison with our table (15) shows that the extremity of the scale **a** of the *heavy trains* cannot be lowered more than a few tenths of a ton at the most, in order to keep above the loads representing the French regulations of 1891, which, as we know, only take into account tenders with two axles weighing 24 tons (2).

8. — *Application of our scales of load.*

For longitudinal runners and transverse girders without exception, as well as for the main girders of all ordinary bridges, we can safely use our scales **a** and **b** of load. This comprises generally all bridges with independent spans, all bridges with straight girders continued over several spans, the cantilever bridges of various systems, etc. (3).

As up to the present there are only two large countries, Russia and Austria, where the calculations of resistance are made exclusively by means of equivalent loads uniformly distributed, in accordance with several scales of load very carefully worked out and made compulsory for constructors by decrees of the Government,

(1) We have before us the *Report of the board of railroad commissioners of the State of New York*, issued June 30th, 1891. Commissioners: William E. Rogers, Isaac V. Baker, Fr. Michael Rickard. This report represents a considerable amount of work on the part of the executive committee of New York. In it the calculations of resistance for 669 bridges out of a total of 2,500 have been re-made The reporter relates that many railway directors were very much astonished to learn that in many cases the loads imposed upon the bridges almost attained to the breaking strain. Unfortunately, it does not seem that up to the present uniform and carefully studied regulations as to load have been established in the United States of America.

(2) According to a communication that His Excellency M. Thielen, Minister of Public Works at Berlin, was kind enough to send us in February 1895, the regulations of load are now in course of being made uniform for the whole system of Prussian railways.

(3) As regards rather important exception, it is only for *arched bridges*, that we should have to go back to the typical load trains. Again, it seems, from some comparisons made, that the scales **a** and **b** are also very well suited to these bridges, if we assume everywhere that the loaded serves as the key-note to these scales.

we think it will be useful here to recapitulate the manner in which our scales should be used : —

The loads that are to enter into the calculations of resistance consist of the weight of the structure itself (dead load) and the loads imposed upon it by the rolling stock (moving load). We must also take into account wind pressure, and charges of temperature in so far as the system of construction renders it necessary. In chapter IV of our report will be found sufficient data to enable us to estimate in advance the proper weight of any bridge to be constructed. As to wind pressure, it has been agreed almost everywhere to keep (within certain modifications) to the coefficients admitted in England; for this purpose we must refer to the stipulations of § 3, lit. *f*, of the Austrian regulations for 1887 which we reproduce in the appendix; we have therefore only to occupy ourselves with the moving load, i. e. with the application of our scales of load.

(*a*) For the calculation of the chords in the maingirders of bridges with independent spans, the moving load to be allowed per running metre of track as being uniformly distributed over the whole span, reckoned between the centres of the supports, will be that of scale **a**.

When dealing with the chords of arched main girders with or without rigid spandrels, we can again with perfect safety, in order not to go back to the typical trains, use the same scale **a**; only we must consider as the basis the length loaded (1) and not the span.

(*b*) For the calculation of the web-plate or the web-bracing in these same main girders as to the shearing strains we must use the scale **b**, taking as the basis, not the span of the bridge, but the length of bridge loaded (1). For the usual independent spans this length will be different for each section, and will extend from this to one or other of the supports to be considered according to the direction of the shearing strain sought (2).

(*c*) For bridges with continuous girders resting on more than two supports, the

(1) In arched bridges, the length or the two lengths of the bridge to be subjected to the load, in order to obtain the maximum effect in a portion considered, are the object of a special research.

(2) For a given bridge, we must take a charge per metre different for each panel, and this seems to involve fresh complications. This, however, is only apparent and as the load for the same length remains the same in all bridges of all spans, it can be established once for all in the form of numerical tables always applicable. This calculation is then simpler than the calcul ation according to the old system.

chords should be calculated by allowing to the bays loaded, such live loads, as according to scale **a**, correspond to their spans, and at the same time taking into account the combinations of load that produce the greatest bending strains.

In calculating, the web-bracing of the same bridges, we must allow to the span in question the loads in scale **b**, and to the combinations of other spans simultaneously loaded, we must allow the loads in scale **a**.

(*d*) For cantilever bridges (Firth of Forth system), we can also use our scales. We shall of course treat the central structure resting on the cantilevers, as a bridge of independent span, the loads on the supports calculated by the help of scale **b** being the strains supposed to be applied at the end of the cantilevers. We shall moreover take into account the moving loads that these have directly to support by using our two scales as follows : —

For the calculation of the chords the cantilevers will be loaded according to scale **a** along their whole length using twice this as the basis in our table (1).

For the calculation of the diagonals, the cantilevers will be loaded according to scale **b** from their extremity as far as the section in question, taking this loaded length increased by half, as the basis in our table (2).

> *Remark.* — To the rules that we quote for bridges with straight girders continued over several spans and for cantilever bridges, the objection might be raised that they involve in a sense an excess of security since they take for granted the simultaneous presence of several trains on the same road of the bridges in order to produce the loads introduced into the calculations of resistance. But the constructors of iron bridges have always up to the present been of opinion that most unfavorable combinations should be taken into account, and this idea is therefore, so to speak, bound up with these systems of construction.

(*e*) The longitudinal runners will be treated as the main girders of small bridges, resting on transverse girders, considered as piers or abutments.

(*f*) The transverse girders will be considered as piers or abutments supporting the longitudinal runners considered as main girders.

(1) It is easy to show theoretically that this mode of procedure is strictly correct. It rests on the principle of the equivalent uniform load as regards the bending strain above the pier where the bending strain is at the maximum.

(2) The rule that we give here has been established by researches that cannot be considered of a theoretical nature. The shearing strain to be considered is always equal to the sum of the loads resting on the length indicated, which gives a simple calculation in all cases. Our rule for using scale **b** is practically correct; and will do away with the necessity of having recourse to typical trains for subsequent researches.

For the calculation of intermediate transverse girders, we shall allow as the moving load half of the total load which, according to scale **a**, would be applicable to a bridge having for its span the distance between the two transverse girders on the immediate right and left of the one considered (1).

The calculation of the end transverse girders will be made in each special case according to their position in the structure, replacing that one of the neighbouring girders which is wanting, by a theoretical support of the road taken at a convenient distance in order to apply the above rule. This distance must be at least 3'3" (one metre) in order to allow for the usual distance between the sleepers; in the case of cantilever longitudinals, it must be increased by the double span of these cantilevers (theoretical span). In the case of abutment longitudinals, it will be equal to their span (skew bridge) (2). We need not say that the load imposed on each transverse girder must be supposed to be transmitted to the point where it is really applied (the connection with the longitudinal runners). In general, we cannot too strongly recommend that the end transverse girders should be made as strong as the similar intermediate neighbouring transverse girders.

9. — *Conclusions.*

To sum up, all these propositions that we are about to submit to the Congress are intended to prove to all our colleagues that the regulation of loads by typical trains is merely an expedient to get over the difficulty rather than a serious investigation as to the effects of all the trains in use and a deduction once for all of a general solution of the problem, enabling constructors to dispense with subsequent researches.

We have proved that with two scales of uniformly distributed loads, we can, in all practical cases, make the calculations in the simplest manner. The bridges thus calculated will be very safe, as in their construction all the rolling stock in use will have been taken into account. In the employment of our scales **a** and **b** of loads, it must be remembered that we always reckon from the *lengths of the bridge that are loaded.*

(1) This proposition may be shown theoretically to be strictly accurate, even if the intervals between the transverse girders are unequal. See p. 77 of the work already quoted : *Calculs des ponts métalliques à une ou plusieurs travées*. Paris, Baudry, 1889. It is based on the universally established custom of calculating the transverse girders as resting freely on the main girders and the longitudinal runners as resting freely on the transverse girders.

(2) In the arrangement of iron work thus necessitated which is often very complicated, we can deal separately, according to our rule, with each kind of longitudinal runner.

APPENDIX TO CHAPTER III.

EXAMPLE OF CALCULATION.

Extra-heavy express train.

As the methods of calculation used in the foregoing and which we recommend for estimating loads uniformly distributed per metre of track, equivalent to the effects of a given train (either for bending strains or shearing strains) are certainly not known to all the members of the Congress, we thought that it would be desirable to give here at least one instance of these calculations; this one relates to our *extra-heavy express train*, the heaviest in the world. The reader will thus see what it is to have regulations of load given by means of a typical train or given by means of scales of uniform equivalent loads that can be applied immediately without further researches.

1. — *Bending strains.*

For each span we must place on the middle of this span the axle which gives a maximum bending strain. We then take the greatest of the values found. We will call :

(21) . . . . . $l = 2a$ . . . . the span of the bridge;
$P_1\ P_2\ P_3 \dots P_n$ . . . . . the axle-loads;
$a_1\ a_2\ a_3 \dots a_n$ . . . . their distance from the middle of the span (1).

We then find easily that the equivalent load uniformly distributed over the whole span, per metre of track, is :

$$(22) \quad p = \frac{P_1 + P_2 + \dots P_n}{a} - \frac{a_1\ P_1 + a_2\ P_2 \dots a_n\ P_n}{a^2} = \frac{1}{a}\left[\Sigma P_n - \frac{\Sigma a_n P_n}{a}\right]$$

This mode of calculation introduced by the writer already in 1873 offers the great advantage that for increasing spans $1 = 2a$, the values of both Σ remain constant as long as no fresh axles come upon the bridge; when more axles come upon the bridge the new values of Σ are obtained by calculating the values of Σ for the new axles and adding these values to the old ones already known. If then the same axle remains on the middle of the bridge whilst the span increases indefinitely, it will be sufficient to draw up a table of the values of the Σ for those spans that involve fresh

(1) The success of this method is attributable to this circumstance that all the lengths are brought into relation with the middle of the span.

axles being brought upon the bridge. By means of this table which is easely obtained by addition means of simple we can afterwards, for any intermediate span whatever, at once calculate p by means of formula (22) by putting in the Σ of the table corresponding to the span $1_n = 2a_n$ immediately lower. This calculation only requires two divisions. The curve of the values of p shows a set of singular points corresponding to the spans in the table of the Σ.

The condition on which an axle placed in the middle of the span gives a maximum there is that this axle should constitute a *medial force* of that part of the train placed on the bridge. This means that the sums of the loads applied on each side of the centre of the span be so nearly equal that if the axle in question is added to one of them, that sum should always represent the majority of the loads imposed upon the bridge (1).

(1) If instead of trying to find the maximum at the middle of the bridge we wished to find it for any section whatever dividing the length l of the span into two unequal detached parts a' and a'' to the right and left of this section we should have to place upon it the *proportional medial force*. We thus designate as P_m a force which is such that the slight displacement considered above would always leave on the side of P_m that part of the combined forces that is *proportionately the greater*. This new conception and the rule relating to it are derived from the following calculation. We find :

$$(23) \ldots\ldots \quad \text{Bending moment} = \frac{a'a''}{2a}\,\Sigma P_n - \frac{1}{2a}\left[a''\Sigma a'_n P'_n + a'\Sigma a''_n P''_n\right] = M$$

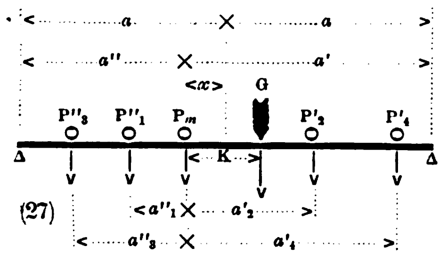
$$(24) \ldots\ldots\ldots\ldots \quad p = \frac{\Sigma P_n}{a} - \frac{1}{a}\left[\frac{\Sigma a'_n P'_n}{a'} + \frac{\Sigma a''_n P''_n}{a''}\right]$$

p is a maximum when the factor within brackets is a minimum. A very slight displacement x of the point X about which moments are taken towards the point X, situated to the right gives for this new origin of moments :

$$(25) \ldots\ldots \left(\frac{\Sigma a'_n P'_n}{a'} + \frac{\Sigma a''_n P''_n}{a''}\right)_1 = \left(\frac{\Sigma a'_n P'_n}{a'} + \frac{\Sigma a''_n P''_n}{a''}\right) - x\left(\frac{\Sigma P'_n}{a'} - \frac{\Sigma P''_n}{a''}\right)$$

and this produces a diminution or augmentation of the factor in question according as :

$$(26) \ldots\ldots\ldots\ldots\ldots\ldots \quad \frac{\Sigma P'_n}{a'} \gtrless \frac{\Sigma P''_n}{a''}$$



(27)

We deduce from this the idea of the *proportional medial force* that must be placed on the section in in order to obtain the maximum.

These considerations also lead us directly to the theoretical maximum maximorum in the most general case.

Let G be the centre of gravity (27) of all the forces of ΣP_n and K its distance from the force P_m, When we have a typical train to consider, comprising trucks in front and rear there are only for each span three or four axles from among which to choose the axle forming the medial force. But for a typical train having only trucks behind, like those prescribed in France and Switzerland, the problem is much more complicated, and for increasing spans we have to try at least a dozen axles to get the medial force. We find several medial forces for almost every span, and out of all

and lasty let x be the distance of the latter from the centre of the span; we get:

$$a' = a + x \qquad a'' = a - x \qquad \Sigma a'_n P'_n - \Sigma a''_n P''_n = K \Sigma P_n$$

The substitution in the equation (23) after reduction gives:

$$(28)\ldots \quad M = \frac{a^2 + Kx - x^2}{2a} \Sigma P_n - \frac{1}{2}\left[\Sigma a'_n P'_n + \Sigma a''_n P''_n\right] \qquad \text{and } \frac{dM}{dx} = \frac{1}{a}\left(\frac{K}{2} - x\right) \Sigma P_n$$

The maximum obtained over a given section, by placing upon it the proportional medial force consequently becomes a maximum maximorum with regard to all the sections, when we get at the same time $x = K : 2$ or, in other words, *when the centre of gravity* G *and the proportional medial force* P_m *of the train are on opposite sides of the middle of the span of the bridge and equally distant from it.* From this very simple rule, which has moreover long been known, we see that when we have obtained the maximum at the middle of the bridge by the help of the method indicated in the text, we shall generally want only a slight displacement to get the maximum maximorum, for according to the usual composition of trains, G and P_m are almost always two forces very close to one another and P_m when determined as the medial force or the middle of span continues to remain the proportional medial force for the neighbouring points.

For any section whatever, dividing the span l into two unequal parts a' and a'', the *proportional medial force* to be placed on the section would be obtained in a simple manner by dividing in the ratio $a' : a''$ the total length obtained by means of forces placed end to end. If, by this construction, the point of division falls exactly on a point forming the common end of two forces, it is then the space comprised between the corresponding axles of the train, and that we will call the ***proportional medial interval*** which should come placed in whatever position over the section considered of the bridge, in order that the greatest possible moment may be obtained.

If the bridge had to support not loaded axles but a continuous load (uniform or not) the ***medial force*** or ***proportional medial force*** should be replaced by a vertical line dividing the load into ***equal parts or parts proportional*** to a' and a'', etc.

By calling P_w the uniform load of the trucks per metre and l'_w l''_w the lengths loaded on each side, we get for the center of span the most general formula:

$$(29)\ldots\ldots\ldots \quad p = \frac{1}{a}\left[\Sigma P_n - \frac{1}{a} \Sigma a_n P_n + p_w \frac{l'_w + l''^2_w}{l}\right]$$

the values of p thus found we must then choose the greatest. Our solution (1) for meeting these difficulties consists in drawing up in a table the axle loads of the train and the parts of the span where each of the heavy axles constitutes a medial force. This table which we reproduce (30) can be understood by constructors.

Each of the heavy axles A, B, C, is successively supposed to be placed in the middle of the bridge for spans increasing indefinitely; which gives so many horizontal lines of the table. In each line and for both sides of the axle tried, will be found the abscissal a_n and also the corresponding sums of loads; we can then at once see whether the required condition is satisfied or not (2). We have shown by arrows the regions where each axle is the medial force; this indication is repeated on each side of the axle tried considered as the starting point.

Our table seems more complicated than it really is. The figures in each horizontal line are deduced from the line preceding, by the simple addition or subtraction of a constant number, depending on the displacement of the origin. We can then easily draw up the whole table by additions and subtractions as we proceed downwards. When the table is once made out, an experienced constructor will only have to choose in each case, between two or three medial forces. We reproduce (31), (31), the tables of the Σ that serve for the application of our formula (22) as far as they are to be considered for the maximum of the load p, We have marked by asterisks those of the values of p that belong undoubtedly to the general diagram of the maximums to be considered for the given train.

2. — *Shearing strains.*

The investigation of equivalent uniform loads as regards shearing strains offers much less difficulty than the preceding investigation; we know that in order to get the greatest shearing strain on a support, the head of the train must be brought upon it, i. e. we must concentrate upon it the heaviest axles.

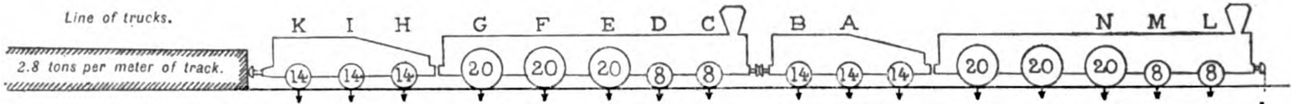
(1) We know that we can solve the problem by the graphic method. We construct a funicular polygon for the whole train, on which is to be traced chord with a horizontal projection constantly equal to the span. The position of this chord at which the distance between it and the polygon is the greatest possible, is the position sought.

This solution, which is very nice for a small number of axles, becomes inadmissible for long trains, in which case we must return to numerical calculations.

(2) We refer the reader for fuller details to the work already quoted : *Calcul des ponts métalliques à une ou plusieurs travées*, Paris, Baudry, 1889.

(30). . . . . Bending moments : Table of axle to be placed on the middle of the bridge.

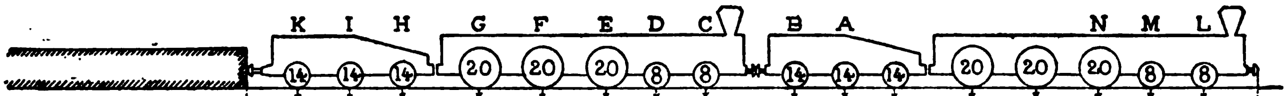
British measures.



6'2 3/4 × 5'3 × 5'10 3/4 × 10'6 × 6'6 3/4 × 6'6 3/4 × 4'3 1/8 × 5'3 × 12'9 1/2 × 5'3 × 5'10 3/4 × 10'6 × 6'6 3/4 × 6'6 3/4 × 4'3 1/8 × 5'3 × 5'6 3/4

						K	I	H	G	F	E	D	C	B	A				N	M	L		
Sum of abscissae on **A**. . . .					68'6 5/8	62'3 7/8	57'0 7/8	51'2 1/8	40'8 1/8	34'1 3/8	27'6 5/8	23'3 1/2	18'0 1/2	5'3	O	5'10 3/4	16'4 3/4	22'11 1/2	29'6 1/4	33'9 3/8	39'(?) 3/8	45'7 1/8	**A**
Sum of loads without A. . .							118	104	90	70	50	30	22	14		14	34	54	74	82	90		
Sum of abscissae on **B**. . . .					63'3 5/8	57'0 7/8	51'9 7/8	45'11 1/8	35'5 1/8	28'10 3/8	22'3 5/8	18'0 1/2	12'9 1/2	O	5'3	11'1 3/4	21'7 3/4	28'2 1/2	34'9 1/4	39'0 3/8	44'3 3/8	50'10 1/8	**B**
Sum of loads without B. . .						118	104	90	76	56	36	16	8		14	28	48	68	88	96	104		
Abscissae. . . .			69'3 1/4		50'6 1/8	44'3 3/8	39'0 3/8	33'1 5/8	22'7 5/8	16'0 7/8	9'6 1/8	5'3	O	12'9 1/2	18'0 1/2	23'11 1/4	34'5 1/4	41'0	47'6 3/4	51'9 7/8	57'0 7/8	63'7 5/8	**C**
Loads.			128			110	96	82	68	48	28	8		14	28	42	62	82	102	110	118		
	82'9 1/4	64'0 1/4	62'4	52'10	45'3 1/8	39'0 3/8	33'9 3/8	27'10 5/8	17'4 5/8	10'9 7/8	4'3 1/8	O	5'3	18'0 1/2	23'3 1/2	29'2 1/4	39'8 1/4	46'3	52'9 3/4	57'0 7/8	62'3 7/8	68'10 5/8	**D**
	134	118	116 56	108·44		102	88	74	60	40	20		8	22	36	50	70	90	110	118	126		
	125'4 1/2	78'6	57'1	43'11 1/2	41'0	34'9 1/4	29'6 1/4	23'7 1/2	13'1 1/2	6'6 3/4	O	4'3 1/8	9'6 1/8	22'3 5/8	27'6 5/8	33'5 3/8	43'11 3/8	50'6 1/8	57'0 7/8	61'4	66'7	73'1 3/4	**E**
	154	114	95·72	84·52		82	68	54	40	20		8	16	30	44	58	78	98	118	126	134		
	165'8 1/8	118'9 3/4		50'6 1/8	34'5 1/4	28'2 1/2	22'11 1/2	17'0 3/4	6'6 3/4	O	6'6 3/4	10'9 7/8	16'0 7/8	28'10 3/8	34'1 3/8	40'0 1/8	50'6 1/8	57'0 7/8	63'7 5/8	67'10 3/4	73'1 3/4	79'8 1/2	**F**
	174	134		75·72		62	48	34	20		20	28	36	50	64	78	98	118	138	146	154		
	178'1 1/4	131'2 3/4		35'5 1/8	27'10 1/2	21'7 3/4	16'4 3/4	10'6	O	6'6 3/4	13'1 1/2	17'4 5/8	22'7 5/8	35'5 1/8	40'8 1/8	46'6 7/8	57'0 7/8	63'7 5/8	70'2 3/8	74'5 1/2	79'8 1/2	86'3 1/4	**G**
	194	154		48·44		42	28	14		20	40	48	56	70	84	98	118	138	158	166	174		
	210'11	178'1 1/4		23'7 1/2	17'4 1/2	11'1 3/4	5'10 3/4	O	10'6	17'0 3/4	23'7 1/2	27'10 5/8	33'1 5/8	45'11 1/8	51'2 1/8	47'0 7/8	67'6 7/8	74'1 5/8	80'8 3/8	84'11 1/2	90'2 1/2	96'9 1/4	**H**
	208	180		33.32		28	14		20	40	60										194		
	243'8 5/8	210'11		16'4 3/4	11'5 3/4	5'3	O	5'10 3/4	16'4 3/4	22'11 1/2	29'6 1/4	33'9 3/8	39'0 3/8	51'9 7/8	57'0 7/8	52'11 5/8	73'5 5/8	80'0 3/8	86'7 1/8	90'10 1/4	96'1 1/4	102'8	**I**
	222	194		18·2		14		14	34	54											208		
	270'6 3/8	243'8 5/8		11'1 7/8	6'2 3/4	O	5'3	11'1 3/4	21'7 3/4	28'2 1/2	34'0 1/4	39'0 3/8	44'3 3/8	57'0 7/8	62'3 7/8	58'2 5/8	80'8 5/8	85'3 3/8	91'10 1/8	96'11 1/4	101'4 1/4	107'11	**K**
	236	208		4.2			14	28	48												222		

Metric measures.



1·9 × 1·6 × 1·8 × 3·2 × 2·0 × 2·0 × 1·3 × 1·6 × 3·9 × 1·6 × 1·8 × 3·2 × 2·0 × 2·0 × 1·3 × 1·6 × 2·0

						K	I	H	G	F	E	D	C	B	A		N			M	L		
Sum of abscissae on **A**					20·9	19·0	17·4	15·6	12·4	10·4	8·4	7·1	5·5	1·6	O	1·8	5·0	7·0	9·0	10·3	11·9	13·9	**A**
Sum of loads without A							118	104	90	70	50	30	22	14		14	34	54	74	82	90		
Sum of abscissae on **B**					19·3	17·4	15·8	14·0	10·8	8·8	6·8	5·5	3·9	O	1·6	3·4	6·6	8·6	10·6	11·9	13·5	15·5	**B**
Sum of loads without B						118	104	90	76	56	36	16	8		14	28	48	68	88	96	104		
Abscissae	21.114				15·4	13·5	11·9	10·1	6·9	4·9	2·9	1·6	O	3·9	5·5	7·3	10·5	12·5	14·5	15·8	17·4	19·4	**C**
Loads	128					110	96	82	68	48	28	8		14	28	42	62	82	102	110	118		
	25·228	19·514	19·0	16·1	13·8	11·9	10·3	8·5	5·3	3·3	1·3	O	1·6	5·5	7·1	8·9	12·1	14·1	16·1	17·4	19·0	21·0	**D**
	134	118	116·56	108·44		102	88	74	60	40	20		8	22	36	50	70	90	110	118	126		
	38·214	23·928	17·4	13·4	12·5	10·6	9·0	7·2	4·0	2·0	O	1·3	2·9	6·8	8·4	10·2	13·4	15·4	17·4	18·7	20·3	22·3	**E**
	154	114	95·72	84·52		82	68	54	40	20		8	16	30	44	58	78	98	118	126	134		
	50·500	36·214		15·4	10·5	8·6	7·0	5·2	2·0	O	2·0	3·3	4·9	8·8	10·4	12·2	15·4	17·4	19·4	20·7	22·3	24·3	**F**
	174	134		75·72		62	48	34	20		20	28	36	50	64	78	98	118	138	146	154		
	54·286	40·000		10·8	8·5	6·6	5·0	3·2	O	2·0	4·0	5·3	6·9	10·8	12·4	14·2	17·4	19·4	21·4	22·7	24·3	26·3	**G**
	194	154		48·44		42	28	14		20	40	48	56	70	84	98	118	138	158	166	174		
	64·286	54.286		7·2	5·3	3·4	1·8	O	3·2	5·2	7·2	8·5	10·1	14·0	15·6	17·4	20·6	22·6	24·6	25·9	27·5	29·5	**H**
	208	180		33.32		28	14		20	40	60										194		
	74·286	64·286		5·0	3·5	1.6	O	1·8	5·0	7·0	9·0	10·3	11·9	15·8	17·4	19·2	22·4	24·4	26·4	27·7	29·3	31·3	**I**
	222	194		18·2		14		14	34	54											208		
	84·286	74·286		3·4	1·9	O	1·6	3·4	6·6	8·6	10·6	11·9	13·5	17·4	19·0	20·8	24·0	26·0	28·0	29·3	30·9	32·9	**K**
	236	208		4.2			14	28	48												222		

(31) . . . . . Extra-heavy train. Equivalent loads for bendings strains.

British measures.

$l_n=2a_n$	Abscissae a_n to the left.	Abscissae a_n to the right.	P_n	ΣP_n	a_nP_n	Σa_nP_n	l_w	$\frac{l_w^2}{l}$	Maximum.	Singular points p	*Examples.*	
Axle A on the middle.												
0'0"	0'0"	0'0"	14	14	0 0	0·0						
10'6"	...	5'3"	14	28	73·50	22·4	...	...		8·750		
											13'1 1/2" .	9·100
11'10"	5'11"	...	14	42	82·9	47 6	...	...		8·642	16'5" . . .	9·184
											19'8" . . .	8·711
32'10"	16'5"	...	20	62	328·0	147·6	...	...		6·496	26'3" . . .	7·525
Axle B on the middle.												
44'7 1/2"	...	22'4"	20	98	446·2	413·2	...	...		5·476		
											49'3" . . .	5·721
56'5"	28'3"	...	20	118	564·2	585·2	...	...		5·809		
57'9"	...	28'10"	20	138	577·5	761·2	...	...		5·852		
											65'7" . . .	6·188
69'7"	34'9"	...	20	158	695·8	973·2	...	...		6·244		
70'11"	...	35'5"	20	178	709·2	1189·2	...	...		6·286		
78'1"	39'0"	...	8	186	312·3	1284·4	...	...		6·500		
Axle C on the middle.												
95'2"	45'11"	...	20	220	951·7	1787·6	...	...		6 670		
											98'5" . . .	6·722
101'0"	...	50'6"	Starting point of the train of trucks.				...	...		6·748		
103'8"	51'10"	...	8	228	414·7	1914·0	1'3 3/4"	0·016		* 6 764		
											114'10" . .	* 6·802
114'2"	57'1"	...	8	236	456·7	2053·2	6'6 3/4"	0·377		* 6·800		
											131'3" . . .	* 6·741
138'6"	...	69'3"	...	236	...	2053·2	18'9"	...				
Axle D on the middle.												
		45'3"	Starting point of the train of trucks.									
124'8"	62'4"	...	8	236	...	2078·8	17'0 3/4"	2·336		6·767		
											131'3" . . .	6·738
128'0"	...	64'0"	...	236	...	2078·8	18'9"	2·746				
											164'0" . . .	6·395
165'6"	...	82'9"	...	236	...	2078·8	37'6"	8·491				
Axle E on the middle.												
0'0"	0'0"	0'0"	20	20	0.0	0·0	...	...		...	3'3 3/8" .	*40·000
											4'11" . .	*26·667
8'6"	4'3"	...	8	28	34·0	10·4	...	...		* 15·384	6'6 3/4 . .	*20·000
											7'3" . . .	*18·182
13'1 1/2	...	6'7"	20	48	131·2	50·4	...	...		* 11·400	7'10" . .	*16·667
											8'2" . . .	*16·000
19'0"	9'6"	...	8	56	76 0	73·6	...	...		10·559	8'6" . . .	*15·384
											9'2" . . .	*14·694
26'3"	...	13'1 1/2"	20	76	262·5	153 6	...	...		9·400	9'10" . . .	*14·046
											11'10" . . .	*12 346
44'7 1/2"	22'4"	...	14	90	312·4	248·8	...	...		7·855	13'9" . . .	*11·429
											15'9" . . .	*11.250
47'3"	...	23'7"	14	104	330 7	349·6	...	...		7·701	17'9" . . .	*10·864
55'1"	27'7"	...	14	118	385 6	467 2	...	...		7·426	32'10" . .	9·056
59'1"	...	29'6"	14	132	413 6	593 2	...	...		7·343	49'3" . . .	7·652
											65'7" . . .	7 268
66'11"	33'6"	...	14	146	468·4	736·0	...	...		7·240		
69'6"	...	34'9"	14	160	486·5	884·4	...	...		7·223		
82'0"	...	41'0"	Starting point of the train of trucks.				...	...		7·140		
87'11"	43'9"	...	20	180	879·2	1152·4	2'11 3/8"	0 038		7·021		
											98'5" . . .	* 6·917
101'0"	50'6"	...	20	200	1010·0	1460·4	9'6"	0·896		* 6·879		
114'2"	57'1"	...	20	220	1141·7	1808·4	16'1"	2 264		6·782		
											114'10" . .	6·781
122'8"	61'4"	...	8	228	490·7	1958·0	20'4"	3·373		6·747		
											131'3" . . .	6·702
133'2"	66'7"	...	8	236	532·7	2120 4	25'7"	4·918		6 687		
157'0"	...	78'6"	...	236	...	2120·4	37'6"	8·953				
164'0"	...	82'0"	...	236	. .	2120·4	41'0"	10·253		...	164'0" . . .	* 6·397
196'10"	...	98'5"	...	236	...	2120·4	57'5"	16·745		...	196'10" . .	* 5·987
229'8"	...	114'10"	...	236	...	2120·4	73'10"	23·727		...	229'8" . . .	* 5·590
250'9"	...	125'4 1/2"	...	236	...	2120·4	84'4 1/2"	28 386				

Metric measures.

$l_n = 2a_n$	Abscissae a_n to the left.	Abscissae a_n to the right.	P_n	ΣP_n	$a_n P_n$	$\Sigma a_n P_n$	l_w	$\frac{l_w^2}{l}$	Maximum.	Singular points p	*Examples.*
Axle A on the middle.											
0·0	0·0	0·0	14	14	0·0	0·0					
3·2	...	1·6	14	28	22·4	22·4	...	...		8·750	4 .... 9·100
3·6	1·8	...	14	42	25·2	47 6	...	...		8·642	5 .... 9·184
											6 .... 8·711
10·0	5·0	...	20	62	100·0	147·6	...	...		6·496	8 .... 7·525
Axle B on the middle.											
13·6	...	6·8	20	98	136·0	413·2	...	...		5·476	15 .... 5·721
17·2	8·6	...	20	118	172 0	585·2	...	...		5·809	
17·6	...	8 8	20	138	176·0	761·2	...	...		5·852	
21·2	10·6	...	20	158	212 0	973·2	...	...		6·244	20 .... 6·188
21·6	...	10 8	20	178	216·0	1189·2	...	...		6·286	
23·8	11·9	...	8	186	95·2	1284·4	...	...		6·560	
Axle C on the middle.											
29·0	14·5	...	20	220	290·0	1787·6	...	...		6 670	30 .... 6·722
30·8	...	15·4	Starting point of the train of trucks.				...	...		6·748	
31·6	15·8	...	8	228	126·4	1914·0	0·4	0·005		* 6 764	35 .... * 6·802
34·8	17·4	...	8	236	139·2	2053·2	2·0	0·115		* 6·800	40 .... * 6·741
42·228	...	21·114	...	236	...	2053·2	5·714	..			
Axle D on the middle.											
		13·8	Starting point of the train of trucks.								
38·0	19·0	...	8	236	...	2078·8	5·2	0 712		6·767	
39·028	...	19·514	...	236	...	2078·8	5·714	0·837			40 .... 6·738
50·456	...	25·228	...	236	...	2078·8	11·428	2·588			50 .... 6 395
Axle E on the middle.											
0·0	0·0	0·0	20	20	0·0	0·0	...	...		...	1·0 ... * 40·000
											1·5 ... * 26·667
2·6	1·3	...	8	28	10·4	10·4	...	...		* 15 384	2·0 ... * 20·000
											2·2 ... * 18·182
4·0	...	2·0	20	48	40·0	50·4	...	...		* 11·400	2·4 ... * 16·667
											2·5 ... * 16·000
5·8	2·9	...	8	56	23 2	73·6	...	...		10 559	2·6 ... * 15·384
											2·8 ... * 14·694
8·0	...	4·0	20	76	80·0	153 6	...	...		9·400	3·0 ... * 14·045
											3 6 ... * 12 346
13·6	6·8	...	14	90	95·2	248·8	...	...		7·855	4·2 ... * 11·429
											4·8 ... * 11.250
14·4	...	7·2	14	104	100 8	349·6	...	...		7·701	5·4 ... * 10·864
16·8	8 4	...	14	118	117 6	467 2	...	..		7·426	10. ... 9·056
18·0	...	9·0	14	132	126 0	593 2	..	...		7·343	15. ... 7·652
											20. ... 7·268
20·4	10·2	...	14	146	142·8	736·0	...	...		7·240	
21·2	...	10·6	14	160	148·4	884·4	...	...		7·223	
25·0	...	12·5	Starting point of the train of trucks.				...	...		7·140	
26·8	13.4	...	20	180	268·0	1152·4	0·9	0·030		7·021	
30 8	15·4	...	20	200	308·0	1460·4	2·9	0·273		* 6·879	30. ... * 6 917
34·8	17 4	...	20	220	348·0	1808·4	4·9	0 690		6·782	
37·4	18·7	...	8	228	149·6	1958·0	6·2	1 028		6·747	35. ... 6·781
40·6	20·3	...	8	236	162·4	2120·4	7·8	1·499		6 687	40. ... 6·702
47·856	...	23 928	...	236	...	2120·4	11·428	2·729			
50·0	...	25·0	...	236	..	2120·4	12·5	3·125		...	50. ... * 6·397
60·0	...	30·0	...	236	...	2120·4	17·5	5 104		...	60. ... * 5·987
70·0	...	35·0	...	236	...	2120·4	22·5	7·232		...	70. ... * 5·590
76 428	...	38·214	...	236	...	2120·4	25·714	8 652			

(32) . . . . . Extra-heavy train. Equivalent loads for bending strains.

British measures.

$l_n = 2a_n$	Abscissae a_n to the left.	Abscissae a_n to the right.	P_n	ΣP_n	$a_n P_n$	$\Sigma a_n P_n$	l_w	$\frac{l_w^2}{l}$	Maximum.	Singular points p	Examples.
Axle F on the middle.											
0'0"	0'0"	0'0"	20	20	0·0	0·0					
13'1½"	6'7"	6'7"	40	60	262·5	80·0	...	...		10·000	13'9" . . . 10·430
21'8"	10'10"	...	8	68	86·7	106 4	...	...		*10·836	15'1" . . . 10·964 15'9" . . . 11·111
32'2"	16'1"	...	8	76	128·7	145·6	...	...		* 9·446	16'5" . . . *11·200 17'1" . . . *11·243
34'0"	...	17'0"	14	90	238 0	218·4	...	...		* 9·231	17'9" . . . *11 248 18'5" . . . *11·225
45'11"	...	23'0"	14	104	321·5	316 4	...	...		* 8 400	19'8" . . . *11·111 21'8" . . . *10 836
56'5"	...	28'3"	14	118	394·4	436·8	...	...		7·815	23'0" . . . *10·743 24'7" . . . *10·567
57'9"	28'10"	...	14	132	404 2	560·0	...	...		7 769	26'3" . . . *10 350 27'11" . . *10 109
68'3"	34'1"	...	14	146	477·7	705·6	...	...		* 7·515	29'6" . . . * 9·857 31'2" . . . * 9·600
68'11"	...	43'5"	Starting point of the train of trucks.				...	...		* 7 505	32'10" . . * 9·376 49'3" . . . * 8 242
80'0"	40'0"	...	14	160	560·0	876·4	5'7"	0·387		* 7·254	65'7" . . . * 7·600 98'5" . . . * 6·898
101'0"	50'6"	...	20	180	1010 0	1184·4	16'1"	2·559		6 836	
114'2"	57'1"	...	20	200	1141·7	1532·4	22'8"	4·488		6 653	114'10" . . 6 619
127'4"	63'8"	...	20	220	1273·3	1920·4	29'2"	6·696		6·532	131'3" . . . 6·515
135'10"	67'11"	...	8	228	543·3	2086·0	33'6"	8·245		6 486	
146'4"	73'2"	...	8	236	585·3	2264·4	38'8"	10·243		6·422	
237'8"	...	118'10"	...	236	...	2264·4	84'4"	29 951			
262'6"	...	131'3"	...	236	...	2264·4	96'9"	35·680		•	262'6" . . . * 5·246 295'3" . . . * 4·949
328'1"	...	164'0"	...	236	...	2264·4	129'7"	51 191		•	328'1" . . . * 4·658
331'4"	...	165'8"	...	236	...	2264·4	131'3"	51·975			
Axle G on the middle.											
		27'10⅓"	Starting point of the train of trucks								
262'6"	...	131'3"	...	236	...	2488·4	103'4"	40 692		•	262'6" . . . 5·213
295'3"	...	147'8"	..	236	...	2488·4	119'9"	48·567		•	295'3" . . . 4 937
328'1"	...	161'0"	...	236	...	2488·4	136'2"	56·506		•	328'1" . . . * 4·689
356'2"	...	178'1"	...	236	..	2488·4	150'3"	...			
Axle H on the middle.											
		17'4½"	Starting point of the train of trucks.								
356'2"	...	178'1"	...	236	...	2974·8	60'9"				
360'11"	...	180'5"	...	236	...	2974·8	163'1"	73·672		•	360'11" . . * 4·451
393'8"	...	196'10"	...	236	...	2974·8	179'6"	81·805		•	393'8" . . . * 4·271
421'10"	...	210'11"	...	236	..	2974·8	193'6"	...			
Axle I on the middle.											
		11'6"	Starting point of the train of trucks.								
421'10"	...	210'11"	...	236	...	3298 8	199'5"				
426'6"	...	213'3"	...	236	...	3298·8	201'9"	95 454		•	426'6" . . . * 4·103
459'4"	...	229'8"	...	236	...	3298·8	218'2"	103 633		•	459'4" . . . * 3 9.2
487'6"	...	243'9"	...	236	...	3298 8	232'3"	...			
Axle K on the middle.											
		6'3"	Starting point of the train of trucks.								
487'6"	...	243'9"	...	236	...	3631·6	237'6"				
492'2"	...	246'1"	...	236	...	3631 6	239'10"	116 878		•	492'2" . . . * 3·831
524'11"	...	262'6"	...	236	...	3631 6	256'3"	125 077		•	524'11" . . * 3 717
553'1"	...	276'6"	...	236	...	3631·6	270'3"	...			

Metric measures.

$l_n = 2a_n$	Abscissae a_n to the left.	Abscissae a_n to the right.	P_n	ΣP_n	$a_n P_n$	$\Sigma a_n P_n$	l_w	$\frac{l_w^2}{l}$	Maximum.	Singular points p
Axle F on the middle.										
0·0	0 0	0·0	20	20	0·0	0·0				
4·0	2·0	2·0	40	60	80·0	80·0	...	...		10·000
6·6	3·3	...	8	68	26·4	106·4	...	...		*10·836
9·8	4·9	...	8	76	39·2	145·6	...	...		* 9·446
10·4	...	5·2	14	90	72 8	218·4	...	...		* 9·231
14·0	...	7·0	14	104	98·0	316·4	...	...		* 8 400
17·2	...	8·6	14	118	12)·4	436·8	...	...		7·815
17·6	8·8	...	14	132	123·2	560·0	...	...		7 769
20·8	10·4	...	14	146	145·6	705·6	...	...		* 7·515
21·0	...	10·5	Starting point of the train of trucks.				...	...		* 7·505
24·4	12·2	...	14	160	170·8	876·4	1·7	0·118		* 7·254
30·8	15·4	...	20	180	308·0	1184·4	4·9	0·780		6·836
34·8	17·4	...	20	200	348·0	1532·4	6·9	1·368		6·653
38 8	19·4	...	20	220	388·0	1920·4	8·9	2·041		6·532
41·4	20·7	...	8	228	165·6	2086·0	10·2	2·513		6·486
44·6	22·3	...	8	236	178·4	2264·4	11·8	3·122		6·422
72·628	...	36·214	...	236	...	2264·4	5·714	9·129		
80 0	...	40·0	...	236	...	2264·4	29·5	10·878		...
100·0	...	50·0	...	236	...	2264·4	39·5	15·603		...
101·0	...	50 5	...	236	...	2264·4	40·0	15·812		
Axle G on the middle.										
		8·5	Starting point of the train of trucks.							
80·0	...	40 0	...	236	...	2488·4	31·5	12·403		...
90·0	...	45·0	...	236	...	2488·4	36·5	14·803		...
100·0	...	50·0	...	236	...	2488·4	41·5	17·223		...
106·572	...	54·286	...	236	...	2488·4	45·786	...		
Axle H on the middle.										
		5·3	Starting point of the train of trucks.							
108·572	...	54·286	...	236	...	2974·8	48·986			
110·0	...	55·0	...	236	...	2974·8	49·7	22·455		...
120·0	...	60·0	...	236	...	2974·8	54·7	24·934		...
128·572	...	64·286	...	236	...	2974·8	58·986	...		
Axle I on the middle.										
		3 5	Starting point of the train of trucks.							
128·572	...	64·286	...	236	...	3298 8	60·786			
130·0	...	65·0	...	236	...	3298·8	61·5	29 094		...
140·0	...	70·0	...	236	...	3298·8	66·5	31·587		...
148·572	...	74·286	...	236	...	3298·8	70·786	...		
Axle K on the middle.										
		1·9	Starting point of the train of trucks.							
148·572	...	74·286	...	236	...	3631·6	72·386			
150·0	...	75·0	...	236	...	3631·6	73·1	35·624		...
160·0	...	80·0	...	236	...	3631·6	78·1	38 123		...
168·572	...	84·286	...	236	...	3631·6	82·386	...		

Examples.

Axle F on the middle.	
4·2 . .	10·430
4 6 . .	10·964
4·8 . .	11·111
5·0 . .	*11·200
5·2 . .	*11·243
5·4 . .	*11·248
5·6 . .	*11·225
6·0 . .	*11·111
6·6 . .	*10 836
7·0 . .	*10·743
7·5 . .	*10·567
8·0 . .	*10·350
8·5 . .	*10 109
9·0 . .	* 9·857
9·5 . .	* 9·600
10 0 . .	* 9·376
15·0 . .	* 8·242
20·0 . .	* 7·600
30 0 . .	* 6·898
35 . . .	6·649
40 . . .	6·515
80 . . .	* 5·246
90 . . .	* 4·949
100 . . .	* 4·668
Axle G on the middle.	
80 . . .	5·213
90 . . .	4·937
100 . . .	* 4·689
Axle H on the middle.	
110 . . .	* 4·451
120 . . .	* 4·271
Axle I on the middle.	
130 . . .	* 4·103
140 . . .	* 3·962
Axle K on the middle.	
150 . . .	* 3·831
160 . . .	* 3 717

(40) . . . . Extra-heavy train. Equivalent loads for shearing stress.

British measures.

Abscissae l_n	Loads P_n	ΣP_n	$l_n P_n$	$\Sigma l_n P_n$	l_w	$\frac{l_w^2}{2l}$	Maximum.	Singular points. p'	*Examples.*
			Axle N on the support.						
0'0"	20	20	0·0	0·0					3'3 3/8" . . . . 40·000
4'3"	8	28	34·0	10·4	...	...		30·769	4'11" . . . . 28·090
9'6"	8	36	76·0	33·6	...	...		16·837	6'6 3/4" . . . . 22·800
22'4"	14	50	312·4	128·8	...	...		9·135	8'2" . . . . 19·072
									16'5" . . . . 11·712
			Axle N on the support.						
0'0"	20	20	0·0	0·0	...	...			3'3 3/8" . . . . 40·000
6'7"	20	40	131·2	40·0	...	...		20·000	4'11" . . . . 26·667
13'1 1/2"	20	60	262·5	120·0	...	...		15·000	6'6 3/4" . . . . 20·000
23'7"	14	74	330·7	220·8	...	...		12·037	8'2" . . . . 19·200
29'6"	14	88	413·6	346·8	...	...		10·993	9'10" . . . . 17·778
34'9"	14	102	486·5	495·2	...	...		10·431	16'5" . . . . 14·400
45'11"	8	110	367·4	611·2	...	...		9·358	18'0" . . . . 13·885
52'10"	8	118	422·6	740·0	...	...		8·949	19'8" . . . . 13·333
57'1"	20	138	1141·7	1088·0	...	...		8·675	26'3" . . . . 11·600
63'8"	20	158	1273·3	1476·0	...	...		8·445	32'10" . . . . 10·664
70'3"	20	178	1405·0	1904·0	...	...		8·320	39'4" . . . . 10·122
80'8"	14	192	1129·4	2248·4	...	...		8·179	49'3" . . . . 9·234
86'7"	14	206	1212·4	2618·0	...	...		8·093	59'1" . . . . 8·617
91'10"	14	220	1285·6	3010·0	...	...		8·036	65'7" . . . . 8·420
98'1"	Starting point of the train of trucks.				...	...		7·982	82'0" . . . . 8·165
131'3"	...	220	...	3010·0	33'2"	4·183		...	98'5" . . . . 7·978
164'0"	...	220	...	3010 0	65'11"	13·255		...	131'3" . . . . 7·416
196'10"	...	220	...	3010·0	98'9"	24·770		...	164'0" . . . . 6·844
262'6"	...	220	...	3010·0	164'4"	51·470		...	196'10" . . . . 6·366
393'1"	...	220	...	3010·0	295'7"	110·975		...	262'6" . . . . 5·658
524'11"	...	220	...	3010·0	426'10"	173·538			393'8" . . . . 4·827
			Axle L on the support.						
73'2"	20	174	1483·4	1947·0	...	...		7·775	
79'8"	20	194	1593·4	2433·0	...	...		7·726	
90'3"	14	208	1263·5	2818·0	...	...		7·675	82'0" . . . . 7·734
96'2"	14	222	1346·4	3228·2	...	...		7·633	
101'4"	14	236	1418·6	3660·8	...	...		7·607	98'5" . . . . 7·626
107'7"	Starting point of the train of trucks.				...	...		7·775	
131'3"	...	236	...	3660·8	23'7"	2·126		...	131'3" . . . . 7·315
164'0"	...	236	...	3660·8	56'5"	9·705		...	164'0" . . . . 6·843
196'10"	...	236	...	3660·8	89'3"	20·221		...	196'10" . . . . 6·408
229'8"	...	236	...	3660·8	122'0"	32·431		...	262'2" . . . . 6·039
262'6"	...	236	...	3660·8	154'10"	45·663		...	295'3" . . . . 5·730
295'3"	...	236	...	3660·8	187'8"	59·636		...	229'8" . . . . 5·472
328'1"	...	236	...	3660·8	220'6"	74·079		...	328'1" . . . . 5·252
360'11	...	236	...	3660·8	253'3"	88·870		...	360'11" . . . . 5·065
393'8"	...	236	...	3660·8	286'1"	103·948		...	393'8" . . . . 4·903
426'6"	...	236	...	3660·8	318'11"	119·220		...	426'6" . . . . 4·763
459'4"	...	236	...	3660·8	351'8"	134·653		...	459'4" . . . . 4·640
492'2"	...	236	...	3660·8	384'6"	150·218		...	492'2" . . . . 4·531
524'11"	...	236	...	3660 8	417'4"	165·887		...	524'11" . . . . 4·434

Metric measures.

Abscissae l_n	Loads P_n	ΣP_n	$l_n P_n$	$\Sigma l_n P_n$	l_w	$\frac{l_w^2}{2l}$	Maximum.	Singular points. p'	*Examples.*
			Axle N on the support.						
0·0	20	20	0·0	0·0					
1·3	8	28	10·4	10·4	...	...		30·769	1·0 .... 40·000 1·5 .... 28·090 2·0 .... 22·800
2·9	8	36	23·2	33·6	...	...		16·837	2·5 .... 19·072 5 0 .... 11·712
6·8	14	50	95·2	128·8	...	...		9·135	
			Axle N on the support.						
0·0	20	20	0·0	0·0	...	...		...	1·0 .... 40·000 1·5 .... 26·667
2·0	20	40	40·0	40·0	...	...		20·000	2·0 .... 20·000 2·5 .... 19·200
4·0	20	60	80·0	120·0	...	...		15·000	3·0 .... 17·778 5·0 .... 14·400
7·2	14	74	100·8	220·8	...	...		12·037	5·5 .... 13·885 6·0 .... 13·333
9·0	14	88	126·0	346·8	...	...		10·993	8·0 .... 11·600 10 .... 10·664
10·6	14	102	148·4	495·2	...	...		10·431	12 .... 10·122
14·5	8	110	116·0	611·2	...	...		9·358	15 .... 9·234
16·1	8	118	128·8	740·0	...	...		8·949	
17·4	20	138	348·0	1088·0	...	...		8·675	18 .... 8·617
19·4	20	158	388·0	1476·0	...	...		8·445	20 .... 8.420
21·4	20	178	428·0	1904·0	...	...		8·320	
24·6	14	192	344·4	2248·4	...	...		8·179	25 .... 8·165
26·4	14	206	369·6	2618·0	...	...		8·093	
28·0	14	220	392·0	3010·0	...	...		8·036	
29·9	Starting point of the train of trucks.				...	...		7·982	30 .... 7·978
40	...	220	...	3010·0	10·1	1·275		...	40 .... 7·416
50	...	220	...	3010·0	20·1	4·040		...	50 .... 6·844
60	...	220	...	3010·0	30·1	7·550		...	60 .... 6·366
80	...	220	...	3010·0	50·1	15·688		...	80 .... 5·658
120	...	220	...	3010·0	90·1	33·825		...	120 .... 4·827
160	...	220	...	3010·0	130·1	52·894			
			Axle L on the support.						
22·3	20	174	446·0	1947·0	...	...		7·775	
24·3	20	194	486·0	2433·0	...	...		7·726	25 .... 7·734
27·5	14	208	385·0	2818·0	...	...		7·675	
29·3	14	222	410·2	3228·2	..	...		7·633	30 .... 7·626
30·9	14	236	432·6	3660·8	...	...		7·607	
32·8	Starting point of the train of trucks.				...	...		7·585	
40·0	...	236	...	3660·8	7·2	0·648		...	40 .... 7·315
50·0	...	236	...	3660·8	17·2	2·958		...	50 .... 6·843
60·0	...	236	...	3660·8	27·2	6·165		...	60 .... 6·408
70·0	...	236	...	3660·8	37·2	9·885		...	70 .... 6·039
80·0	...	236	...	3660·8	47·2	13·918		...	80 5,730
90·0	...	236	...	3660·8	57·2	18·177		...	90 .... 5·472
100·0	...	236	...	3660·8	67·2	22·579		...	100 .... 5·252
110·0	...	236	...	3660·8	77·2	27·090		...	110 .... 5·065
120·0	...	236	...	3660·8	87·2	31·683		...	120 .... 4·903
130·0	...	236	...	3660·8	97·2	36·338		...	130 .... 4·763
140·0	...	236	...	3660·8	107·2	41·042		...	140 .... 4·640
150·0	...	236	...	3660·8	117·2	45·786		...	150 .... 4·531
160·0	...	236	...	3660 8	127·2	50·562		...	160 .... 4·434

In the following calculations and tables we shall call :

(33)

p'	the uniform equivalent load required per metre of track,
l	the span of the bridge,
$P_1\ P_2 \ldots P_n$	the loads acting upon the bridge,
$l_1\ l_2 \ldots l_n$	the respective distances from the support on the right.

We then find by the ordinary methods [1] :

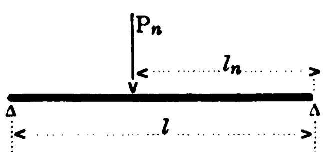
$$(34). \quad p' = 2\,\frac{P_1 + P_2 + \ldots P_n}{l} - 2\,\frac{l_1P_1 + l_2P_2 + \ldots l_nP_n}{l^2} = \frac{2}{l}\left(\Sigma P_n - \frac{\Sigma l_nP_n}{l}\right)$$

This formula is very similar to formula (22) drawn up for the bending moments and may be used in the same way.

If we suppose that the fore-axle of a train of a certain determined load is resting on the right support of the bridge and that the span l continually increases then the sums ΣP_n and Σl_nP_n will only vary each time a new axle appears on the increasing span. We can therefore draw up beforehand a table of the values of these sums for the corresponding spans [2], and this table will then enable us to obtain p' by means of formula (34) for any span l whatever making two divisions only, for we shall utilise the values of the Σ which in the table correspond to the value immediately below $l_n \leqq l$.

The diagram of the values of p' obtained [3] by slotting all the values of p' thus found will be the enclosing curve required giving graphically the greatest values of the load per equivalent metre as regards the shearing strain on a support, which values can also be obtained numerically by means of formula (34).

All the calculations relating to shearing strains which have served as a basis for the Austrian regulations, have been made with the help of the processes above described; we will now show that the results obtained are applicable for the shearing strains produced on any section of the bridge, in accordance with the principle of the lengths loaded.

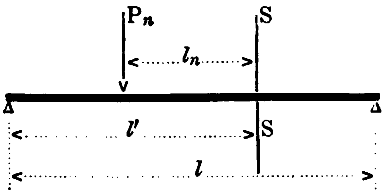


(1) We should get for the single force P_n a shearing strain on the right support estimated at :

$$(35) \; \ldots\ldots \quad V_l = \Sigma\,\frac{l - l_n}{l}\,P_n = \frac{1}{2}\,p'l$$

(2) Working in the same way as for the bending moments principally by making additions for the appearance of each axle.

(3) With p' for the ordinate and l for the abscissa, the head of the train being on the support.



We will consider any section SS of the bridge; let us suppose one of the trains of known load mentioned above to be placed so that the first axle is over the section considered and leaves the part on the right unloaded so that the shearing strain on SS shall be at the maximum. We will call :

(36)
p' . . . . the equivalent uniform load per metre sought at S S;
l . . . . the span of the bridge considered;
l' . . . . the part of this span to the left of SS;
$P_1\ P_2 \ldots P_n$ . . . . . . the various axle-loads acting to the left of S S;
$l_1\ l_2 \ldots l_n$ . . . . their respective distances from the section S S;
$V_{l'}$ . . . . the shearing strain produced on the section. We then find :

(37) . . . $V_{l'} = \Sigma \frac{l' - l_n}{l} P_n = \frac{1}{2}\frac{p'l'^2}{l}$ . . . . . $p' = \frac{2}{l'}\left(\Sigma P_n - \frac{\Sigma l_n P_n}{l'}\right)$

The denominator l has disappeared and the formula thus obtained, giving p' for any section SS, only differs from the similar formula (34) giving p' on the right support, in that here l' comes in place of the span l. Formula (34) therefore only represents a particular case of formula (37) for which $l' = l$ and we recognise more generally that :

The uniform load p' *per metre equivalent to a given train as to the shearing strain on a section SS of a bridge of any span whatever only depends on the length* l' *loaded, comprised between the section and one of the supports according to the direction of the strain sought.* This general principle justifies without further commentary what we said in chapter III with regard to scale **b**.

Inversely, the value of p' calculated for any intermediate section of the bridge, situated at a distance l' from the support on the side from which the load proceeds, must be exactly equal to the value of p' calculated for a support of a bridge with a span l'. It was thus sufficient to calculate the loads intended for scale **b** of the regulations, by considering only the maximum shearing strain obtained on a support for all the spans, even enabling these values of p' to be written down according to the new principle of lengths loaded.

For the calculation of shearing strains for each particular bridge, according to the formula :

(38). . . . . $V_{l'} = \frac{1}{l} \cdot \frac{p'l'^2}{2} = \frac{p'}{2l} \cdot l'^2$

the new principle adopted in Austria again has the advantage of simplifying the calculations. We can, in fact, draw up once for all, a table of the turning moments $\frac{1}{2} p'l'^2$ for all the lengths l' generally. To obtain the shearing moments in a given bridge, we shall merely have to divide by the span of the bridge the values of the moments given by this table for the lengths loaded concerning the several panels.

In the case where behind the locomotives and tenders there is a train of trucks of length l_w on the bridge, weighing p_w per running metre, it follows from the formulæ (34), and (38), that we shall get generally : —

$$(39). \ldots\ldots\ldots\ldots \quad p' = \frac{2}{l}\left[\Sigma P_n - \frac{\Sigma l_n P_n}{l} + p_w \frac{l_w^2}{2l}\right]$$

When discussing the question of loads in chapter III, we showed all the advantage that could be gained from scale **b** for other systems of construction. In the case of the *extra heavy train* one more difficulty occurs. The firts locomotive on the right in our table (30), has, in front of the heavy axles two axles bearing 8 tons each. If we call the three first axles L, M, N, we cannot *a priori* assert that it is always L that must be placed on the section of the bridge or on the support where we wish to have the greatest shearing strain. We should have even theoretically to try the three axles for the different spans. We have made the complete calculations for the axles L and N. We find that we must consider the axle N up to about 164 feet (50 metres) of span, whereas for larger spans the axle L must be chosen. For very small spans, we must consider the cases in which the locomotive is turned one way or the other with regard to the support in question. We have not made calculations for the axle M, for the results that we should thus obtain would be included in those we have already found.

Really, if we wish to apply the established scale **b** of the loads p', as we have just said, to the calculation of the shearing strains on any sections between the supports, we introduce a slight excess on the side of safety into these calculations, for the axle N being on the section, we must wake a deduction for each bearing axle placed in front. Since the employment of scale **b** as it stands, covers all the effects of the train and since, between the values of the scale, which are obliged to be given in round numbers and the effects of the train, there will always be unavoidably some slight differences, this scale will always answer our purpose.

When making the calculations for the axles L and N, we must in our table (30) consider the sums of the abscissae and loads ascertained for the axles C and E towards the left, after they have been prolonged for a second locomotive.

We shall find (40) the complete table of the values of the Σ enabling p' to be calculated for as many values of l as may be required. We have quoted a sufficient number of examples for the tracing of the required curves.

IV. — The manufacture of iron and steel. Qualities required for bridges.

The history of the development of iron and steel structures is closely connected with that of the great progress made in the processes of manufacturing the metal. The possibility of procuring at a moderate price and within a short time large masses of iron and steel, naturally brings with it facilities for bridging over large openings by means of iron bridges, and since the art of constructing these has originated in England, it seems only logical that we should find there also the most important inventions, constituting marked steps in the history of the working of iron.

1. — *The manufacture of weld and ingot iron* (1).

Since the old methods of charcoal refining have fallen into disuse, the only iron that engineers have had at their disposal until recently is that obtained by means of puddling cast iron, which is then hammered out with the steam hammer and rolled. This is what has long been called puddled iron, wrought iron or welded

(1) The *Annales des ponts et chaussées* (December 1886, p. 72) give an international nomenclature for the various kinds of iron, which is also quoted in vol. V of the *Encyclopédie chimique* (M. Bresson's article on steel). This nomenclature, established in 1876, by the International Committee of Philadelphia, has been adopted by the general assembly of delegates of the Association of German railways, at their meeting at Hamburg (August 1st and 2nd in the year 1878).

It may be summed up thus :

a) *Fer soudé, Schweisseisen, weld iron, wälljern,* made by uniting by means of welding soft masses heated to white heat, previously obtained from bundles of iron bars or some other source, not capable of tempering;

b) *Acier soudé, Schweissstahl, weldsteel, wällstal,* made like *a* and capable of tempering;

c) *Fer fondu, Flusseisen, ingot iron, götjern,* made by melting and hardly capable of tempering;

d). *Acier fondu, flussstahl, ingot steel, götstal,* made like *c* and capable of tempering.

In addition to this excellent classification, which we should like to see adopted, we must state a number of conditions in order to define exactly a given quality of steel (*Zeitschrift des Vereins deutscher Eisenbahnverwaltungen*, n° 62, August 12th 1878, p. 851 and 858). A few years ago the Prussian Government extended this nomenclature to all the terms used in commerce. In France and England, it seems to have been only partially followed, but as the Congress had adopted it at previous sessions we will follow it here.

iron. This iron has only become cheaper gradually, as means have been found to manufacture it in larger quantities, and the processes of rolling developed. Nearly thirty years ago, Sir Henry Bessemer's invention brought about a complete revolution in metallurgy throughout Europe. The Bessemer converters placed on the market a new kind of iron, obtained by melting and possessing to a certain extent the properties of steel. This metal possesses, when the finest qualities are selected, that is to say those containing least carbon, properties greatly akin to those of puddled iron of good quality. The Bessemer process has been improved by the basic lining of the retorts, which enables the mass in process of melting to be de-phosphorised. This method, known as the Thomas Gilchrist or basic process, enables us to obtain from inferior ores, such as those of Bohemia or Lorraine, a metal which, in the mild qualities, is in no way inferior to that produced from the better ores of Spain or Styria. It is however less reliable than the Siemens Martin process, which consists in heating in a reverberatory furnace (1), by means of a current of gas, superheated by passing through a Siemens regenerator, a trough of cast iron into which are introduced successively quantities of iron measured so as to reduce the percentage of carbon to a fixed proportion (2). The principal advantage of the Siemens-Martin process, as regards the quality of the products, is the slowness of the operation which can be continued until the samples taken from the liquid metal in the melting furnace show that the required quality is exactly obtained.

2. — *Weld iron (Schweisseisen-puddled iron).*

It is generally admitted that the two surest tests for ascertaining the quality of the metal are *the resistance to breaking and the elongation* measured in the direction of the grain. The resistance to breaking has been fixed in Austria at a limit of not less than 47,000 to 51,000 lbs per square inch (33 to 36 kilograms per square millimetres), so as not to exclude the excellent soft irons of Styria. The additional regulation which fixes that elongations should vary from 20 to 12 p. c., according to the resistance to breaking, is formulated with the object of preventing the employment of bad qualities of iron and is chiefly directed against the iron imported into Austria which is generally more brittle. The test-samples prescribed

(1) The basic lining can be used in the Siemens Martin furnace as well as in the Bessemer converter.

(2) We can, instead of iron, add ore; this last process is applied on a large scale in England.

[having a section of 3/4 of a square inch (5 square centimetres) and a length of 8 inches (20 centimetres) between elongation marks] correspond with the custom established in the greater number of the iron-works of Central Europe. These somewhat broad regulations determine from the special point of view of the government department for the inspection of railways, the minimum of the conditions to be fulfilled. It is for the Railway Administrations to ensure more complete guarantees of safety by inserting in their specifications special conditions (resistance cross the grain, resistance to bending and hammering) according to the quality of the iron ordered and the purpose for which it is to be used.

Most of the iron of commerce is rolled only in one direction; certain kinds should however be rolled in both directions successively.

3. — *Ingot iron* (*Flusseisen*).

Ingot iron (or mild Bessemer steel) has only been admitted into the construction of bridges very gradually. The writer remembers that when visiting the offices of Sir J. Fowler and Mr. B. Baker in London, in 1882, he was somewhat surprised to find that it had been decided to construct the Forth Bridge of mild steel. This metal had been almost abandoned in Austria after some tests made from 1879 1884, which do not seem to have been encouraging. The steel, used in the bridges where it was tried, should have had a breaking resistance of 64,000 lbs per square inch (45 kilograms per square millimetre) with a sectional contraction of 45 p. c. The formula used at this period stipulated more generally that the sum of the numbers representing the breaking strain (in kilograms per square millimetre) and the contraction should be equal to 90.) The specifications were very strict and the iron-works had not then arrived at a very regular method of manufacture, for many of the samples of iron presented were rejected. An accident that happened to the Talfer Bridge (with a span of 102 feet) (31 metres) in which several pieces of steel were broken by the shock of an empty truck that hat been derailed, and some other accidents of still more recent occurrence, seemed to confirm the unfavourable impression caused in Germany by the comparative experiments made at the Harkort Works, Duisbourg, on iron and steel girders; these led to the temporary abandonment in Austria of these metals. However, bridges soon began to be constructed again with steel, such as is produced by the Siemens-Martin process.

In Germany the ingot and steel industry was more advanced than in Austria at the same time, and even than in France from certain points of view. Thus, whilst in this latter country the use of mild steel plates for boilers had been temporarily abandoned about 1880, this metal was in pretty general use on certain German railways in 1881.

It is to the French Admiralty Department that we owe the great progress realised in France in the employment of malleable metal for purposes of construction; their success, which has been complete, is due to two causes. They have sought to produce in this metal iron of superior quality and not steel; and they have required from the ironworks that supply them absolute homogeneity as to all furnished pieces. Their requirements in this last respect have certainly rendered considerable service to metallurgy; the French works are now in a position to manufacture, even with the converter, mild steel with a resistance within 1 1/4 tons per square inch (2 kilograms per square millimetre) above or below the limit concerning quality they try to produce, and the elongation of which, for a given resistance, is almost constant. The engineers of the French navy consider that, for naval construction ingot-iron (which they designate by the name of mild steel) is preferable to weld iron, not only as regards economy and lightness, but also as regards resistance to shocks.

The success obtained in the construction of vessels exposed to violent shocks and continual distortion, could also be achieved in the construction of bridges, that is, if metal of the same quality were used and the same precautions taken; besides with the present fitting up of iron works, it is merely a question of care.

As for weld iron, so the best method of ascertaining the quality of ingot-iron or mild steel consists in measuring the resistance to tensile strain and the elongation (1), but these measurements are in this case of much greater importance since they alone show the nature of the metal and its homogeneity. In short, whereas the different qualities of puddled iron produced by the same works present only comparatively slight differences of resistance and elongation, we can with the same ore produce in the Bessemer converter and even in the Siemens-Martin furnace all the varieties of malleable iron, from almost pure soft iron to hard steel; the same charge even may produce ingots of different hardness and the ingots themselves are only homogeneous if the casting has been conducted with certain precaution. We therefore really only know the quality of the steel by the tests to which it is subjected; but these tests can only be considered conclusive if they furnish proof that the

(1) It would be useful to determine also the limit of elasticity; up to the present engineers have been deterred by the uncertainty attending this measurement, which is very delicate when performed by the ordinary methods. The specifications therefore generally deal with the breaking strain, the elongation and the contraction (of the section broken).

samples of steel presented for acceptance satisfy generally the stipulated conditions. We cannot in fact try the pieces that are really used, and it would be almost impossible to try samples of all the bars from which these pieces are cut. The rejection of the lots from which the test pieces have been taken that have given unsatisfactory results does not therefore give us any guarantee against the employment of bars of the same quality unless we can assure ourselves that they are of homogeneous quality. Now it is easy to see not only that the employment of hard steel instead of mild steel introduces into the work an element of brittleness but that the juxtaposition in the same piece of elements that are not homogeneous has the effect of diminishing its resistance to an extent that is often very considerable (1). To convince ourselves of this, we have only to draw out on the same diagram the curves representing the resistances of the various kinds of steel taking for abscissae the elongations and for ordinates the ultimate tensile strains of the bars of different qualities considered. If we suppose these bars to be of equal section, and to be arranged so that they cannot be elongated independently of one another, like the flange plates of a double T girder for instance, we see that for each value of elongation, the resistance of the whole will be about the sum of the ordinates of the curves, measured for the corresponding abscissa. At the moment of breaking of the hardest bar, the other bars, if the difference of the coefficients of elongation is great, will still be a long way from the strain represented by their breaking strain.

It is to effects of a similar nature produced in a bar even and to the molecular tensions resulting from irregular tempering or from mechanical strains that we must attribute in the majority of cases the brittleness so often attributed to steel (2). These strains are not produced in mild steel, at least not to any important extent, when its resistance is less than 64,000 lbs (45 kilograms per square millimetre), as

(1) It is probably to effects of this kind that we must attribute the unfavourable results arrived at for steel during the comparative tests made in 1877, at the request of the Dutch engineers, at the Harkort Works, Duisbourg.

The results of tests of elongation are only comparable if the test pieces have the same or geometrically similar dimensions. In France, the two formulæ $l^2 = 80$ S and $l^2 = 50$ S are generally used to measure the ration of the length to the section. The conditions laid down in Austria satisfy the first of these two formulæ, where the length l and the section S are estimated in centimetres. The corresponding cylindrical test-pieces are 8 diameters in length. In Germany Professor Bauschinger has recommended test pieces 10 diameters in length; they are used by some Railway Administrations.

(2) Notwithstanding the general opinion, the percentage of carbon does not of itself enable us to estimate, even approximately, the hardness of different qualities of steel. This depends in fact, on other elements (manganese, phosphorus, silicion, etc.) which are always associated with it to

it is not very much affected by the tempering and as its malleability almost annuls the effects of mechanical strains; for this reason constructors have up to the present agreed to fix the resistance of mild steel to be used for bridges below this limit or at any rate below 71,100 lbs (50 kilograms per square inch). There are, however, slight differences of opinion on this point; whereas some, wishing above all to avoid the effects of tempering limit the maximum of resistance to 62,000 or 64,000 lbs (44 or 45 kilograms per square millimetre)(1); others, trying to raise the resistance and the limit of elasticity as high as prudence will allow, prefer a somewhat harder metal the resistance of which may amount to 71,100 lbs (50 kilograms per square millimetre) (2); for the Forth Bridge, the limit of 82,500 lbs (58 kilograms per square millimetre) has even been allowed, but only for those parts in compression. The elongation varies almost in inverse proportion to the resistances; it is best to order it as great as the normal conditions of manufacture will allow; we may assume that the elongation, measured on test pieces 8 inches (20 centimetres) long and with 3/4 of a square inch (5 square centimetres) of section, should be at least 24 p. c. for a resistance of 59,750 lbs (42 kilograms), and at least 20 p. c. for a resistance of 71,100 lbs (50 kilograms). We can scarcely indicate generally which quality should be employed in preference. For work on a large scale, in which it is important to be able to raise the coefficient of resistance of the metal in order to reduce the weight, and the details of which are likely to be subjected to careful scrutiny, there is evidently every advantage in employing steel with the greatest possible resistance; for bridges with shorter spans where the coefficient of resistance has less influence on the weight and the execution of the work is not sub-

a greater or less extent. Manganese, particularly, is even introduced during the manufacture even in the Bessemer and Thomas Gilchrist processes, for which it is indispensable.

(1) When the basic process is employed, we cannot produce very hard steel, but the resistance of the metal can vary from 57,000 to 85,000 lbs (40 to 60 kilograms) or even more. We can see what vast differences can occur in the nature and quality of the metal from the following fact:

For the construction of the Arnhem bridge in 1876, the Dutch engineers had arranged for the employment of steel offering a minimum resistance of 85,000 lbs (60 kilograms), and a minimum elongation of 17 p. c. The resistance of the bars submitted for approval varied from 71,100 to 110,900 lbs (50 to 78 kilograms), and their elongation from 5.1 to 22.5 p. c. The samples rejected amounted to 40 p. c. For the Nimeguen bridge, constructed about the same time, the resistance varied from 79,600 to 101,000 lbs (56 to 71 kilograms) and the elongation from 4 to 27 p c.; in this case the rejections amounted to 49 p. c.

(2) In the works that are most noted for the quality of their steel, the quality of the metal produced from each charge is determined not only by mechanical tests, but by chemical analysis, even when no test is demanded by the buyers.

jected to such minute examination, it will, generally, be best to use a softer metal.

The use of mild steel in bridges requires special precautions; the holes for the rivets must be drilled instead of punched, or, what is simpler, the holes may be punched to a diameter 2/25 to 3/25 of an inch (2 to 3 millimetres) less than the diameter required and then rimed; we must also avoid shearing the bars and drifting the holes. Still these precautions are only absolutely indispensable when the resistance exceeds 64,000 lbs (45 kilograms).

In short, from all the information that we have gathered and a great deal of which has been supplied by our eminent colleague and former collaborateur M. Charles Bricka, it follows that almost throughout Europe the coefficients of breaking and of elongation really admitted for mild steel to be used in bridges do not greatly differ from those admitted by the Congress during its third session at Paris, in 1889 (1); the extent of the interval within which each coefficient should be comprised, has, rightly or wrongly, been greatly varied, at the same time the values prescribed being increased, so that really the conditions imposed seem to be extremely variable.

4. — *Diagram of the coefficients of breaking and of elongation.*

During the course of the year 1891, endeavours have been made in Austria to consolidate and ameliorate the conditions of acceptance of the mild steels to be used in bridges, with the object of obtaining a metal as homogeneous as possible for each class of structure. In Germany, a similar movement has been set on foot by bridge engineers. But the Association of metallurgical engineers, at the sitting of 1889, at Dusseldorf (2), passed a series of resolutions according to which mild steel for bridges shoud have an elongation of 20 p. c. the breaking strain varying from 54,000 to 64,000 lbs (38 to 45 millimetres). These stipulations were regarded as authoritative for some time in Germany, where more than 20 p. c. of elongation could not be demanded from manufacturers for any quality of mild steel; England was quoted with regard to this subject, as the Board of Trade did not demand a greater elongation than this. The iron-masters of Austria therefore agreed amongst themselves that they would not accept any specification requiring an elongation of more than 20 p. c.,

(1) Elongation of 24 to 22 p. c. for breaking strain of 56,900 to 64,000 lbs (40 to 45 kilograms).

(2) *Vorschriften für Lieferungen von Eisen und Stahl, aufgestellt vom Vereine deutscher Eisenhüttenleute*, Düsseldorf, 1889.

and even the Association of Engineers and Architects of Austria who took up the question for a time, could obtain no further concession from them.

In 1891, the Commerce Department admitted the necessity of establishing compulsory rules as to the conditions to be imposed upon manufacturers for steel (*Flusseisen*) to be used in the construction of bridges. On this occasion the writer, who was also the reporter to the committee of inquiry nominated by the department, had to collect all the specifications then in use, and also the regulations issued by the Governments in certain countries. It was by showing those interested that in a great number of cases, particularly in France, Russia, and North Germany ([1]), the acceptance or rejection of steel was carried out according to very severe specifications, that an understanding was at length arrived at based on very fair conditions, which are, moreover, very similar to those voted by the Congress during the third session at Paris, in 1889. The ordonnance of the Commerce Department of the 29 January 1892, fixed these conditions definitively, viz : for a breaking strain varying from 49,800 to 64,000 lbs per square inch (35 to 45 kilograms per square millimetre), an elongation of 28 to 22 p. c., measured on test pieces 8 inches (200 millimetres) long and having 3/4 of a square inch (500 square millimetres) of section. For extra mild steel, intended for rivets, an elongation varying from 32 to 26 p. c. was allowed for a breaking strain of 49,800 to 56,900 lbs (35 to 40 kilograms). In the course of the year 1892, the Commerce Department appointed a Committee of Inquiry for consolidating the detailed technical conditions of specifications with regard to the acceptance of iron intended for bridges. It was then, that on the basis of the conditions already fixed by the ordinance of the 29th of January 1892, and with the concurrence of the Administration of the State Railways, and the principal private Railway Administrations and the most important ironworks of Austria, a kind of standard specification was established. This contains all those technical conditions for which an agreement has been entered into on this understanding, that more can be demanded, but never less. We think that particularly as regards bending tests made with bars partly cut and bars intact, according to conditions depending both on the thickness and the hardness of the test-pieces accepted, the stipulations then made, on the basis of numerous experiments, are not wanting in interest for our colleagues of other nationalities. We have therefore given this standard specification in the appendix to our report.

([1]) In these three countries an elongation of 25 p. c. had been prescribed since 1888 and this created no difficulty as to the passing of samples.

We also add a diagram (plate II) which we have drawn up with the object of comparing the conditions as to breaking strains and elongations laid down for different qualities of steel, in the various specifications sent to us, and which seemed to us characteristic (¹).

What at once strikes the eye with regard to our diagrams is the tracings of the *hyperbolas of « quality »* from 7 to 13, that are observed to incline slightly to the right. The idea of these curves is based upon the opinion of metallurgical engineers that for the same furnace, the same original materials, and all other conditions being equal, the metals of various qualities as to hardness produced give elongations varying almost in inverse ratio to the breaking strains. This is a fact that has already been quoted by our eminent collaborateur M. C. Bricka, at the time of the sectional discussions of this question at the session held in Paris, 1889. Now, to admit this empirical law, is to admit that for the same quality of metal produced, the two functions (breaking strain and elongation) serving as coordinates in our table, have a constant product. This at once leads us to the conception of the *hyperbolas of « quality »* that figure in our table and for which the constant product in question remains equal to 7, 8, 9, 13, etc. If we glance over our diagram from the softest metal with a breaking strain of 49,800 lbs (35 kilograms) to the hardest metal, that used for the Forth bridge, we are led to think that the idea of curves of « quality » is justified by the facts stated. It seems to follow that the horizontal lines representative of the specifications should give place to oblique lines similar to those resulting from the standard specification of Austria. We might say for instance : the metal to be supplied should, according to the breaking strains and elongations measured, remain within the limits of the curves of « quality » 9 and 11. We should thus include almost all the acceptable qualities of steel of our table, for if certain specifications seem to attain the curve 12, we can assume that the metal

(¹) We regret having been obliged to leave out a large number of specifications owing to want of space, for the elongation of 20 or 25 p. c. is demanded so often, that the lines referring to them, placed one over the other, would merely confuse the diagram. Thus, according to a communication from our colleague M. Werchovsky, the regulations of the Russian Government of the 25th of August 1888 prescribed 25 p. c. of elongation for a breaking strain of 48,350 to 56,900 lbs per square inch (34 to 40 kilograms per square millimetre). According to a communication from our colleague M. Baker, the Board of Trade generally prescribes an elongation of 20 p. c. for a breaking strain of 58,300 to 66,850 lbs (41 to 47 kilograms), and it is only under exceptional circumstances that the employment of a much harder steel has been sanctioned for the Forth bridge, the conditions of which are to be found at the right of our diagram. According to the pamphlet : *I primi ponti d'acciaio construiti sulle strade ferrate del Mediterraneo* (Rome 1892) an elongation of 25 p. c. is allowed for a breaking weight of about 62,600 lbs (44 kilograms).

really produced with the required elongation, will remain generally below curve 11 as to the breaking strain [1].

We are of opinion that perhaps precisely on account of the reasons that we have just quoted, the representative horizontal lines, employed up to now, suit very well when we are considering a special consignement of metal, since the available margin given to the right for the breaking strain, involves no inconvenience, whilst the minimum elongation particularly specified should ensure, as far as possible, the homogeneity of the metal supplied. We think therefore that a curve of quality should only be considered as the geometrical locus of the left extremities of the horizontal representative lines to be prescribed in each case.

In this sense also we must consider the oblique representative lines of the Austrian standard specification or of the vote issued by the Congress at Paris, 1889. In conclusion, we think that the attention of the Congress should be drawn to a point still unsettled. In Austria it is at present stipulated that the metal to be supplied for bridges shall be produced by the open hearth process (*Flammofen*, *Martin Siemens*). The greater number of English engineers also specify this. In North Germany and in France, metal produced by the converter (Thomas Gilchrist process, etc.) is also accepted. It would be an advantage for this very delicate question to be discussed before the Congress in 1895.

V. — Limits of internal strain to be allowed in the metal.

1. — *Theories and formulæ for the working strain in the metal.*

For the last thirty years railway engineers have been convinced that only those qualities of iron that satisfy certain determined conditions should be accepted for bridges, and that the working strain to be allowed per unit of surface of the metal used, should be regulated by a higher limit for large bridges than for small ones,

(1) The lines representing the large bridge over the Danube, near Czernawoda, now in course of construction, correspond well with the text of the specification. But these conditions are only alternative, and, with regard to rivets in particular, it is probable that under the ordinary form indicated here, they will not be realised. Moreover, Roumanian engineers have introduced a new and very interesting method for measuring the elongation. We deduct from the normal length [= 8 inches (200 millimetres)] of the test pieces the 1 1/5 inch (30 millimetres) comprising the contraction near the broken section, and we distribute the elongation over the remaining part, of course prescribing less severe conditions on this account.

because in the latter the dynamic effects of the moving load and the consequences of inequalities of internal structure depending on the mode of manufacture have a much more important influence.

It is only as to the application of these principles that engineers are still at variance, and this disagreement has been considerably increased by the theories that have for some time been promulgated in Germany and other countries.

The most important accessory conditions that need be studied in order to settle what dimensions are to be given to various parts of the structure according to the strains found by the calculations of resistance are roughly speaking as follows :—

1. — The quality and source of production of the materials used for the construction.

2. — The mode of manufacture as compared with the kind of work to which they will be subjected when the structure is completed.

3. — The augmentation of the working strain pure and simple in consequence of the unequal distribution between all the fibres of the section.

4. — The consideration of strains repeated a number of times.

5. — The consideration of alternate strains (tension and compression), or more generally of the interval within which these strains alternate.

6. — The degree of safety with which we can rely on the calculations of resistance.

We have in chapter IV discussed the manufacture of the iron and steel and the qualities required in these materials for bridges. The unequal distribution of the strain amongst the fibres of one part which we now take into account as far as caused by bending as much as by buckling and even somewhat as caused in riveted connections, must of course increase the weight of the bridges. But we have gone farther than this, we may as well say at once too far, in occupying ourselves unnecessarily with the question of repeated and alternate strains, which have been so fully discussed for the last twenty years.

The most experienced engineers have drawn up formulae or scales of limits for the maximum working strain to be allowed, increasing this latter with the span, and with the ratio of the moving load to the dead load, etc. Up to about 1865 these formulae and scales of admissible working strain were purely empirical in their character, and were considered as a kind of practical amendment of the fixed limits accepted and indeed often prescribed by the Administration.

The very extensive experiments made from 1859 to 1870 by Wöhler (1), and then continued and confirmed by Spangenberg, with regard to the influence of the repetition of strains on materials, have placed the calculation of the dimensions of the sections in quite a new light (2).

The prolonged tests (*Dauerversuche*) related only to the alteration that the repetition of strains brings about in the *resistance to breaking*; they led to the formulating of laws on this point which were soon put into a mathematical form Starting from the laws or functions thus established for the limits of resistance to breaking only, several engineers did not fear to establish complete theories relating to the usual elementary working strain of the materials, although this keeps *far below the limit of elasticity* and remains independent of the more or less complicated laws deduced from the breaking strain, according to which it was desired to determine the dimensions to be given to the sections.

As, about 1847-1857, after the publication of the results obtained by Hodgkinson as to the bending of cast iron, each originator of theories of resistance endeavored to establish is *system of unsymmetrical standard sections for the most advantageous cast-iron girders according to Hodgkinson's breaking limits*, so, from 1870 to 1880, several mathematician felt bound to demonstrate numerically and graphically to the engineering world the superiority and efficacy of *their special system of utilising the breaking limits found by Wöhler to deduce from them the dimensions of the most suitable surfaces of section*. The errors committed in earlier times and more recently really spring from the same cause. All the conceptions derived from our theories of resistance of materials concern comparatively slight strains which do not affect the elasticity of the material (3). We reckon from the breaking strain in order to characterise to some extent the degree of safety as regards breaking offered by the limit allowed for the working strain in construction, but this comparison is in many cases not very logical and of doubtful value, since the molecular grouping in the two cases is quite dissimilar, *and because it would not be allowable to deduce from the phenomena observed just before breaking, i. e. for strains quite outside those allowed in structure, complete formulae and theories applicable to the calculation of sections to be*

(1) A. Wöhler, *On the resistance of iron and steel;* Erbkam, *Zeitschrift für Bauwesen*, 1870, p. 74. See also Spangenberg's article in the same journal, 1874, p. 474 and 1875, p. 77.

(2) See *Annales des ponts et chaussées*, April 1885, p. 693. Chapter IV of M. Considere's articles on iron and steel.

(3) Elasticity, understood as practical men of all periods have understood it, and not as M. Bauschinger and other learned experimentalists have defined it.

adopted, i. e. to our theories on the resistance of materials which only relate to very slight strains 12,800 lbs per square inch (9 kilograms per square millimetre) within the limit of elasticity of the material.

Towards the middle of this century, engineers soon went back to cast-iron girders of symmetrical section (1) and after more than 20 years of useless discussions relating to the new theories, we have simply resolved to return to the known laws relating to the elasticity of materials (2), which we can reconcile with the practical rules mentioned above, without exceeding the somewhat restricted limits imposed upon constructors. The formulae and theories according to which the limit of the elementary working strain to be allowed in all possible cases would depend solely on the interval within which the strains acting on a certain part of the structure oscillate, have never been accepted by the Commerce Department of Vienna, where they were found no to be in accordance with the principles admitted in the calculations of resistance. At the time of the investigations which preceded the publication of the Austrian regulations of the 15th of September 1887 the most important particulars of the results obtained by Professor Bauschinger of Munich in his experiments on the limits of elasticity of materials (3) were already known; there was therefore no occasion to discuss methods of calculation which were proved to be of little value.

Nevertheless, as the formulae concerning these methods and known as Wöhler's, Gerber's, Launhardt's, Weyrauch's formulae, have been very generally used and frequently applied in Germany and are even in favor in France with certain engineers, we think it best to speak of them here, quoting them in the form in which they have been most used lately (4).

(1) See pages 62 to 74 of the work by Love, already quoted, then pages 79 to 111 of Pirel's work already quoted, for studies of unsymmetrical sections. Then see p. 23 of the work already quoted by L. Bresse (edition of 1859) for the sudden revulsion then observed in favour of symmetrical sections attributable to the fact that the coefficients of elasticity are almost equal for compression and extension.

(2) See amongst other works an article by MM. Laissle and Schübler, of the 4th of April 1885 (*Centralblatt für Bauverwaltung*, nº 14) in which these well known practical engineers make a formal opposition to Winkler's propositions.

(3) See *Mittheilungen aus dem tech. mechan Laboratorium der k. techn. Hochschule in München*, J. Bauschinger, Th. Ackermann, Munich, 1886, 13. Heft. — See also the articles in the *Annales des ponts et chaussées* for December 1886 and December 1887. M. Bauschinger has died since, deeply regretted by engineers.

(4) It would be incorrect to assert that the theories and formulæ in question have entered quite

We will call :

(41)
- S_{min}. . . . . the strain least in absolute value coming upon a certain part ;
- S_{max} . . . . the strain greatest in absolute value coming upon the same part ;
- i_0 . . . . . . a certain initial limit of the international working strain ;
- i . . . . . . the limit of working strain to be taken into account.

Then, according as the strains S are in the same direction, or in opposite directions, the theories in question lead to the following formulae : —

(42). . . . . $i = i_0\left(1 + \frac{1}{2}\frac{S_{min}}{S_{max}}\right) \qquad i = i_0\left(1 - \frac{1}{2}\frac{S_{min}}{S_{max}}\right)$

which may be merged into one if we use S in an algebraical sense.

This amounts really to stating that for a girder bearing a load constantly, we can increase i_0 by half its value, where as in the case of strains sometimes alternating, we must decrease i_0 by half its value.

Now these formulae do not take into account the span or, what amounts to the same thing, the ratio of the moving load to the dead load. They only take these particulars into account indirectly in the case of strains of the same kind, since, for increasing spans, the ratio of the dead load to the total load goes on increasing, and therefore causes the ratio of S_{min} to S_{max} to increase. This happens for instance, if we are calculating the chords of a girder resting freely on two supports. Thus, if we take for iron $i^o = 10,000$ lbs per square inch (7 kilograms per square millimetre), agreeing with the authors of this theory, we find :

(43)

For the spans. . . .	0 ft (0 m.)	130 ft (40 m.)	260 ft (80 m.)	390 ft (120 m.)	520 ft (160 m.)
The working strains. i =	10,000 lbs (7 k.)	11,500 lbs (7.1 k.)	12,400 lbs (8.7 k.)	12,800 lbs (9 k.)	13,200 lbs (9.3 k.)

which suits fairly well and agrees to all intents with what is generally allowed, without using any formula.

Thus, if we except the somewhat high coefficient $i_0 = 10,000$ lbs (7 kilograms per square millimetre) which might have been better chosen as $i_0 = 9,250$ lbs (6.5) or $i_0 = 9,670$ lbs (6.8) so as to agree with the usual practice of constructors, we

into common use in Germany; the Association of German unions of architects and engineers took up the question of metal structures in 1886. The result of the deliberations was a kind of standard specification : *Normalbedingungen für die Lieferung von Eisenconstructionen für Brücken- und Hochbau, aufgestellt vom Verbande deutscher Architecten- und Ingenieur-Vereine, etc.* The specification states in detail the scales to be allowed for the materials, but not the limits of load and elementary working strain.

can allow that formula (42) for strains of the same kind give results that may be accepted for the calculation of the chords.

The same cannot be said for the web-bracing and the difference is particularly evident for those bars that are near the middle of the span where the shearing strains alternate completely and give $S_{min} : S_{max} = -1$, which would require according to the formula *that the working strain of the iron should be limited to 5,000 lbs per square inch (3·5 kilograms per square millimetre) wherever possible* (for bridges of 65 feet [20 metres] as well as for those of 260 feet [80 metres]). Usualy, values are fixed that vary with the span; the limits chosen increasing with the ratio of the dead load to the total load, as is shown indirectly by the comparison of the results, should be equally suitable from this point of view for all the component parts of the same girder. What we have just stated with regard to the web-bracing of bridges with independent spans, might be repeated for the analogous web-bracing of bridges with continous girders or for the portions of the chords which, in these bridges, correspond to the intersection points in the diagram of bending moments, where the parts of the parabolas of negative moments overturned towards the top cut the curve of positive moments. If we wish to apply the formula strictly to those parts of the chords which correspond as we know, to the moments that are least in absolute value, and if we only allow for them a working strain of less than 5,000 lbs per square inch (3·5 kilograms per square millimetre), we should be led not only not to diminish the sections of the chords at this part, but even to increase them on account of the continuity. We might almost say the same of the chords situated over the whole of the middle of the spans, where, as we know, the negative moments are greater than the positive moment, although the latter also attain to considerable values.

This special theory then would lead us to allow, for continuous girders a system of sections that would involve not only extreme complication of the calculations, but a considerable increase in the weight of the metal; the consequence would be that the arrangement of continuous girders sanctionned by long experience would be abandoned, unless we conclude, on the other hand, that the formula and all the deductions drawn from it lead to inadmissible results.

The erroneous principle, represented by the formula, according to which the admissible limit of working strain should, wherever possible, depend solely on the interval within which the strains oscillate, and might be chosen as much higher as this interval is smaller, contradicts the practice of constructors the laws of elasticity in metals and still more the results published by M. Bauschinger of Munich in 1886, of his experiments with regard to the limits of elasticity in various kinds of iron and steel. Plate-girders strained to 10,000 lbs per square inch (7 kilograms per square millimetre) at the time a train is passing and scarcely to 1,000 lbs per square inch (0.7 per square millimetre) all the rest of the time, will no doubt preserve their elasticity much better than similar girders belonging to structures subjected continuously to the greater strain. This is in fact a general principle for the preservation of the elasticity that can be tested every day with any kind of spring, either by pulling it and then letting it go immediately, or by keeping it constantly stretched.

2. — *Review of the limits at present fixed in various countries.*

We will now quote briefly and in chronological order the limits recently fixed in various countries :

1887. Austria. — The Regulations of the Commerce Department of the 15th of September 1887 fixes these limits for weld iron, according to the span :

(44)						
Spans		0 ft (0 m.)	130 ft (40 m.)	260 ft (80 m.)	390 ft (120 m.)	520 ft (160 m.)
Limits	per square inch	10,000 lbs.	11,100 lbs.	12,000 lbs.	12,500 lbs.	12,800 lbs.
	per square millimetre	(7 kilogr.)	(7.8 kilogr.)	(8.4 kilogr.)	(8.8 kilogr.)	(9 kilogr.)

For intermediate spans, we must proceed by rectilinear interpolation; the abscissae are chosen so that we shall always get the results in round numbers. For the wind, the extreme limit is 14,200 lbs (10 kilograms) in all cases; for the shearing strain, it is 8,500 lbs (6 kilograms) in the case of strains of the same kind, 7,100 lbs (5 kilograms) in the case of strains of opposite kinds.

The ministerial ordinance of the 29th of January 1892 has extended the use of these limits first to Siemens-Martin mild steel. There has not yet been occasion to fix higher limits for exceptional work or very important contracts.

1888. Russia. — The ordinance of the 25th of August 1888, fixes these limits for ingot iron or mild steel according to the span and the parts of the structure as follows :

(45) ACCORDING TO THE SPAN.	GIRDERS.				WIND.				SHEARING FORCE.	
	Chords.		Lattice bars.		Extension.		Compression.			
	Lbs.	Kil.	Lbs.	Kil.	Lbs.	Kil.	Lbs.	Kil.	Lbs.	Kil.
1. Plate girders up to a span of 50 feet (15 mètres) . .	9,250	6.5	...	...	...	...	...	...	5,350	3·75
2. Girders from 50 to 105 feet (15 à 32 mètres)	10,300	7.25	10,300	7·25	12,800	9·0	11,400	8·0	6,050	4·25
3. Girders of more than 105 feet (32 mètres)	11,000	7.75	10,650	7·5	13,500	9·5	12,100	8·5	6,750	4.75

1891. FRANCE. — The ministerial circular of the 29th of August 1891 fixes these limits as follows [1] :

		Weld iron.	Ingot iron. (Mild steel.)
(46)	Main girders up to 98 feet (30 metres). . .	9,250 lbs. (6.5 k.)	12,100 lbs. (8.5 k.)
	Longitudinals and transverses girders. . .	7,800 — (5.5 k.)	10,700 — (7.5 k.)
	Parts subjected to alternate strains. . . .	5,700 — (4 k.)	8,500 — (6 k.)
	Main girders of more than 98 feet (30 metres).	12,100 — (8.5 k.)	16,350 — (11.5 k.)

For the wind we take 1,400 lbs (1 kilogram) more.

1892. ENGLAND. — The Board of Trade in the new regulations keeps generally for steel the limit of 14,600 (10·24 kilograms) fixed in 1882. Consulting Engineers themselves establish the limits which they allow. For the Firth of Forth the general limit has been raised to 16,800 lbs (11·8 kilograms), in consideration of the exceptional metal used. We extract from a specification for steel issued by the famous engineer Benjamin Baker the following :

		According to the span.
47)	Plate girders, main-girders, traverses girders or longitudinals runners	10,080 to 12,300 lbs. (7.09 k. to 8.66 k.)
	Main lattice-girders or truss-girders according to the span and the parts considered .	12,300 to 15,700 lbs. (8.66 k. to 11.02 k.)
		For any span.
	Wind-bracings for all spans	19,000 lbs. (13.38 k.)
	Shearing strain of rivets.	11,200 — (7.88 k.)

For weld iron 9/10 of these values are allowed.

1892. SWITZERLAND. — The regulations of the Federal Government, published August 19th 1892, indicate the formulae :

(48) . . Weld iron . . . . 9,900 lbs (7 k.) $\pm 2. \frac{S_{min}}{S_{max}}$ per square millimetre.

Ingot iron or mild steel . . . 11.375 lbs (8 k.) $\pm 2{\cdot}5 \frac{S_{min}}{S_{max}}$ per square millimetre.

For the wind pressure we reckon 1,420 lbs (*1 kilogram*) more, and for the shearing stress 1/10 less than the quantity resulting from the formulae. These regulations, moreover, contain fixed formulae for compression (*flambage*) by buckling [2].

1892. ITALY. — Up to the present no limits have been fixed uniformly by the Government. For weld iron the old coefficients of 8,530 and 9,950 lbs (6 and

(1) The circular addressed simultaneously to all the prefects, sanctions the employment of certain continuous formulæ for calculating the limits admissible; we do not take them into account as the « regulation » fixes the figures of the text exactly, whereas the formulæ merely indicate them.

(2) A delicate question, which other governments have preferred to leave for further study, considering that the formulæ employed are sufficient for practical purposes.

7 kilograms) are allowed. For the steel bridges constructed by the Mediterranean Railway Company were allowed :.

(49)	For the chords of the main girders	14,200 lbs	(10 k.)
	For the web-bracing of these girders	11,380 —	(8 k.)
	For the uprights over the supports	7,100 —	(5 k.)

1895. GERMANY. — According to a communication from the Public Works Department at Berlin which reached us in February 1895, preparations are now being made to render uniform for the Prussian railways, the limits to be allowed in weld and ingot iron. In Saxony, ten years ago, the formulae (42) known as the Launhardt-Weyrauch formulae were used; then the limits depending both on the moving load and the dead load came into force again. In Bavaria, the formulae known as the Gerber formulae which are very complicated came into use again a few years ago [1].

According to the latest information received from that country before going to press, some new rules are going to be prepared now.

The Bromberg administration (Prussia) allowed in 1892 : —

		Weld iron.	Ingot iron. (Mild steel.)
(50)	For transverse girders and longitudinals . .	8,530 lbs (6 k.)	... ...
	For main girders.	10,660 — (7.5 k.)	... ...
	For wind-pressures	15,650 — (11 k.)	... ...
	For main girders of 423 feet (129 metres) . .	14,220 — (10 k.)	17,070 lbs (12 k.)

The Hanoverian administration (Prussia) allows, for 1895 : —

		Weld iron.	Ingot iron.
(51)	For transverse girders and longitudinals . .	8,530 lbs (6 k.)	9,950 lbs (7 k.)
	For main girders.	10,660 — (7.5 k.)	12,800 — (9 k.)

3. — *The writer's conclusions.*

To sum up, we see that the extreme limits allowed vary for weld iron from 8;500 to 12,800 lbs (6 to 9 kilograms), and for steel from 9,240 to 17,070 lbs (6·5 to 12 kilograms), and even 19,050 lbs (13·4 kilograms) for wind-pressures in very large bridges.

We wished to find out what we could obtain practically by the help of formulae. Taking for S_{min} : S_{max} not the ratio as demanded by the publishers of formulae, *but the ratio of the dead load to the total load*, so as to agree with the great majority of constructors, we find that the formulae would give results that could be accepted,

[1] With regard to this point we refer the reader to pages 112 and 115 of the work already quoted : *Calculs des ponts métalliques*, Paris, Baudry, 1889.

being available for all main-girders. Starting from this point of view, we calculated the ratio S_{min} to S_{max} = R according to the mean value of the weights taken from chapter VI.

According to the scale a of the *heavy-trains*, drawn up in chapter III, we find :

(52) . . . . Comparative table of formulae.

Spans. $S_{min.} : S_{max.} = R$	0' 0 0	33' (10 m.) 0·14	66' (20 m.) 0·22	131' (40 m.) 0·32	197' (60 m.) 0·40	262' (80 m.) 0·48	328' (100 m.) 0 53	394' (120 m.) 0·58	459' (140 m.) 0 62	525' (160 m.) 0.66
	lbs	lbs	lbs	lbs	lbs	lbs	lbs	lbs	lbs	lbs
$8{\cdot}534\left(1+\frac{1}{2}R\right)$. . =	8·534 (6·0)	9·103 (6·4)	9 530 (6·7)	9·956 (7·0)	10·240 (7·2)	10·525 (7·4)	10·809 (7·6)	10·952 (7·7)	11·236 (7·9)	11·378 (8·0)
$9{\cdot}245\left(1+\frac{1}{2}R\right)$. . =	9·245 (6·5)	9·956 (7·0)	10·240 (7·2)	10 667 (7·5)	11·094 (7·8)	11·378 (8·0)	11·663 (8·2)	11·947 (8·4)	12 090 (8·5)	12·374 (8·7)
$9{\cdot}672\left(1+\frac{1}{2}R\right)$. . =	9·672 (6·8)	10·383 (7·3)	10 667 (7·5)	11·236 (7·9)	11·663 (8·2)	12·090 (8·5)	12·374 (8·7)	12·516 (8·8)	12·658 (8·9)	12.800 (9·0)
$9{\cdot}956\left(1+\frac{1}{2}R\right)$. . =	9 956 (7·0)	10·667 (7·5)	11·094 (7·8)	11·520 (8·1)	11·947 (8·4)	12·374 (8·7)	12·658 (8·9)	12·800 (9·0)	13·085 (9·2)	13·227 (9·3)
$11{\cdot}805\left(1+\frac{1}{2}R\right)$. . =	11 805 (8·3)	12 658 (8·9)	13·085 (9·2)	13·654 (9·6)	14·223 (10·0)	14·650 (10·3)	14·934 (10·5)	15·361 (10·8)	15·503 (10·9)	15·645 (11·0)
$12.090\left(1+\frac{1}{2}R\right)$. . =	12·090 (8·5)	12·943 (9·1)	13·370 (9·4)	14·081 (9·9)	14·507 (10·2)	15·076 (10·6)	15·361 (10·8)	15·645 (11·0)	15·930 (11·2)	16.072 (11·3)
$9{\cdot}956 + 2\ R\ (1{\cdot}422)$. =	9·956 (7·0)	10·383 (7·3)	10·525 (7·4)	10·809 (7·6)	11·094 (7·8)	11·378 (8·0)	11·520 (8·1)	11·663 (8·2)	11·663 (8·2)	11.805 (8·3)
$11{\cdot}378 + 2{\cdot}5\,R\,(1422{\cdot}3)$. =	11·378 (8·0)	11·805 (8·3)	12·232 (8·6)	12·516 (8·8)	12·800 (9·0)	13·085 (9·2)	13·227 (9·3)	13.370 (9·4)	13·512 (9·5)	13.654 (9·6)

We have added to this table the two Swiss formulae which are the only ones prescribed by a government. It seems to us that the formulae starting from i_o = 9,672 lbs (6.8 kilograms) for weld iron and from i_o = 11,805 lbs (8.3 kilograms) for mild steel woud be the best for practical purposes.

If we wished afterwards to take into account alternate strains, we should propose to multiply the above results by a suitable factor of reduction. Calling R' the ratio $S_{min} : S_{max}$ in the sense originally assumed (i. e. the ratio < 1 of the greatest absolute values of the alternate strains), we might accept the factor of reduction (1 — $^1/_4$ R') which reduces the limits to three quarters of the above values in the case of complete reversal. With regard to this it will be remembered that according to Professor Bauschinger's very complete experiments, in 1887, if we do not exceed half the limit of elasticity of the metal we shall be perfectly safe as regards alternate strains. Our reduction is therefore more than sufficient, since the coefficients of the table already satisfy the condition stated, which in our opinion should always be respected. Therefore, finally, if formulae must be used, we propose the following: —

(53) . . . For weld iron . . . . $i = (6{\cdot}8)\,(1 + {}^1/_2\,R)\,(1 - {}^1/_4\,R')$ per square mill.
For ingot iron or mild steel $i = (8{\cdot}3)\,(1 + {}^1/_2\,R)\,(1 - {}^1/_4\,R')$ — —

This should give in english tons on the square inch as used in the specifications given by the Board of Trade:

For weld iron . . . . $i = 4{\cdot}3\,(1 + {}^1/_2\,R)\,(1 - {}^1/_4\,R')$
For ingot iron . . . . $i = 5{\cdot}3\,(1 + {}^1/_2\,R)\,(1 - {}^1/_4\,R')$

However, practical engineers almost always prefer, as we have already stated, to allow limits fixed beforehand according to the span and according to the parts considered, which limits they also vary a little according to the quality of the iron at their disposal. We think of course they are quite right.

When the limits are to be prescribed by Government, they must be arranged on as liberal a scale as possible so as to leave a sufficient margin for engineers. In such a case, the authorities might confine themselves to prescribing limits according to the span in the form of the polygonal lines recommended in Austria which are well adapted as comprehensive curves of similar regulations issued non-officially. We should propose: —

(54). . .

Spans	0 ft. (0 m.)	130 ft. (40 m.)	260 ft. (80 m.)	390 ft. (120 m.)	520 ft. (160 m.)	Wind.
Weld iron. .	9·950 (7 k.)	11·100 (7.8 k.)	11·950 (8.4 k.)	12·500 (8.8 k.)	12.800 (9 k.)	14·200 (10 k.)
Ingot iron. .	12·800 (9 k.)	13·950 (9.8 k.)	14·800 (10.4 k.)	15·360 (10.8 k.)	15·650 (11 k.)	17·780 (12.5 k.

with the usual rectilinear interpolations for intermediate spans.

The parts or members where the alternate strains are produced are always constructed (for practical reasons) with larger dimensions than those that would result from the above limits; for this we must depend upon the discernment of engineers, as regards the reduction of the limits working strain for these particular cases.

Lastly, as to the limits for the shearing strain, we might allow 8,530 and 7,100 lbs. (6 and 5 kil.) for weld iron and 9,950 and 7,820 lbs (7 and 5.5 kil.) for steel according as the strains are of the same kind or of several kinds.

We may remark, in conclusion, that when higher limits require to be applied for steel, we must assume unreservedly that this metal exactly fulfils the requirements of the specification. This will occur whenever important contracts are in question, for which the Administration that undertakes the construction is prepared to take special precautions as to the manufacture of the material and the selection of the samples submitted.

When on the other hand unimportant contracts ar in question, concerning structures with short spans scattered along the line, for which the arrangements are often left entirely to the manufacturers, it seems that it would be advisable to be rather more prudent and apply the somewhat lower limits allowed for weld iron.

VI. — Quantity of metal to be used in bridges under different condidions of span and height.

1. — *General remarks.*

When a railroad has been mapped out and it is required to bridge over a wide stream or a deep ravine, the railway engineer must first determine the position of the piers and abutments of the bridge or viaduct to be constructed; he will then have to choose the system of construction best suited for the ironwork spans. As this has often been decided upon beforehand, the position of the piers will have to depend upon it somewhat (continuous girders, arched bridges, and so on). The study of such questions, of a financial interest chiefly, depends mainly on those local circumstances which, in each case, must be taken into consideration by the engineer and although they embrace many technical questions, often very interesting, we cannot discuss them here.

We take therefore as the starting point of the comparisons to be made the data of the problem such as they are laid before the constructor who has to deal with iron bridges. We refer all our weights to the theoretical span measured between the centres of the supports. In certain cases only where one structure embraces several spans and it is either inconvenient or practically impossible to give the weights separately, we take a kind of mean theoretical span for the whole (continuous girders, cantilevers). Our weights do not include the road and the timber flooring. A collection of weights of bridges, similar to that which the writer wished to submit to the Congress, was drawn up in 1879 on the basis of the information then available in France and Austria. The work : *Das Eisenbahnwesen in Frankreich* (Vienna 1880, Gerold's Sohn) distributed among the members of the Congress in Brussels in 1885, contained this first list which referred to 165 bridges with spans of 82 to 540 feet (25 to 165 metres) and a series of short-span types. It consisted of a numerical table giving the most interesting details for each bridge and a graphic table of weights per metre of track.

The writer would have liked to submit the present work under the same form to his colleagues at the fifth session. But the facts arrived somewhat late and they relate to more than a thousand bridges. Under these conditions wich show the special interest taken by our colleagues in this question, we can only regret having been obliged to give up our intention of drawing up the descriptive numerical table for the session. This table, which involves a great deal of work cannot be published until later and for the session we will content ourselves with quoting the larger bridges.

To make up for this unavoidable omission, we have endeavored to render our graphic tables of weights as complete as possible (plates III and IV). Plate IV contains two figures, the larger of which concerns bridges with span of from 0 to 985 feet (300 metres). A second figure on a large scale comprises the small types. Lastly on plate III a third figure represents on a small scale what we should probably get if we could extend our table to the right sufficiently far to take in the span of 1,710 feet (521 metres) of the Forth Bridge.

From all the facts collected, we have constructed two polygonal traces which in our opinion may be considered as fixing the limits of that zone in the table that includes all the bridges that are neither excessively heavy nor excessively light and that correspond to what we have called *the heavy trains* in chapter III. The middle line between these traces, represents the line of mean weights for all spans.

If it was somewhat bold to trace such lines of demarcation, it will appear still bolder of course to extend them to the right so as to take in the Forth Bridge. But our curves are drawn pretty clearly on the table in plate IV for bridges up to 540 feet (165 metres) of span. It was this zone with its width at this point that we wished to prolong up to the Forth Bridge assuming that this bridge approaches the mean line. The completed plan of the New Jersey cantilever bridge, with its central arch of 2,100 feet (640 metres) (to which we shall refer later) furnished us with a second instance of extraordinary spans. This bridge being calculated for six lines of rail, we have assumed that the weight per metre of track might be a little under that which would result from our minimum line. Taking all these considerations into account, we were enebled to extend our curves as shown by the diagrams in plate III and IV (1).

On comparing the present diagram with that of 1879, we shall find that the upper curve has had to be raised considerably especially between spans of 65 and 390 feet (20 to 120 metres).

(1) Our outlines are indicated by weights in round numbers; the abscisses are chosen so that the usual rectilinear interpolation shall always give simple fractions.

2. — *Types of short spans.*

For types of small bridges, we can connect, by straight lines, the points that relate to one and the same Administration and to one system of construction. These lines are fairly regular; thus, representing by Ω Π *H U* the types with the track on the top chord, those with the track below the top chord, those with the track between the main girders and those with the track on the bottom chord, we can quote the typical lines of the following Administrations :

(55)	GERMANY :	Eisenbahn (Direction Bromberg)	Ω Π *H*
	—	— (— Hanover)	*U*
	ENGLAND :	London and North-Western Railway	*H* Ω
	AUSTRALIA :	South Australian Railway	Ω
	AUSTRIA :	Böhmische Westbahn.	Ω Π
	—	Kaiser Ferdinand-Nordbahn	Ω Π *U*
	—	Oesterreichische Staatsbahnen	Ω Π *U*
	—	Oesterr. Ungarische Staatseisenbahngesellschaft .	Ω Π *U*
	FRANCE :	Chemins de fer de l'État.	Ω *H*
	—	Chemins de fer du Midi	Ω *H*
	—	Grande Ceinture de Paris	Ω Π *U*
	—	Chemins de fer du Nord.	*U*
	ITALY :	Strade ferrate della Sicilia	*U*
	PORTUGAL :	Société royale des chemins de fer portugais . .	Ω
	RUSSIA :	Moscou-Brest Railway.	Ω
	SWEDEN :	State Railways	Ω
	SWITZERLAND :	Gotthardbahn	Ω *U* Π

We should have many more of these typical lines to quote, if we took rather earlier collections of types, compiled from the construction of important lines, but these types no longer answer to the present regulations of load. The headings of our table render it unnecessary to explain further these indications of details. We will merely remark that certain comparatively very heavy bridges have an iron flooring.

3. — *Lattice or Truss Girders.*

Our table shows the comparatively light weight of the bridges now in use as compared with the weights of the wellknown large English bridges with plate-girders. Taking for our modern bridges the mean line of the weights of iron found and adding in every case 880 lbs per 3 feet 3 inches (400 kilogrammes per metre) of track, for the flooring and the rails, we calculate the ratio of the dead load q per metre to the total load $(q + p)$ per metre, as follows : (p being taken from scale **a** for *heavy trains*).

(56). Table of the values q, p and $q : (p + q)$ up to $l = 525$ feet (160 metres).

Spans	33' (10 m.)	66' (20 m.)	131' (40 m.)	197' (60 m.)	262' (80 m.)	328' (100 m.)	394' (120 m.)	459' (140 m.)	525' (160 m.)
Weight per feet (per metre) in tons.	0·30 (1·0)	0·43 (1·4)	0·67 (2·2)	0·88 (2·9)	1 10 (3·6)	1·31 (4·3)	1·50 (4·9)	1·68 (5·5)	1 86 (6·1)
With platform (400 kilos) . . $q =$	0·43 (1·4)	0 55 (1·8)	0·80 (2·6)	1·00 (3·3)	1·22 (4·0)	1·43 (4·7)	1·62 (5·[illegible])	1·80 (5·9)	1·98 (6·5)
Scale **a** . . . . $p =$	2·60 (8·5)	1·98 (6·5)	1·71 (5·6)	1·53 (5·0)	1·34 (4·4)	1·25 (4·1)	1·16 (3 8)	1·10 (3·6)	1·04 (3·4)
$p + q$ . . . . $=$	3 03 (9·9)	2 53 (8·3)	2·51 (8·2)	2·53 (8·3)	2 56 (8·4)	2 68 (8·8)	2·78 (9·1)	2·90 (9·5)	3·02 (9·9)
$q : (p + q)$. . . . . $=$	0·14	0·22	0·32	0·40	0·48	0·53	0·58	0·62	0·66

The remarkable fact about this table is that the total load $(p + q)$ is almost invariable. It is 3.03 tons per feet (9.9 tons per metre) for 33 feet (10 metres) of span and also for 525 feet (160 metres), whereas between 66 and 262 feet (20 and 80 metres) it might be taken invariably at 2.53 tons per feet (8.3 tons per metre). On the other hand, the ratio $q : (p + q)$ increases very regularly in proportion to the span.

We will now give, for all spans, the weights of iron per metre of track that represent our polygonal traces of the diagram :

(57). Table of the weights of iron up to $l = 1{,}640$ feet (500 metres) in metric tons per metre track.

Spans	0 m.	33' (10 m.)	164' (50 m.)	328' (100 m.)	656' (200 m.)	984' (300 m.)	1312' (400 m.)	1640' (500 m.)
Maximum weight	0·5	1·4	3·5	5·6	9·0	12·0	14·8	17·5
Mean weight	0·35	1·0	2·6	4·3	7·3	10·1	12·8	15·5
Minimum weight	0·2	0·6	1·7	3·0	5·6	8 2	10·8	13·5

It will be remarked that many points in the graphical table are found to be beyond our limits; by studying these points, we can almost always ascertain the reasons that explain an abnormal weight.

Moreover the consideration of the weight of iron structures alone is not sufficient to influence the choice of a system of construction in each particular case. Structures calculated for the same moving loads with the same coefficients of working strain for the metal, may however, if they belong to very differents systems, offer such advantages or disadvantages that the engineer will often decide to recommend the heaviest system.

4. — *Comparative safety procured by calculations of resistance in bridges.*

The carefully-studied calculations of resistance now applied to designs for iron bridges, for determining the dimensions to be given to all the parts, introduce a very satisfactory element of safety into them; this safety is however very different in the various cases that present themselves, according as the trains in use give more or less the weight, arrangement and extent of the moving loads taken into account in the calculations.

The weight per metre of the moving load depends mainly on the rolling stock in use; the arrangement and the extent of this load, on the contrary, depend much less on the composition and length of the trains than on the system of construction adopted for the bridges. *The usual bridges with one track and with independent spans* are subjected, within a little, at the time each heavy train is passing, to the maximum ot working strain provided for in all their component parts.

Arched bridges with one track, are subjected, when a train passes over them to the maximum working strain provided for only in those parts adjacent to the abutments. The middle part of the arch is only subject to the most unfavorable load when the load is on this part alone, the extremities of the arch not being loaded, or when the middle part is not loaded the extremities being then simultaneously loaded. These conditions, which require that the train should be separated into at least two parts producing the maximum load together or each one separately, are rarely realised.

Continuous girder bridges carrying one track will scarcely ever be subjected in the greater number of their component parts to the maximum working strain provided for; in many cases it would even be extremely difficult to produce, with the rolling stock available, all the combinations as to load provided for theoretically, and it must be evident to every practical engineer, that these hypotheses, only possible in extreme cases, will never be realised under the ordinary conditions of the train service, so far as bridges with large spans are concerned.

As to bridges carrying two tracks constructed with two main girders only of different systems, the probability of the maximum working strain provided for in the metal being realised under normal conditions will be still less, seeing that the crossing of the heaviest kind of trains on these bridges may be looked upon as an event of very rare occurrence.

These explanations will be sufficient to show that among the most common kinds of bridges, those with a double line, constructed with two continuous main girders, offer far greater security than the greater number of those constructed otherwise; we may add that, in consequence of the continuity the ratio of the live and dead loads is considerably lowered, which again increases the safety.

Lastly, amongst bridges with exceptional spans (of more than 525 feet [160 metres]) we may say that cantilever bridges (Forth bridge system) constructed with two main girders for more than one track and calculated, as we explained in chapter III, offer very great security, since the loads provided for, consisting of a certain number of trains placed simultaneously in the most unfavorable position are scarcely ever brought to bear in practice, and further the effect of the loads, generally, is a lower one as regards the dead load.

5. — *Systems of construction to be recommended under various conditions of span and height.*

After having studied the weights indicated for a very large number of structures, often widely different, by collecting all the facts obtained from our colleagues and lastly by profiting by experiments made in Austria for a quarter of a century, we arrive at the following conclusions [1]:

a) *Rolled joists.*

Rolled joists were formerly little used in iron bridges owing to the small variety of sections and the narrowness of the flanges at our disposal. Since pieces of 1 ton and 1 1/2 tons have been able to be rolled without difficulty and since larger sections and wider flanges have been adopted, the use of these joists is getting more and more general, for they form an excellent solution to the problem of main girders for small bridges and of longitudinal stringers for bridges.

In parts subjected to excessive strain, it is very advantageous to be able to introduce as less riveted connections as possible. Thus in Saxony for the last ten years, these joists are specially recommended for small structures when there is not much height available for them and when they are to be used in pairs with wooden stringers between. In Prussia they are in general use large spans. In Austria, the question, which has been carefully studied, is quite decided. Engineers and

[1] Wet regret that we cannot include in what follows the American bridges, especially the pin connected bridges, the American administrations not having answered our appeal.

manufacturers have combined to adopt an excellent scale of sections; we cannot do better than recommend them to our colleagues of other nationalities (1).

b) *Solid-web girders of plates and angles.*

1. — *The types of solid-web girders used by the greater number of Railway Administrations* comprise spans up to 46 feet (14 metres) (in exceptional cases 59 feet [18 metres]). The height of the girders varies from 1/8 to 1/12 of the span; the ratio 1/8 is more generally allowed for smaller spans and the ratio 1/12 for larger spans. This height, moreover is limited in the latter case by the width of the plates supplied by the iron works which is generally 4 feet 7 inches (1·40 metre) at the most (in exceptional cases 5 feet 3 inches [1·60 metre]) and allows of their being used, with the ratio of 1/12 for spans up to 59 and 62 feet (18 and 19 metres).

2. — *Where we have sufficient height at our disposal, bridges with the track on the top chord* (2) *are the most advantageous for all spans.* — The track is laid on wooden cross-sleepers fixed to the main girders and bearing with their ends the outer flooring in countries where wood is cheap (3); where it is not, a track laid upon wooden stringers fixed to the main girders is used; the flooring of the bridge is then laid on these and on outside iron brackets, even on the abutments themselves.

(1) Sections of rolled joints uniformly adopted by engineers and manufacturers in Austria.

HEIGHT.		WIDTH.		MEAN THICKNESS. Flange.		MEAN THICKNESS. Web.		SURFACE of section.		MOMENT of inertia about the neutral axis.	MODULUS of inertia about the neutral axis.	WEIGHT per feet	WEIGHT per met.
Inches.	Mill.	Inches.	Mill.	Inches.	Mill.	Inches.	Mill.	Sq. ins.	Sq. centim.	Fourth power of centimetres.	Cubic centimetres.	Lbs.	Kilog.
7 874	200	3 779	96	0 472	12	0·315	8	5 75	37.12	2402.0	240.2	19.4	28.9
8·661	220	4·016	102	0·512	13	0·354	9	6·82	43.98	3392.2	308.4	22·9	34.3
9·449	240	4·252	108	0·571	14.5	0·374	9.5	7·96	51 37	4730 7	394.2	26·8	40.1
10·236	260	4·488	114	0 611	15.5	0·413	10.5	9·20	59.39	6339.4	487.6	31·0	46.3
11·024	280	4.724	120	0·669	17	0·433	11	10·52	67 86	8429 7	602.1	35·3	52.9
11·811	300	4·960	126	0·709	18	0·472	12	11·94	77 04	10870.2	724.7	40 1	60.1
12·598	320	5·197	132	0·748	19	0·512	13	13·46	86 82	13805.9	862.9	45·2	67.7
13·779	350	5·551	141	0 827	21	0 551	14	15 86	102.34	19455.6	1111 8	53·3	79.8
15·748	400	6·141	156	0 945	24	0·630	16	20·34	131.20	32316.8	1615.8	68·3	102.3
17·716	450	6 732	171	1 063	27	0·709	18	25·36	163.62	50676.7	2252.3	85·1	127.6

(2) For the expressions used here and especially for the track on the top chord and on the bottom chord, see our nomenclature of the Paris Congress in 1889.

(3) This system is not used in France; the rails there are generally laid on longitudinal timbers, and when they are laid upon cross sleepers, the length of these latter scarcely ever exceeds the distance between the girders on which they rest.

3. — *Iron girders are generally recommended only for spans of more than 6 1/2 feet (2 metres), since, for shorter spans than this we can* with advantage use timber beams which then form so to speak part of the permanent way.

4. — *When the available height is limited and the span does not exceed 20 feet (6 metres), bridges composed of twin girders of* section with timber stringers will be more economical; the flooring will, in this case, rest on these stringers, on outside iron brackets and on the abutments themselves.

5. — *When the available height is limited and the span is between 16 and 26 feet (5 and 8 metres), it will be to our advantage to choose bridges with track below the top chord* and the flooring will be laid outside the main girders on special iron brackets. In structures of this kind, even for spans of 26 feet (8 metres), we shall find an available height of 2 feet 4 inches (70 centimetres) sufficient from the underside of the girders to rail level.

6. — *For spans between 26 feet and 46 feet (8 and 14 metres) (in exceptional cases 60 feet [18 metres]) we shall have three types of bridges to consider;* these are the types already mentioned (2 and 5) where the height available for the structure is sufficient, and the *types with the track on the bottom chord,* when the contrary is the case. The track and the flooring are in this last case laid on the cross-girders and longitudinal runners. Structures of this kind, which unfortunately occur very frequently in practice are much heavier and more expensive in consequence of the insufficient available height, than those we first quoted; this is chiefly owing to the long cross-girders required. Howevor, with this system, we do not require more than a height of 2 feet 4 inches (70 centimetres), from the underside of the girders to rail level [1].

7. — *Special main girders for the parapets are to be avoided* as a rule, to save expense, for we can, at less cost, carry the outer flooring on iron brackets and on the abutments themselves For structures with several lines of rail, for those situated at the approaches to stations and where special landings and platforms frequently have to be constructed, we must always allow for the main girders in question and it will then be advisable to calculate them for a minimum moving load of 70 lbs per square foot (340 kilograms per square metre), even when this is not demanded.

c) *Truss and lattice girders in general.*

8. — For spans from 49 to about 115 feet (15 to 35 metres), girders with straight

(1) On the Austrian North Western Lines, the height has been reduced even to 21 inches (54 centimetres), which implies a considerable increase in the quantities of iron required and necessitates exceptional structures which it is best to avoid.

chords and double or quadruple lattice work may be used with advantage. The bracing generally composed of flat bars for parts in tension and of angles for parts in compression, should be connected as far as possible directly with the vertical plates of the chords (of T section) as the use of special gusset plates at the connections does not appear to be economical. It will be well to endeavour to find connections known as symmetrical, that is to say where the rivets are in doubles shear. The most economical bridges are those with track upon top chord placed on cross sleepers forming brackets where the main girders, spaced at from 5 to 8 feet (1·50 to 2·50 metres) from one solid structure with the cross girders and diagonal bracing. In countries where wood is dear, stringers are used and the parapets are fixed on iron brackets. When the available height of the structure is limited bridges with track below top chord or with track on bottom chord are built; the latter are always materially heavier than those with track upon top chord (1).

9. — For spans of from about 115 to 150 feet (35 to 45 millimetres) there would still be an advantage in constructing bridges with straight chords, and double or quadruple lattice bracing or a double truss system with diagonal ties can be used. In France for spans of this extent sextuple lattice bracing, in which the diagonal ties are made of flat bars and the diagonal struts of ⊏ bars and rivets are working in single shear has been frequently recommended. The rivets at the connections are in single shear.

The same principles of construction as hitherto may, however, be recommended in this case : direct connection of diagonal to chords arranged as far as possible so as to have the rivets in double shear and so as to avoid the special gusset plates and packings; amongst these latter we do not include the very useful rectangular plates which in Austria are inserted where the diagonals struts are connected with the chords in order to increase the stiffness and distribute the pressure (2).

(1) The structures on the single truss system with diagonals ties built for many spans in Austria and Germany are not recommended; they had been calculated without taking secondary effect into consideration and by this means comparatively light bridges were obtained. The damages subsequently discovered in some of the bridges, the accident to the bridge on the Itter near Hopfgarten, which gave way under a passing goods train in 1886 and many other facts, have fully confirmed the objections raised against these structures and railway companies have long since decided to abandon that system.

(2) The connections between the diagonals and the chords constitute the weak points in our modern open lattice bridges in which our calculations of resistance are inadequate. Secondary strains are doubtless produced in these which give rise to a considerable excess of working strain in certain parts. In quadruple and sextuple lattice systems these disadvantages are certainly far less.

As to the distance which should be allowed between the main girders for the purposes of stability, even in the case of bridges with track upon top chord, this involves the necessity of admitting transverse girders; under these conditions a track below top chord arrangement is almost always adopted because in this way without materially increasing the cost of construction the maintenance is much facilitated. These structures when properly braced transversely and diagonally are very rigid and are very much lighter than structures of the same span with track on bottom chord; these latter require more iron both for the long cross girders and for the gussets which connect them with the uprights and which serve to keep the upper chords in horizontal position. This excess weight, however, has a tendency to disappear in proportion as the span is increased.

10. — *For spans of about 148 to 180 feet (45 to 55 metres), bridges with track on bottom chord* present certain structural difficulties because, owing to the clear height to be left for the passage of the rolling stock ([1]), the main girders must either be comparatively very high so as to be braced over the top, or else comparatively very shallow in order to have sufficient lateral stiffness. To overcome this difficulty bow string girders have often been used in which the upper bracing only extends along a certain length near the middle of the span. These bow string girders are usually made with a double truss system of diagonal ties or even of recent date with two systems symmetrically arranged and with common vertical uprights. As regards bridges with track upon to chord of the spans under discussion, we might repeat what we have said in n° 9 for smaller spans.

11. — *For spans of from about 180 to 260 feet (55 to 80 metres)* we have to use almost as much iron for bridges with track upon top chord as for bridges with track upon bottom chord. The former arrangement is always deserving of the preference provided the prescribed conditions of height allow of its adoption; the latter however is the one which, in practice, we are most frequently compelled to adopt. In either case the uper chords as well as the lower chords must be firmly connected.

For double track bridges it is desirable not to use more than two main girders and long cross girders rather than two separate structures; in that case the girders must be built with double chords (upper chords of channel section). For single track bridges single chords as well as double chords are used, the former arrrangement, however, would always seem to be the more economical when large-sized angle irons are available.

([1]) In Austria and on the lines of the « Verein D. E. V. » this height is restricted to 15 feet 9 inches (4·80 metres).

Lastly, as regards the form of the main girders for these bridges, straight chord girders with 4 or 6 systems of lattice bracing of with a double system of diagonal ties can be placed parallel with bow string girders having almost always a double system of diagonal ties. It would seem, however, that up to a span of about 230 feet (70 metres) the use of straight chord girders is always economical (1), particularly if they can be utilised as continuous girders; we may add that straight girders also offer undisputed advantages as regards maintenance and to any impartial observer they present a more agreeable ensemble.

12. — *For spans of from 260 to about 390 feet (80 to 120 metres)* the best bridges (which have generally the track on bottom chord) appear to be those built with curved upper chords and with a double or triple system of diagonal ties. In the case of such large spans it is customary to construct the top chords of (⊐⊏) section and the lower chords in the form of twin chords (⊥ ⊥). These bridges, which are very numerous in Austria, in Holland and in Germany, can scarcely be termed bow string and generally have (or ought to have) vertical uprights on supports sufficiently high to permit of the main girders being braced over the top.

Finally, we may regard these structures as something between the bow string and the straight girder, somewhat more nearly approaching the latter system (2), and having in its favor the advantage which is obtained in the case of such spans as these by increasing the height of the girders in the middle region of the span rather than simply strengthening the chords there.

The difficulties occasioned in smaller spans by the vertical plates of the chords

(1) This also appears to be accepted in France where straight girders have hitherto been almost exclusively made for spans of this extent. In Holland a higher practical limit seems to have been formerly accepted, but it was subsequently reduced to about 210 feet. See the pamphlet entitled : *Les travaux publics dans le royaume des Pays-Bas*, by L.-C. van Kerkwyk, the Haye, 1878, and the *Annales des ponts et chaussées*, March 1887.

(2) The French term *poutres à bande courbe* (girders with curved chords) would probably be the most general description of this system; the curved chord may be parabolic, circular, eliptic or of any other form without materially affecting the resistance to bending or even the calculations to be used; hence also the terms « parabolic girders » or « semi-parabolic girders » used by certain authors may be regarded as generally improper.

Nor do these girders absolutely present the distinctive characteristics of the parabolic (bowstring) girders properly so-called, that is to say almost constant sections of chords, identical sections of all the vertical uprights, almost equivalent sections for all diagonals and counter-braced diagonal system (*Gegenstreben*) extending over the whole span.

are no longer of the same importance in this case where between two consecutive rivetted connections these plates are of such lengths (from 13 to 20 feet [4 to 6 metres]) and of such weights that they can be generally obtained from the iron works, and there would be consequently no necessity to cut them or shape them into the form of a polygon.

Where the track is on the top chord we have the alternative of adopting straight upper and lower chords or of giving the lower chords a curved form (fishbellied) to the detriment of the general appearance of the work and often also at the expense of economy. Therefore, the former course is generally preferable.

13. *For spans of from 395 to 525 feet (120 to 160 metres)*, the experiments already made have been carried out at such different periods and with regard to too limited a number of bridges for it to be possible to deduce any general principles concerning the system to be recommended, according to the present ideas of engineers. It may, however, be stated that the bridges recently constructed are comparatively much lighter than similar bridges constructed with solid web plates or with close lattice work, ever since the origine of iron bridges.

It appears that the great span at Kuilenbourg of about 507 feet (154.5 metres) is the one where the system of independent girders with curved chords has been carried as far as possible. The large structures erected since then in America near Poughkeepsie, Memphis, etc., as also those at Cernawoda, in Roumania, were designed on the cantilever or bracket girder system whereby a notable saving is effected, particularly in the spans including the cantilevers. As the eminent engineers of the Forth bridge have very justly observed the system is not new, and the only novelty is that it has been recently applied to very large spans; this, however, does not prevent us from admiring their work at a period when nothing similar has yet been produced.

It is interesting to note that this cantilever system leads generally to the introduction in the same structure of a neighbouring unequal span. The cantilever arches with large spans are those whose weight per foot is the least, whereas the masses of metal are mare collectrd on the small adjoining spans. In the Forth bridge these small and heavier spans have been reduced to a minimum which can, to some extent, appear to be a system of twin piers. In the Poughkeepsie, Memphis and Cernawoda bridges these spans have been made much larger and are, comparatively speaking, heavy.

It is also remarkable that the idea of cantilevers in the United States adapts itself very well to the system of pin connected bridges very much in vogue in the new world, as this system allows of the central independent structure being suspended from the adjacent cantilevers without any accessory support, by taking advantage of the expansion arrangement. The great bridge of Memphis of 790 feet (241 metres) span is built on this system (1).

The above remarks refer generally to railway bridges in the open country. When we have to bridge over a deep ravine in solid rock, the arched bridge is that which at once suggests itself. Arched bridges are also advantageous at the entrance of large towns where it is desirable to impart a pleasing aspect to the structures. This system of construction has been overlooked in many cases where it would have effected a material saving in the cost of construction. We have nevertheless two remarkable examples of Austrian arched bridges with rigid spandrels quite recently constructed; we have the district railway bridge over the Danube canal at Vienna with a span of 228 feet (69.6 metres) and the road bridge with a span of about 200 feet (60 metres) constructed on the road from Cles to Dermullo (South Tirol), over the Noce Gorge which is 452 feet (138 metres) deep (2).

In France there are numerous and varied examples of arched bridges; among the more recent we may mention the Erdre bridge, of 312 feet (95 metres) span; the Nantes bridge consisting of five arches with a span of 200 feet (61 metres), the steel bridge at Rouen with three arches, spans 131 feet, 160 feet and 179 feet (40, 48.8 and 54.6 metres), moreover lastly, the Garabit viaduct, the great arch of which has a span of 540 feet (165 metres), the height of the rail level being 400 feet (122 metres) above the level of the valley of Truyère.

The Viaur bridge on the line from Carmaux to Rodez built erected just now for the French State with a single track below top chord by the Société de construction des Batignolles, carries the line at a height of 383 feet (116.8 metres) above low water mark, by means of a central arch of 820 feet (250 metres) span. This structure which looks like a rigid spandrel arch with three pin connections (on piers

(1) See *The Memphis bridge*, by Geo. S. Morrison, chief engineer, New-York, John Wilay and Sons, 1893. The illustrious engineer who is an authority in the United States has courteously favored us with all the particulars respecting this interesting bridge. See our diagram.

(2) The arch bridge built in 1884 for the District Railway has a versine of 20 feet 9 inches (6·327 metres) which in the span of 228 feet (69·60 metres) gives a rise of 1 : 10.9; this bridge consists of four iron arches carrying two tracks; the dead load on each arch is 1,000 lbs per feet (1,500 kilograms per metre) run. The road bridge over the Noce built in 1888 has a versine of 33 feet (10 metres) which in the span of 198 feet (60 metres) gives a rise of 1 : 6. The roadway is 20 feet (6 metres) wide, it consists of a layer of timber 6 inches (15 centimetres) thick and rests on two arches simply, each of which has a dead load of 600 lbs per feet (900 kilograms per metre) run of arch. The two bridges have trussed spandrels *and have jointed abutments.*

and middle of span in reality represents a combination of this system with the system of cantilevers which are here in the direction of the banks.

In Germany two arched bridges have recently been erected without rigid spandrels, over the Baltic canal (Nord-Ostsee Canal), one near Grünenthal in 1891 with 513 feet (156·5 metres) span for the West-Holstein railway, the other near Levensau, in 1884, with a span of 535 feet (163·4 metres) for the line from Kiel to Eckernförde.

15. — Eminent engineers in both hemispheres have frequently discussed the problem of the largest spans which it would be possible to attain with iron structures. Ever since 1879 a rigid bridge to connect the city of New-York with Long Island and for which an arch of 754 feet (230 metres) was admitted as a principle, has been under discussion (1). As the works in the Forth Bridge in the course of their execution demonstrated the possibility of rigid spans of 1,710 feet (521 metres), whereas the celebrated suspension bridge known as the East-River Bridge, connecting New-York and Brooklyn, had only a span of 1,595 feet (486·2 metres), engineers again turned their whole attention to rigid spans. The universal exhibition in Paris in 1889 contained several plans for bridges intended to connect France with England by means of rigid spans of from 1,970 to 2,300 feet long (600 to 700 metres) (2). In America where engineers recommend pin-connected bridges and suspension bridges it has always been recognised that suspension bridges are preferable for very large spans (3).

At the time we are preparing this report we are informed of the important transactions which have just taken place (4) in New-York respecting a bridge of immense span (the largest in the world) which is to be built over the Hudson river to connect New-York and New-Jersey over the docks on the two banks, starting between streets Nº 59 and 69 on the New-York side.

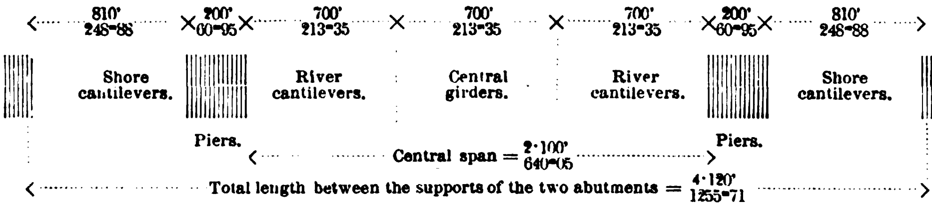
(1) See the sketches and the result of this competition in *Zeitschrift des Archit.- und Ingenieur-Vereines zu Hannover*, part 2, from 1879.

(2) We cannot help regretting that engineers of such high standing in bridge work should have associated their names with such a scheme, which from a practical point of view can only be described as utopian, whereas the tunnel scheme prepared ever since 1878 was certainly more practicable.

(3) Refer to the pamphlet *Report of Board of Engineer Officers as to maximum span practicable for suspension bridges*, Maj. C.-W. Raymond, Cap. W.-H. Bixby, Cap. E. Burr. Washington Government printing office, 1894. The authors believe in a possible span of 4,335 feet (1,331 metres) for suspension bridges; they admit a width sufficient to take 6 tracks.

(4) *New-York Herald*, Wednesday, 3rd December 1894. — *Yorker Staats-Zeitung*, 14 to 15th December 1894. This paper under the titles of « No pillar in the river » and « How nice it would have been » gives a detailed history ofthe transactions which preceded the decisions arrived at.

A limited company was established in New-York under the tittle of « The New-York & New-Jersey Bridge Company ». On the basis of a fully worked-out plan this company entered into a contract with the Union Bridge Company at New-York, Broadway N° 1 to construct a bridge on the cantilever system with two large double piers 3 spans given by the following is the diagram :



This scheme prepared for a width sufficient for six railway tracks would according to the particulars which have been officially communicated to us necessitate a total weight of iron work of 106,685 metric tons (1). The plan was submitted to the United States Congress and was sanctioned by vote of the Assembly on the 7th of June 1894, but President Cleveland after careful examination of the question vetoed it, particularly owing to the fact that a pier placed in the centre of the river might create a serious obstacle to navigation. A special commission was appointed to study the possibility of bridging over the river with a single span on the suspension bridge system. Colonel Lamont, secretary for War, had the same question under consideration and on the 4th of December 1894 he decided that the bridge should be thrown across the river in a single span of 3,200 feet (975.30 metres), such a suspension bridge being not only practicable but also admissible from an economical point of view as the total expenses would not exceed 23,000,000 dollars (115,000,000 francs), the interest on which would be covered by the probable traffic.

At the moment of going to press we have received the extremely interesting pamphlet on this matter entitled the « Report of Board of Engineers on New-York and New-Jersey Bridge », containing not only the report of the commission entrusted with the surveys and the comparison of the alternative proposals, but also a large number of tables, sketches and calculations (2).

(1) This would make about 15.68 tons per metre of track for 3,720 feet (1,133.80 metres) being the total of the free spans.

(2) The report was dated the 23rd August 1894 and the pamphlet bears the inscription *Washington Government printing office*, 1894. The members of the committee are : G. Bouscaren, W.-H. Burr, Theodore Cooper, Geo. S. Morison, C.-W. Raymond. The annexes refer mostly to plans for suspension bridges proposed by G.-H. Schwab, W. Hildenbrand, G. Lindenthal and others, as also the cantilever project by C. Macdonald of the Union Bridge Company.

The conclusions of the report comprise some remarkable results : the cost of a single span of 3,100 feet (944.90 metres) amounting to double the cost of the bridge of smaller spans, such a plan appears impracticable; the cost of the large span calculated on the suspension bridge system does not exceed the cost of the smaller spans by more than a third at most; this plan is not an impracticable one. We have already stated that it has been decided to bridge over the river with a single span of 3,200 feet (975.30 metres) which will be the largest in the world.

VII. — Resolutions proposed for question IV-A.

The quantities of iron used or to be used for the construction of iron bridges are extremely variable, even apart from the conditions of span and height imposed on the engineer by local circumstances. For bridges of the same span the quantity of metal per metre of track varies so much that sometimes twice as much is required in one case as in the other, according to the prescribed loads, the limits of internal working-strain assigned to the various parts, the system of construction adopted and particularly according to the engineer who draws up the plans.

Besides, the general formulæ frequently submitted on the basis of very logical considerations for the purpose of calculating beforehand the weight of a bridge, are almost always defective. It is far preferable to prepare a statement of weights of a large number of bridges in existence and to proceed by way of comparison.

The tables drawn up by the author might render useful service for this purpose. Nevertheless, the most efficacious comparison each engineer can make is that which is the outcome of his own designs.

2. — The loads prescribed, as regards rolling stock, are of greater importance for bridges of small span in which such loads are of far greater moment than dead weights and wind pressure. It is the inverse in the case of bridges of large span and when this amounts to about 330 feet (100 metres) and certainly when it exceeds 390 feet (120 metres) it is the two last influences which play the most important part in the calculations of resistances which, in the case of exceptional spans, often assume an unexpected form.

Thus in the great arches of the bridge with 1,710 feet (521 metres) of span our illustrious colleagues Sir John Fowler and Benjamin Baker, who prepared the plans, state that the load of two heavy coal trains does not exceed 5 p. c. of the dead weight.

3. — It should be recommended, if not in every country, at least in every great railway system, to study carefully the effects of the load, produced by the rolling

stock in use, in order to deduce therefrom the rules for loads applicable to iron bridges, either already constructed or about to be erected.

These rules might be issued either in the form of typical train loads or in the form of two scales of loads uniformly distributed (per meter) per foot of track, one referring to the bending strains and the other to the shearing strains, both being applicable to all ordinary bridges, provided that the length of the track loaded is always taken as a basis.

In the former system it is desirable always to consider at least two typical trains representing the two extremes of the traffic, that is to say an express train with the heaviest axle loads, the heaviest engine and the heaviest tender, and a proportionate train of carriages, then a goods train with engine having heavily loaded and numerous axles close together, an ample tender and a long train of wagons or trucks of the heaviest kind. We should, of course, admit the maximum effects of load resulting from either of these trains, if we assume them to be placed in the most unfavourable positions.

The latter system is one to which engineers will most frequently have recourse in order to work out current calculations, even when the moving loads have been prescribed under the form of typical trains. Instead of recommencing the study of these trains for each bridge plan or even of introducing them effectively into the calculations of resistance it *is much more advantageous to make this calculation once for all* and to prepare the scales of uniform equivalent loads which may afterwards be at once applied to all spans or lengths loaded without having to make a fresh calculation.

Important progress has been effected in this kind of calculation especially by introducing the principle of lengths loaded serving as a basis for the scale of loads and by extending the use thereof to the calculations of transverse girders and longitudinal stringers.

4. — The Congress is of opinion that for the last ten years the weight of locomotives, tenders and waggons has materially increased through almost the whole of Europe and especially in the United States of America. The author has submitted to the Congress a complete plan of load regulations which would suffice to meet the requirements of the heaviest trains now running on the largest lines where the traffic is greatest both in Europe as well as in the United States. He distinguishes between two groups of lines on which run extra-heavy trains or simply heavy trains and for the two cases he submits his regulations either under the form of typical trains or under the form of scales of uniform equivalent loads.

By comparing these scales with the regulations recently published in various countries it will be recognised that they are not exaggerated and that even as regards extra-heavy trains they have already been exceeded by recent specifications. It would seem desirable that the permanent way and the bridges on large international lines should be of sufficient resistance for heavy trains by assuming the maximum axle load, at any rate, being comprised at least as between 14 and 15 tons [1].

5. — The Congress is of opinion that the use of ingot iron (or mild steel) for bridges is greatly extending, whereas the use of weld iron (or wrought iron) is becoming more rare. Opinions are generally agreed now as regards the qualities of hardness of the steel to be recommended for bridges; it should have about 25 p. c. of elongation for an ultimate tensile strain of at least 56,900 lbs per square inch (40 kilograms per square millimetre). However, in the case of bridges of exceptional span a harder metal should be sought, according to the greater care taken in the manufacture the choice of the materials used and the method of erection.

In the former case, that is for ordinary work, we might admit, as in the case of weld-iron, the limits of working-strain from 8,500 to 12,800 lbs per square inch (6 to 9 kilograms per square millimetre) for the metal, whereas for exceptionally large main-girders these limits may be increased to from 11,400 to 17,100 lbs per square inch (8 to 12 kilograms per square millimetre) with about one-eighth more for wind pressure. It is desirable in all cases that the working-strain allowed shall never exceed half the limit of elasticity of the metal used; in the case of alternating strains it is even well to still further slightly reduce this limit.

6. — As to the action of the wind on bridges it is agreed almost on all hands to adopt the co-efficients specified by English engineers about 1881 [2].

However, continental engineers in both hemispheres have somewhat modified these regulations by admitting that a pressure of 35 lbs per square foot (170 kilograms per square metre) is sufficient so long as trains are able to run, whereas the traffic would of necessity be interrupted by a wind pressure equal to 55 lbs per square foot (270 kilograms per square metre).

7. — As regards bridges properly constructed in accordance with the conditions

(1) This is in accordance with the vote of the Congress at the 4th session of Saint-Petersburg in 1892, which vote admitted two vehicles each with 4 axles of 14 tons separated by a distance of 4 feet (1.20 metre). It should merely be added that the total wheel-base to be taken into consideration is about 16 feet (4.80 metres) and the 2 locomotives should be taken as placed head to head.

(2) *Report of the committee appointed to consider the question of windpressure on railway structures.* London, 1881. G. Edw. Eyre and Spottiswoode.

laid down above it appears to follow from the investigations of the author covering the weights of more than 1,000 structures supplied by the railway departments that the quantities of metal to be used in bridges are about as follows (1) :

Spans		0' (0 m.)	33' (10 m.)	164' (50 m.)	328' (100 m.)	656' (200 m.)	984' (300 m.)	1312' (400 m.)	1640' (500 m.)
		Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Weight per metre of track	Minimum	0·2	0·6	1·7	3·0	5·6	8·2	10·8	13·5
	Medium	0·35	1·0	2·6	4·3	7·3	10·1	12·8	15·5
	Maximum	0·5	1 4	3 5	5·6	9·0	12·0	14·8	17·5

The weights indicated however cannot be regarded as justified by present practice except up to spans of 660 feet (200 metres) or thereabouts owing to a want of a sufficient number of examples of bridges of larger span.

8. — Lastly the Congress considers that it would be useful to study in the various countries whether the increasing loads imposed on the permanent way by the ever-increasing weight of the rolling stock used in the traction service are properly warranted by the advantages which they confer.

This investigation applies particularly to the permanent way and to iron bridges of a medium span, the reconstruction of which, while the line is still being worked, gives rise to inconveniences and to considerable expenditure. As regards iron bridges of small span their renewal can easily be effected by pushing them on from the side between the passage of two trains. As regards iron structures of very long span, reconstructions or renewals can hardly ever be carried out (Conway, Britannia, Saltash) on account of the unimportant part which the moving loads play in them. But as regards all kinds of structures comprised between these extremes as well as regards the permanent way, the investigations in question is of very considerable importance.

Resolution proposed for question IV-B.

That the initial and periodical test loads applied in almost all countries for iron railway bridges are indispensable; they constitute a guarantee of safety to which the travelling public and the railway staff are entitled. Nevertheless, the favorable results furnished by these tests are simply for the guidance of the engineers. They do not in any way supersede the necessity for careful inspection and maintenance of all the component parts of each structure.

(1) This scale admits, for intermediate spans, the usual rectilinear interpolation. The weights named do not include the permanent way and the timber flooring.

APPENDIX 1.

Order of the Imperial Royal Ministry of Commerce (Austria) of 15th September 1887, concerning the safeguards to be observed in regard to Railway Bridges, Bridges passing over Railways and Road Approach Bridges.

According to the Regulations regarding Railway working (decreed 16th November 1851, the following rules hold good :

(A). — Projected Railway Bridges.

§ 1. — *Presentation of schemes.*

The scheme for proposed Railway-Bridges must, before work is commenced, be submitted to the Ministry of Commerce for approval.

The scheme must contain :

(a). A general plan of the Bridge on a scale of 1 : 1,000 — also general and detailed plans of the piers on a scale of 1 : 100, and further a plan of the distribution of the various materials, a general and detailed plan of the superstructure, the latter being on a scale of 1 : 10 (for certain details separately shown a scale of 1 : 15 or 1 : 20 may be used). The materials used to be specified on the plans, both as regards quality and dimensions with a view to calculated resistance.

(b). Information as to the weight of the structure (permanent load).

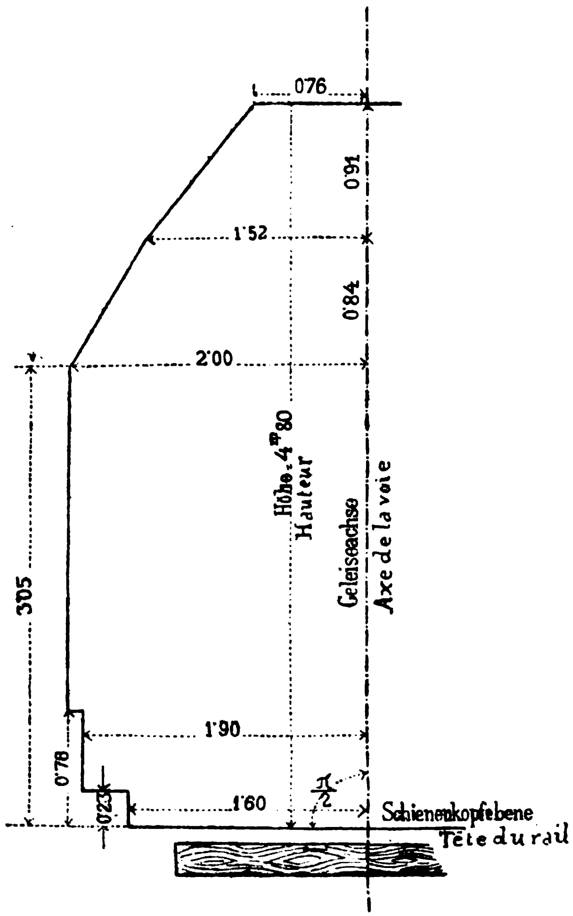
(c). The calculations by which the dimensions are obtained; and for local and industrial lines a report is to be added of the load-effects produced by the heaviest rolling-stock used thereon.

(d). For bridges of over 22 yards (20 metres) span or of unusual system or form of construction, a calculation of the peculiar deflection produced by the live load.

§ 2. — *Clear space on Bridges.*

The bridge must be arranged of such width, that both in the case where the line is carried on the top chord of the girders or where it is carried below there is a distance of at least 7 feet (2.15 metres) between the gauge axis, and the nearest hand-rail or outer edge of the platform. In the case of when the line is carried on the top chords of main girders, or laid betwen the latter there must be the same clearance between the gauge-axis and the booms or the diagonals, to a height of 6 feet 6 $^1/_2$ inches (2 metres) above the platform.

The clearance to the uprights or vertical bracing bars may be reduced, but as regards this and the clearance in all directions not previously mentioned the following profile holds good :



Explanation : Hauteur = height, 4m80 = 15' 7". Axe de la voie = Axis of gauge. Tête du rail = Rail level. 0m76 = 2' 6". 1m52 = 5' 0". 1m90 = 6'3" 1m60 = 5'3". 3m05 = 10' 0". 0m76 = 2' 6". 0m23 = 9".

§ 3. — *Loads.*

The loads to be allowed for in calculating stresses are the weight of the structure itself (permanent load) and the occasional loads due to rolling stock (live load).

The effects of wind pressure must also be taken into account and, when necessary for the superstructure, the alteration of temperature. For reckoning loads the following tables are to be used :

(*a*). To calculate the truss-booms, assuming the bridge to be of the usual type with free supported girders and the load equally distributed over the whole span, reckoned from the centres of the supports, the following table is to serve as standard for each track :

Table a.

SPAN.		LIVE-LOAD		SPAN.		LIVE-LOAD.		SPAN.		LIVE-LOAD.	
Metres.	Feet.	Tons (km.)	English tons.	Metres.	Feet.	Tons (km.)	English tons.	Metres.	Feet.	Tons (km.)	English tons.
1·0	3·3	30	29·7	5	16·5	11·5	11·31	40	131	5·6	5·52
1·5	4·93	20	19·8	10	33·0	8·5	8·4	80	262	4·4	4·36
2·0	6·55	15	14·85	15	49·5	7·0	6·92	120	395	3 8	3·77
2·5	8·2	13·5	12·98	20	65·5	6·5	6·42	160	525	3·4	3·37

For intermediate spans rectilinear interpolation is to be made use of.

(*b*). For calculating the bracing of the main-girders for each cross-section of a bridge, the greatest shearing stress, in one direction or the other, due to the live-load is so determined by considering the load only between the section in question and the corresponding abutment. This load is to be reckoned for each metre of length loaded, independently of the span, according to the following table :

Table b.

LENGTH OF LOADED PART.		LOAD ON LOADED PART.		LENGTH OF LOADED PART.		LOAD ON LOADED PART.		LENGTH OF LOADED PART.		LOAD ON LOADED PART.	
Metres.	Feet.	Tonnes per m.	Tons per feet.	Metres.	Feet.	Tonnes per m.	Tons per feet.	Metres.	Feet.	Tonnes per m.	Tons per feet.
1·0	3.3	30	9.69	5	16.5	14·0	4.52	40	131	6·2	2 00
1·5	5.0	25	8.075	10	33.0	10 0	3.23	80	262	4·8	1 55
2·0	6.5	20	6.46	15	49.5	8·5	2.74	120	395	4·0	1.29
2·5	8.2	18	5.81	20	65.5	7·6	2.45	160	525	3.5	1.13

For intermediate loaded lengths a rectilinear interpolation is to be made use of.

(*c*). For calculating the booms of continuous girders resting on more than two supports, loads are to be reckoned on according to table a, at the same time taking into account the load-combinations which produce the greatest bending-moments.

For calculating the bracing of the above, within the opening considered, the live-loads are to be reckoned by table b; but for the simultaneous effects on the above opening, of loads peated on other openings, table a is to be used.

(*d*). For other forms of construction than those contemplated in (*a*), (*b*), and (*c*), (viz : suspended or abutted systems arched bridges, anchored girders, etc.), when the simple application of tables

A kilometric ton = 19 cwt. 2 qrs. 23 lbs. The difference is so slight that it has not been thought necessary in this paper to work out the kilometric tons to their exact English equivalent, except in special cases.

a and **b** is not admissible, such train-loads are to be chosen, as correspond approximately to the loads given for bridges of usual form, and for this the following data are admissible :

The train-load is to be considered as consisting of 3, eight-wheeled locomotives each of 12 feet (3.6 metres) total wheel-base and 29.6 feet (9.5 metres) total length, together with their six-wheeled tenders each having a total wheel-base of 10 feet (3 metres) and 20.4 feet (6.1 metres) total length, together with the necessary number of 4 wheeled wagons each with a wheel-base of 10 feet (3 metres) and total length of 26 feet (7 metres), and the loads on each axle are to be taken as : Locomotives 13 tons, tenders 10 tons, and wagons 8 tons.

In the case of small spans, the load-effect of the train is increased, being reckoned on the basis of a load on each axle of 14 tons; in the case of very large spans it may, however, be somewhat reduced in view of the probability that the loads on all the axles and the distances, between them will not simultaneously happen to be in the most unfavourable combination.

(*e*). In calculating intermediate cross girders, the live load is to be taken (according to table **a**), as half the total load on a bridge, whose span is equal to the distance between the two cross girders on each side of the one under consideration.

End cross-girders can be reckoned by the same rule, by assuming an imaginary support of the track at suitable distances beyond them, as substitutes for the omitted neighbouring cross-girders.

The rail-bearers are to be considered in the same way as main-girders supported on cross-girders.

(*f*). The wind-effect is to be found by reckoning either on a pressure of 53 : 3 lbs. per square foot (270 kilogrammes per metre) on an unloaded bridge or a pressure of 35 lbs per square foot (170 kilogrammes per metre) on a loaded bridge; whichever of the above two conditions gives the most unfavourable result, is the one to be taken into account, thus : —

(1). For an unloaded bridge the whole surface exposed to the action of the wind on the windward side is to be taken into account; the surface exposed on the corresponding side of the other girder is found in the same manner and then reckoned by making a reduction according to the following table :

In the case of a loaded bridge the train is to be regarded as a continuous rectangle 8.25 feet (2.5 metres) high and 1.65 ft. (0.5 metres) above the rails. The total exposed surface is the surface of the train added to the surface of the windward girder not occupied by the train and to the corresponding area of the other girder reduced according to the table :

Table

FOR FINDING THE EFFECTIVELY EXPOSED SURFACE ON THE 2ND (LEE SIDE) GIRDER.

Proportion of area of Openings to total area of one side.	Proportionate Reduced area of the second (lee side) girder.
0·40	0·2
0·60	0·4
0·80	1·0

For intermediate values a rectilinear interpolation is to be made use of.

(*g*). In case the method of construction entails internal stresses owing to change of temperature (for example arched bridges, continuous girders on high iron supports, etc.), such stresses must, of course, be taken into account.

The dynamic effects due to the condition of the line and the permissible speeds are also to be taken into account.

In systems of construction where there is no elastic medium to moderate the shock due to rolling stock, an addition of 10 p. c. must be made to the live-load considered.

(*h*). In the case of local and industrial lines, which are of standard gauge on which the heavy eight-wheeled locomotives do not run, the loads mentioned in (*a*) and (*b*) are to be reduced in the following manner :

(1). A reduction of 20 p. c. for those lines where the bridges are not subject to a greater load than that of 6 wheeled locomotives with 12 tons weight on each axle, 4 feet (1.2 metres) distance between axle-centres and 25 1/4 feet (7.7 metres) total length; together with their 6 wheeled tenders of 25 tons total weight and 20.7 feet (6.3 metres) total length.

(2). A reduction of 40 p. c., when the bridges are not subject to a greater load than that of 6 wheeled tank-engines, of 8.5 tons weight on each axle, 3.6 feet (1.1 metre) distance between axle centres and 23.7 feet (7.2 metres) total length.

§ 4. — *Stresses.*

The loads and stresses specified in § 3; (*a*), (*b*), (*c*), (*d*), (*e*), (*g*), (*h*), together with the permanent load (weight of structure), should not produce any greater strains on the effective cross-section (allowing for rivet-holes and ineffective portions) per square centimetre, than as follows :

(*a*). For wrought iron (tension, compression and shearing).

(1). Under 132 feet (40 metres) span, 4.45 tons per square inch (700 kilogrammes) increased by 2 kilograms for each metre increase of span;

(2). Above 132 feet (40 metres):

For 132 feet (40 metres) . .	4.95 tons per square inch	(780 kilog. per square centimetre).
— 264 — (80 —) . .	5.2 — — —	(840 — — — .
— 395 — (120 —) . . .	5.59 — — —	(880 — — — . .
— 527 — (160 — and above).	5.72 — — —	(900 — — — .

intermediate spans being reckoned by means of rectilinear interpolations.

The cross girders and longitudinal beams are to be reckoned according to their span, as above.

(3). For calculating strength of rivets (as regards shearing) : in one direction only, 3.8 tons per square inch (600 kilogrammes) but when in several directions 3.17 tons per square inch (500 kilogrammes) is allowable and care must be taken that the projection of the surface of the rivet-hole is not strained beyond 8.9 tons per square inch (1,400 kilogrammes per square centimetre).

(4). For shearing strength parallel to direction of rolling 3.17 tons per square inch (500 kilogrammes per square centimetre).

(5). Wrought iron must have, with a breaking strength of 23 tons per square inch (3,600 kilogrammes) and over, at least 12 p. c. extension, length-wise. With a lower breaking strength, there must be a correspondingly greater extension, which should, in the case of the lowest admissible breaking strength of 21 tons per square inch (3,300 kilogrammes), be at least 20 p. c.

The extension is to be measured by means of a test-piece of 725 square inches (5 square centimetres) cross section and 7.9 inches (20 square centimetres) marked distance. If the use of a test-piece of other dimensions is unavoidable, the squares of the marked distances must be proportional to the cross-sections.

(*b*). For *cast-iron* (which should not be used for any portion of the superstructure), the stress-limits are fixed at : 4.45 tons per square inch (700 kilogrammes) for compression 1.27 tons per square inch (200 kilogrammes) for simple extension, and 1.9 tons per square inch (300 kilogrammes) for tension in case of bending.

(*c*). For *wood* the limit is fixed at 1.5 ton per square inch (80 kilogrammes) for compression and tension in the direction of the fibres.

(*d*). For all portions in compression the necessary resistance to buckling is to be provided for.

(*e*). The maximum combined stresses on the materials of the wind stresses specified in § 3 (*f*) and of the above-mentioned stresses, should not exceed the following limits for the various materials considered :

For § 4 (*a*) 1 and 2 . . .	6.35 tons per square inch.	(1,000 kilog. per square centimetre).
— § 4 (*a*) 3	4.45 — —	(700 — — —).
— § 4 (*a*) 4	3.8 — — —	(600 — — —).
— § 4 (*c*).	0.57 — — —	(90 — — —).

§ 5. — *Provisions for safety.*

(*a*). For all bridges and viaducts with a total length exceeding 65.5 feet (20 metres) measured between the last sleepers on the ballast at each end special provision must be made against the dangerous consequences of a derailment.

The check rails must not be more than 3 centimetres higher than the running-rails, and between them and the latter a space of 16 centimetres must be left as clearance for the wheel-flanges.

The check-rails must reach the ballasted sleeper at each end and must protect the whole rail-distance between them.

(*b*). The influence of temperature variation must be guarded against by moveable supports and the expansion of the permanent way must be provided for.

(*c*). Parapets must be placed on all bridges which are not further than 2,640 feet (800 metres) from the nearest switch-points of stations, stopping-places and sidings, which are provided with distant signals; or not more than 655 feet (200 metres) from the middle of any such place not provided with distant-signals and not used for trains to pass one another.

In the case of local lines the above distances are reduced, viz : — for stations provided with distant-signals, the distance is 328 feet (100 metres) beyond those signals and for those without distant-signals 1,320 feet (400 metres) beyond the furthest switch-point and for stopping places without crossings 328 feet (100 metres) from their centres.

All structures without exception, which are more than 65.5 feet (20 metres) long between the last ballasted sleepers are to have parapets and where wing-walls parallel to the line occur the parapets are to extend over them.

§ 6. — *Exceptional cases.*

(*a*). For lines where unusually heavy rolling-stock is to be used, for steam tramways, for lines of usual gauge without steam traction, for lines of unusual gauge, and in cases where constructive materials of an unusual quality are used, and any other exceptional cases, the above specification may be altered to suit the nature of the case.

(*b*). For materials such as stone, brick, lead, etc., which are not included in § 4, also for those portions (cantilevers, pillars, etc.) not included in the main-cross and longitudinal girders, special data are to be used based as far as possible on practical experience.

§ 7. — *Superintendence of construction.*

To ensure the construction of bridges according to official specification, the State department of railways is to superintend the construction, or if desirable, make tests of the materials to be used, at the cost of the railway Administration.

§ 8. — *Procedure preliminary to official test.*

Before being opened for traffic, new bridges must be officially examined and tested. For this purpose a chief commissioner will be appointed by the R. I Department for the superintendence of the Austrian railways.

This appointment is made, on receipt of a requisition from the railway Administration, which must contain a list of the works to be inspected, with the government decrees containing approval of the scheme and also information on the following points : —

(1). A descriptive sketch of the trains to be used for the load-test, which should produce, as nearly as possible the same bending moments as the loads specified in § 3 (also § 6).

The trains for each track must be composed of at least one, two or three locomotives for spans up to 49 feet (15 metres) 82 feet (25 metres) or above 82 feet (25 metres) respectively. The locomotives are to be completely fitted and of the heaviest type to be used on the line and a sufficient number of fully loaded wagons are to be added to cover the greatest length of structure to be tested.

(2). The calculated percentage of the prescribed load-effect obtained by the test-train, and the greatest deflection calculated on for the train.

(*b*). For the official test, the railway Administration is to appoint a responsible representative, who is to have the original approved plans and the decrees containing their approval.

The Administration has to provide the test trains and necessary measuring apparatus and also the permanent level marks as specified in § 11.

§ 9. — *Carrying out of load-tests*

(*a*). The test of each opening of a bridge has to be done with a stationary as well as a moving load.

If there are several bridges of similar construction, and equal span of less than 33 feet (10 metres) span, it is not necessary to extend the tests over all these, if, in the opinion of the R. I. inspecting official, the results previously attained are sufficiently decisive.

(*b*). For testing with stationary load, the test-trains specified in § 8 (*a*) are to be placed successively in the positions which are the most disadvantageous for the structures and are to be left in each of these positions until no further increase of deflection is perceptible.

For ordinary superstructures with free supported girders it is sufficient to test the bridge when one half and the whole of its length have been successively loaded.

For arches of large span, separate tests must be made, firstly with the load in the middle of the arch and the neighbourhood of the abutments unloaded, and secondly with the middle unloaded and the load placed on the two sides near the abutments of the arch.

For continuous girders, two testing-trains are necessary for each track, long enough to load two openings simultaneously.

For testing a pier and the portion of the girders thereon, the two openings adjacent to the point of test must be loaded simultaneously on their whole length.

To test the girders at the middle of an opening the load must cover successively the half and the whole of the opening, but also simultaneously in the first case the whole length of the largest contiguous opening and in the second case the largest of the next two (1).

(c). For moving line-load tests, a train as specified in § 8 (*a*), 1, but with only two locomotives must run over each track at a speed of about 12 1/2 miles (20 kilometres) an hour.

Afterwards a run must be made with the same trains at a speed of 25 to 32 miles (40-50 kilometres) an hour.

In case the masonry, or the connections of the superstructure thereto, is not properly set, these tests with rolling load may be made at a later date.

(*d*). For bridges for two or more tracks, having a common bearing-structure, the above load-tests must be made on all the tracks simultaneously, after having been first carried out on each track separately.

(*e*). For local and industrial lines the tests with rolling load (c. above) may be omitted.

§ 10. — *Official report.*

A report must be drawn up of the official examination and test, which should contain the data specified in § 8.

The report must contain an account of the permanent and elastic deflections, and also the readings on the permanent level-marks (§ 11) and must also report whether the structure is in accordance with the approved plans.

Finally the official of the Austrian R. I. Railway inspecting department shall specify whether the bridges may be unconditionally or conditionally opened for traffic or whether the matter must be deferred for reference to a higher authority.

§ 11. — *Periodical inspection.*

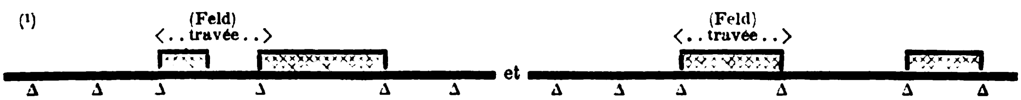
The railway Administration must (apart from their own independent supervision) at least every six years, undertake examinations and tests according to the rules specified in § 9 (*b*) and (*d*).

For this purpose it is allowable, in ascertaining the elastic deflection in the case of continuous girders, to limit the load to the span under consideration and for every kind of structure up to 79 feet (25 metres) to use the regular trains as live load.

(*b*). The observation and tests made should be recorded for each bridge separately, for examination by the authorities.

To facilitate the investigations, all bridges of more than 65.5 feet (20 metres) span, should be provided with permanent level-marks at the middle of the openings and at the supports of the main girders, which will enable observation to be taken of any permanent deflection which may appear in the course of years.

(1)



1. Charge pour les efforts tranchants. 2. Charge pour les moments de flexion.

(c). The result of examinations and tests made must be reported to the R. I. Inspecting Department of Austrian Railways; this report if showing any diminution in the efficiency of a structure is to be made immediately; but otherwise not until the end of the year.

§ 12. — *Restrictions in the use of rolling stock.*

Bridges may not, without consent of the R. I. Inspecting Department of Austrian Railways, be traversed by rolling stock of a kind which would put any greater strains on them than the loads calculated on and specified in § 3 and § 6, and which are contrary to the limits of size specified in § 2.

B. — PROPOSED OVER-BRIDGES AND ROAD-APPROACH BRIDGES.

§ 13. — *Note on the application of the following rules.*

With regard to over-bridges and road approach bridge which the railway Administration are to make at their own cost, the Ministry of Commerce will proceed in regard to inspection testing and use of such bridges according to the following rules (§§ 14-17) which are also to hold good for all administrativs acts of the « General Inspecting Department of Austrian Railways » in respect to the above matters.

§ 14. — *Propositions.*

In regard to schemes proposed for railway bridges the rules in §§ 1 and 19 hold good.

§ 15. — *Load.*

The calculations of strength are to be made, apart from the permanent load, by two alternate methods in respect to the liveload, as follows :

(a). The greatest possible number of vehicles collected on the roadway and at the same time the greatest possible number of persons on the side-walks and other spaces.

(b). A crowd of persons on both roadway and sidewalks.

The most disadvantageous of these two kinds of loading, is the one to be taken into account.

With the object of obtaining a standard of the weight of persons to include to a square metre or the number of heavy wagons to be included in the load, all street-bridges are divided into three classes, for which, except in exceptional cases, the following are the specified loads :

Class 1.

1. A human load of 98 lbs. per square foot (460 kilograms per square metre).
2. A four-wheel wagon of 12·19 tons (12 tonnes) total weight, 25·56 feet (7·8 metres), total length (without pole), 4·68 feet (2·5 metres) wide, 14·1 feet (3·8 metres) wheel-base, 5·28 feet (1·6 metres) gauge, with a team of four horses of a total weight of 3·32 tons (3 tonnes) and 23·7 feet (7·2 metres) length.

Class 2.

1. A human load of 86 lbs. per square foot (400 kilograms per square metre).
2. A four-wheeled wagon of a total weight of 6·64 tons (6 tonnes), and 17·7 feet (5·4 metres) length (without pole), 7·92 feet (2·4 metres) wide, 9·24 feet (2·8 metres) wheel-base, and 5 feet (1·5 metre) gauge, with a team of two horses of a total weight of 1·66 tons (1·5 tonnes) and 11·85 feet (3·6 metres) length.

Class 3.

1. A human load of 73 lbs. per square foot (340 kilograms per square metre).

2. A four-wheeled wagon of 3·32 tons (3 tonnes) total weight, and 17·7 feet (5.4 metres) length (without pole), 7·56 feet (2·3 metres) wide, and 9·24 feet (2·8 metres) wheel base and 5 feet (1·5 metre) gauge with a team of two horses of a total weight of 1·66 tons (1·5 tonnes) and 11 85 feet (3·6 metres) length.

The classification of proposed road-bridges in the above three classes is to be fixed by a traffic-commission, or other authoritative body, who are to take into account any exceptional demands which may be made on the structure.

(c). The wind-pressure is to be reckoned for in the manner specified in § 3 (b) and the human or waggon load is to be considered as a moving continuous rectangle 6 feet 6 inches (2 metres) high.

(d). The influence of temperature-variation is also to be taken into account, as regards the system of construction or to be guarded against by the procedure mentioned in § 5 (b).

§ 16. — *Stresses.*

Considering the load and other effects mentioned in § 15 (a), (b) and (d) together with that of the permanent load, the maximum calculated stress on the effective cross-section of any of the material (allowing for rivet holes and ineffective portions) should not exceed the following limits :

(a). *Wrought Iron* [as mentioned in § 4 (a), (5)], 4·76 tons per square inch (750 kilograms per square centimetre) with an addition of 2 kilograms per square centimetre for each additional metre span up to a maximum of 5·72 tons per square inch (900 kilograms per square centimetre), and cross-girders, longitudinal bearers, and intermediate parts are to be calculated in the same way according to their span.

(b). For cast-iron the admissible stress-limits are those specified in § 4 (b).

(c). The rules laid down in § 4 (a) Nos. 3 and 4; (c), (d) and (e) (also § 6) (b) regarding railway-bridges, hold good also for road-bridges.

§ 17. — *Examination, testing and traffic regulation.*

(a). Completed over-bridges and road approach bridges are, before being used, to be subjected to an official examination in reference to the then proper workmanship and agreement with the approved plans.

For this purpose a requisition with the necessary documents appended is to be fowarded to the general inspection department of Austria Railways, and their authorities shall in every case make due enquiry and decide as to whether, in addition to the above inspection, a load-test should be made; such decision in this matter not to affect the demands of any other competent authority or body, who may insist upon further legitimate requirements.

(b). Completed bridges must also be officially inspected at least every six years, or if desirable, tested, by the methods specified in this order in § 11 (d) and (c).

(c). The passage of vehicles over the bridge, which may put greater stresses upon the material than has been reckoned on, by the calculations of resistance is to be prohibited.

To inform the public, in a simple manner, what loads are admissible, a notice to this effect should be put in a visible position on every bridge.

C. — Existing bridges.

§ 18.

(a). Railway bridges.

(1) A tabular statement concerning existing bridges on the various lines is to be drawn up giving information on at least all the following points : Position, the year of construction, the number of tracks, the span, the angle of skew, the system of construction, position of track (above or below the structure), the quality and source of the materials, the heaviest loads actually borne at the time of the report, and the resulting stresses of the materials and also as to the conditions of approval of the structure.

This statement is to be delivered by every Railway Administration to the R I. General Inspection Department of the Austrian Railways, within 3 months of the publication of this order.

This Department, after checking the report by actual inspection, and getting whatever additional information and reports they may desire, must take as soon as possible the necessary measures to ensure the safety of the traffic, either in their own official capacity, or if necessary, by referring the matter to the Ministry of Commerce.

(2). Apart from the report and specification above mentioned, the Railway administrations must inspect and test their bridges (except to the extent they have already been so tested) by means of a train, on each track, consisting of two of the heaviest locomotives in use on the line, and of the heaviest wagons, and in other respects according to the procedure specified in section 11 of this ordinance, and must keep a record of the results.

This procedure must be commenced immediately after the day of publication of this ordinance.

In the case of unsatisfactory results of the load-tests, or in case the calculated stresses should exceed the maximum permissible stresses per cm^2 of effective cross-section, given below, the Railway administration must report the same immediately to the General Inspection department of the Austrian Railways with appropriate suggestions.

These limits are :

1. Wrought Iron (Tension Compression and shearing) 6.04 tons per square inch (950 kilograms).

2. Rivets (shearing) 4.76 tons per square inch (750 kilograms).

3. Wood (Tension and Compression in the direction of the fibres) 51 tons per square inch (80 kilograms).

For the maximum total stresses, consisting of the wind-effects mentioned in § 3 (*f*), together with the internal stresses above mentioned the limits are :

for (1)	6.65 tons per square inch		(1,050 kilograms).
— (2)	5 10 —	—	(800 kilograms).
— (3)	5.72 —	—	(90 kilograms).

(b). Over-bridges and road-approach bridges.

With regard to over-bridges and road approach bridges, § 13, the Railway administration are to make a similar tabular statement to that specified in (*a*) N° 1 above, and to include therein particulars of the arrangement and width of the driveways and footways.

In this statement information must be given as to who are the proper authorities for the control and supervision of the roads passing over the structures under consideration.

Independently of these proceedings, the railway Administration are to assure themselves in a proper manner, of the efficiency of the structures to carry the actual loads; they must also communicate with the authorities in control of the streets, so that the precautionary measures specified in § 17 (*b*) and (*c*) may be applied equally in these cases.

(*c*). — *Investigation by the I. R. General-Inspection Department.*

The above department has the right of inspecting and testing according to the above specifications, or in any way that they see fit, the railway bridges mentioned in (*a*) and also the overbridges and road approach bridges mentioned in (*b*) to the extent that their authority allows (§ 13).

D. — FORMALITIES REGARDING DELIVERY OF PARTICULARS AND OFFICIAL REPORTS.

§ 19.

(*a*). All information delivered in accordance with §§ 1, and 14 and also §§ 6, 12, 17 (*a*), (*b*), (*c*), and § 18 (*a*) and (*b*) of this ordinance, as well as the documents and report drawn up according to §§ 8 and 10, must be of uniform size of 21 × 34 centimetres.

(*b*). The accompanying plans and calculations are to be folded or bound in the same size and to be delivered in duplicate and at least the copies intended for official use must be on such paper or cloth and produced with such ink, colour or printing materials as will assure their durability.

(*c*). After the approval of the documents sent in according to §§ 1 and 14 or §§ 6, 12, 17 (*a*), (*b*), (*c*) and § 18 (*a*) and (*b*) and the official action detailed in §§ 8, 9, 10, 17 (*a*), and 18 (*c*), the duplicates are to be returned to the representative of the Railway Administration.

E. — FINAL RULES.

§ 20.

The rules of this order shall be applicable, without exception, to the lines belonging to private Companies, but as regards the lines belonging to the State, they shall be subject to the following restrictions.

(*a*). As far as it is in accordance with the statute on the organization of State Railways in the kingdoms and countries represented in the « Reichsrath » published with the ordinance of the Minister of Commerce dated 23rd June, 1884 (R.-G.-B., 103); or in accordance with special powers granted by the Minister of Commerce, by which the I. R. Department of State Railways are to undertake the approval of projects for new constructions, or extensions and re-constructions on the lines in question, the above department shall also undertake the approval of projects for the construction and alteration of railway-bridges, over-bridges and road approach bridges and in this case the procedure mentioned in § 1 and § 14 or in § 6 shall be omitted.

(*b*). In such a case (as *a*) the official procedure specified in §§ 8, 9, 10, 17 (*a*) shall also be ordered by the I. R. Department of State Railways. The I. R. General Inspection Department should be summoned in good time, a copy of the statements and documents specified in this ordinance being sent to them. The representative of the inspecting authorities shall also interfere in this procedure in matters which, under the present ordinance, come under their control.

(*c*). If the General Inspection Department of Austrian Railways, after receiving statements and particulars specified in §§ 11 and 18, shall decide, on examining such documents, that measures for the security of traffic should be taken, they must forthwith bring the matter under the notice of

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the I. R. Department of State Railways and at the same time report to the Ministry of Commerce on their action.

§ 21.

This ordinance goes in force on the day of publication. At the same time the ordinance of the Ministry of Commerce of 30th August, 1870 (R.-G.-B., 114) also the rules laid down in § 21 (3) and (4) of the ordinance of 25th January, 1879 (R.-G.-B., 19) are rescinded.

(*Signed*) Bacqehm.

APPENDIX 2.

Fundamental Rules for the Supply and Erection of Iron Bridges.

§ 1. — NATURE OF MATERIALS.

The materials to employ for the iron superstructures of Bridges are : (*a*) Wrought iron; (*b*) basic Martin steel and for the supporting portions : (*c*) cast iron, (*d*) steel, are also used.

(*a*) Wrought iron must have, with a breaking strength of 23 tons per square inch (3,600 kilograms per square centimetre) and over, an extension of 12 p. c. lengthwise.

With a lower breaking strength there must be a correspondingly greater extension, which with the lowest admissible breaking strength of 21 tons per square inch (3,300 kilograms per square centimetre) must be at least 20 p. c.

The iron to be used for rivets and bolts must have, with a breaking strength of 23 tons per square inch (3,600 kilograms per square centimetre), an extension of at least 18 p. c.

Such iron as will, according to construction, be subjected to strains in various directions such as web-plates and their covers and connecting plates, etc., etc., must have a breaking strength, crosswise, of at least 19 tons per square inch (3,000 kilograms per square centimetre) and an extension of at least 5 p. c.

(*b*). The basic Martin steel employed in the superstructure must have, with a breaking strength lengthwise of from 22 1/4 to 28 1/2 tons per square inch (3,500 kilograms to 4,500 kilograms per square centimetre) an extension of from 28 p. c. for the lower breaking limit to 22 p. c. for the higher and an extension for intermediate strength deduced by interpolation.

Further, in every bridge, the breaking strength of all portions of the superstructure must not vary over a range of 4·45 tons per square inch (700 kilograms per square centimetre).

(*c*). The Martin mild steel (Martinflusseisen) to be used for rivets must have with breaking strength of from 22·25 to 25·4 tons per square inch (3,500 to 4,000 kilograms per square centimetre) an extension of 32 to 26 p. c.

For tests of tensile strength at right angles to the length, the above figures are correct for the breaking strengths, but should be reduced by 2 units as regards the percentage of extension.

The cast iron to be used must have a strength of 7·5 tons per square inch (1,200 kilograms per square centimetre) in tension, and of 32 tons per square inch (5,000 kilograms per square centimetre) in compression.

The Martin ingot steel (flussstahl) to be used in all parts of bearings, must have a breaking strength of at least 36·2 tons per square inch (5,700 kilograms per square centimetre) with an extension of at least 10 p. c.

§ 2. — THE PRODUCTION OF ROLLED IRON.

The various kinds of rolled iron are manufactured either from (*a*) wrought iron or (*b*) basic Martin steel.

(*a*). For the production of wrought iron for rolling, only the best kind of pig iron should be used. If the intended use of the rolled product entails strains in more directions than in the direction of rolling, then the iron should be crosspiled and rolled as plates such pieces are the web-plates, their covers and the connecting plates.

(*b*) The rolled pieces produced from Martin mild steel (flusseisen) should be rolled out of large castings; after rolling, a sudden or irregular cooling is to be avoided.

The commencement of the production of the material should be made known in good time to the buyer in order that he may direct the carrying out of tests of the materials.

§ 3. — GENERAL PROPERTIES OF THE MATERIALS.

The iron (wrought iron or Martin steel) must have a homogeneous texture; it should not become brittle either from heat or cold, it should permit of jumping, and should have an even surface. Faulty places should not occur.

The cast iron portions should be made from soft grey pig iron and should be free from flaws.

The steel pieces should be well made, without faults. The lead to be used should be pure and ductile.

§ 4. — TESTS OF MATERIALS.

Materials may be accepted, according to the results of the following tests. These include tensile bending, breaking and other tests.

(*a*). General conditions.

With a view to the test of the materials to be delivered, a specification of these materials should be given to the agent appointed to receive them; which specification should contain, as regards Martin Steel portions, the numbers of the charge out of which those portions were rolled.

With this object each piece of Martin steel should be distinctly marked immediately after rolling with the number of the charge from which it was rolled.

The receiving agent should have the right at any time to examine the charge-book of the works. Usually the agent selects five out of every hundred pieces for testing purposes, but he should be free to select a geater number, if he desired. The selection of pieces for testing should be always arranged, so that at least one test is made on each charge of Martin steel and of each bloom of wrought iron.

In case one of the selected pieces does not fulfil the required conditions, supplementary tests are made and for this object three additional pieces are selected from the same charge or bloom as the case may be, and tested in exactly the same manner.

Should any one of these three test pieces not fulfil the conditions, then all the pieces from the charge or bloom under consideration are to be rejected.

Similarly if any two of the originally selected test-pieces fail to fulfil the conditions the whole product of that charge or bloom is to be rejected.

The samples for test are to be cut off cold, care being taken that no injury is thereby done to the texture of the material.

No further work is permitted to be done on the test samples than what is necessary for their preparation. The straightening of the test samples, when necessary, may only be done by pressure at normal temperatures. Annealing of test-pieces to be tested cold, is not allowed under any circumstances. Cold bending tests shall be undertaken at temperatures of from 10° to 20° C above zero. The material accepted, according to specification, is to be marked as such by being stamped.

The rejected portions are also to be marked in such a manner that their rejection is rendered unmistakable, but without rendering them useless for other purposes.

(b) Special conditions.

1. *Tests of Tensile Strength.*

For the tests of tensile strength of plate, bar, angle and other such forms of iron, the necessary test pieces are prepared by means of milling, and planing machines, and their broad sides are to be left black.

The extension is to be measured by means of a test piece of ·725 square inch (5 square centimetres) cross-section and 7·9 inches (20 centimetres) marked distance. If the use of a test piece, of less than the above cross section, but not under ·465 square inch (3 square centimetres) is unavoidable, then the marked distance should be equal to $\sqrt{80\ S}$ where S represents the cross section.

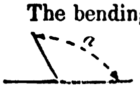
The rivet iron is to be tested black and without any previous preparation.

The test pieces shall, on demand, be marked in centimetres along their whole length.

When a test piece gives an unsatisfactory test of tensile strength owing to visible defective workmanship or to being wrongly treated in the testing process or when the breakage occurs outside the middle one-third of the marked distance, then the test is not valid.

2. *Bending and other Tests.*

The bending test must be carried out by means of a press.



The bending angle is the angle described by the portion of the plate which is operated on by the bending action.

For the purpose of testing hardened pieces, the pieces must be hardened by plunging in tepid water not exceeding 28° C.

The tests to be carried out are as follows :—

(α) *Wrought iron.*

(1). Bars of metal, 2 to 3.15 inches (50 to 80 millimetres) broad and cut lengthwise from the plate bar, or angle iron, must be bent round a curve, whose radius = twice the thickness of the bars, to an angle of at least 150° without any cracks being produced at the bend. In a red hot state the bars should be bent to an angle of 180° one-half being completely doubled back on the other without cracks being produced at the bend.

Bars cut from a sheet in a direction at right angles to the length must show the same properties and be bent through the same angle. The curve round which they are bent however, should have a radius of twelve times the bar thickness for cold bars and eight times for red hot bars.

(2). Test bars, which have been cut 1 to 2 millimetres deep across their length, and bent to leave the cut on the outside must show a sound structure, and should not entirely break apart at the bend on being completely doubled up.

(3). In a red-hot state a bar 1.2 to 2.0 inches wide (30 to 50 milimetres) should be capable of being hammered out in a direction parallel to its length to 1.5 of its original width, without showing any signs of parting.

(4). Cold rivet iron when bent double and hammered, should form a loop at the bend, whose diameter is equal to half the diameter of the iron itself, without showing any traces of parting in the bent portion.

The same iron bent over a curve of radius equal to its own to an angle of 45°, and then bent completely back again, should show no signs of tearing.

A piece of red-hot rivet iron of a length equal to twice its diameter, must permit of being jumped together to one third of its length without developing flaws.

Rivet heads when red-hot, must permit of being hammered out flat, without showing any tears or cracks.

(β). *Martin mild steel « Martin Flusseisen ».*

(1). *In an intact condition* a piece of plate, bar, or angle-iron, of a width of 2 to 3.15 inches (from 50 to 80 milimetres) must bear bending to an angle of 180° without tearing.

This bending in the case of materials of 28 1/2 tons per square inch (4,500 kilograms) breaking strength, is to be done round a curve of diameter equal to the thickness of the piece; but with materials of 22 1/4 tons per square inch (3,500 kilograms) breaking strength, the bar should be bent completely back on itself,

(2). *In a damaged condition*, that is to say after an incision has been made by means of a sharp chisel across the whole breadth of the piece, to one-tenth of its depth, bars of plate flat and angle iron of a breadth of 2 to 3.15 inches (from 50 to 60 millimetres) on being bent over a curve whose diameter is equal to 5 times the thickness of the piece should not show any sudden breakage until it has formed an angle of 90° for materials of 28 1/2 tons per square inch (4,500 kilograms) breaking strength and 150° for materials of 22 1/4 tons per square inch (3,500 kilograms) breaking strength.

(3). In a red-hot state, pieces as above should permit of being sharply double and completely beaten together without flaws being produced.

(4). Rivet metal ought to allow of being bent double and both limbs being entirely hammered together, without showing any trace of parting at the bending point.

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(5). After being bent round a curve of radius equal to the radius of the piece to an angle of 90° rivet metal should bear being bent back straight without showing signs of injury.

(6). The rivet metal must allow of butting when cold to the extent of forming a flat head of 1.5 times the diameter of the bar, without cracks.

(7). When red-hot a rivet head must permit of being hammered out flat, without showing cracks, and on cooling to a blue heat should permit of further hammering without showing any faulty places.

(8). Hardened material should, on undergoing bending tests, show no worse results than the limits specified in section 1 and 2.

(γ) *Cast Iron.*

If a casting is struck directly on a right-angled corner with a set-hammer, it should be capable of receiving an impression without the edge breaking off.

§ 5. — RIVETS AND BOLTS.

The rivets and bolts for the suerstructure are to be of the same material as that to which they are applied.

The rivets are to be made by machinery, and overheating is to be carefully avoided.

For rivets of equal diameter, a variation of 1/2 millimetre is allowable. The rivet heads must be exactly concentric with the bodies.

The screw bolts must have head and body forged out of one piece, and in no case must the head be welded on. The screws are to be cut according to the Whitworth Standard. The threads must be clean cut and sufficiently long, and all the bolts and screws must be equally cut so that the nuts and bolts are perfectly interchangeable. The nuts should not turn either too loosely or too tightly on the threads. Bolt heads and nuts must be turned on the surfaces coming into contact with the plates. When the nuts are tightened up at least two turns of the screw thread should project; these projections are to be rounded off with a file.

The bolts employed for fastening portions of the bridge together, are to be provided with safeguards against the slacking back of the nuts.

§ 6. — MANIPULATION OF CAST IRON AND STEEL PIECES.

Perfect workmanship is required in the production of the cast iron and steel portions of the structure. Particular care is to be applied to the preparation of the bearing structures. At the points of support all contact surfaces of iron must be exactly planed, milled or turned and the rockers or rollers are to be of the same height.

§ 7. — MANIPULATION AND DRESSING OF ROLLED IRON.

All kinds of rolled iron before being used, are to be straightened, dressed and cleaned from scale.

The cut ends of rolled iron are to be planed, milled or ground for 2 millimetres, or a hand chisel and file may be used.

The use of the dressing chisel is prohibited. The corners of all rolled pieces must be straight with clean edges.

All pieces must be of the dimensions indicated on the plans and the variation in thickness must not be greater than a 3 p. c. excess or a 2 p. c. deficiency above or below the specified dimensions.

Portions of bridges, which are shown on the plans as consisting of one piece, may not be constructed of more than one piece by means of welding or riveting.

Pieces, which are, according to the plans, to be bent, must be bent at a red heat without overheating.

§ 8. — MAKING RIVET HOLES.

The following rules are to be observed.

All rivet holes are to be drilled.

For the connection of the members of the bracing to the booms each rivet hole is to be bored at once through all the pieces which are to be connected together, which renders it unnecessary to drill any piece beforehand for use as a template.

The burrs due to drilling are to be removed and the lubricant used in drilling is to be cleaned off.

In erecting, the corresponding rivet holes must fit well together; not varying from concentricity more than 5 p. c. of the diameter of the hole, but in case of a variation the holes must be made uniform by being rimered out. In these holes which have been enlarged not more than 5 p. c. by the use of the rimer, correspondingly large rivets are to be used. Under no circumstances may any holes be enlarged by drifting with steel service bolts.

The distribution of the rivet holes must in all cases be in accordance with the working drawings and the distance of one hole from another may not vary more than 1 millimetre from the distance specified in the drawings.

Holes for one size of rivets must, of course, be of equal diameter, viz :— about 0·5 millimetre greater than the diameter of the rivet.

The edges of holes on which a rivet head will rest must be coned out to a depth of 1 millimetre to avoid contact of sharp corners.

According to the order of the R. I. Ministry of Commerce dated Jan 29th 1892 (R. G. H. XI, No. 28), the punching of rolled iron is allowed up to Jan. 1st. 1894, to that date the following temporary rules hold good :—

The rivet holes for the connection of members of the bracing to the booms, and of sleeper-bearers to the cross girders, and of the latter to the main girders, and for all joint cover-plates are to be drilled, and for the first-named pieces the holes are to be drilled at one operation through all the pieces to be connected.

Similarly the holes in all rolled iron of 15 millimetres thickness and over, must be drilled. The remaining holes may be punched, means being provided for punching such holes without injury to the material and for making them straight and exact. The iron to be punched must be of a temperature of at least + 10° C.

The burrs produced by punching must be removed so that the pieces to be riveted can lie flat against each other.

All punched holes must be made 3 millimeters smaller in diameter and afterwards drilled or bored out to the exact diameter. The resulting burrs must be removed and to do this the pieces to be connected together should be separated.

§ 9. — RIVETTING.

In the construction of parts of bridges, the rivetting is to be done by machinery whenever practicable. In the case of hand rivetting by means of a cup-set, the use of a lever to hold the rivet in position is not permitted — this object should be preferably attained by the use of a strong base screwed against the rivet tup head or by a heavy tup-hammer.

The hammer to form the head should weigh at least 4·2 lbs (2 kilograms) and the one to complete the rivet head not less than 8·8 lbs (4 kilograms). The completed rivet heads should have their edges cleaned of all superfluous metal and should be free from cracks, they should be concentric with the bodies of the rivets and well formed, and for this purpose the rivet should be made fully long enough.

Care must be taken to avoid injury to the ironwork, either by badly directed blows with the hammer or by use of a sharp edged set.

The rivets after being cleared of scale, are to be driven red-hot into the rivet holes, which latter are to be previously cleaned out. Overheating of rivets is to be carefully avoided.

After rivetting, a test should be made to find whether the rivets are firm and without play. All rivets which are loose and do not fulfil the above conditions, should be removed, and replaced by others fulfilling the conditions. Tightening up by hammering the rivets after cooling is prohibited.

The portable fires for heating the rivets must be placed as near as possible to the work, to prevent cooling of the rivets in being carried or thrown at any considerable distance. The pieces to be rivetted must be brought to their right position by means of service bolts and be temporarily held there and these, can be removed as the rivets are put in. The number of bolts must be equal to at least one quarter of the rivet holes.

All contact surfaces must, before rivetting, be cleaned of dirt and rust and coated with red lead.

§ 10. — ERECTION IN THE WORKSHOPS.

All portions of bridges must be accurately fitted in the workshop, and temporarily erected, according to the plans. The separate pieces may, however, only be connected by service bolts of soft iron. The commencement of the erection of bridges must be notified in good time to the purchasing agent.

Main Girders of 49 feet (15 metres) span and over are to be erected with the deflection as specified above. Those portions which can be transported as a whole, can be assembled immediately in a permanent manner. All these operations must be carried out on solid supports.

Care must be taken that the joints are all perfectly closed and that there are no recesses capable of retaining water. In constructing T girders without head or foot plate, the horizontal limb of the angle iron must not project beyond the edge of the web-plate, but it is rather to be desired that the web plate should project a little above the top surface of the limb of the angle irons, and the resulting ridge dressed off without making use of the dressing chisel.

After complete erection in the workshop the bridge or portions therefore, are to be sent to the destination properly marked and numbered.

§ 11. — ERECTION AND POSITION.

In loading and unloading and likewise in erection any injury or bending is to be avoided, and any piece bent or injured may be excluded from the construction on demand of the buyer's representative.

The commencement of the erection of the ironwork « in situ » is to be duly notified to the purchaser.

Care is to be taken that the setting up of the several pieces is carried out with the greatest accuracy and so that false strains are avoided in any portion. In this operation only soft iron service-bolts are to be used.

The rivetting must be made with the same care as in the workshop and the finished bridge should have no open joints, bends, or twists.

Further, it must be provided that all portions shall be under similar initial stress, that is to say, that the girders shall be erected on the scaffolding with their above specified proper deflection as was the case in the workshop, and that the ties at their intersections with the struts or with one another should be finally connected only when the main girders are resting on their permanent supports and not on temporary ones.

The holes for sleeper bolts are to be made, after the superstructure is in position, either by drilling or taking out rivets.

The Bed Plates for bridges of up to 82 feet (25 metres) span, are to be placed on a thick cement bed; but in the case of larger bridges, and of all which are to be traversed by locomotives immediately after construction, a leaden plate 1 centimetre thick should be introduced between the masonry and the bed plates.

Particular care must be taken in posing the superstructure on its permanent bearings, that the supported part of the structure rests evenly and with full surface on its supports.

The rollers and rockers should always be normal to the supporting surface and should be placed in a position corresponding to the temperature at the time of erection.

§ 12. — PAINTING.

Bridges and their railings with all sleeper and fastening-bolts should be painted with oil paint.

Three coats of paint must be put on, no coat being put on till the former one is quite dry.

For painting in the open air, dry warm weather must be chosen.

The surfaces to be painted must first be cleaned with wire brushes, all rust, inequality, roughness and dirt being removed and then well dried.

Those surfaces which cannot be reached after erection are to receive before erection a thick durable coat of lead oxide paint.

The first coat of all visible surfaces is also to be of lead oxide paint.

The first coat must be put on with a stiff brush, so that the paint enters all surface inequalities.

After erection the first coat is to be touched up before going on with the second.

When the first coat is dry, the puttying is proceeded with, a putty of red lead and linseed oil being used.

For the second and third coats, thicker paints are used. The third coat should be preceded by a touching up of the second. To distinguish the third coat from the second, the third should be of a darker colour. If the three coats do not completely cover the parts to be painted, the contractor can be made to put on a fourth without compensation.

Those portions of the iron work on which sleepers lie, must have three coats of paint before the sleepers are placed in position.

§ 13. — TESTING BRIDGES.

Completed bridges will be tested according to the rules in the order of the R. I. Ministry of Commerce, of Sep. 15th 1887.

The permanent deflection must not be more than one-fifth of the elastic deflection. Any change of form observed during the test ought never to be caused by faulty materials or workmanship.

§ 14. — GUARANTEE OF MATERIALS AND WORKMANSHIP.

The contractor is to guarantee the bridge for one year.

The beginning of the guarantee is to be specified in the contract.

APPENDIX 3.

Collection of technical terms used by Engineers for calculus of resistance.

1.	Querschnittsfläche.	Aire de la section.	Area of section.
2.	Statisches Moment.	Moment statique.	Statical moment.
3.	Schwerppunct.	Centre de gravité.	Centre of gravity.
4.	Trägheitsmoment.	Moment d'inertie.	Moment of inertia.
5.	Trägheitsellipse.	Ellipse d'inertie.	Ellipsis of inertia.
6.	Trägheitsmodul.	Module d'inertie.	Module of inertia (1).
7.	Trägheitsradius.	Rayon de giration.	Radius of giration.
8.	Lichtweite.	Ouverture libre.	Span in the clear.
9.	Stutzweite.	Portée théorique.	Span between centres of bearings.
10.	Einzellast.	Charge isolée.	Single force, single charge.
11.	Achsdruck.	Charge d'essieu.	Axle charge, axle load.
12.	Raddruck.	Charge de roue.	Wheel charge, wheel load.
13.	Auflagerdruck.	Charge sur appui.	Charge on centre of bearing.
14.	Gleichförmige Last.	Charge uniforme.	Equally distributed load.
15.	Knotenlast.	Charge sur nœud.	Charge on apex of web triangle.
16.	Bleibende Last.	Charge permanente.	Permanent load, dead load.
17.	Bewegliche Last.	Charge mobile, surcharge.	Rolling load, live load, moving load.
18.	Menschenlast.	Charge de piétons.	Live load men standig closely packed.
19.	Wagenlast.	Charge de charrettes.	Live load for carriages or wagons.
20.	Biegungsmoment.	Moment de flexion.	Bending strain, bending moment.
21.	Scherkraft.	Effort tranchant.	Shearing force.
22.	Schubkraft.	Cisaillement longitudinal.	Longitudinal shearing force.
23.	Mittlere Kraft.	Force médiane.	Medial force (2).
24.	Mittleres Kräfte Intervall.	Intervalle médian des forces.	Medial interval of the forces.
25.	Verhältnissmassig mittlere Kraft.	Force médiane proportionnelle.	Proportionately medial force (2).
26.	Verhaltnissmässiges mittleres Kräfte Intervall.	Intervalle médian proportionnel des forces.	Proportionately medial interval of the forces (2).
27.	Gurtbelastungszug.	Train fléchissant.	Bending train (2).
28.	Strebenbelastungszug.	Train tranchant.	Shearing train (2).

(1) According to the nomenclature established for the International Railway Congress at Paris 1889; the module of inertia is the quotient obtained in dividing the moment of inertia by the height of the most entended compressed fibre above the neutral axis.

(2) These expressions are not made use of by engineers ordinarily; they have been introduced by the reporter and explained in the report.

Collection of technical terms used for bridge superstructures.

1.	Brücke mit obenliegender Bahn	Ponts à voie en dessus.	Bridge with track upon top chord (1).
2.	Brücke mit versenkter Bahn.	Ponts à voie contrebaissée.	Bridge with track below top chord (1).
3.	Brücke mit zwischenliegender Bahn.	Ponts à voie intermédiaire.	Bridge with track between main girders (1).
4.	Brücke mit untenliegender Bahn.	Ponts à voie en dessous.	Bridge with track on bottom chord (1).
5.	Hauptträger.	Maitresse poutre.	Main girder; bridge girder.
6.	Querträger.	Poutre transversale.	Transverse girder; cross beam.
7.	Längsträger.	Longeron.	Longitudinal stringer.
8.	Bahn, Fahrbahntafel.	Tablier de voie; voie (chaussée).	Sleeper girder, tie girder bridge floor.
9.	Windverstrebung.	Contreventement.	Windbracing.
10.	Querverbindung.	Entretoisement.	Tranverse bracing.
11.	Bleckträger.	Poutre à âme pleine.	Plate girder.
12.	Fachwerkträger.	Poutre à triangles.	Trussgirder. Truss.
13.	1, 2, 3 faches Fachwerk.	Triangulation simple, double, triple.	Single, double, triple Truss System.
14.	Gitterwerksträger.	Poutre en treillis.	Lattice girder.
15.	1, 2, 3 faches Gitterwerk.	Treillis simple, double, triple.	Single, double, triple Lattice System.
16.	Obergurt.	Bande supérieure.	Top chord; top boom.
17.	Untergurt.	Bande inférieure.	Bottom chord; bottom boom.
18.	Einfacher Gurt.	Bande simple, bande en T.	Single chord, chord with T profile.
19.	Doppelgurt, Kastengurt.	Bande double, bande en caisson.	Double chord, chord with channel profile.
20.	Knotenpunct.	Nœud, sommet des triangles, attache.	Riveted connection; apex of web triangles.
21.	Knotenblech.	Tôle d'attache; tôle de nœud.	Connecting plate.
22.	Stehblech.	Ame pleine; tôle verticale.	Web plate, vertical plate.
23.	Winkeleisen.	Cornière.	Angle; angle iron.
24.	Kopfbleche, Gurthamelle.	Plate bande; tôle de bande.	Cover plate.
25.	Gewalzte Träger.	Poutrelles laminées.	Rolled beams.
26.	U-eisen.	Fers en U.	Channel bars.

(1) It is only possible to discern whether a bridge is built with track on top chord or on bottom chord; in the first case the main girders are placed at a distance of nearly two metres or less, in the second case the width between them must be four metres at least.

Bridges with track below top chord or with track between main girders, are to be considered as special forms of the two categories of bridges described before.

PLATE I.

Diagrams of uniformly distributed loads per metre of track equivalent to the typical trains.

(Tableau graphique des surcharges uniformément réparties par mètre de voie équivalentes aux trains-types.)

REFERENCES (LÉGENDE EXPLICATIVE)

b^{I}	Extra-heavy trains.	Proposed scales of load for the calculation of shearing strains according to the length loaded.
b	Heavy trains . .	
a^{I}	Extra-heavy trains.	Proposed scales of load for the calculation of bending moments according to the length of the span.
a	Heavy trains . .	
	Locomotive L_1 .	Equivalent load per metre of track for shearing strains.
	Locomotive L_2 .	
	Locomotive L_3 .	
	Locomotive L_4 .	
	Locomotive L_1 .	Equivalent load per metre of track for bending moments.
	Locomotive L_2 .	
	Locomotive L_3 .	
	Locomotive L_4 .	

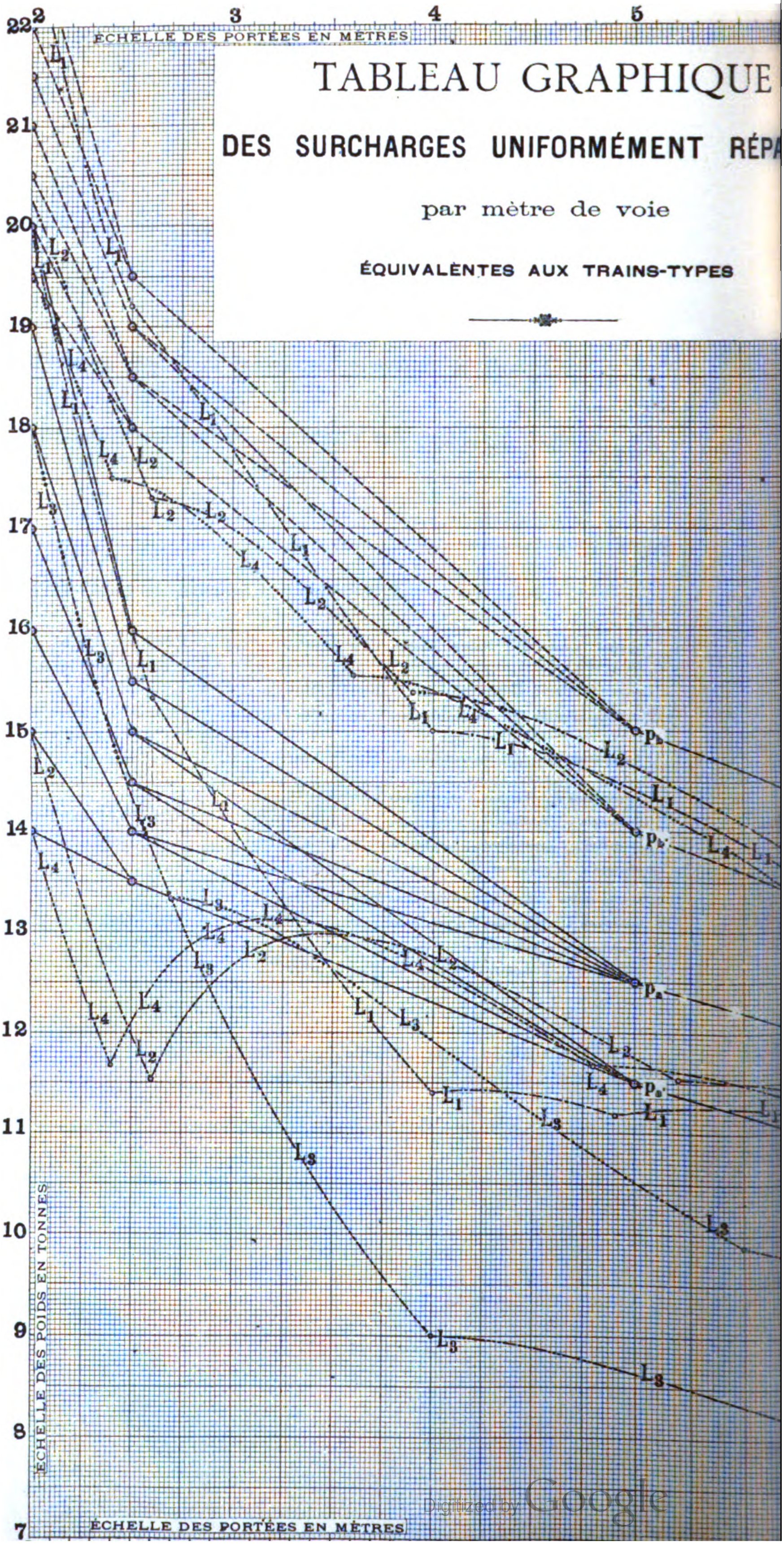
Scale of spans in metres. (Échelle des portées en mètres.)
Scale of weights in tons. (Échelle des poids en tonnes.)

TABLEAU GRAPHIQUE

DES SURCHARGES UNIFORMÉMENT RÉPA

par mètre de voie

ÉQUIVALENTES AUX TRAINS-TYPES



Pl. I.

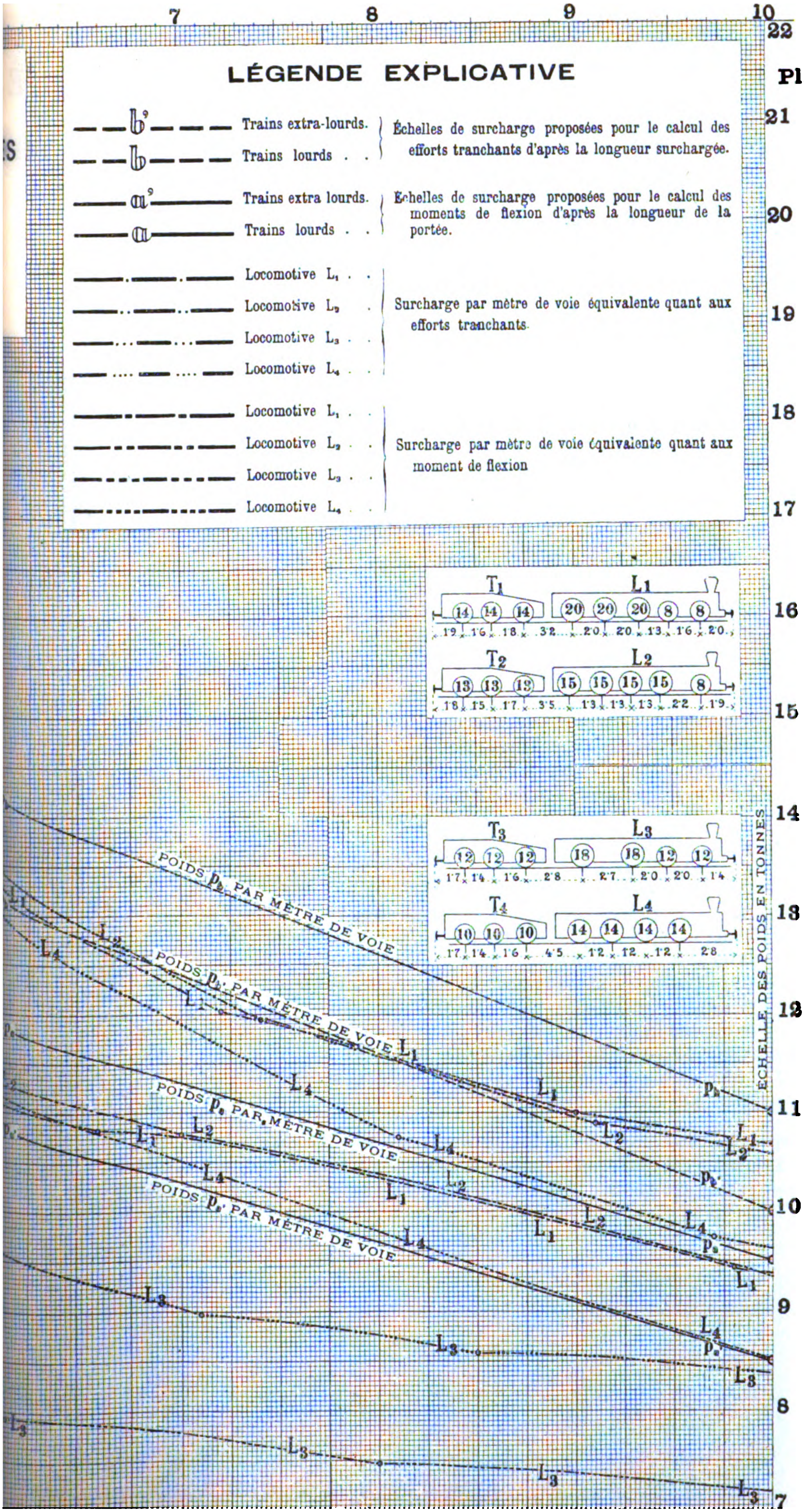

LÉGENDE EXPLICATIVE
b' Trains extra-lourds.
b Trains lourds
Échelles de surcharge proposées pour le calcul des efforts tranchants d'après la longueur surchargée.
a' Trains extra lourds.
a Trains lourds
Échelles de surcharge proposées pour le calcul des moments de flexion d'après la longueur de la portée.
Locomotive L1
Locomotive L2
Locomotive L3
Locomotive L4
Surcharge par mètre de voie équivalente quant aux efforts tranchants.
Locomotive L1
Locomotive L2
Locomotive L3
Locomotive L4
Surcharge par mètre de voie équivalente quant aux moment de flexion
T1
L1
T2
L2
T3
L3
T4
L4
POIDS P PAR MÈTRE DE VOIE
ÉCHELLE DES POIDS EN TONNES
7
8
9
10
22
21
20
19
18
17
16
15
14
13
12
11

PLATE II.

Diagrams of the characteristic coefficients of rupture and of elongation specified or allowed in different countries, for different qualities of steel.

(Tableau graphique des coefficients de rupture et d'allongement caractéristiques prescrits ou admis dans divers pays, pour fers fondus et aciers.)

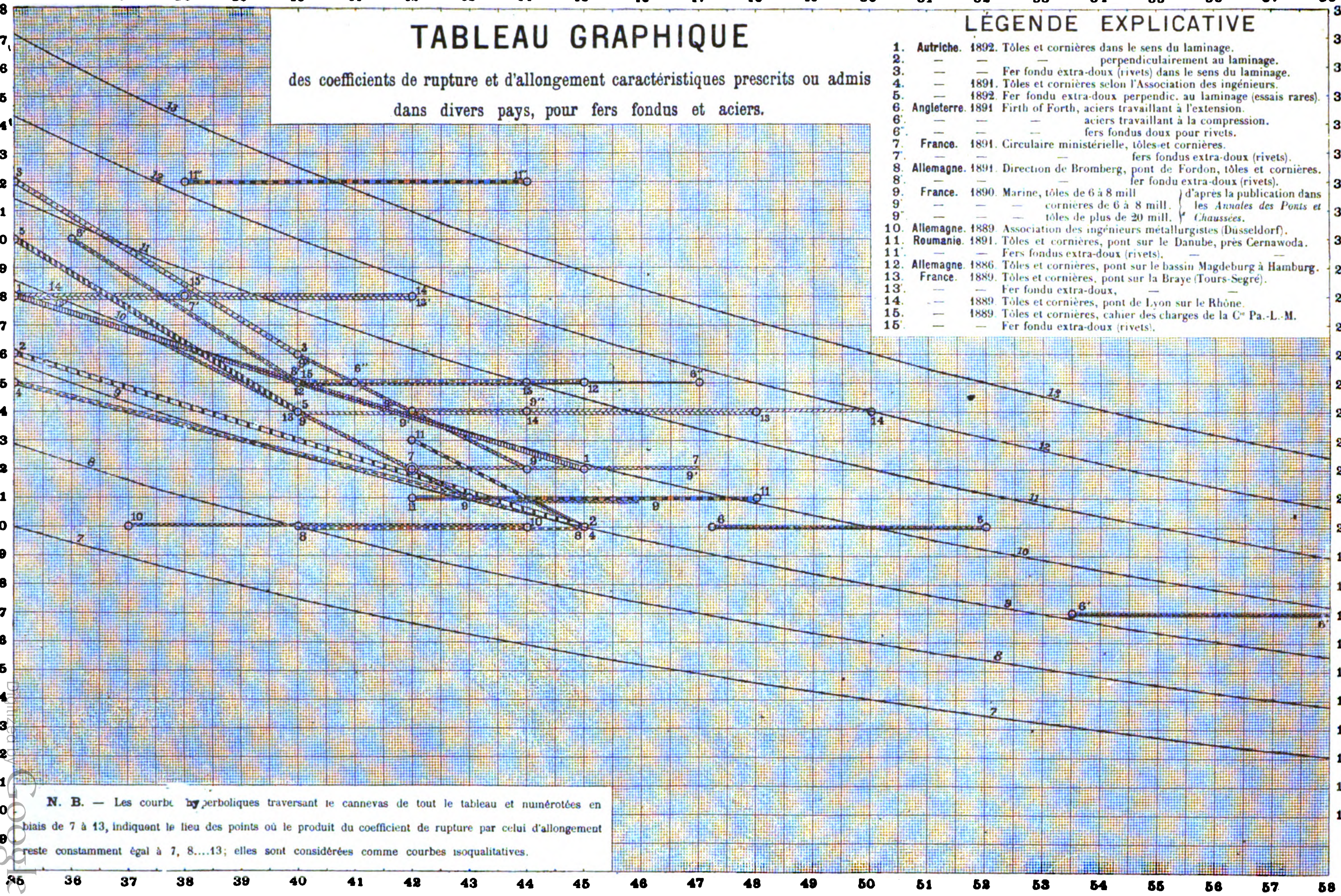
REFERENCES. (LÉGENDE EXPLICATIVE.)

1.	AUSTRIA.	1892.	Plates and angles in the direction of the grain.	
2.	—	—	— across the grain.	
3.	—	—	Extra mild steel (for rivets) in the direction of the grain.	
4.	—	1891.	Plates and angles according to the Association of engineers	
5.	—	1892	Extra mild steel across the grain (rare tests).	
6.	ENGLAND.	1891.	Firth of Forth, steel in tension.	
6'.	—	—	— steel in compression.	
6".	—	—	— mild steel for rivets.	
7.	FRANCE.	1891.	Ministerial circular, plates and angles.	
7'.	—	—	— extra mild steel (for rivets).	
8.	GERMANY.	1891.	Bromberg department, Fordon bridge, plates and angles.	
8'.	—	—	— extra milde steel (for rivets)	
9.	FRANCE.	1890.	Navy, plates from 6 to 8 millimetres.	According to the publication in the *Annales des ponts et chaussées*.
9'.	—	—	— angles from 6 to 8 —	
9".	—	—	— plates of more than 20 —	
10.	GERMANY.	1889.	Association of metallurgical engineers (Düsseldorf).	
11.	ROUMANIA.	1891.	Plates and angles, bridge over the Danube, near Cernawoda.	
11'.	—	—	Extra mild steel (for rivets).	
12.	GERMANY.	1886.	Plates and angles, Magdeburg, dock bridge to Hamburg.	
13.	FRANCE.	1889.	Plates and angles, bridge over the Braye (Jours-Segré).	
13'.	—	—	Extra mild steel — —	
14.	—	1889.	Plates and angles, Lyon bridge over the Rhone.	
15.	—	1839.	Plates and angles, specification of the P.-L -M. Company.	
15'.	—	—	Extra mild steel (for rivets).	

N. B. — The hyperbolic curves crossing the diagram from one side to the other and numbered on the slant from 7 to 13 indicate the position of the points where the product of the coefficient of rupture and tnat of elongation remain constantly equal to 7, 8... 13; they are considered as isoqualitative curves.

TABLEAU GRAPHIQUE

des coefficients de rupture et d'allongement caractéristiques prescrits ou admis dans divers pays, pour fers fondus et aciers.



REFERENCES FOR PLATE III.
(LÉGENDE EXPLICATIVE DE LA PLANCHE III.)

—— p_a —— Loads **a** for bending moments.	Extra-heavy trains.		Fig. 1.
— — p_b — — Loads **b** for shearing strains.			
—— $p_{a'}$ — — Loads **a'** for bending moments.	Heavy trains.		
— — $p_{b'}$ — — Loads **b'** for shearing strains.			

————	Full lines with explanations : curves for the weight of iron used per metre of track.	Fig. 2.
q_m . .	Mean dead load composed of the mean weight of iron used and 400 kilogrammes for permanent way.	
q_m+ . .	Total loads obtained as the sum of the mean dead load and each of the loads of fig. 1. (These values are not taken into account for the partial loads, in accordance with the principle of the lengths loaded.)	Fig. 3

Scale of spans in metres (Échelle des portées en mètres).
Scale of weights in tons (Échelle des poids en tonnes).

PLATE III.

Diagrams of uniform loads per metre of track equivalent to the typical trains for bending moments and for shearing strains, showing also the limiting curves for the weight per metre of track of material to be used in iron bridges according to the span, as well as the mean values of the total load to be taken into account in the calculations.

(Tableau graphique des surcharges uniformes par mètre de voie équivalentes aux trains-types, quant aux moments de flexion et aux efforts tranchants, indiquant, en outre, les contours limites du poids par mètre courant de voie du fer à investir dans les ponts métalliques suivant la portée ainsi que les valeurs moyennes de la charge totale à admettre dans les calculs.)

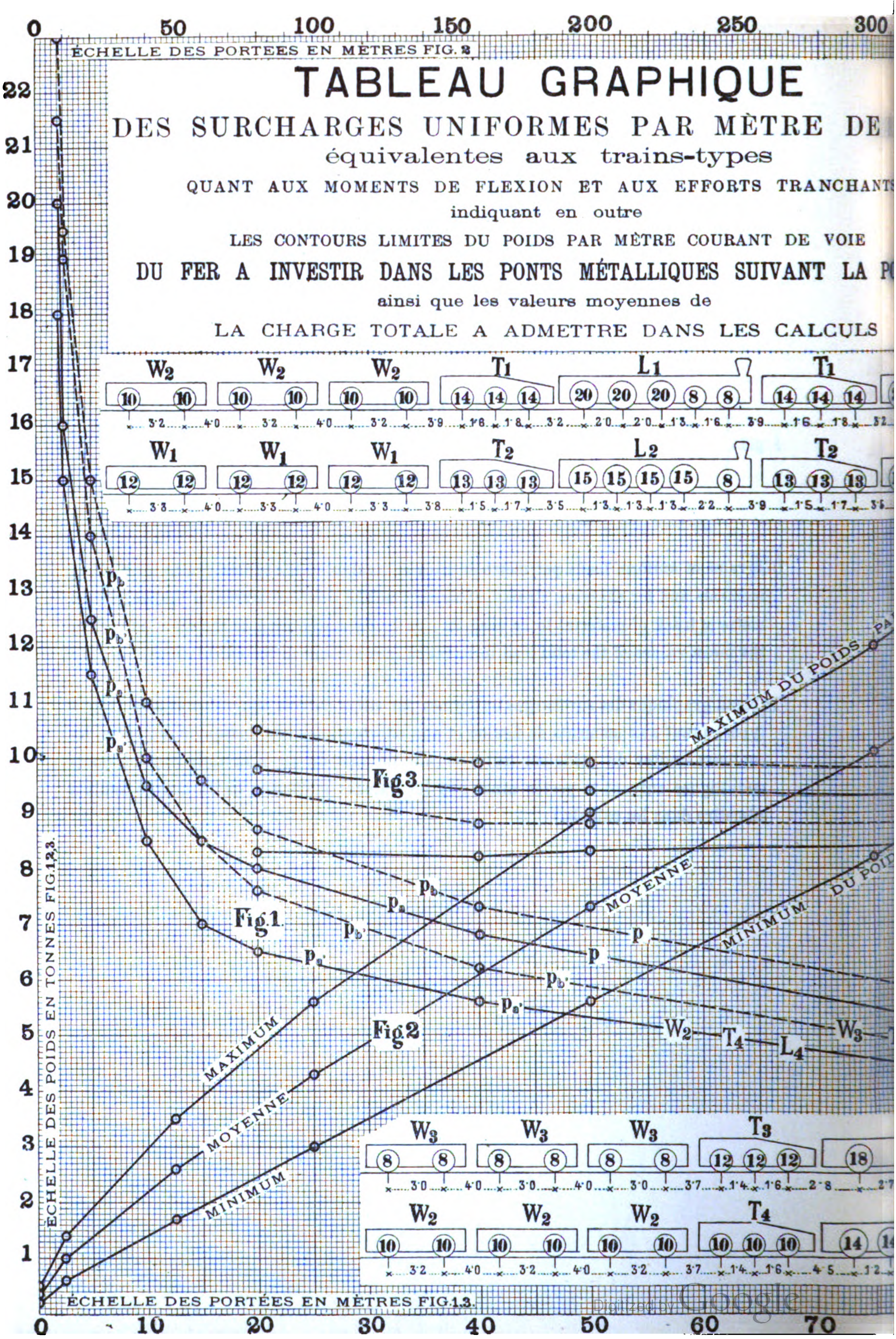
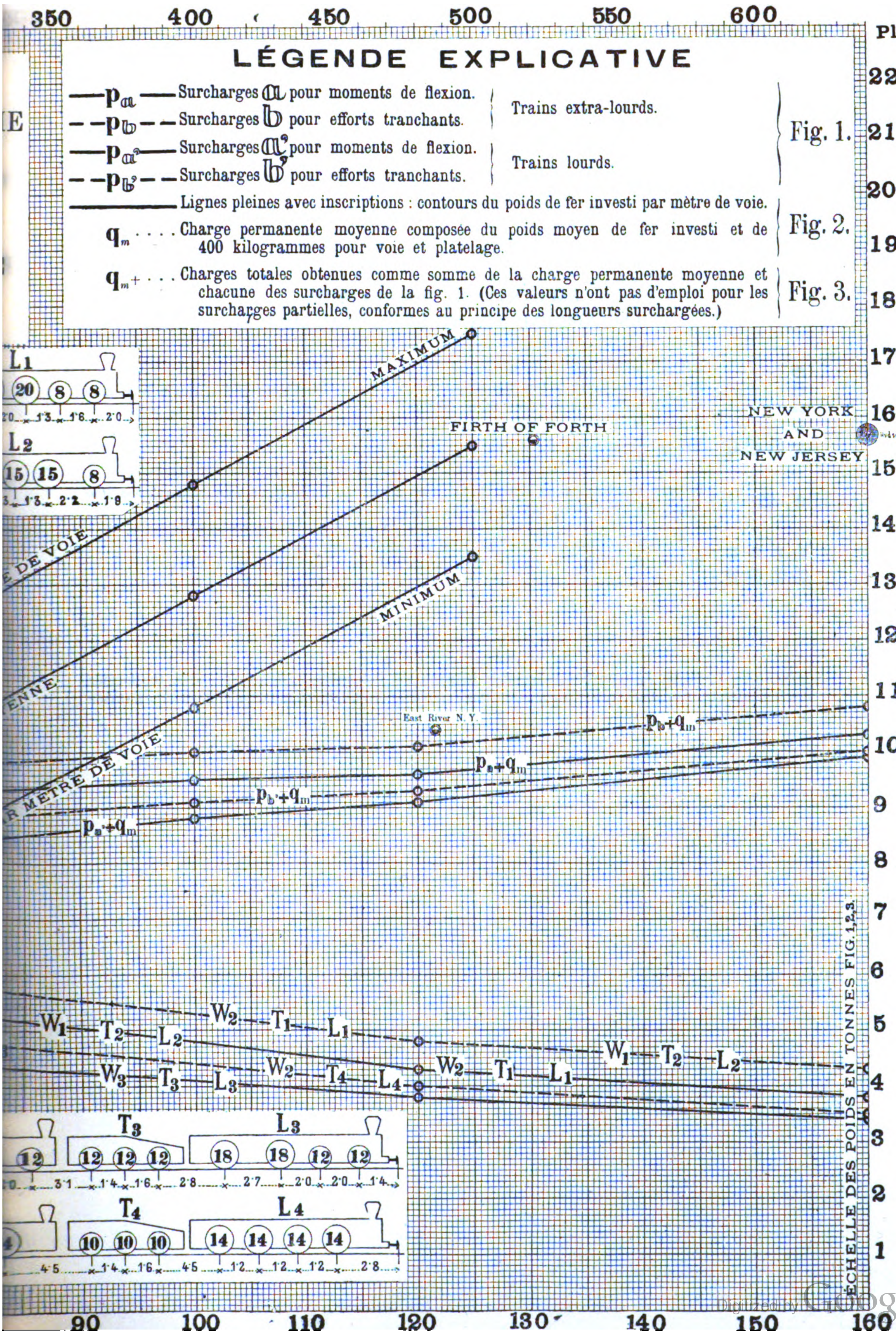


TABLEAU GRAPHIQUE
DES SURCHARGES UNIFORMES PAR MÈTRE DE
équivalentes aux trains-types
QUANT AUX MOMENTS DE FLEXION ET AUX EFFORTS TRANCHANTS
indiquant en outre
LES CONTOURS LIMITES DU POIDS PAR MÈTRE COURANT DE VOIE
DU FER A INVESTIR DANS LES PONTS MÉTALLIQUES SUIVANT LA P
ainsi que les valeurs moyennes de
LA CHARGE TOTALE A ADMETTRE DANS LES CALCULS
ÉCHELLE DES PORTÉES EN MÈTRES FIG. 2
ÉCHELLE DES PORTÉES EN MÈTRES FIG.1.3.
ÉCHELLE DES POIDS EN TONNES FIG.1.2.3.
Fig.1
Fig.2
Fig.3
MAXIMUM
MOYENNE
MINIMUM
MAXIMUM DU POIDS
MINIMUM DU POID
W2
W1
W3
T1
T2
T3
T4
L1
L2
L4


350
400
450
500
550
600
LÉGENDE EXPLICATIVE
pa Surcharges a pour moments de flexion. Trains extra-lourds.
pb Surcharges b pour efforts tranchants.
pa' Surcharges a' pour moments de flexion. Trains lourds.
pb' Surcharges b' pour efforts tranchants.
Fig. 1.
Lignes pleines avec inscriptions : contours du poids de fer investi par mètre de voie.
qm . . . . Charge permanente moyenne composée du poids moyen de fer investi et de 400 kilogrammes pour voie et platelage.
Fig. 2.
qm + . . . Charges totales obtenues comme somme de la charge permanente moyenne et chacune des surcharges de la fig. 1. (Ces valeurs n'ont pas d'emploi pour les surcharges partielles, conformes au principe des longueurs surchargées.)
Fig. 3.
L1
20
8
8
L2
15
15
8
MAXIMUM
FIRTH OF FORTH
NEW YORK
AND
NEW JERSEY
MINIMUM
DE VOIE
ENNE
R METRE DE VOIE
East River N. Y.
pb+qm
pa+qm
pb'+qm
pa'+qm
W2 T1 L1
W1 T2 L2
W3 T3 L3
W2 T4 L4
T3
L3
12
12
12
12
18
18
12
12
3·1
1·4
1·6
2·8
2·7
2·0
2·0
1·4
T4
L4
10
10
10
14
14
14
14
4·5
1·4
1·6
4·5
1·2
1·2
1·2
2·8
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
ÉCHELLE DES POIDS EN TONNES FIG. 1, 2, 3.
90
100
110
120
130
140
150
160

EXPLANATIONS FOR PLATE IV.
(LÉGENDE EXPLICATIVE DE LA PLANCHE IV.)

.... Bridges with track upon top chord . . . . Bridges with track below top chord . . . . Bridges with track between main girders . ... Bridges with track on bottom chord . . .	Constructed for a single line, normal gauge, or a little more.

Bridges constructed for double line normal gauge.

..... Bridges constructed as above to be used either as Railway or foot bridges; the line and the road being one above the other.

Bridges as above, but constructed for an unusual gauge of about a metre.

N. B. — To enable a distinction to be made between the indications of figures 1 and 2, the former are indicated by a smaller circle. In general, the number of circles for each bridge indicates the number of lines thereon.

PLATE IV.

Illustrative table of weight of iron used per metre of line for more than a thousand iron arches.

(Tableau graphique des poids du fer employé par mètre courant de voie pour plus d'un millier de travées métalliques.)

EXPLANATION OF FRENCH TERMS USED ON THE PLATE IV.
(LISTE ALPHABÉTIQUE DES ABRÉVIATIONS DÉSIGNANT LES ADMINISTRATIONS DES CHEMINS DE FER.)

Alphabetical list of abbreviations used to distinguish different Railway Administrations. (Liste alphabétique des abréviations désignant les Administrations de chemins de fer.)

Scale of weights in tons. (Échelle des poids en tonnes.)

Scale of spans in metres. (Échelle des portées en mètres.)

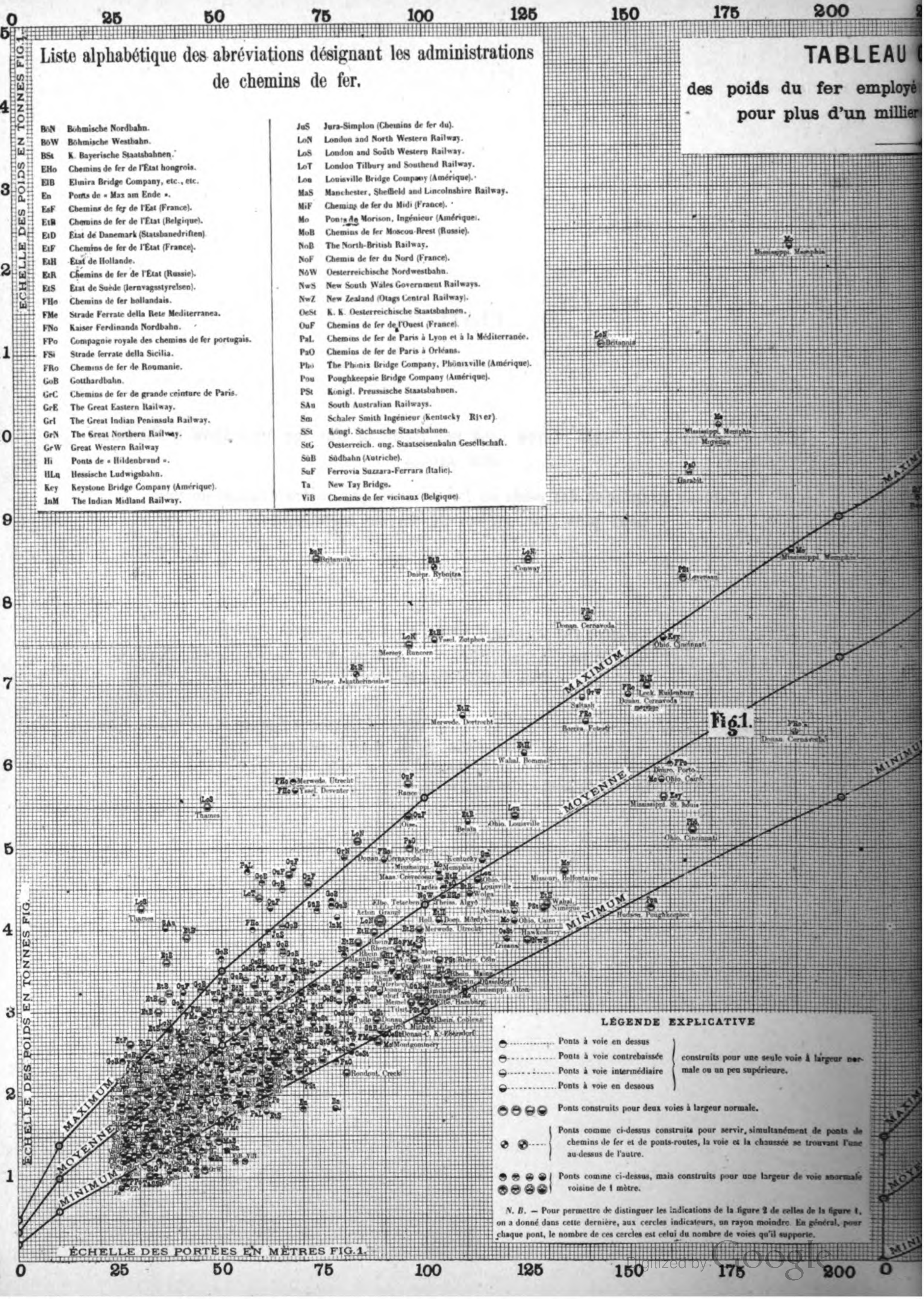


TABLEAU
des poids du fer employé
pour plus d'un millier
Liste alphabétique des abréviations désignant les administrations de chemins de fer.
BöN Böhmische Nordbahn.
BöW Böhmische Westbahn.
BSt K. Bayerische Staatsbahnen.
EHo Chemins de fer de l'État hongrois.
ElB Elmira Bridge Company, etc., etc.
En Ponts de « Max am Ende ».
EaF Chemins de fer de l'Est (France).
EtB Chemins de fer de l'État (Belgique).
EtD État de Danemark (Statsbanedriften).
EtF Chemins de fer de l'État (France).
EtH État de Hollande.
EtR Chemins de fer de l'État (Russie).
EtS État de Suède (Iernvagsstyrelsen).
FHo Chemins de fer hollandais.
FMe Strade Ferrate della Rete Mediterranea.
FNo Kaiser Ferdinands Nordbahn.
FPo Compagnie royale des chemins de fer portugais.
FSi Strade ferrate della Sicilia.
FRo Chemins de fer de Roumanie.
GoB Gotthardbahn.
GrC Chemins de fer de grande ceinture de Paris.
GrE The Great Eastern Railway.
GrI The Great Indian Peninsula Railway.
GrN The Great Northern Railway.
GrW Great Western Railway
Hi Ponts de « Hildenbrand ».
HLu Hessische Ludwigsbahn.
Key Keystone Bridge Company (Amérique).
InM The Indian Midland Railway.
JuS Jura-Simplon (Chemins de fer du).
LoN London and North Western Railway.
LoS London and South Western Railway.
LoT London Tilbury and Southend Railway.
Lou Louisville Bridge Company (Amérique).
MaS Manchester, Sheffield and Lincolnshire Railway.
MiF Chemins de fer du Midi (France).
Mo Ponts de Morison, Ingénieur (Amérique).
MoB Chemins de fer Moscou-Brest (Russie).
NoB The North-British Railway.
NoF Chemin de fer du Nord (France).
NöW Oesterreichische Nordwestbahn.
NwS New South Wales Government Railways.
NwZ New Zealand (Otago Central Railway).
OeSt K. K. Oesterreichische Staatsbahnen.
OuF Chemins de fer de l'Ouest (France).
PaL Chemins de fer de Paris à Lyon et à la Méditerranée.
PaO Chemins de fer de Paris à Orléans.
Pho The Phœnix Bridge Company, Phœnixville (Amérique).
Pou Poughkeepsie Bridge Company (Amérique).
PSt Konigl. Preussische Staatsbahnen.
SAu South Australian Railways.
Sm Schaler Smith Ingénieur (Kentucky River).
SSt Köngl. Sächsische Staatsbahnen.
StG Oesterreich. ung. Staatseisenbahn Gesellschaft.
SüB Südbahn (Autriche).
SuF Ferrovia Suzzara-Ferrara (Italie).
Ta New Tay Bridge.
ViB Chemins de fer vicinaux (Belgique).
ÉCHELLE DES POIDS EN TONNES FIG. 1.
ÉCHELLE DES POIDS EN TONNES FIG.
ÉCHELLE DES PORTÉES EN MÈTRES FIG. 1.
MAXIMUM
MOYENNE
MINIMUM
Fig.1.
LÉGENDE EXPLICATIVE
Ponts à voie en dessus
Ponts à voie contrebaissée
Ponts à voie intermédiaire
Ponts à voie en dessous
construits pour une seule voie à largeur normale ou un peu supérieure.
Ponts construits pour deux voies à largeur normale.
Ponts comme ci-dessus construits pour servir, simultanément de ponts de chemins de fer et de ponts-routes, la voie et la chaussée se trouvant l'une au-dessus de l'autre.
Ponts comme ci-dessus, mais construits pour une largeur de voie anormale voisine de 1 mètre.
N. B. — Pour permettre de distinguer les indications de la figure 2 de celles de la figure 1, on a donné dans cette dernière, aux cercles indicateurs, un rayon moindre. En général, pour chaque pont, le nombre de ces cercles est celui du nombre de voies qu'il supporte.

Pl. IV.

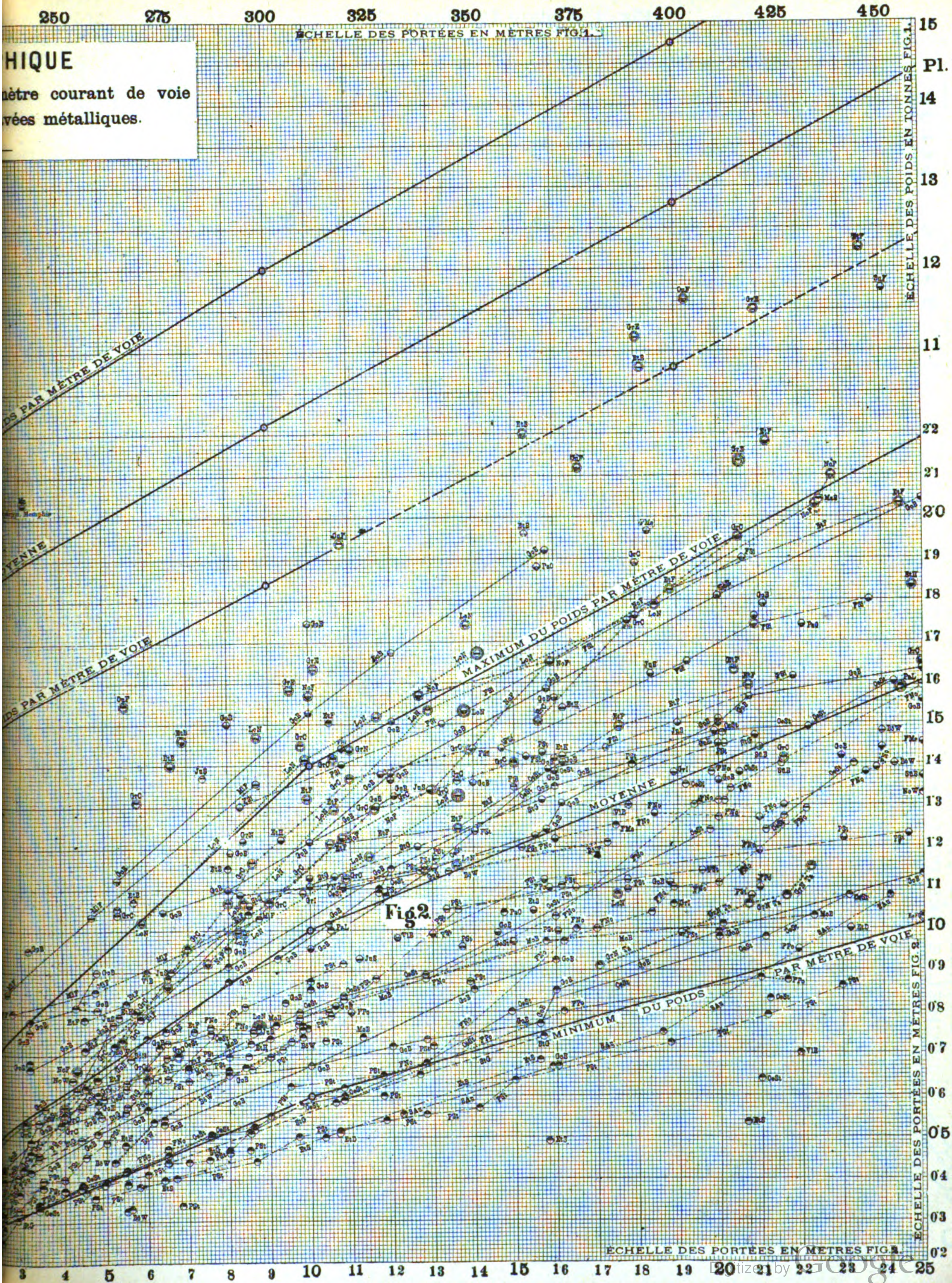
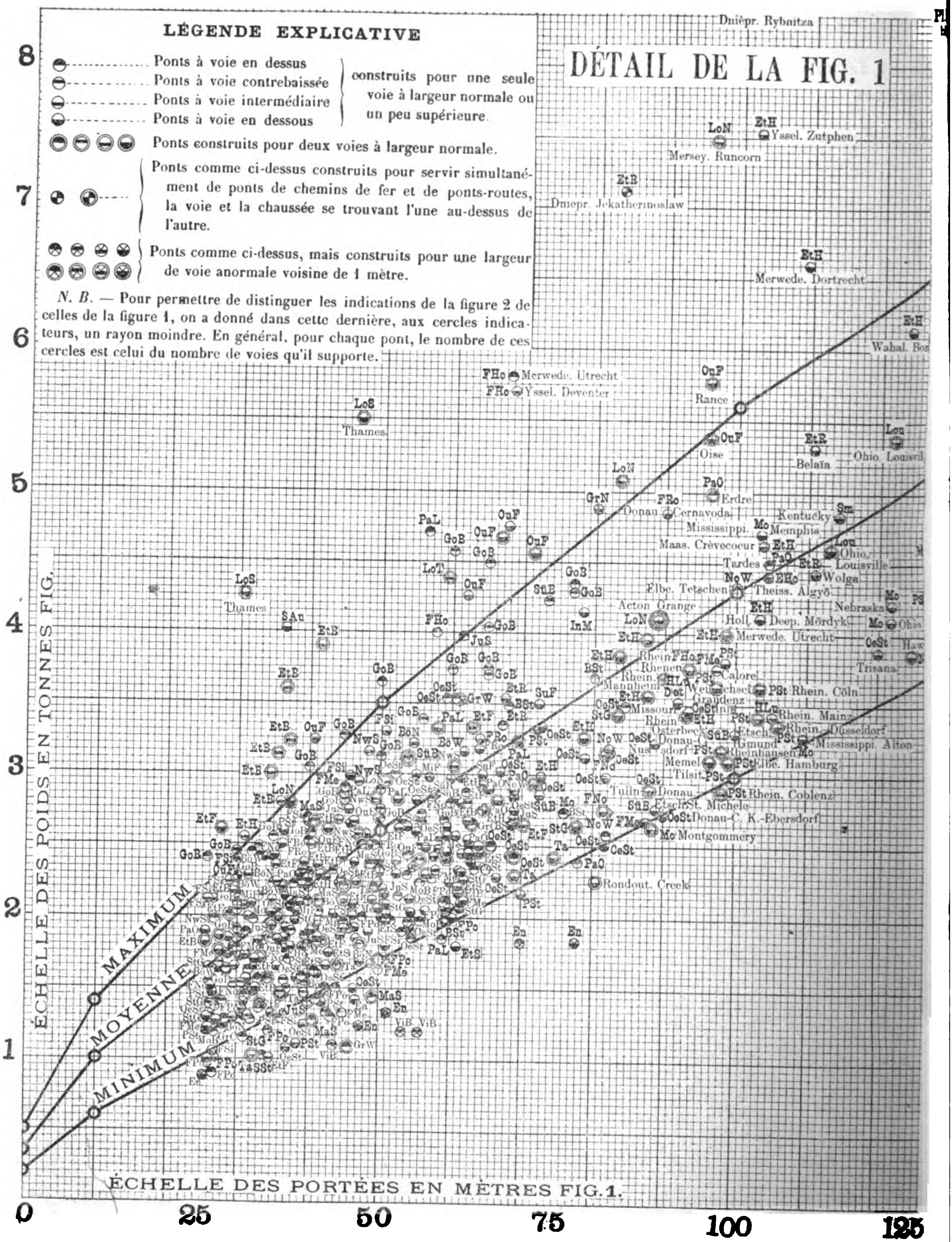

HIQUE
mètre courant de voie
vées métalliques.
ECHELLE DES PORTÉES EN MÈTRES FIG.1.
250 275 300 325 350 375 400 425 450
ECHELLE DES POIDS EN TONNES FIG.1.
15 14 13 12 11
PDS PAR MÈTRE DE VOIE
MOYENNE
DS PAR MÈTRE DE VOIE
MAXIMUM DU POIDS PAR MÈTRE DE VOIE
MOYENNE
MINIMUM DU POIDS PAR MÈTRE DE VOIE
Fig.2.
2'2 2'1 2'0 1'9 1'8 1'7 1'6 1'5 1'4 1'3 1'2 1'1 1'0 0'9 0'8 0'7 0'6 0'5 0'4 0'3 0'2
ECHELLE DES PORTÉES EN MÈTRES FIG.2.
ECHELLE DES PORTÉES EN MÈTRES FIG.2.
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

Fig. 1 of plate IV enlarged.



DISCUSSION BY THE FIRST SECTION

July, 4, 1895 (morning).

MR. JEITTELES, PRESIDENT, IN THE CHAIR

Mr. von Leber, *Reporter*. (In French.) — Gentlemen, I must first of all warn you that I have no intention of asking the Congress to settle any definite rules on this important question. My aims are far more modest.

I have simply tried to state what results have been obtained and to group them together in such a way as to better appreciate their value.

I first investigated the standard engines and bridges in use in different countries, and on this point I have collected plenty of information. The load regulations at present in force in some countries, taking as a basis definite typical engines, give results which vary very much according to the span of the bridges.

Plate I, following page 102 (English edition) in my report, shows the curves produced by the engines on bridges of spans of from 6 feet 7 inches to 32 feet 10 inches (2 to 10 metres).

My intention in preparing these diagrams was to show you that when the method of using a typical engine is adopted, very different results are arrived at according to the span of the bridges concerned. Indeed if we take short spans we find that, for a span of about 10 feet (3 metres), there is a marked variation in the case of most typical engines. This variation is done away with if the regulations are drawn up for uniform loads, and all these different results can be replaced by a series of straight lines.

Before going further let me say a few words to explain this.

Generally when we speak of the loads on bridges the maximum axle loads are meant, but the importance of this factor is quite exaggerated. The axle loads only affect bridges of short span, 16 feet (5 metres) at most. Let us first deal with these short spans where the axle loads only have to be taken into consideration. These vary in practice from 12 to 20 tons and reach in one case in America as much as 22 tons according to Mr. Toucey. I confess I used to think 20 ton loads as the heaviest needing consideration.

According to my researches, the axle loads of an express engine with a capacious boiler, large cylinders and large wheels, will be not less than 6 feet 7 inches (2 metres) apart.

*

When the loads are less, the distance between the axles will be correspondingly less. There is then necessarily a certain ratio between the distance between the axles and the maximum loads that they can be estimated as carrying.

The following is approximately the ratio :—

Axle loads	12 t.	13 t.	14 t.	15 t.	16 t.	17 t.	18 t.	19 t.	20 t.
Minimum distance . . .	3'3" ($1^{m}00$)	3'7" ($1^{m}10$)	3'11" ($1^{m}20$)	4'3" ($1^{m}30$)	4'7" ($1^{m}40$)	5'1" ($1^{m}55$)	5'7" ($1^{m}70$)	6'1" ($1^{m}85$)	6'7" ($2^{m}00$)

We can therefore see that some engines with heavy axle loads but axles far apart may produce a less strain on one class of structure than engines with lighter axle loads but axles nearer together.

The result of the scale which I have established is to considerably simplify the question of loads on bridges of short span. In fact, suppose to a bridge of given span we applied one after another all the standard engines with axle loads varying from 12 to 20 tons, the distances between the axles being proportionate to the axle loads, we could not load that bridge above what is shown in the table inserted on page 44 of my report, whatever the vehicles in question were. For each span and each maximum axle load I have taken the highest result obtained in all experiments. The figures given in my table for spans of from 3 feet to 16 feet (1 to 5 metres) have been taken as the nearest ton and half-ton, but they are quite near enough.

Let us now consider longer spans.

In these we must necessarily investigate the results given by express trains and goods trains as representing the two extremes.

On the continent in bridge calculations a 4 coupled engine, whose axle loads are not very great, is taken; as a rule the loads hardly exceed 14 tons. On the other hand the axle loads of express engines are greater; in Germany and Austria they do not exceed 15 tons, while in France they are as much as 17 tons, and in England they exceed 18 tons.

I have divided the railways and the loads prescribed under two heads, one of which takes in practically all Europe and the other America, but I have had to leave as it were a margin for future developments. In both categories I have taken into consideration the two extremes of traffic, namely, the fastest passenger train and the heaviest goods train. The express train has the heavier axle loads, engine and tender, but the goods train has the heavier vehicles.

I have come to the conclusion that these two classes of loads which I have just indicated are such as to ensure the perfect safety of bridges, and that, besides, these loads are not excessive, for sometimes they are even greater than I have considered.

The vote I am asking you to pass is only to affirm the statements I lay before you. I have just told you these loads are not excessive and that they are not so great as are prescribed in some countries, especially America.

Here are the results of specifications sent me by the following American engineers: Theodore Cooper, 1890; G. Bouscaren, 1890, and J.-A.-L. Waddel, 1893. As a rule, a distinction is made between several (3 to 7) classes of railways on which the typical trains differ only in their axle loads. For comparison, I give the following :—

Span	16 ½ ft. (5m00)	33 ft. (10m)	49 ft. (15m)	65 ½ ft. (20m)	
Extra heavy trains . . .	12.5 t.	9.5 t.	8.5 t.	8.0 t.	Proposed in my report.
American typical trains .	13.8 t.	11.3 t.	9.9 t.	9.0 t.	Proposed by Waddel.

I must say on this point that the typical engine taken in America for calculating seems to me difficult to picture, for they take four loads of 20 tons and axles only 5 feet (1m50) apart. What we really require to arrive at, gentlemen, is a system of loads embracing as far as possible the strains produced by trains which are actually running on all railways, and not the strains produced by imaginary engines which will perhaps never be built and which each engineer may imagine as heavy as he likes, according to the excess of safety which he intends to allow for.

Let me, gentlemen, say a few words about the scale of loads I am proposing, based on the rolling stock in actual use.

(The speaker here drew on the blackboard explanations of the diagrams contained in his report.)

As I have just shown you, two loads must be taken into consideration, one to calculate the bending moments and the other to calculate the shearing strains.

For the benefit of those of my audience who are not conversant with this question I shall take the liberty of going into a few details.

Ten years ago, the same scale of loads was used to calculate both the chords and the web-bracing of bridges. Then two scales were used, one for the maximum bending moment at the middle of the bridge, the other for the shearing strains near the abutments. The results so obtained were not very exact. In fact, if I take an equivalent load for the bending moment towards the middle of the bridge there is an error for the sections towards the ends; on the other hand, if I take an equivalent load for the shearing strains near the supports of the bridge it will not agree with that at the middle of the bridge where the error may be from 20 to 50 p. c. However, we have succeeded in avoiding this serious inconvenience without having to use more than two scales of loads, one for the bending moments and the other for the shearing strains at all points of the bridge. For the bending moments, the error only occurs for spans between 33 feet and 100 feet (10 and 30 metres); for the shearing strains there is no error if the new principle of commencing with the lengths loaded is adopted.

Suppose we want to calculate the bracings of a bridge of 132 feet (40 metres) span near its centre; to get the greatest shearing strain it will be necessary to apply a load on 66 feet (20 metres), that is, one half of the bridge. In the case of a bridge of 66 feet span (20 metres), the web-bracing under consideration being near the abutment, it will still be 66 feet (20 metres), the entire span, that will have to be loaded. Well then, in the two cases it is exactly the same load per foot run which takes the place of the train. In a word, the load depends not on the span, but on the length loaded;

that is what is called the principle of lengths loaded, and it is mathematically exact.

The scales which I have established and which are obtained by the application of this principle are applicable to all bridges, including arches and continuous girders.

Some very interesting verifications founded on the principle of lengths loaded have been made in Austria in the case of an arch bridge of 230 feet (70 metres) span. The train once in position on the bridge, each chord and each piece of web-bracing has been investigated in its most unfavourable position with regard to the train. In this way it has been possible to calculate exactly the sections and to make the comparisons of which I speak.

It is quite unnecessary for me to tell you that an undertaking of this kind is very complicated. In the first place exact results have been obtained and then a method has been devised of arriving at these same results more simply.

I am quite convinced that the proper method is to use the scales of loads uniformly distributed over the length of the bridge.

I have no intention, as I said at the outset, of asking you to recommend universally the adoption of the rules which I have mentioned in my report. I simply express the opinion that each country and railway Company should make researches and investigations similar to mine and that in each Company the calculations made should have for their object the obtaining of fixed scales of uniformly distributed loads which would embrace all the trains running on the lines under consideration. This is a work that has only to be done once. When these scales of loads have been established, they can at once be applied to all spans or lengths loaded without involving fresh calculations. I propose therefore on the basis of all the data actually collected for the Congress to submit for your approval the two following tables of loads. (*Applause.*)

Table of loads uniformly distributed per foot of track equivalent to the loads of typical trains.

SPAN OR LENGTH LOADED.	EXTRA-HEAVY TRAINS.		HEAVY TRAINS.	
	a. Bending strains. — Load per foot of span.	b. Shearing strains. — Load per foot of length loaded.	a. Bending strains. — Load per foot of span.	b. Shearing strains. — Load per foot of length loaded.
3 1/4 feet.	12 tons.	12 tons.	10·8 tons.	10·8 tons.
5 —	8·1 —	8·4 —	7·2 —	7·8 —
6 1/2 —	6 —	6·9 —	5 4 —	6·5 —
8 —	4·8 —	5·9 —	4·5 —	5·7 —
16 1/2 —	3·8 —	4·5 —	3·5 —	4·2 —
33 —	2·9 —	3·3 —	2·5 —	3·0 —
49 —	2·5 —	2·9 —	2·1 —	2·5 —
66 —	2·4 —	2·6 —	2·0 —	2·3 —
132 —	2·0 —	2·2 —	1·7 —	1·9 —
262 —	1·6 —	1·7 —	1·3 —	1·4 —
394 —	1·3 —	1·4 —	1·1 —	1·2 —
525 —	1·1 —	1·3 —	1·0 —	1·0 —

N. B. — For intermediate spans or lengths loaded proceed by rectilineal interpolation.

Table of loads uniformly distributed per foot of track equivalent to the loads of typical vehicles, according to the maximum axle-load considered.

SPAN OR LENGTH LOADED.	TRAINS.	14 tons.		15 tons.		16 tons.		17 tons.		18 tons.		19 tons.		20 tons.	
		a	b	a	b	a	b	a	b	a	b	a	b	a	b
3 1/4 feet.	Extra heavy, or heavy, or any class.	8·4	8 4	9·0	9·0	9·6	9 6	10·3	10 3	10·9	10 9	11·5	11·5	12·0	12 0
5 —	Extra heavy, or heavy, or any class.	5·7	7·2	6·0	7·5	6·3	7·5	6 8	7·8	7·2	7·8	7·7	8·1	8·1	8·4
6 1/2 —	Extra heavy, or heavy, or any class.	4·2	5·9	4·5	6·0	4·8	6·2	5·1	6 3	5·4	6·5	5·7	6·6	6·0	6·9
8 —	Extra heavy, or heavy, or any class.	4·1	5·4	4·0	5·4	4·2	5·6	4·4	5 6	4·5	5·7	4 7	5·9	4·8	5·9
16 1/2 —	Extra heavy,	...	...	...	...	3·8	4·5	3·8	4·5	3·8	4·5	3·8	4·5	3·8	4·5
16 1/2 —	heavy.	3·5	4·2	3·5	4·2	3·5	4·2	3 5	4·2	3·5	4·2	...	...	...	...

N. B. — For intermediate spans or lengths loaded proceed by rectilineal interpolation, those spans between 8 and 16 1/2 feet (2·5 and 5 metres) being considered in the group to which they are nearest.

Mr. Moïse, Western Railway of France. (In French.) — I have not the least intention of criticising the admirable report of Mr. von Leber. I simply wish to express the ideas that have been suggested to me by it.

In the first place I must point out a slight mistake which occurs at page 10 (English edition) of Mr. von Leber's report, where he says : " Between 1871 and 1876, nearly all the principal European Railway Companies had come to adopt types of locomotives with coupled axles for express trains, and it seemed as if this innovation would result in a proportionate lightening of the load borne by one single axle, and also of the strain brought to bear on iron structures by such an axle. Subsequent experience, however, proved the contrary, at least as far as the continent was concerned. "

In connection with this subject I would remind you that, as far back as 1856, the Western Railway of France were using express engines with two axles coupled. There were twelve of these engines and they gave good results.

I must also take exception to the first part of the report which is an answer to the question (letter A) : " What are the quantities of metal used and required to be used in bridges according to the regulations in force? "

I do not know if this wording was such as to require such detailed investigation as to the method of calculation of metallic structures and to oblige the reporter to establish scales for the calculation. I quite admit, however, that Mr. von Leber has said that he does not in any way wish to impose his scales of loads.

We all know how laborious calculations with typical trains are for iron bridges if the weight on each axle is taken into account. It is much simpler, instead of using the axle loads of the typical train, to adopt a method of uniformly distributed loads. I quite agree with Mr. von Leber as to the advantages of this principle. But there are several methods of applying it as regards bending moments. It should be observed that the results differ according to the method adopted in substituting the uniformly distributed loads for the concentrated loads.

When the several axle loads are considered a curve is obtained which is more elliptical than parabolic, so that the uniformly distributed loads do not give quite exactly the bending moments at all points of the girder. Several methods have been devised to eliminate the error resulting from the calculation by uniformly distributed loads. A parabola can be drawn which gives the greatest moment accurately at the centre, but then the moments are too low between the centre and the points of support. A parabola can also be drawn embracing all the moments produced at the different points of the girder by the concentrated loads. In this case the greatest moment at the centre is too high. It has been proposed to adopt this parabola, but to cut it with a straight line so as to reduce the greatest moment to that given by calculation from axle loads.

Another method is to employ two uniformly distributed loads, one for the length covered by the engine, the other for the length covered by the wagons. By means of this last method a scale of loads is obtained which more nearly approaches to the true scale than that obtained by using one uniform load.

I do not recommend any one of these methods. I have merely mentioned them because they have led me to the opinion that it would not be right to stick too closely to the conclusions arrived at in the report, where only one method is mentioned, whereas there are three used in practice and many others could be found.

The method of calculation which Mr. von Leber recommends should not be adopted to the exclusion of the others, and I consider that the Congress will be right in confining itself to stating that the method of calculation by uniformly distributed loads on the whole or on part of the length of the span is to be recommended, without, however, modifying the existing regulations based on calculations with typical trains.

Mr. von Leber, *Reporter*. (In French.) — I do not think it is any use to discuss the question from an historical point of view raised by Mr. Moïse because it is really of no great importance. I will only say that the information which I have given on the subject was taken from a work by Mr. Jacqmin, whose authority cannot be disputed.

The question of lateral bending moments on the other hand is one of great importance. It has been studied very thoroughly in Austria and was stated in detail in the Russian regulations of 1884. These regulations take into consideration the various methods alluded to by Mr. Moïse. They fix three scales of loads : one for the bending moments at the middle of the span, another for the shearing strains near the supports, and the third embracing both the bending moments near the supports and the shearing strains at the middle of the span. For intermediate sections the necessary interpolations can be made.

We have endeavoured to simplify this system by making a number of calculations with our typical trains for a large number of spans, and this is the curious result which has been arrived at as regards the bending moments.

The difference obtained between the maximum equivalent load for bending moments found on the lateral sections and the corresponding equivalent load towards the middle of the bridge is generally not by any means so great as Mr. Moïse supposes. It is found that there is an appreciable difference only in the case of a limited number of spans, say from 33 feet up to 100 feet (10 metres to 30 metres). For other spans the difference is not worth taking into account and in any case never exceeds 18 p. c. It is probable that, if Mr. Moïse's researches had been spread over a larger number of spans, he would have arrived at the same result.

We had two alternatives, either to draw up several scales of loads or to use one only, which latter method, however, involves some slight errors. We have preferred to divide the error and have said :— Let the scale of loads between 33 feet and 100 feet (10 metres and 30 metres) span be slightly increased, and let a mean be taken between what is found for the central section and the lateral sections respectively in such a way that the error never exceeds 9 p. c. If this is done and the calculations are made for a bridge whose span is between 33 feet and 100 feet (10 metres and 30 metres) the section at the middle will be found to be a little too great, whereas the lateral sections will be a little too small. But in practice we have found that there is no error when bridges of such spans are considered.

It is a fact that the length of plate girders has now reached a limit of 50 feet (15 metres); and further their lateral sections have always got a high resistance according to the parabolic law. For longer lattice girders the sections of the chords are always made a little larger than is necessary to facilitate the riveting where the lattice bars meet the chords. From practical experience we have found that it sufficed to slightly raise the line of uniformly distributed loads for spans between 33 feet and 100 feet (10 metres and 30 metres) to give very satisfactory results.

In a work which I published in 1888, I established a comparison between the results given by the above process and those given by adopting the Russian regulations. The differences are very slight and for that reason I recommend the system of mean loads or one single scale for bending moments which satisfies all requirements in practice.

Mr. Belelubsky, Russian State Railways. (In French.) — I think, gentlemen, that we ought to thank the International Commission for inviting us to discuss in England the question which is now occupying our attention.

The reporter, Mr. von Leber, has thus had an opportunity of stating at the beginning of his paper that English engineers and metallurgists have always held and still hold the foremost place amongst those who are concerned with the construction of metallic bridges. Only those who have had the good fortune to visit the Forth Bridge can appreciate the importance of that gigantic work, a proper idea of which cannot be got from descriptions or photographs.

The work of Mr. von Leber divides itself under four distinct heads which treat of: — 1st The historical aspect of the question; 2nd The loads; 3rd The coefficients of safety; 4th The best types of construction to adopt, based on the results of recent experience. I think that each part should be considered separately, for each one contains not only much information but also the opinions formed by the reporter.

If you will allow me I will give some explanations as to the Russian regulations of 1884, between which and the Austrian regulations of 1887 Mr. von Leber has drawn a parallel.

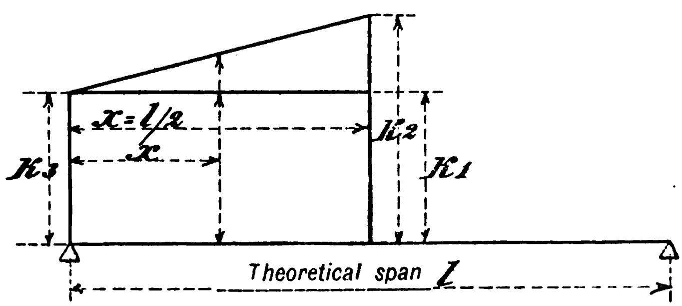
As you have seen, the reporter compares the two methods of calculation. I find at pages 24, 25 and 26 (English edition) of his report the following passages :—

The Russian circular of the 5th (17) of January 1884, No. 60, published in the *Journal of the Ministry for Ways and Roads* of the 10th of February 1884, addressed to inspectors, directors and managers of railways concerning "the technical conditions to be observed in iron structures for railway bridges", contains the most complete regulations about live loads, amongst all similar rules previously published. In it are fixed the equivalent loads, for the bending and shearing strains, for those parts of the bridge near the supports and for those near the middle of the span, with directions to proceed by interpolation for the intermediate parts of the bridge . . . .

. . . .

The resulting complication of the practical application of these carefully studied regulations causes their scientific value to be forgotten, for constructors generally prefer to make their calculations directly by means of equivalent train loads which are also indicated by the Russian circular, rather than have recourse to all the interpolations that we have just mentioned.

I would like, gentlemen, to say a few words in explanation of the table given in the Russian circular of 1884, so as to give you a better idea of the simplicity of the calculations :—



According to the table at page 25 of the report (English edition) we have three equivalent live loads : (1.) K_1 for the moment M_x, if $x = \frac{l}{2}$; (2.) K_2 for V_x, if $x = \frac{l}{2}$; and (3.) K_3 for V_x and M_x quite close to the supports. For example let us take a span of 49 feet (15 metres). Then,

$$K_1 = 1.80;\ K_2 = 2.94;\ K_3 = 2.19 \text{ tons per foot run.}$$

It is necessary to add that K_1 or K_3 for the moments M_x covers the total span, and that K_2 or K_3 for the shearing strains V_x embraces that part of the span between the section taken for V_x and the support furthest distant (or vice-versa).

The values of K_1, K_2 and K_3 being given for a bridge of any span, it is only necessary to interpolate for all the abscissae x of the span between K_1 and K_3 or K_2 and K_3 in order to obtain the total or partial loads corresponding to the maximum M_x or maximum V_x in the section of the girder taken. Russian engineers always apply the circular of 1884 according to this method.

This is the table which has been prepared from the Russian regulations and which is found at page 25 of the report (English edition).

Comparative table of loads prescribed in Russia according to three scales.

SPAN.	MOVING LOAD a	b		SPAN.	MOVING LOAD a	b	
	for M_x if $x = \frac{l}{2}$	for M_x and V_x if $x < 2^m$	for V_x if $x = \frac{l}{2}$		for M_x if $x = \frac{l}{2}$	for M_x and V_x if $x < 2^m$	for V_x if $x = \frac{l}{2}$
3 1/4 feet.	9·00 tons.	9·00 tons.	18·00 tons.	98 feet.	1·65 ton.	1·89 ton.	2·19 tons.
5 —	6·00 —	6·81 —	12·00 —	131 —	1·59 —	1 77 —	1·98 —
6 1/2 —	4·50 —	6·00 —	9·00 —	164 —	1·56 —	1·68 —	1·89 —
8 —	4·17 —	5·61 —	8·01 —	197 —	1·50 —	1·59 —	1·83 —
16 1/2 —	3·64 —	4·35 —	5·58 —	262 —	1·38 —	1·44 —	1·74 —
33 —	2·27 —	2·55 —	3·72 —	328 —	1·29 —	1·35 —	1·68 —
49 —	1·80 —	2·19 —	2·94 —	394 —	1·20 —	1·26 —	1·62 —
66 —	1 69 —	2·04 —	2·52 —	525 —	1·11 —	1·14 —	1·47 —

* Values added in accordance with the axle load of 15 tons prescribed by article II and with the distance between the axles of 4 1/3 feet (1m32) both for M_x at the middle of the span and for V_x in the two last columns.

As given for a span of 197 feet (60 metres), there is no great difference between the moment near the middle and the moment near the supports. So, in Russia, the three scales of which I have just spoken are used for bridges of a span from 33 feet to 197 feet (10 to 60 metres).

Mr. von Leber at page 31 (English edition) of his report says :—

The equivalent loads in regard to the bending moments or to the shearing strains have really a special value for each part of the chord or web-bracing; it had however previously been the custom amongst engineers to accept for the calculation of the entire chords the equivalent load for the bending strains at the middle of the span, and, for the calculation of all the web-bracing, the equivalent load for the shearing strain near a support.

I must say that in Russia we have always admitted that the equivalent load for the calculation of the web-bracing is greater at the middle of the span; this was done each time, when we made the difference between the equivalent loads for bending moments and shearing strains.

I would draw your attention, gentlemen, to the fact that the method of equivalent uniformly distributed loads for the shearing strains as well as for the bending moments has been discussed by Professor Laissle and Mr. Schubler in their work on metallic bridges which appeared in 1865. I have translated this work into Russian; it has also been translated into French by one of the authors. It contains a table (XV) which gives the regulations for the Wurtemberg train.

Mr. von Leber's report mentions the French circulars of 1868 and 1870, and the Austrian circular of 1870, but no mention is made of the Russian circular of 1875. Up to that year no regulations had been published in Russia for the construction of bridges. Those given in the above-mentioned work of professor Laissle and Mr. Schubler were the only ones followed.

Their typical train, composed of three engines with three axles, each of which carried a load of 12 tons, resembled very closely the heavy trains running on our system, and for this reason, up to the year 1875, we used two equivalent loads in making the calculations for bridges, one for the shearing strains and the other for the bending moments as given by Messrs. Laissle and Schubler. In 1875 the first Russian circular was issued, and it specified only one scale without making any distinction between the loads for bending moments and those for shearing strains (web-bracing). The calculations of bridges built in accordance with the regulations given in this circular are not so exact as those for bridges built later. Since 1880 several bridges have been built on the lines of the State Railway in the construction of which these regulations have not been followed. On the other hand, the method of three equivalent loads was adopted, a method which was published officially in the circular of 1884. The reporter, while remarking favourably on it, at the same time points out the complication in the calculations to which this circular appears to give rise.

From the explanations which I have given, you will see that the regulations allow of simple calculations being made which are sufficiently accurate for practical work.

I will now say a word about heavy loads. Some weeks previous to the opening of the present session of the Congress, the permanent commission on bridges appointed by the Russian Ministry of Ways and Communications, after comparing the data derived from 36 railways, resolved to adopt as the typical train two engines with four axles, each axle carrying a load of 15 tons. The spacing of the axles of the vehicles composing the typical train adopted by the commission and the loads carried by each axle are given below in figures *a*, *b* and *c* :

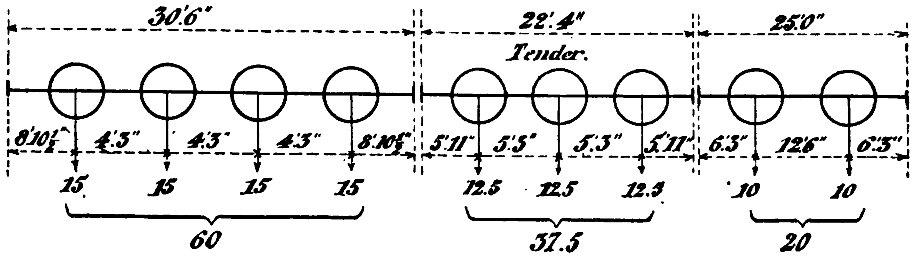


Fig. *a*. Fig. *b*. Fig. *c*.

A typical train is composed of two engines (*a* and *b*) and wagons (*c*).

In all countries locomotive superintendents aim at increasing the loads per axle, and they do not fail to grumble when any one tries to prevent them. In connection with this I may remark that the late Mr. Belpaire said, at the St. Petersburg Session of 1892, in the discussion on my paper — Question V-B :— " On the relation between bridges and rolling stock ", that it was impossible to tie the hands of locomotive superintendents. I think, however, that a curb should be put upon locomotive engineers in this direction so that permanent way engineers should not always be compelled to strengthen existing bridges. The best solution of the question of how to increase the tractive force — and one which meets all the requirements of the case — is, to my mind, not to increase the load on the axles but rather the number of axles, or, better still, to adopt electric traction.

In conclusion, I wish to say a word on the subject of the historical aspect of the question as dealt with by the reporter, a question which is sure to occupy the attention of the Congress at some future time. At pages 5 and 6 (English edition) the following words occur :—

> We will merely draw attention to the fact that in 1845, when it was proposed seriously to span long distances by means of iron structures, plate girders for smaller spans were already in general use. Their dimensions were determined either by direct tests or by considerations of similitude connected with these experiments, when larger spans were being considered. It was by methods of this kind that the plans of the first large tubular structures of the Conway and Britannia Bridges were arrived at; at this time the calculations for determining theoretically what section should be adopted for the various parts were unknown. But from 1885 new theories respecting the resistance of materials such as are now admitted commenced to develop themselves.
>
> . . . .
>
> To the French engineers Navier, Bresse and Clapeyron must be given the credit of having really established the fundamental bases of our theories as to the resistance of materials, in the form that they have since been applied universally. Important improvements have been made in them by eminent mathematicians in all parts of the world.

I must state that, since the year 1852, the name of General Jouransky has always been associated with these works. The Nicholas Railway was made between the years 1847 and 1854. It has several large timber bridges built according to the plans of the Russian engineers who were sent to America to study the systems in use in that country. Of these bridges two are conspicuous as consisting of nine continuous spans of 215 feet each (65·50 metres). To calculate these the method of the resolution of forces was used. Only 30 years after they were built they were replaced by iron bridges. The first calculations for lattice girders were made by General Jouransky, and it was he who first adopted the system. His name, therefore, should be given in the list of engineers and experts rightly mentioned by Mr. von Leber as having been mainly instrumental in establishing the theories and methods of calculation for lattice girders. The theoretical investigations of General

Jouransky are mentioned by the French experts Saint-Venant and Colignon, and more particularly by Professor Lang (of Hanover, formerly of Riga) in his work entitled " Geschichte der Spannwerke ". (*Applause.*)

Mr. Schüle, Postal and Railways Department, Switzerland. (In French.) — I have read with great interest the work of Mr. von Leber. It contains very useful information on the methods used in bridge calculations. In view of the fact that the regulations in different countries have all the same tendency, namely, to increase the safety, I doubt whether the question of the method of calculation properly so-called by concentrated or by uniformly distributed loads has as much importance as the reporter attaches to it. In actual practice, with the methods at present taught in engineering schools, the engineer runs little risk of making mistakes in his calculations for iron bridges, whether he uses the method of concentrated loads or of uniformly distributed loads. I think in common with several other delegates who have spoken to me on the subject that the only really important question is as regards existing bridges.

We know that the regulations in force at present stipulate much heavier loads than existing bridges can carry, and consequently we have to see to what degree they must be strengthened and up to what point the metal can be strained. An exchange of views on these two points is to my mind very necessary.

According to the Swiss federal regulations the increase in the strain allowed for new bridges can be in certain cases as much as 30 p. c. over that allowed for existing bridges.

Side by side with the question of the composition of the load on a bridge is that of the degree of safety to be allowed. To what degree is it necessary to strengthen an existing bridge to ensure that it will be quite safe? These two questions should, in my opinion, be dealt with simultaneously.

Mr. von Leber. (In French.) — I think Mr. Schüle wishes to know how the regulations for new bridges should be applied to existing bridges. The difficulty is to distinguish between the severity of the regulations as applied to new bridges and to old bridges. A similar question was raised before at the St. Petersburg Session, but it was not thought advisable by the Congress to go into the matter at the time.

It was proposed at the general meeting that a margin of 20 p. c. should be allowed on existing bridges. But the objection was raised, and with reason, that it could not be stated with certainty that the iron of old bridges was being strained 20 p. c. over that of new bridges. This has been found not to be the case in Switzerland, and we have found the same in Austria, so the matter had better be passed over in silence. (*Laughter.*)

Mr. Belelubsky, Russian State Railways. (In French.) — It had been decided at the St. Petersburg Session that the detailed list of questions should be drawn up for the London Session so as to arrive at the practice employed by the various Railway Companies for strengthening existing bridges in order to carry heavy loads. The International Commission, however, has not thought it advisable to include this in the list of questions they drew up.

Mr. Schüle. (In French.) — I should like to remark that the increase of 30 p. c. recommended by the Swiss federal regulations is only specified when there is no fault in the construction and when the iron is of the highest quality.

Since, according to the reporter, it is not advisable to discuss the question which I have raised, I think I might, without inconvenience, make the proposal that Railway Administrations should carry out experiments with a view of extending our present knowledge regarding the effective safety of bridges.

The President. — We may regard the general discussion as finished. (*Agreed.*)

On Saturday we will proceed to discuss the resolutions proposed by Mr. von Leber.

The meeting adjourned at 12.15 p. m.

July, 6, 1895, at 10 a. m.

PRESIDENT : MR. RICHARD JEITTELES

The President. — At the last meeting the general discussion was finished, and we will now proceed to the discussion of the resolutions proposed by Mr. von Leber.

You would like, I suppose, to conclude the examination of the question this morning. If it is found necessary to meet again on Monday, there will be some difficulty in preparing the report which should be submitted to the general meeting on Tuesday. So I take the liberty of asking the speakers to be as brief as possible in their remarks.

The first proposition made by the reporter for Question IV is as follows :—

" I. The quantities of iron used or to be used for the construction of iron railway bridges are extremely variable, even apart from the conditions of span and height imposed on the engineer by local circumstances. For bridges of the same span the quantity of metal per foot of track varies so much that sometimes twice as much is required in one case as in another, according to the loads prescribed, the limits of internal working-strain assigned to the various parts, the system of construction adopted, and particularly to the engineer who draws up the plans.

" Besides, the usual formulae, which are for the most part arrived at on the basis of very logical considerations for the purpose of calculating beforehand the weight of a bridge, are almost always defective. It is much preferable to prepare a statement of the weights of a large number of bridges in existence and to proceed by way of comparison.

" The tables drawn up by the author might render useful service for this purpose. Nevertheless, the most efficacious comparison each engineer can make is that which is the outcome of his own designs. "

Mr. F. E. Robertson, East Indian Railway. — I wish to offer some observations regarding permissible unit strains which will of course govern the weight of metal in bridges. While doing full justice to the very able and comprehensive report on this subject, there are certain statements referring to the permissible working stresses on which I wish to offer a few remarks, because it appears to me that some of them cannot logically be justified, whatever opinions may be held as to the elastic behaviour of metals. The notation given in the text for the formulae appears to agree with what I have understood from them, and with what is, I believe, generally taken; but I do not understand the remark on page 82 of the English and pages 73-74 of the French edition. The reporter says : " Taking for S_{min} : S_{max} not the ratio as demanded by the publishers of formulae, but the ratio of the dead load to the total load, so as to agree with the great majority of constructors, etc. " What other ratio was intended by the authors of the formulae? Again, on page 78 of the English and page 69 of the French edition it is said : " These formulae do not take into account the length of span or, what amounts to the same thing, the ratio of the moving load to the dead load. " As I understand them it is precisely on these relations that the formulae are based, and they therefore express the effect of length of span on the limiting stresses in a much more accurate and practical way than does the bare statement of the length of span under consideration. To take an example, is it reasonable to assign the same limiting stress to the main girders of two bridges of the same span but in which, from local circumstances, the ratios of live to dead load are very different? Or, to take the common case of a cantilever bridge of very large span, would it not be reasonable to give the members nearer the abutment a higher unit strain than is allowed in those at the nose? The difference would be considerable in the very large spans projected nowadays. The bare rule of assigning the stress by the length of span would not provide for this judicious economy which the Launhardt formula fully provides for. I must venture to differ from the reporter and say that the formulae in question, as I understand them, accurately take into consideration the span so far as it affects the permissible stresses, and that the allotment of these, by stating the span only, does roughly what the formula does more accurately. The reporter further cites as a defect in the formula that it assigns the same unit stress to a brace in a large bridge as it would to the corresponding member in a small bridge provided they both undergo similar alterations in stress, and he would apparently vary the stress in proportion to the size of the bridge. Now, if there is any conclusion to be drawn from the numerous experiments of Wöhler, Bauschinger and Baker, it is that the endurance of a piece depends upon the limits between which the stress ranges. It does not appear that the actual size of the piece has anything to do with the question. I do not therefore quite understand the objection raised. If the writer means to say that the formula does not take into account any and every possible variation in the limits of stress between large and small bridges, I can only say that he does not read the formula in the sense in which I believe it is generally used. If, on the other hand, he means that a member in a large bridge whose stress varies from say + 2 tons to — 2 tons per square inch is under any different circumstances to a similar member in a smaller bridge with the same unit stress, I would point out that this view implies that the admissible unit strain in a member is a function of its absolute size and not of its stress conditions. The reporter further criticises the formula as unsuitable to continuous girders. Really I cannot see that this is anything against the formula. All that can be deduced from this argument is, that if the formula is rational, it is so much the worse for the continuous girders as now built. It is more probable that ancient practice is wrong, than that the long series of recent experiments is inconclusive. I think it is possible that the author exaggerates the effect of this formula as applied to continuous girders, for the parts on which it would have most effect, as at the points of contra-flexure, are just those where the sections cannot for practical reasons be diminished to the extent which the ordinary theory would allow. It is not, however, worth while to enter into a numerical examination of this detail, for what we are concerned with is not whether the formulae would make a particular type of structure heavier than has been the custom, but whether they are justified by facts. And it is just on this point that I differ from what the author has said on page 79 of the English and page 70 of the French edition, namely, that " this erroneous principle is in contradiction with practice, with the laws of elasticity, and with the results of Bauschinger's experiments ". To advance against a theory that it is contrary to past practice is the last accusation a scientific man should make, and proves nothing as to which is right. As to the statement that Launhardt's formula is contrary to the laws of elasticity and Bauschinger's experiments, that is pure assertion, and can only be met by the counter-assertion that it is precisely upon the alleged correct interpretation of these laws and experiments that the formula is based. The author concludes this part of his comprehensive report by saying that a girder subject to strains varying from half a ton to 4 $^1/_2$ tons per square inch will without any doubt preserve its elasticity better than a similar girder subjected to the greater load permanently applied. With all deference to his opinion, this is a statement which I must oppose, and assert that such a constant stress will produce no more effect than the smaller alternating stress. If the author's assertion is true, the deduction is that a constant load should be smaller than a live load, which is opposed to his own figures. Has the author any experiments to prove that a spring will stand any indefinite number of applications of a load which will destroy it by constant pressure? How does he explain the fact established by Wöhler that, if a bar is subjected to repeated strain of N tons per square inch, it will break with a certain number of repetitions, but, if a permanent strain of M tons is left on, instead of taking the load off entirely, the number of repetitions required to destroy the bar increases with M instead of diminishing. To quote only one instance, a steel bar which broke with 72,450 repetitions of a strain of 42·95 tons per square inch required regularly more and more repetitions to break it as the load left on increased, until, when the permanent load had reached 28·65 tons, leaving a variation of strain of 14·30 tons as against 42·95 tons with a permanent load of zero, the bar was not broken with 33,600,000 repetitions. And as this is not an isolated experiment, but typical of all, I can scarcely see how it can be said that the limits of strain do not affect the question. It is true that these experiments refer to breaking strains, but it is probable that the same causes would affect ordinary working strains There are really two issues between the reporter and myself: firstly, is the Launhardt formula a better way of controlling the limiting strains in bridge members than an arbitrary scale based on the length of span, and, secondly, is the formula a logical deduction from the experiments on repeated strains made by Wöhler, Baker and Bauschinger, the results of which I may note are brought together into a very convenient form in Professor Unwin's "Testing of the materials of construction"? On the first point I will ask, upon what are the limiting stresses for different spans based but upon the considerations expressed in the formula, namely, the proportions of live and dead load, and is it not better to use a rational formula itself rather than an arbitrary deduction from it which cannot cover all cases? The second point is one of more interest and importance, and can only be decided by careful reasoning from undoubted facts. To state as briefly as possible the facts established by the above-mentioned experiments, they are these. Taking wrought iron of say an average breaking strength of 23 tons under a single load, it is found that some few millions of repetitions of a load of 13 to 15 tons will produce fracture, but below this figure the number of repetitions to produce fracture is unknown. But the same bar will, if the strain varies from + to — only stand roughly half the load, or the same total range. Further it is found that, if the load be not wholly removed, the number of repetitions required to break the bar increases as the range of stress diminishes. Nothing is more clearly pointed out than this. It is not, I believe, known what constant load a bar can support without deterioration. It is also well to remember two important points that appear to be established by Bauschinger's experiments. One, that the real, that is to say, the unalterable elastic limit is much less than the so-called elastic limit or yield point, and cannot be put higher than from 7 to 8 tons for iron and 9 tons or a little more for mild steel; and the other, that testing a bar affords no indication whatever either in ultimate strength or extension of its deterioration from fatigue. From these data the formulae are established on the following reasoning, as I understand. Somewhere about 7 tons seems to be universally admitted to be a safe dead load for wrought iron, and it may be remarked in passing that it practically agrees with Bauschinger's elastic limit. This gives a factor of safety of about 3. In dealing then with loads repeated or reversed, what we have to consider is, not the ultimate strength of the bar under a single load, but that under the conditions specified, repeated or alternate, and we should allow the same factor of safety, the more so as these variable loads are the very ones regarding whose intensity there is the most uncertainty. It seems to me that the Launhardt formula is based upon exact theory. We know by that, that for a perfectly elastic material, if a gradual load produces a unit strain of *s*, half this load applied suddenly but without shock produces the same strain, while an alternating load of one third will produce the same strain. In actual fact materials are imperfectly elastic, and experiment differs from pure theory from the interference of plasticity, but I do not think it can be either proved or disproved with our present knowledge just what effect this latter consideration should have on our calculations. In fact we do not know everything about the behaviour of the materials of construction, and it is therefore rash to dogmatise without proof. There must be, for some time at least, a certain difference of opinion as to the best way of expressing the limiting strains, and I hardly think that the reporter is justified in his condemnation without proof of the Launhardt formula. What we really differ about is not so much the amount of strain that can safely be allowed in different cases as the method by which these results should be arrived at, and the subject is one of so much importance that a free discussion of it will always be profitable.

Mr. von Leber, *Reporter.* (In French.) — I had hoped to conciliate all the opinions of those of my colleagues who advocate the use of formulae by adopting formula No. 53 given on page 84 of my report (English edition). Mr. Robertson may be prejudiced; he advocates the use of another formula which does not take into account the relation of live load to dead load or rather that of live load to total load. I have already said and I still maintain that the simplest calculation is that based on this last relation. I do not consider it necessary to prove it anew.

Mr. Robertson is of opinion that the relation between live load and total load is not always constant for the same span of bridge. He is right and I have admitted it in a general manner in my conclusions.

The weights of bridges would be found to vary considerably if you indicated graphically by means of a table a thousand bridges belonging to different railway administrations and in different countries. But this variation does not exist for the engineer who only considers the bridges of the Company to which he belongs. To him, the ratio of dead load to live load or vice versâ does not vary much for the same span.

Mr. Robertson does not agree with me when I say that the conditions of a railway bridge girder are more favourable than those of a girder in a building. The former is only loaded intermittently during the passage of a train; as soon as the train has passed, it resumes its natural condition. The latter, on the contrary, is loaded continuously and is always strained to its maximum. I am therefore right in saying that the bridge girder is under more favourable conditions than the girder of a building as far as the preservation of the elasticity of the metal is concerned. It is like the case of the spring which is kept constantly stretched. It is certain that the spring will lose its elasticity more quickly than if it is only stretched at intervals and remains unstretched the rest of the time. Mr. Robertson asks for a proof of this. But, gentlemen, there is no need to prove it. Everyone knows by experience that, when a spring is kept constantly stretched, it loses its elasticity. However, Mr. Robertson thinks the contrary, and, according to him, the spring which is kept constantly stretched preserves its elasticity longer. It is useless for me to dwell longer on this point; every clockmaker or mechanic will tell you the same.

Mr. Robertson thinks that the Launhardt formulae are not applicable to continuous girders and consequently that, if my views were adopted, it would be necessary in a manner to discontinue the construction of continuous girder bridges. I must again differ from Mr. Robertson on this point. He has misunderstood me. I would be the last to say that the system of continuous girder bridges is bad, and, if it were necessary for me to choose between a bridge of independent spans built according to the formulae and a bridge of continuous girders calculated in the usual manner, I should not hesitate to choose the latter system, because continuous girder bridges have been sanctioned by long experience.

I must say that the uneasiness which they cause is exaggerated. Some engineers think that, when one of the supports sinks, the whole theory is upset. This is really not so and in Austria many continuous girder bridges exist where the piers have sunk. No ill effects have resulted because, the sinking once having taken place and definitely settled, the girders resume their condition of equilibrium, the metal returning gradually to its original molecular state.

I will take the case of the Iglawa viaduct. The support at one end sank 12 inches (30 centimetres). You may think that this resulted in the bridge giving way, but no such thing happened. The girders were brought back to their normal position, and express trains now cross over them as if nothing had happened. It may be that in a case like this the metal, which is relieved from all strain for some time, has an opportunity of returning to its original molecular state.

I am, therefore, still quite of the same opinion, namely, that practical considerations are of more account than formulae of doubtful origin in the design of metallic structures. At the same time I treat with respect the contrary opinion of Mr. Robertson.

The President. (In French.) — I did not choose to interrupt Mr. Robertson, but his remarks really belonged to the general discussion which was closed at the last meeting.

Mr. Belelubsky. (In French.) — I have to explain, Mr. President, that up to now I have only dealt with the 1st and 2nd parts of Mr. von Leber's report. Mr. Robertson has made some remarks particularly bearing on the 3rd part of his work, and I should like to do the same, so will ask to be allowed to make a few remarks although the general discussion is closed.

The President. (In French.) — I suppose the meeting will not object to reopening the discussion on Mr. von Leber's first conclusion.

Mr. Belelubsky. (In French.) — The tables given in the report contain much information concerning existing bridges built under various conditions according to the regulations in force. These tables show that there is a difference between the maximum and the minimum of as much as 50 p. c. This is inevitable with general practical formulae. A large number of bridges have been built in Russia according to the formula : $\rho = \alpha l + C$, and the difference between the maximum and the minimum does not exceed 5 to 10 p. c. The formula $\rho = \alpha l + C$ represents the weight per metre run; αl corresponds to the weight of the girders (including wind-bracing), and C to the weight of the floor; α is a coefficient found by experiment depending on the regulations in force in the country and is practically constant for the spans investigated. With the above formula the net weight of bridges can be determined sufficiently accurately for all practical purposes.

Mr. Schüle, Postal and Railways Department, Switzerland. (In French.) — I have two alterations to suggest, gentlemen, in the third paragraph of the first conclusion. In the first place I think it should not be stated without reservation that " the general formulae frequently submitted on the basis of very logical considerations for the purpose of calculating beforehand the weight of a bridge are almost always defective ". This may apply to designs made in engineering schools, but it is not correct for those carried out by Railway Companies. The statement is too categorical.

In the second place, the sentence : " It is much more preferable to prepare a statement of the weights of a large number of bridges in existence and to proceed by way of comparison ", should be modified as follows : " It is much more preferable to prepare a statement of the weights of a large number of bridges in existence and to proceed by way of trial and error. "

In fact, when a bridge of a new type is to be constructed, the weight of the bridge should be obtained approximately by means of some formula. When the bridge is designed the exact weight can then be found and the sections increased slightly if necessary.

Mr. Bell, Indian State Railways. — It appears to me that the proposition made by the last speaker tends to invade the province of the designer. This is scarcely, I venture to think, the intention or province of this section or indeed of this Congress. I would suggest that it only concerns us to assign the limits which we consider essential to public safety and not to lay down exact Government rules for the guidance of designers in each minute detail. To do this would end in stereotyping methods which, however good, may and probably will be bettered as time goes on, and may very shortly be found to hamper progress instead of helping it. As, therefore, to the methods by which those who either originally design girders or those who finally inspect and pass them for public use arrive at their conclusions by calculation, I think the Congress should avoid any too exact definition of the system it approves. " Not less than so much metal of such a standard quality to meet so much calculated dead and so much calculated live load stress " is all I could recommend the Congress to insist on.

Mr. Belelubsky. (In French.) — We might omit the last sentence of the conclusion : " Nevertheless, the most efficacious comparison each engineer can make is that which is the outcome of his own designs. "

Mr. von Leber, *Reporter.* (In French.) — I did not mean to say that if an engineer applies the general formulae in the calculations for a bridge which he designs himself they would be defective. Nor am I opposed to what seems to Mr. Schüle to be satisfactory. The third paragraph in the first conclusion might be amended as follows : " The general formulae frequently submitted on the basis of very logical considerations for the purpose of calculating beforehand the weight of a bridge, only apply to designs of bridges drawn up for the same railway company or by the same engineer. "

Mr. Belelubsky. (In French.) — Would it not be better to say " for the same country " and omit " or by the same engineer " ?

Mr. von Leber. (In French.) — That would be going too far. In France, for instance, the designs of the various railway companies are not always carried out according to the general formulae. But you might say " for the same country or for the same company ".

The President. (In French.) — Mr. von Leber proposes the following wording for the first sentence of the third paragraph : " The general formulae frequently submitted on the basis of very logical considerations for the purpose of calculating beforehand the weight of a bridge are only applicable for designs of bridges drawn up for the same railway company or by the same engineer ".

The proposal suggested by Mr. Schüle for the second sentence reads as follows : " It is far preferable to prepare a statement of the weights of a large number of bridges in existence and to proceed by way of trial and error ".

Mr. von Leber. (In French). — I agree to that amendment.

Mr. Bell. — Which is the better method?

Mr. von Leber. — There is only one. You can only calculate by trial and error.

— The first conclusion worded as follows was adopted :—

" The quantities of iron used or to be used for the construction of iron railway bridges are extremely variable, even apart from the conditions of span and height imposed on the engineer by local circumstances.

" For bridges of the same span the quantity of metal per foot of track varies so much that sometimes twice as much is required in the one case as in the other, according to the prescribed loads, the limits of internal working strain assigned to the various parts, the system of construction adopted, and particularly according to the engineer who draws up the plans.

" The general formulae frequently submitted on the basis of very logical considerations for the purpose of calculating beforehand the weight of a bridge are only applicable for designs of bridges drawn up for the same country or by the same railway company. It is far preferable to prepare a statement of the weights of a large number of bridges, and to proceed by way of comparison or by way of trial and error.

" The tables drawn up by the author might render useful service for this purpose. "

The President. (In French.) — The second resolution proposed reads as follows :—

" The loads prescribed as regards rolling stock are of great importance for bridges of small span in which such loads are of far greater importance than dead loads and wind pressure. On the contrary in the case of bridges of large span of about 330 feet (100 metres) and certainly when the span exceeds 390 feet (120 metres) the two last influences play the most important part in the calculation of resistances, which, in the case of very large spans, often assume an unexpected form.

" Thus, in the great arches of the Forth Bridge with 1,710 feet (521 metres) of span, our illustrious colleagues, Sir John Fowler and Sir Benjamin Baker, the authors of the design, state that the load of two heavy coal trains does not exceed 5 p. c. of the dead weight. "

Mr. Belelubsky. (In French.) — I propose that the second conclusion be struck out.

Mr. von Leber. (In French.) — The section will decide whether it is to be maintained or not.

— Mr. Belelubsky's proposition was put to the vote and rejected. The conclusion proposed by Mr. von Leber was adopted.

The President. (In French.) — The third conclusion reads as follows :—

" If not in every country at least in every great railway system, the effects of the load produced by the rolling stock in use should be carefully studied, in order to deduce therefrom the rules for loads applicable to iron bridges either already constructed or about to be constructed.

" These rules might be issued either in the form of typical train loads or in the form of two scales of loads uniformly distributed per foot of track, one referring to the bending strains and the other to the shearing strains, both being applicable to all ordinary bridges, provided that the length of track loaded is always taken as a basis.

" In the former system it is desirable always to consider at least two typical trains representing the two extremes of the traffic, that is to say, an express train with the heaviest axle loads, the heaviest engine, the heaviest tender and a proportionate train of carriages; then a goods train with engine having heavily loaded and numerous axles close together, an ample tender and a long train of wagons of the heaviest kind. We should, of course, admit the maximum effects of load resulting from either of these trains, if we assume them to be placed in the most unfavourable positions.

" The latter system is the one to which engineers will most frequently have recourse in order to work out their calculations generally, even when the live loads have been prescribed under the form of typical trains.

" Instead of recommencing the study of these trains for each bridge plan or even of introducing them effectively into the calculations of resistance, it is much more advantageous to make this calculation once for all, and to prepare the scales of uniform equivalent loads which may afterwards be at once applied to all spans or lengths loaded without having to make a fresh calculation.

" Important progress has been effected in this kind of calculation, especially by introducing the principle of lengths loaded serving as a basis for the scale of loads, and by extending the use thereof to the calculations of transverse girders and longitudinal stringers. "

Mr. de Kounitsky, Ministry of Ways of Communication, Russia. (In French.) — With reference to the third resolution, I should like to mention the classic work of Mr. von Leber : " Das Eisenbahnwesen in Frankreich ", which has been of valuable service to many Russian engineers, and which was consulted in the preparation of that part of the Russian ministerial circular of 1884 which deals with the loads imposed by typical trains and their axle loads. The typical train adopted in that circular is similar to the one given in the above-mentioned work. However, I should state that in the present report of Mr. von Leber it is proposed to compose the typical train of two locomotives only while in his treatise it is composed of three. It would be very interesting to know the reason of this. It would also be interesting to know if one ought not to take into consideration a train composed of more than three locomotives with carriages behind or a train composed entirely of locomotives and their tenders. In actual practice there are trains similar to these.

This said, I should like to be allowed to make a remark on the principal idea of the third conclusion. It is evident that there is a tendency in this conclusion to adopt uniformly distributed loads in preference to typical trains. It seems to me that it is not desirable to put a resolution of this nature to the International Railway Congress, for the following reasons :—

1st The exact determination of the uniformly distributed loads for some systems of bridges, namely, continuous, arch and cantilever bridges, presents certain difficulties and should be made for each system of bridge separately, giving for different systems different values for the uniformly distributed loads.

2nd It is the usual practice in Germany and has been in Russia for some years past to use the method of graphic statics in the calculation of bridges, and particularly the lines of influence which, with the help of the typical train, allow of a bridge design being made easily and quickly.

If we adopt the resolution proposed we condemn the use of the method of graphic statics which takes into consideration the actual concentrated loads, and particularly the method of lines of influence of which I have just spoken. This seems to me an undesirable course to take.

The typical trains with their actual concentrated loads could be agreed upon by the Railway Administrations of the whole world; it would therefore be preferable to use the expression " typical trains " and not to speak of the scales of uniformly distributed loads.

Consequently I propose to omit altogether the second paragraph of the third resolution, and in the third paragraph to omit the words " in the former system "; also to omit altogether the fourth and fifth paragraphs, so as to confine to the third conclusion only the mention of typical trains.

Mr. Belelubsky, Russian State Railways. (In French.) — At the last meeting the method of making scales of loads was discussed. The resolution must therefore make some mention of it.

The only question at issue seems to be whether two or three scales shall be allowed, and in my opinion the best way to avoid the difficulty is not to specify the number of scales to be adopted.

Mr. von Leber. (In French.) — I agree to that.

Mr. Étienne, Paris, Lyons, Mediterranean Railway, Algerian lines. (In French.) — I have a proposition to make which is somewhat more radical. The first conclusion of the reporter gives a satisfactory answer to Question IV-A.

I do not think that the Congress should be called upon to decide upon the various methods of calculation. The accuracy of any method of calculation is not put to the vote. The discussion to which it would lead would be more suitable for a theoretical treatise than for the deliberations of a Congress. I propose, therefore, to omit the third conclusion altogether.

Mr. de Kounitsky. (In French.) — I entirely agree with Mr. Étienne and I think that it would be better to leave engineers and Administrations free to choose their own method of calculation.

Mr. von Leber, *Reporter*. (In French.) — I propose that the Section adopt Mr. Belelubsky's amendment which says " ... either in the form of scales of loads uniformly distributed per foot of track, referring to the bending moments and the shearing strains and applicable ... ".

We must respect the practices adopted in a great country and at the same time leave the engineers free to combine the scales as they think fit. I am, however, of opinion that the Congress should decide between the scale of uniformly distributed loads and the typical train loads in favour of the former. When regulations for loads are drawn up for a great country or for a great railway company, one of two methods is adopted : either the typical train or the scales. It is clear that the legislator or the functionary would prefer the typical train system on account of its simplicity. The second system, namely, that of scales of loads, is much more complicated. In fact, a legislator or official has to make a very thorough study of the matter, not only for one train but for all the trains running in the country or on the railway under consideration. The question is, shall the legislator study the matter thoroughly once for all, or shall he draw up his regulations on the basis of an investigation much less complete which necessitates the constructors and engineers making all the calculations and investigations anew every time a bridge has to be constructed.

As I have said in my report, the typical train method presents many disadvantages; for you cannot represent by one typical train or even by two all the combinations of vehicles that run on any one railway system. With this method two trains at least have to be selected; one an express train with the heaviest axle loads, the heaviest engine, the heaviest tender and a proportionate train of carriages; the other a goods train with an engine having a greater number of axles closer together with less weight per axle, a lighter tender, but very heavy goods trucks. That is how the two trains should be composed.

I repeat that, if the method of typical trains is adopted, it is necessary to consider two trains in order to arrive at a more or less correct result. This is the practice both in England and America.

I think, therefore, that the Congress should agree with what I have said.

I have spoken in my conclusions of the two systems because both are used, but I am convinced that the method of scales of loads is the more practical of the two.

Sir Douglas Fox, Manchester, Sheffield and Lincolnshire Railway. — In England we have no actual law laid down by the legislature as to this question of rolling loads for test purposes, but the Board of Trade, who are the inspecting body, do lay down certain rules. Mr. von Leber mentioned that my friend Sir Benjamin Baker had sent to him certain weights of trains used for testing, but that might lead to a false impression.

The rule in Great Britain is very distinctly this : we have to provide in our main line structures for loading bridges with the heaviest locomotives that are running in the country at the time, and for branch lines with the heaviest locomotives likely to pass over them. The Board of Trade do not tell us what the load is; they leave us to find that out, but we are liable, as engineers, to satisfy them that the bridges, when we present them for inspection before the opening of the railway, are sufficiently strong in all their parts to deal with these heaviest locomotives, loading the bridge with locomotives from end to end. Therefore there is no question with us of a different type of train; we are to take the very heaviest that is known. But there is a foundation for what Mr. von Leber said, as I have been able to ascertain from our friend General Hutchinson, who has for many years represented the Board of Trade, that, in the case of the Forth Bridge which was a very exceptional case, the Board of Trade did alter their regulation and allowed a typical train to be accepted. Of course it is evident that, with such a very large structure as the Forth Bridge, to load with locomotives from end to end would have led to excessive results, and therefore the Board of Trade in that case altered their rule. We have found, at any rate in our experience of heavy trains at high speeds, that much more attention must be paid than has been the case in former years, not so much to the strength of the main girders as to that of the cross girders and rail bearers. The main girders are all right enough and easily calculated, and the Board of Trade take good care that we allow a large margin of safety; but the more difficult question we have to deal with is that of impact on the cross girders, and I think engineers should turn their careful attention to that matter. We have had cases, I will not say in England, but in my Indian practice I have known cases, where, whilst the bridges themselves were of ample strength, we have had considerable difficulty with the cross girders and the rail bearers arising from the fact that, when these brides were designed some 15 or 20 years ago, whilst these cross girders and rail bearers complied with the rules for the ordinary rolling load, they had not margin enough to properly deal with the effect of impact caused by the rapid running of a train on to the platform of the bridge.

Major General Hutchinson, Board of Trade, Great Britain. — I would only remark, with regard to what Sir Douglas Fox has said, that it is quite true that the Board of Trade require the bridges to be constructed so as to bear trains with the heaviest engines in use, not, as Sir Douglas Fox stated, in the country, but the heaviest engines that are liable to be used on that line, because in some cases we have isolated lines where the heaviest engines in the country would not be liable to run. That has been known to be the case in many smaller lines where of course it would be an excessive requirement that the bridges of these lines should be able to carry engines which would never be likely to come on them. I only wish to mention that point.

Mr. de Kounitsky. (In French.) — Notwithstanding what has just been said, I am still in favour of the typical train because it represents the same range of concentrated loads whatever the length and the system of the bridge may be.

If we take the same scale for different systems of bridge, we have for some systems a fictitious load (uniformly distributed) producing a greater effect than the actual load (concentrated) while for other systems the contrary is the case. Many engineers think that it would be necessary to have a special scale for each system of bridge.

Mr. Bell. — I rise to say that I have listened with very great pleasure and much benefit I hope to the paper and the discussions which have been carried on, but I venture to suggest at this point an amendment for your consideration. It was to my mind exceedingly unfortunate that so vast and important a subject, treated with so much skill and research as it as been by our reporter, should unfortunately have come into the hands of many of those experts, who hold views on the question, too late to enable them to exactly formulate such improvements as they might think desirable. I myself can scarcely say that I have yet got the first aperçu, so to speak, of the whole drift of the paper. There are many points in it that seem to me to be exceedingly dark. I imagine from the comparison, for instance, of the effect of a weight upon its spring that Mr. von Leber contends that the Forth Bridge, which has an immense dead weight on it, should have a stricter unit stress on account of its dead weight than a bridge which has a preponderance of live weight. There are many other points I need scarcely go into. We are now discussing the preference that some feel for the typical train and others for the distributed load. I do not think that, in the resolutions which the reporter has proposed to us, there is any single proposition that will meet with such an exact accord as it would suit this Section to deliver, and I venture to suggest for your consideration whether we might not better thank the honourable reporter for the excellent treatment that he has so far given to the subject, and, as he has stated that further information is still coming in which this paper has not yet utilised, that he might be asked to carry this subject over to a future Session of the Congress, and that we should for the moment merely express our thanks to him without formulating any decision which might tie this Congress for perhaps another century. I hope I have made my views plain to you that I do not wish to reject Mr. von Leber's admirable propositions, but I do not think the time is ripe for us to criticise the details. (*Applause.*)

The President. — When did you get the English edition of the paper?

Mr. Bell. — On Monday morning last.

The President. — This being a proposition for adjournment there is no discussion and a vote can only be taken.

— Mr. Bell's proposition for the adjournment of Question IV to the next Congress was then put and carried.

The President. (In French.) — I invite all the members interested in the question to send their remarks and opinions in writing. These will be printed in the appendix to Mr. von Leber's report. In this way the ground will be well prepared for discussion at the next Session and we may then perhaps be able to come to some definite conclusion.

Messrs. Petsche and Brière have handed me a note in which they state that they agree with the conclusions of Mr. von Leber's remarkable report and especially with the resolution proposed for Question IV-B. They, however, suggest the following addition :

" Tests carried out with old bridges may afford interesting data thus completing the results arrived at by calculations, and it would be advisable to take this into consideration before going to the expense of strengthening or reconstructing existing bridge structures. "

In view of the vote just taken we must confine ourselves to merely taking note of this proposition.

Mr. Simon, Ministry of Waterstaat, Commerce and Industry, Holland. (In French.) — I desire to mention that I have handed to Mr. von Leber a note of some observations and information regarding the new method of the periodical tests of large bridges carried out in Holland, and I will ask the meeting to decide that the note be printed in Mr. von Leber's report.

The President. (In French.) — This shall be done.

Gentlemen, we are now at the end of our sectional work. The hope I expressed at the beginning of our first meeting is as fully realised as is possible, and I can say with confidence that our discussions, if not our conclusions, will greatly contribute to the progress of construction of railway works. If we have succeeded so well it is due to the excellent reports which have been presented to us, and I have much pleasure in congratulating Messrs. Ast, Hunt, Sabouret, Zanotta and von Leber. (*Applause.*)

I have also to thank very heartily our principal secretary, Mr. Debray, for his good services in devoting all his time and his profound knowledge to our work. (*Applause.*) At the same time, I can state that the secretary-reporters have performed in a highly satisfactory manner the duties allotted to them; they have translated the communications in their respective departments, and I ask you to thank them for their zeal. (*Applause.*)

And now, gentlemen, I must thank you all for the tokens of friendship you have given me, and I will not say good-bye, but express the wish to see you all at the next Congress. (*Applause.*)

Mr. Bell. — It is an English custom which it gives me exceedingly great pleasure to take upon myself on this occasion, to ask you before parting — as the hour is late I will not elaborate the subject — to convey a hearty vote of thanks to the President for his uniform courtesy and the able way in which he has conducted our discussions in this room. I propose the thanks of the whole Section to the President. (*Carried by acclamation.*)

The President. — I again thank you very much.

— The proceedings concluded at 12 o'clock.

DISCUSSION AT THE GENERAL MEETING

July, 8. 1895, at 2.

LORD STALBRIDGE, PRESIDENT, IN THE CHAIR

The President. — I will call upon Mr. Debray, secretary of the first Section, to read the sectional report in French, after which Mr. Leslie Robinson, secretary-reporter of the Section, will read the English translation of the sectional report.

Mr. Debray :

Report of the 1st Section.

Le rapporteur résume son rapport et donne lecture des projets de résolutions qui le terminent :

" LITTÉRA A.

" 1. — Les quantités de fer employées ou à employer pour la construction des ponts métalliques de chemins de fer sont extrêmement variables, abstraction faite des conditions de portée et de hauteur imposées à l'ingénieur par les circonstances locales.

" Pour des ponts de même portée, la quantité de métal par mètre de voie varie souvent du simple au double, suivant les surcharges prescrites, suivant les limites de travail intérieur assignées aux diverses pièces, suivant le système de construction adopté et surtout suivant l'ingénieur qui dresse les projets.

" Aussi les formules générales souvent proposées sur la base de considérations très logiques, pour estimer d'avance le poids d'un

Mr. L. Robinson :

The reporter summarized his report and read the conclusions which occur at the end of his report.

" LITTERA A.

" 1. — The quantities of iron used, or to be used, for the construction of iron bridges are extremely variable, even apart from the conditions of span and height imposed on the engineer by local circumstances.

" For bridges of the same span the quantity of metal per foot of track varies so much that sometimes twice as much is required in the one case as in the other, according to the prescribed loads, the limits of internal working strain assigned to the various parts, the system of construction adopted and particularly according to the engineer who draws up the designs.

" Further the general formulae that are frequently submitted on the basis of very logical considerations for the purpose of cal-pont, sont presque toujours en défaut. Il est bien préférable de faire le relevé des poids d'un grand nombre de ponts construits et de procéder par voie de comparaison.

" Les tableaux dressés par le rapporteur pourront, à cet effet, rendre des services utiles. Toutefois, la comparaison la plus efficace pour chaque ingénieur est celle qui résulte de ses propres projets;

" 2. — Les surcharges prescrites, quant au matériel roulant, ont une importance majeure pour les ponts de faible portée, où elles priment absolument sur les poids morts et les effets du vent. C'est l'inverse pour les ponts de grande portée, et lorsque celle-ci atteint 100 mètres, sûrement lorsqu'elle dépasse 120 mètres, ce sont les deux derniers effets qui jouent le rôle le plus important dans les calculs de résistance, lesquels, pour des portées exceptionnelles, affectent une forme souvent inattendue.

" Ainsi pour les grandes arches du Frith of Forth, avec 521 mètres de portée, nos illustres collègues sir John Fowler et sir Benjamin Baker, qui en ont dressé les projets, relatent que la surcharge fournie par deux trains lourds n'excède pas 5 p. c. du poids mort;

" 3.— On doit recommander de faire, sinon pour chaque pays, du moins pour chaque grand réseau de chemins de fer, une étude sérieuse des effets de surcharge provoqués par le matériel roulant en circulation, pour en déduire les prescriptions de surcharges concernant les ponts métalliques à construire ou déjà construits.

" On peut émettre ces prescriptions, soit sous la forme de trains-types de surcharge, soit sous la forme de deux échelles de charges uniformément réparties par mètre de voie, concernant, l'une, les moments de flexion, l'autre, les efforts tranchants et convenant ensemble pour tous les ponts usuels, pourvu que l'on y prenne toujours comme entrée la longueur de voie surchargée.

culating beforehand the weight of a bridge are almost always defective. It is much better to prepare a statement of weights of a large number of bridges in existence and to proceed by way of comparison.

" The tables drawn up by the author may render useful service for this purpose. Nevertheless, the most useful comparison each engineer can make is that which is the outcome of his own designs.

" 2. — The loads prescribed, as regards rolling stock, are of great importance for bridges of small span in which such loads are of far greater importance that the dead loads and wind pressure. On the contrary, in the case of bridges of large span of about 330 feet (100 metres), and certainly when the span exceeds 390 feet (120 metres), the two last influences play the most important part in the calculation of resistances, and in the case of very large spans they often assume an unexpected proportion.

" Thus, in the great arches of the Forth Bridge with 1,710 feet (521 metres) of span, our illustrious colleagues, Sir John Fowler and Sir Benjamin Baker, the authors of the design, state that the load of two heavy trains does not exceed 5 p. c. of the dead weight.

" 3. — It is very desirable, if not in every country at least in every great railway system, that the effects of the load produced by the rolling stock in use should be carefully studied, in order to deduce therefrom the rules for loads applicable to iron bridges, either already constructed or about to be erected.

" These rules might be issued either in the form of typical train loads or in the form of two scales of loads uniformly distributed (per metre) per foot of track, the one referring to the bending strains and the other to the shearing strains, both being applicable to all ordinary bridges, provided that the length of track loaded is always taken as a basis.

" Dans le premier système, il est recommandable de considérer toujours au moins deux trains-types représentant les deux extrêmes du trafic ; à savoir : un train à grande vitesse avec les plus grandes charges d'essieu, la plus lourde locomotive, le plus lourd tender et une suite convenable de voitures, puis un train de marchandises avec une locomotive à essieux lourds, nombreux et peu écartés, un tender suffisant, et une longue suite de wagons de la plus lourde espèce. On admettra naturellement les plus grands effets de surcharge résultant de l'un ou l'autre de ces trains, supposés placés dans les positions les plus défavorables.

" Le deuxième système est celui auquel les ingénieurs auront le plus souvent recours pour effectuer les calculs courants, même si les charges mobiles ont été prescrites sous forme de trains-types. Au lieu de recommencer pour chaque projet de pont l'étude de ces trains, ou même d'introduire ceux-ci effectivement dans les calculs de résistance, il est bien plus avantageux *de faire cette étude une fois pour toutes*, et d'établir les échelles de surcharges uniformes équivalentes, qu'on pourra ensuite appliquer immédiatement à toutes les portées ou longueurs surchargées, sans aucune étude nouvelle.

" Des progrès importants ont été réalisés dans ce genre de calculs, surtout en y introduisant le principe des longueurs surchargées servant d'entrée aux échelles de surcharges, et en étendant l'usage de celles-ci aux calculs des poutres transversales et de longerons.

" 4. — Le Congrès constate que depuis une dizaine d'années le poids des locomotives, tenders et wagons, a notablement augmenté dans presque toute l'Europe et surtout aux États-Unis d'Amérique. Le rapporteur a soumis au Congrès un projet complet de prescriptions de surcharges, qui suffiraient pour tenir compte actuellement des trains les plus lourds circulant sur les grandes lignes les plus fatiguées, tant en Europe qu'aux États-

" In the former system it is always desirable to consider at least two typical trains representing the two extremes of the traffic, that is to say, an express train with the heaviest axle loads, the heaviest engine and the heaviest tender and a proportionate train of carriages, and then a goods train with engine having heavily loaded and numerous axles close together, an ample tender and a long train of wagons or trucks of the heaviest kind. We should, of course, admit the maximum effects of the load resulting from either of these trains if we assume them to be placed in the most unfavourable positions.

" The latter system is one to which engineers will most frequently have recourse in order to work out current calculations, even when the moving loads have been prescribed under the form of typical trains. Instead of recommencing the study of these trains for each plan or even of introducing them effectively into the calculations of resistance, *it is much more advantageous to make this calculation once for all*, and to prepare the scales of uniform equivalent loads which may afterwards be at once applied to all spans or lengths loaded without having to make a fresh calculation.

" Important progress has been effected in this kind of calculation more particularly by the introduction of the principle of " the length loaded " serving as a basis for the scale of loads, and by extending the use thereof to the calculations of transverse girders and longitudinal stringers.

" 4. — The Congress is aware that during the last ten years the weights of locomotives, tenders and wagons have materially increased throughout almost the whole of Europe and especially in the United States of America. The author has submitted to the Congress a complete plan of load regulations which would suffice to meet the requirements of the heaviest trains now running on the largest lines where the traffic is greatest both in

Unis d'Amérique. Il distingue deux groupes de lignes où circulent *des trains extra-lourds* ou bien seulement *des trains lourds,* et présente pour les deux cas ses prescriptions, soit sous la forme de trains-types, soit sous celle d'échelles de charges uniformes équivalentes. En comparant ces échelles aux prescriptions publiées dernièrement dans divers pays, on reconnaît qu'elles ne paraissent pas exagérées, et que même pour *les trains extra-lourds* elles ont déjà été dépassées. Il paraît désirable que sur les grandes lignes internationales la voie et les ponts aient une résistance suffisante pour *les trains lourds,* en y supposant la charge d'essieu maximum au moins comprise entre 14 et 15 tonnes (1).

" 5. — Le Congrès constate que l'emploi du fer fondu pour les ponts métalliques se répand de plus en plus, tandis que l'emploi du fer soudé devient plus rare. On est généralement d'accord maintenant quant aux qualités de dureté du fer fondu à préconiser pour les ponts métalliques; celui-ci doit avoir environ 25 p c. d'allongement pour une limite de rupture d'au moins 40 kilogrammes par millimètre carré. Toutefois, pour des ponts de portée exceptionnelle, on recherchera un métal plus dur, quitte à surveiller de plus près la fabrication, les fournitures et le montage.

" Dans le premier cas, qui est celui des ouvrages courants, on pourra, comme pour le fer soudé, admettre des limites de travail de 6 à 9 kilogrammes par millimètre carré pour le métal, tandis que pour des maîtresses poutres exceptionnellement grandes on pourra

(1) Ceci reste d'accord avec le vote du Congrès dans sa quatrième session à Saint-Pétersbourg, en 1892, vote admettant deux véhicules ayant chacun quatre essieux de 14 tonnes avec 1m20 d'écartement. Il y faudrait ajouter seulement que l'empattement total à considérer doit être de 4m80 environ et supposer les deux locomotives placées tête à tête.

Europe and also in the United States. He distinguishes between two groups of lines on which *extra-heavy trains* run or simply *heavy trains,* and for the two cases he submits his regulations either under the form of typical trains or under the form of scales of uniformly distributed loads. By comparing these scales with the regulations recently published in various countries, it will be seen that they are not exaggerated, and that even as regards *extra-heavy trains* they have already been exceeded by recent specifications. It would seem desirable that the permanent way and the bridges on large international lines should be of sufficient resistance for *heavy trains* by assuming the maximum axle load at any rate to be at least between 14 and 15 tons (1).

" 5. — The Congress is of opinion that the use of ingot iron (or mild steel) for bridges is greatly extending, whereas the use of weld iron (or wrought iron) is becoming more rare. Engineers are generally agreed now as regards the qualities and hardness of the steel to be recommended for bridges; it should have about 25 p. c. elongation with an ultimate tensile strain of at least 56,900 lbs per square inch (40 kilograms per square millimetre). However, in the case of bridges of exceptional span a harder metal should be sought, according to the greater care taken in the manufacture, the selection of the materials used, and the method of erection.

" In the former case, that is for ordinary work, we might admit, as in the case of weld iron, the limits of working strain to be from 8,500 to 12,800 lbs per square inch (6 to 9 kilograms per square millimetre), whereas for exceptionally large main girders these

(1) This is in accordance with the vote passed by the Congress at the 4th Session at St. Petersburg in 1892, which vote embodies vehicles each with 4 axles of 14 tons separated by a distance of 4 feet (1·20 metres). It should merely be added that the total wheel-base to be taken into consideration is about 16 feet (4·80 metres), and the two locomotives should be taken as placed head to head.

élever ces limites de 8 à 12 kilogrammes par millimètre carré, avec 1/8 environ en plus pour les effets du vent. Il est recommandable dans tous les cas que le travail admis ne dépasse jamais la moitié de la limite d'élasticité du métal qu'on emploie; dans le cas d'efforts alternés, il convient même de réduire encore quelque peu cette limite;

limits may be increased to from 11,400 to 17,100 lbs per square inch (8 to 12 kilograms per square millimetre) with about one-eighth more for wind pressure. It is desirable in all cases that the working strains allowed should never exceed half the limit of elasticity of the metal used; in the case of alternating strains it is even well to slightly reduce this limit still further.

" 6. — Quant à l'action du vent sur les ponts, on est d'accord presque partout pour se rallier aux coefficients fixés par les ingénieurs en Angleterre vers 1881 (1).

" Toutefois, les ingénieurs du continent dans les deux mondes ont adouci quelque peu ces règles en admettant que la pression de 170 kilogrammes par mètre carré suffit en tant que les trains sont encore en circulation, tandis que par un vent de 270 kilogrammes par mètre carré le service est forcément interrompu.

" 6. — As to the action of the wind on bridges it is almost universally agreed to adopt the co-efficients specified by English engineers in 1881 (1).

" However, continental engineers in both hemispheres have somewhat modified these regulations by admitting that a pressure of 35 lbs per square foot (170 kilograms per square metre) is sufficient so long as trains are able to run, whereas the traffic would of necessity be interrupted by a wind pressure equal to 55 lbs per square foot (270 kilograms per square metre).

" 7. — Pour des ponts convenablement construits, conformément aux conditions citées plus haut, il semble résulter du travail de recensement du rapporteur, concernant les poids de plus d'un millier de constructions citées par les Administrations, que les quantités de métal à investir dans les ponts seraient environ les suivantes (2) :

" 7. — As regards bridges constructed in accordance with the conditions laid down above, it appears, from the investigations of the author which cover the weights of more than 1,000 structures supplied by the railway departments, that the quantities of metal to be used in bridges are approximately as follows (2) :—

Portées (Spans).		0 m. (0')	10 m. (33')	50 m. (164')	100 m. (328')	200 m. (656')	300 m. (984')	400 m. (1312')	500 m. (1640')
		Tonnes. (Tons.)	Tonnes. (Tons.)	Tonnes. (Tons.)	Tonnes. (Tons.)	Tonnes. (Tons.)	Tonnes. (Tons.)	Tonnes. (Tons.)	Tonnes. (Tons.)
Poids par mètre de voie. (Weight per metre of track.)	Minimum	0·2	0·6	1·7	3·0	5·6	8·2	10·8	13·5
	Moyenne. (Medium.)	0·35	1·0	2·6	4·3	7·3	10·1	12·8	15·5
	Maximum	0·5	1·4	3·5	5·6	9·0	12·0	14·8	17·5

" Toutefois, les poids indiqués ne peuvent être considérés comme justifiés par la pratique

" The weights indicated, however, cannot be regarded as justified by present practice

(1) *Report of the committee appointed to consider the question of wind pressure on railway structures.* London, 1881. Eyre and Spottiswoode.

(2) Cette échelle admet, pour des portées intermédiaires, l'interpolation usuelle rectiligne. Les poids cités ne comprennent pas la voie et le platelage de bois.

(1) *Report of the committee appointed to consider the question of wind pressure on railway structures.* London, 1881. Eyre and Spottiswoode.

(2) This scale admits of the usual rectilinear interpolation for intermediate spans. The weights named do not include the permanent way and the timber flooring.

actuelle, que jusqu'à des portées de 200 mètres environ, faute d'un nombre suffisant d'exemples de ponts ayant des portées plus grandes.

" 8. — Enfin, le Congrès estime qu'il serait utile d'étudier, dans chaque pays, si les charges croissantes imposées aux services de la voie et de l'infrastructure, par les véhicules de plus en plus lourds mis en circulation par le service de la traction, sont bien justifiées par les bénéfices qui en résultent.

" Cette étude concerne surtout la voie et les ponts métalliques de portée moyenne dont la reconstruction en cours d'exploitation occasionne des dérangements et frais considérables. Pour les ponts métalliques de faible portée, les remplacements s'effectuent facilement par lancement latéral entre le passage de deux trains. Pour les travées métalliques de très grande portée, les reconstructions ou remplacements ne s'effectuent presque jamais (Conway, Britannia, Saltash), vu le rôle peu important qu'y jouent les charges mobiles. Mais pour tous les ouvrages compris entre ces extrêmes ainsi que pour la voie, l'étude dont il s'agit conserve une grande importance.

" Littéra *B*.

" Les surcharges d'épreuve initiales et périodiques, usitées dans presque tous les pays pour les ponts métalliques de chemins de fer, sont indispensables; elles constituent une garantie de sécurité que l'on doit au public des voyageurs et au personnel de service.

" Toutefois, les résultats favorables fournis par ces épreuves ne constituent qu'une indication pour les ingénieurs ; ils ne dispensent en aucune façon du service détaillé de surveillance et d'entretien concernant toutes les parties composantes de chaque construction. "

Deux longues séances ont été consacrées par la section à la discussion du rapport; plusieurs

except up to spans of 660 feet (200 metres) or thereabouts owing to want of a sufficient number of examples of bridges of larger span.

" 8. — Lastly, the Congress considers that it would be useful to study in the various countries whether the increasing loads imposed on the permanent way by the ever-increasing weight of rolling stock are properly warranted by the advantages which they confer.

" This investigation applies particularly to the permanent way and the iron bridges of a medium span the reconstruction of which, while the line is still being worked, gives rise to much inconvenience and to considerable expenditure. As regards iron bridges of small span, their renewal can easily be effected by pushing them on from the side in the interval during the passage of two trains. As regards iron structures of very long spans, reconstructions or renewals can hardly ever be carried out (Conway, Britannia, Saltash) on account of the unimportant part which the moving loads play in them. But as regards all kinds of structures comprised between these extremes and also as regards the permanent way, the investigations in question are of considerable importance.

" Littera *B*.

" That the initial and periodical test loads applied in almost all countries to iron railway bridges are indispensable; they constitute a guarantee of safety to which the travelling public and the railway staff are entitled.

" Nevertheless, the favourable results furnished by these tests do not alone suffice for careful inspection and the guidance of the engineers. They do not in any way supersede the necessity for careful inspection and maintenance of all the component parts of each structure. "

The section discussed this report at great length during two long sittings when membres, notamment Messrs. Belelubsky, Moïse (Ouest français), Schüle (Suisse), Robertson (East Indian Railway), Bell (Indes anglaises), de Kounitsky (Gouvernement russe), Étienne (Paris-Lyon-Méditerranée), sir Douglas Fox (Manchester, Sheffield and Lincolnshire Railway), général Hutchinson (Ministère du commerce, Grande-Bretagne), Brière (Paris-Orléans), Petsche (Est français), ont présenté de nombreuses et importantes observations, beaucoup moins pour contredire au rapport de Mr. von Leber et en attaquer les conclusions, que pour fournir des renseignements complémentaires et affirmer le haut intérêt de la question. Les propositions présentées par le rapporteur sous les numéros 1° et 2° du littéra *A*, ont été votées par la section avec quelques légères modifications acceptées par le rapporteur. (Voir ci-après.)

La proposition n° 3 du même littéra a donné lieu à une assez vive discussion, quelques membres rentrant, à ce sujet, dans la discussion générale.

Mr. de Kounitsky a proposé de conserver au 3° exclusivement les indications concernant les trains-types. Il est d'avis que chaque indication tendant à recommander l'emploi général des surcharges distribuées équivalentes semblerait condamner à tort les méthodes graphiques utilisant les charges réelles (concentrées, isolées).

Finalement, Mr. Bell a émis l'avis qu'en raison de l'époque tardive à laquelle le rapport de Mr. von Leber, et spécialement sa traduction anglaise, avait été distribué, les membres de la section n'avaient pas eu le temps suffisant pour l'étudier avec tout le soin qu'il mérite pour recueillir et coordonner les renseignements complémentaires qu'il y aurait lieu de présenter à la section, pour rédiger, le cas échéant, de nouvelles conclusions, qui, en pareille matière, ne peuvent être improvisées en séance et doivent être longuement travaillées à tête reposée.

Après avoir voté les félicitations les plus

Messrs. Belelubsky, Moïse (Western Railway of France), Schüle (Switzerland), Robertson (East Indian Railway), Bell (Indian Government), Étienne (Paris-Lyons Railway), Sir Douglas Fox (Manchester, Sheffield and Lincolnshire Railway), de Kounitsky (Russian Government), General Hutchinson (Board of Trade), Brière (Orléans Railway), Petsche (Eastern Railway of France) made many important observations, more by way of furnishing supplementary information and emphasising the importance of the subject than of traversing the conclusions presented in the report. The conclusions formulated by the reporter under heads I and II of littera *A* were adopted by the section with one or two slight modifications which were accepted by the reporter. (See below.)

Conclusion No. 3 of the author's paper gave rise to an animated discussion, some members returning to the general discussion of the subject.

Mr. de Kounitsky suggested that in No. 3 only the statements referring to typical trains should be maintained. He expressed the opinion that a tendency to recommend the general use of uniformly distributed loads would wrongly appear to condemn graphical methods which employ actual (concentrated) loads.

Finally Mr. Bell expressed the opinion that, considering the late date at which the author's paper and especially the English edition of it had been distributed to the members, it did not leave the members sufficient time to carefully study the subject with the attention that it merited, or to collect and present supplementary information to the section, or, if necessary, to present further conclusions which could not be formulated during brief discussions, but must be carefully and thoughtfully considered at leisure.

After proposing a sincere vote of thanks sincères à l'éminent rapporteur, Mr. von Leber, pour son admirable travail, — une des œuvres les plus remarquables présentées au Congrès, — Mr. Bell propose de maintenir la question à l'ordre du jour des travaux du Congrès en invitant les membres qui s'y intéressent à faire connaître par écrit leurs observations et propositions, qui seraient imprimées en annexe au rapport de Mr. von Leber; de cette façon, lors de la prochaine session, la discussion serait parfaitement préparée et délimitée, et l'on pourrait peut-être arriver, dans le court espace de temps dont on dispose, à une solution complète.

Cette proposition de Mr. Bell est adoptée par la 1re section.

Après ce vote, Mr Simon (Pays-Bas) annonce qu'il a déjà remis à Mr. von Leber une note d'observations et des renseignements sur la nouvelle méthode relative aux épreuves périodiques des grands ponts aux Pays-Bas. Plusieurs membres annoncent qu'ils suivront le conseil de M. Bell et l'exemple de Mr. Simon.

to the author for his admirable paper — one of the most remarkable presented to the Congress — Mr. Bell suggested keeping the question open for discussion at the next Congress, and inviting members interested in the matter to send in their remarks to be published as an appendix to Mr. von Leber's paper, in order that at the next session of the Congress the material for discussion should be well prepared and defined, and a definite decision could then be arrived at in the short time available for discussion.

The proposition of Mr. Bell was adopted by the 1st Section.

After this vote, Mr. Simon (Holland) announced that he had handed to Mr. von Leber a note containing observations and data referring to the new method of periodical tests for large bridges in Holland. Several members said that they would follow the advice of Mr. Bell and the example of Mr. Simon.

CONCLUSIONS.

" 1. — Les quantités de fer employées ou à " employer pour la construction des ponts " métalliques de chemins de fer sont extrêmement variables, abstraction faite des conditions de portée et de hauteur imposées à " l'ingénieur par les conditions locales.

" Pour des ponts de même portée, la quantité de métal par mètre de voie varie souvent du simple au double, suivant les surcharges prescrites, suivant les limites de " travail intérieur assignées aux diverses " pièces, suivant le système de construction " adopté et surtout suivant l'ingénieur qui " dresse les projets.

" Les formules générales souvent proposées " sur la base de considérations très logiques, " pour estimer d'avance le poids d'un pont, ne " sont applicables que pour des projets con-

" 1. — The quantities of iron used, or to " be used, for the construction of iron bridges " are extremely variable, even apart from " the conditions of span and height imposed " on the engineer by local circumstances.

" For bridges of the same span the quantity of metal per foot of track varies so " much that sometimes twice as much is " required in the one case as in the other, " according to the prescribed loads, the " limits of internal working strain assigned " to the various parts, the system of construction adopted, and particularly according to the engineer who draws up the " design.

" The general formulae, frequently submitted on the basis of very logical considerations for the purpose of calculating beforehand the weight of a bridge, are

" cernant un pays ou une compagnie de chemins de fer. Il est préférable de faire le relevé des poids d'un grand nombre de ponts construits et de procéder par voie de comparaison, par approximations successives.

" Les tableaux dressés par le rapporteur pourront, à cet effet, rendre des services utiles.

" 2. — Les surcharges prescrites, quant au matériel roulant, ont une importance majeure pour les ponts de faible portée, où elles priment absolument sur les poids morts et les effets du vent. C'est l'inverse pour les ponts de grande portée et lorsque celle-ci atteint 100 mètres, sûrement lorsqu'elle dépasse 120 mètres, ce sont les deux derniers effets qui jouent le rôle le plus important dans les calculs de résistance, lesquels, pour des portées exceptionnelles, affectent une forme souvent inattendue.

" Ainsi pour les grandes travées du pont sur le Forth avec 521 mètres de portée, les illustres ingénieurs sir John Fowler et sir Benjamin Baker, qui en ont dressé les projets, relatent que la surcharge fournie par deux trains lourds n'excède pas 5 p. c. du poids mort. "

" only applicable for designs of bridges drawn up for the same country or by the same railway company. It is more desirable to prepare a statement of weights of a large number of bridges, and to proceed by way of comparison or by way of " trial and error ".

" The tables drawn up by the author might render useful service for this purpose.

" 2. — The loads prescribed as regards rolling stock are of great importance for bridges of small spans, in which these loads are of far greater moment than dead loads and wind pressure. On the contrary, in the case of bridges of large span of about 330 feet (100 metres) and certainly when the span exceeds 390 feet (120 metres), the two last influences play the most important part in the calculation of resistances, which, in the case of large spans, often assumes an unexpected magnitude.

" Thus in the great spans of the Forth Bridge with 1,710 feet (521 metres) span, the illustrious engineers, Sir John Fowler and Sir Benjamin Baker, the authors of the design, state that the load of two heavy coal trains does not exceed 5 p. c. of the dead weight. "

These conclusions are adopted by the general meeting which, on the proposal of Mr. de Kounitsky, substituted in the second paragraph of conclusion 2 the words " spans of the Forth Bridge " for the existing words " arches of the Forth Bridge "

APPENDICES

APPENDIX I.

Note on Iron Bridges

By Mr. SIMON
MEMBER OF THE COUNCIL OF SUPERVISION OF THE DUTCH RAILWAYS

In Holland, the State, as well as the Railway Companies, sees that bridges of large span are sufficiently strong.

The Companies undertake the maintenance of the bridges and give particular attention to the removal of rust, the painting of the metallic parts and the renewal of rivets which have become slack, while the State undertakes the tests which are made to prove the strength of the metallic structure.

Very complete tests, made on the majority of our bridges after construction, have furnished data which help us to decide upon the best method in actual practice.

It is at once seen that, in order to test the strength of a bridge, it is not sufficient simply to measure the deflection produced by any load whatever on the bridge. Besides it is not an easy matter to do this without interfering with the traffic, and consequently little reliance can be placed on the results. If, either in the calculations or in the construction, a mistake is made sufficiently serious to cause the structure to fail under certain conditions of loading, but if this only applies to one particular part of the bridge, the effect which it would have on the total distortion would be so insignificant as not to be measurable in the deflection.

As theory does not afford exact methods of calculating the strains produced by blows and as in practice there are inevitably very many circumstances which cannot be taken into consideration in the calculations, the conclusion has been come to that it is better to prove the strength of the structure by a detailed examination of all the metallic parts than to repeat the calculations for the increased loads which have lately been adopted.

To make these investigations the State has at its disposal twenty-four Manet apparatus, well-known instruments which are used to measure the variations of length of the metallic parts caused by the strains which the load produces.

As these variations are almost imperceptible, the object of the instruments is to enlarge them by means of gearing which acts on a needle.

The instruments are furnished with clamps for holding the pieces to be tested; the two points of support are united not by a stiff rod but by a thin flat band wound round a small wheel which is placed on one of the clamps and which enables them to be set at any given distance apart from one another (figs. 1 to 6).

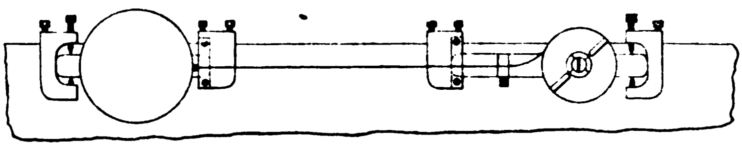


Fig. 1.

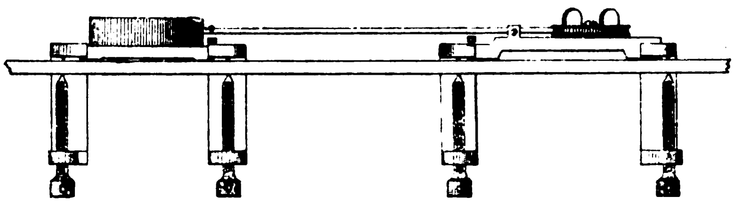


Fig. 2.

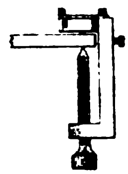


Fig. 3.

Fig. 1-3. — *Clamps for fixing the Manet apparatus (first arrangement).*

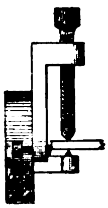


Fig. 5

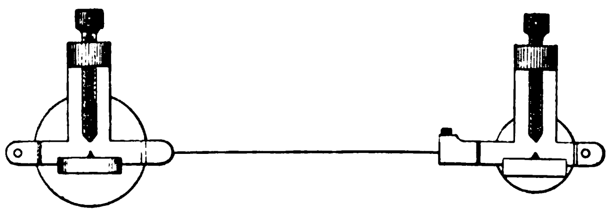


Fig. 4.

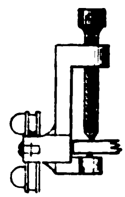


Fig. 6.

Fig. 4-6. — *Clamps for fixing the Manet apparatus (second arrangement).*

By this arrangement they can be fixed quite close to the joints which are strained not only in tension but also by bending on account of their stiffness and have therefore to stand a very high strain.

The arrangement is such that the clamps can be fixed and released very quickly, so that it is possible to make a great number of tests in a short time. Thus the total number of applications of the instruments during the passage of one train generally reaches thirty. A very simple and effective indicator registers the movements of the needle during the passage of the trains.

The use of these instruments has given some interesting results, both as regards strains which are found to exceed their theoretical values and also as regards other strains of which theory takes scarcely any account. Thus it is shown that the wind bracing, although there may be no wind at the time, is strained to an appreciable degree during the passage of trains.

The instruments, by means of which it can generally be seen whether or not the strain exceeds the limits allowed, are not sufficiently accurate for a thorough investigation of any doubtful point.

For this purpose an instrument has been made which requires the use of a microscope to determine the variations (fig. 7).

Two clamps are fixed to the piece to be tested and are united by a copper tube, one end of which is held by the first clamp, while the other end can slide in a circular hole made in the second clamp.

Two very thin rods of triangular section, free to slide parallel to the tube in grooves cut in the second clamp, are moved respectively by two tappets fixed to the tube, in such a way that when it slides in either direction it produces a displacement of one or other of the rods. Upon these rods and the second clamp are marked transverse lines, the variable distance between which is measured by the microscope : the latter has two parallel threads and a micrometer screw on the eye-piece. The reading on the micrometer screw gives the movement of the needles.

In general it may be stated that the joints are the weakest parts of a metallic structure. The investigations on the sliding of riveted joints carried out by Messrs. Considère and Dupuy in France and by Mr. Bach in Germany, as well as those which we have undertaken, have proved to us that an appreciable sliding movement is produced in hand-riveted joints with a slightly high tensile strain. It would, therefore, be interesting to know what is the limit of sliding movement reached by riveted joints in metallic structures.

If this sliding is appreciable the rivets become loose and a line of rust which forms round their heads indicates the defective state of the joint. It is, therefore, important to investigate how far sliding in the joints can take place without producing this defect.

For these investigations the same Manet apparatus is used, only with this difference that the clamps are arranged in such a way that one of the points of support can be fixed on the riveted joint and the other on the piece which is riveted.

If, when these instruments are applied to a riveted joint, a displacement is observed which corresponds to the tensile strain applied to the piece riveted, then one may conclude that the sliding movement is exceedingly slight, whereas, if a great displacement is observed, the inference is that considerable sliding movement takes place.

When the sliding is very pronounced, the rivet at a joint of a lattice bar should be cut out, when it will be seen at once that the rivet hole is badly drilled although the rivet heads may not show the slightest indication of defect.

From experiments made during three years, the conclusion has been arrived at that the pieces at the ends of some swing bridges were too weak to resist the jars produced by

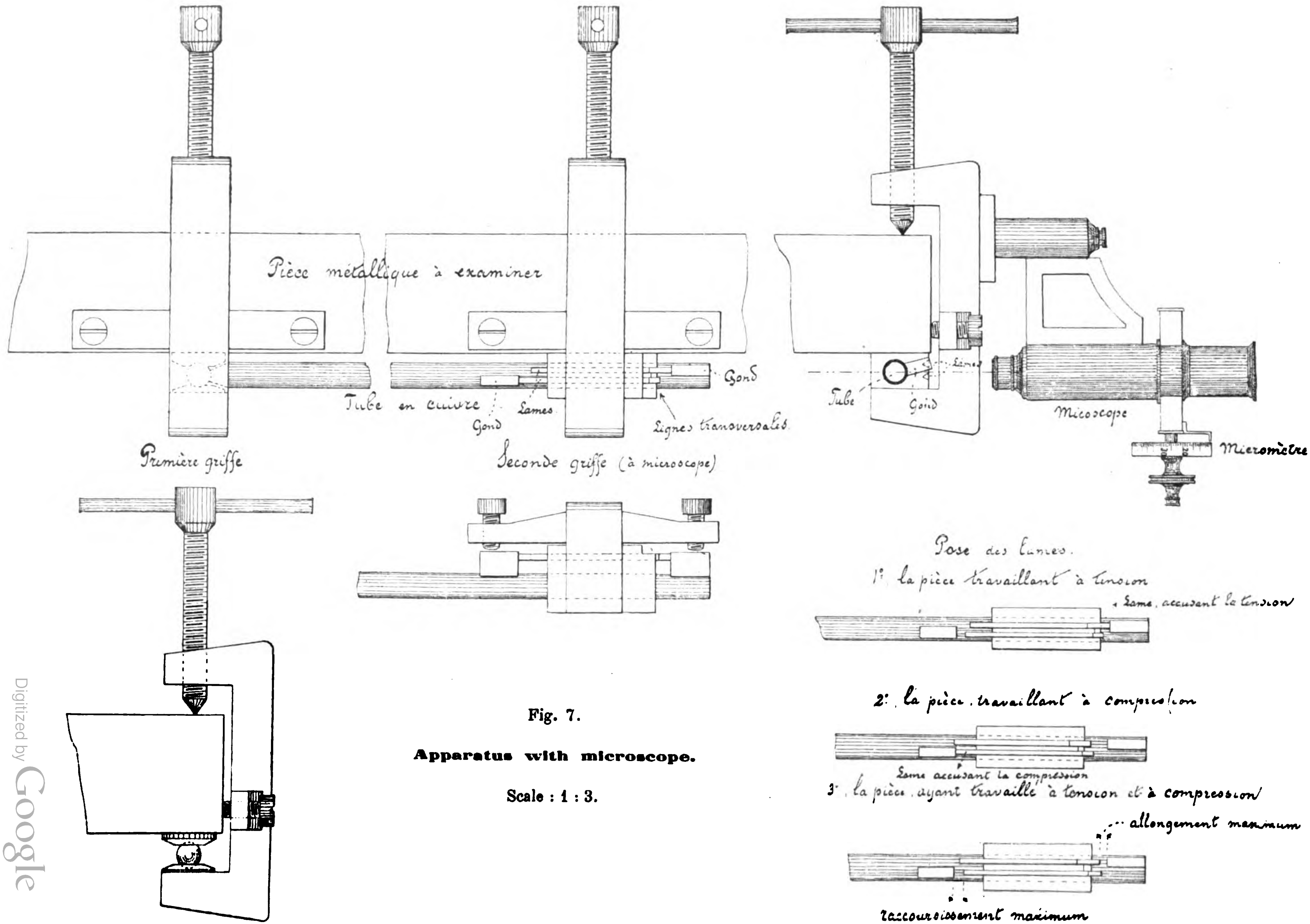


Fig. 7.

Apparatus with microscope.

Scale : 1 : 3.

Explanation of French terms. — ***Pièce métallique à examiner*** = Metallic piece to be examined. ***Tube de cuivre*** = Copper tube. ***Gond*** = Tappet. ***Lames*** = Rods. ***Lignes transversales*** = Transverse lines. ***Première griffe*** = First clamp. ***Seconde griffe (à microscope)*** = Second clamp (carrying a microscope). ***Micromètre*** = Micrometer screw. ***Pose des lames*** = Position of the rods. ***1° la pièce travaillant à tension*** = 1. the piece strained in tension. ***Lame accusant la tension*** = Rod indicating tension. ***2° la pièce travaillant à compression*** = 2. the piece strained in compression. ***Lame accusant la compression*** = Rod indicating compression. ***3° la pièce ayant travaillé à tension et à compression*** = 3. the piece strained in tension and afterwards in compression. [illegible] trains running on to the bridge; that the vertical plates of the top chords were buckled and underwent a bending movement at the passage of each train; that the wind bracings of some bridges were not of sufficient section to resist sudden shocks; and that, in general, the flat bars which form the diagonals, although of sufficient section, were too thin to resist transverse oscillations.

But after all the pieces which compose the metallic structure have been thus examined and the defects more or less remedied, it must not be thought that a perfect state of security has been obtained as regards strength.

There is just a chance that some defect has escaped notice in the examination, and from this another defect might arise.

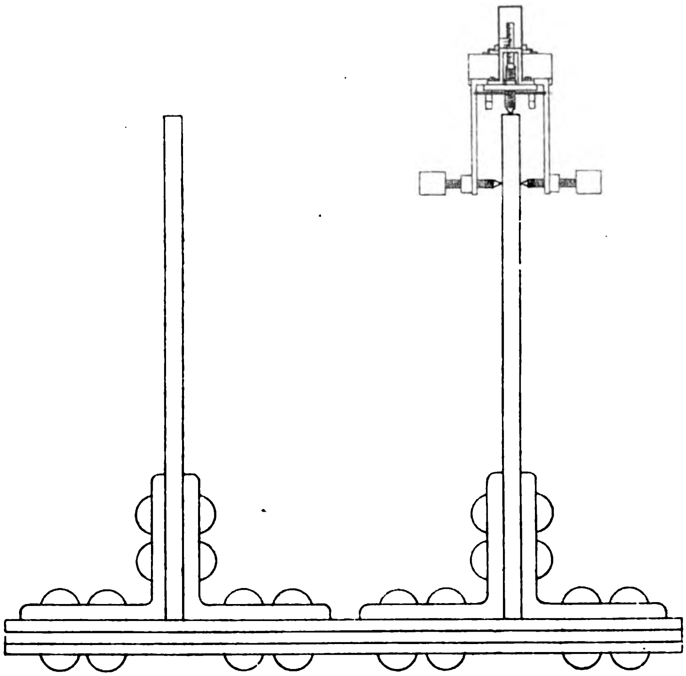


Fig. 8.

In order to be able to say if, after a certain interval of time, the metallic structure is still in the same condition as at the previous examination, it would be necessary to find out whether or not the geometrical form had changed. And if a partial variation was discovered, then one would be able to say what pieces or what riveted joints were the cause of it. A minute investigation of these details would indicate the hidden defects.

The investigation of the geometrical form of lattice girders would entail considerable labour; it is simplified by determining the form of the lower chord only. For this purpose one would have to measure the vertical distance of a series of points on the chord in one plane, but this method, requiring as it does the use of levelling instruments, would not give sufficiently accurate results. Besides, it is preferable to measure the inclination of the chord at the middle of the bays, when a distortion at any particular point would be indicated by a variation in these inclinations.

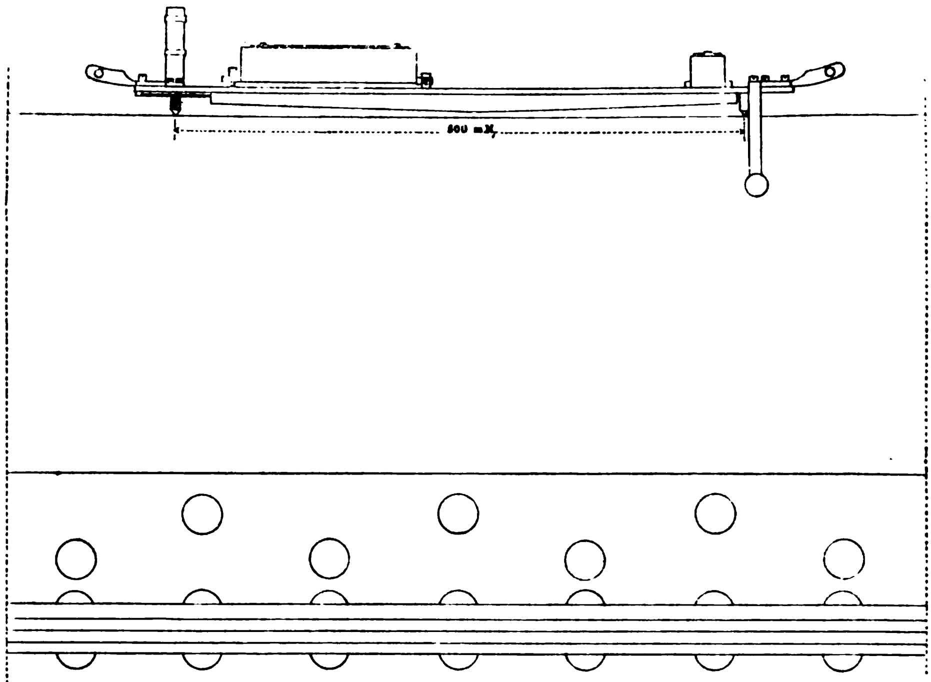


Fig. 9.

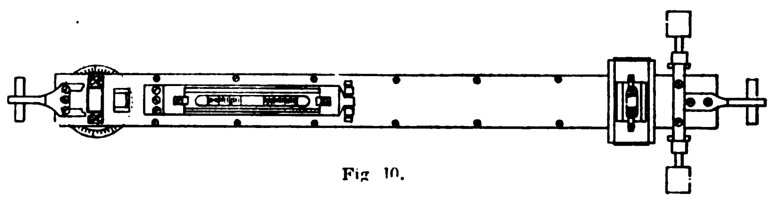


Fig. 10.

Figs 8 to 10. — *Instrument for measuring the variation of the slopes of the vertical plates of the lower chord.*

The instrument used for this purpose is composed of a level resting on two supports of which one is fixed while the other can be moved in a vertical plane by means of a micrometer screw (figs. 8 to 10).

The instrument is placed on the top edge of the vertical plate forming part of the lower chord, the points of support resting in punch-marks made in the edge. When the instrument is in place, the bubble is brought to the centre of the tube by means of the screw, then it is turned end for end and again brought to the horizontal position; the readings of the micrometer screw are taken in the two positions. The difference of the readings thus obtained gives the double of the slope while their sum is always the same, thus checking the readings (figs. 11 and 12).

First position.

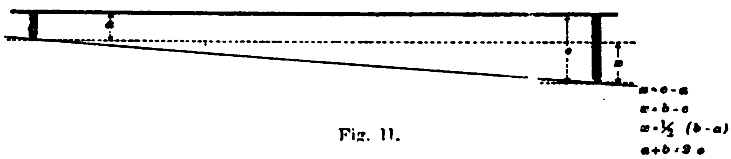


Fig. 11.

Position reversed.

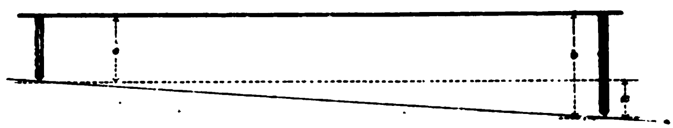


Fig. 12.

Fig. 11 and 12. — *Representing the level in the two positions.*

In consequence of the continual distortions which the structure undergoes through variations of temperature, it is necessary to choose the time of day when this is almost constant to make the experiments. Generally it is sufficient that the sky be overcast, but, in order to form a correct idea of the influence of temperature, two instruments should be used, one being placed near the support of the girder where a change of temperature shows the most marked variation in the slope of the chord.

Then, every time that a measurement is taken with the second instrument of the slope in all the successive bays of the same chord, a measurement should also be taken near the support.

If the latter figures are as near as possible the same in each case, then those obtained by the second instrument can be taken as satisfactory; if, however, the difference becomes marked, then the experiments are stopped and made under more favourable conditions another time.

Great care must be taken to protect the points of support from rust which often forms on the top edge of the chord.

The superintendence of the testing of new bridges as well as of the periodical testing of lattice bridges is one of the duties of the Council of Supervision of Railways.

Mr. Schrœder van der Kolk, the engineer specially appointed by the State, with the help of a deputy engineer and two assistants, has charge of the scientific investigations under the direction of the above-mentioned Council.

It is he who arranged the new method relating to tests for bridges of large span in Holland and who made the improvements in the Manet apparatus.

It is also to him that we owe the use of the level to detect partial distortion in lattice bridges.

The Hague, June 1895.

APPENDIX II.

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Corrigenda in the report by Max Edler von Leber.

Page IV/83 throughout the table itself, the letter *m* has been put instead of the letter K (K = kilog. per square millim.).

In the explanations (*légende explicative*) of Plate I following page IV/102 (1), *instead of:* " **a** and **b** trains lourds " (Heavy trains), *read :* " trains extra lourds " (Extra heavy trains), and *instead of :* " **a'** and **b'** trains extra lourds ", *read :* " trains lourds " (heavy trains).

The last paragraph in large print on page IV/97 should read as follows, in accordance with the correction as published in the French *Bulletin* of June 1895 (2nd part), p. 2626 :—

" The Viaur bridge on the line between Carmaux and Rodez erected lately for the French State with a single track (below the top chord) by the Société de construction des Batignolles, carries the line at a height of 366 feet (111m8) above low water mark, by means of a central arch of 721 feet (220 metres) span. "

(1) See also the separate issue n° 22 in red covers.

SUMMARY

OF THE

1st VOLUME

1st SECTION. — WAY AND WORKS

Question IV. — Construction and tests of metallic bridges.