Automobile Engineering: Gasoline tractors ; Commercial ...

KISSEL SEVEN-PASSENGER TOURING CAR
Courtesy of The Kissel Motor Car Company, Hartford, Wisconsin

Automobile Engineering

A General Reference Work

FOR REPAIR MEN, CHAUFFEURS, AND OWNERS; COVERING THE CONSTRUCTION, CARE, AND REPAIR OF PLEASURE CARS, COMMERCIAL CARS, AND MOTORCYCLES, WITH ESPECIAL ATTENTION TO IGNITION, STARTING, AND LIGHTING SYSTEMS, GARAGE DESIGN AND EQUIPMENT, WELDING, AND OTHER REPAIR METHODS

Prepared by a Staff of

AUTOMOBILE EXPERTS, CONSULTING ENGINEERS, AND DESIGNERS OF THE HIGHEST PROFESSIONAL STANDING

Illustrated with over Fifteen Hundred Engravings

SIX VOLUMES

AMERICAN TECHNICAL SOCIETY
CHICAGO
1920

Authors and Collaborators

CHARLES B. HAYWARD

President and General Manager, The Stirling Press, New York City
Member, Society of Automobile Engineers
Member, The Aeronautical Society
Formerly Secretary, Society of Automobile Engineers
Formerly Engineering Editor, *The Automobile*

C. T. ZIEGLER

Automobile Engineer
With Inter-State Motor Company, Muncie, Indiana
Formerly Manager, The Ziegler Company, Chicago

MORRIS A. HALL

Editor, *Automotive Engineering*
Formerly Managing Editor *Motor Life*, Editor *The Commercial Vehicle*, etc.
Author of "What Every Automobile Owner Should Know"
Member, Society of Automobile Engineers
Member, American Society of Mechanical Engineers

DARWIN S. HATCH, B.S.

Editor, *Motor Age*, Chicago
Formerly Managing Editor, *The Light Car*
Member, Society of Automobile Engineers
American Automobile Association

GLENN M. HOBBS, Ph.D.

Secretary and Educational Director, American School of Correspondence
Formerly Instructor in Physics, The University of Chicago
American Physical Society

HERBERT L. CONNELL, B.S.E.

Late Lecturer, Automobile Division, Milwaukee Central Continuation School
Editorial Representative, *Commercial Car Journal* and *Automobile Trade Journal*
Member, Society of Automobile Engineers
Member, Standards Committee of S. A. E.
Formerly Technical Editor, *The Light Car*

Authors and Collaborators—Continued

HUGO DIEMER, M.E.

Professor of Industrial Engineering, Pennsylvania State College
American Society of Mechanical Engineers

HERBERT LADD TOWLE, B.A.

Specialist in Technical Advertising
Member, Society of Automobile Engineers
Formerly Associate Editor, *The Automobile*

ROBERT J. KEHL, M.E.

Consulting Mechanical Engineer, Chicago
American Society of Mechanical Engineers

EDMOND M. SIMON, B.S.

Superintendent Union Malleable Iron Company, East Moline, Illinois

EDWARD B. WAITE

Formerly Dean and Head, Consulting Department, American School of Correspondence
Member, American Society of Mechanical Engineers

C. A. MILLER, JR.

Associate Editor, American Technical Society
Formerly Managing Editor of *National Builder*
Member, American Association of Engineers

W. R. HOWELL

President, W. R. Howell and Company, London, England

WILLIAM K. GIBBS, B.S.

Associate Editor, *Motor Age*, Chicago

JESSIE M. SHEPHERD, A.B.

Head, Publication Department, American Technical Society

Authorities Consulted

THE editors have freely consulted the standard technical literature of America and Europe in the preparation of these volumes. They desire to express their indebtedness, particularly, to the following eminent authorities, whose well-known treatises should be in the library of everyone interested in the Automobile and allied subjects.

Grateful acknowledgment is here made also for the invaluable co-operation of the foremost Automobile Firms and Manufacturers in making these volumes thoroughly representative of the very latest and best practice in the design, construction, and operation of Automobiles, Commercial Vehicles, Motorcycles, Motor Boats, etc.; also for the valuable drawings, data, illustrations, suggestions, criticisms, and other courtesies.

CHARLES E. DURYEA

Consulting Engineer
First Vice-President, American Motor League
Author of "Roadside Troubles"

OCTAVE CHANUTE

Late Consulting Engineer
Past President of the American Society of Civil Engineers
Author of "Artificial Flight," etc.

E. W. ROBERTS, M.E.

Member, American Society of Mechanical Engineers
Author of "Gas-Engine Handbook," "Gas Engines and Their Troubles," "The Automobile Pocket-Book," etc.

SANFORD A. MOSS, M.S., Ph.D.

Member, American Society of Mechanical Engineers
Engineer, General Electric Company
Author of "Elements of Gas Engine Design"

GARDNER D. HISCOX, M.E.

Author of "Horseless Vehicles, Automobiles, and Motorcycles," "Gas, Gasoline, and Oil Engines," "Mechanical Movements, Powers, and Devices," etc.

AUGUSTUS TREADWELL, Jr., E.E.

Associate Member, American Institute of Electrical Engineers
Author of "The Storage Battery: A Practical Treatise on the Construction, Theory, and Use of Secondary Batteries"

Authorities Consulted—Continued

BENJAMIN R. TILLSON

Director, H. J. Willard Company Automobile School
Author of "The Complete Automobile Instructor"

THOMAS H. RUSSELL, M.E., LL.B.

Editor, *The American Cyclopedia of the Automobile*
Author of "Motor Boats," "History of the Automobile," "Automobile Driving, Self-Taught," "Automobile Motors and Mechanism," "Ignition Timing and Valve Setting," etc.

CHARLES EDWARD LUCKE, Ph.D.

Mechanical Engineering Department, Columbia University
Author of "Gas Engine Design"

P. M. HELDT

Editor, *Horseless Age*
Author of "The Gasoline Automobile"

H. DIEDERICHS, M.E.

Professor of Experimental Engineering, Sibley College, Cornell University
Author of "Internal Combustion Engines"

JOHN HENRY KNIGHT

Author of "Light Motor Cars and Voiturettes," "Motor Repairing for Amateurs," etc.

WM. ROBINSON, M.E.

Professor of Mechanical and Electrical Engineering in University College, Nottingham
Author of "Gas and Petroleum Engines"

W. POYNTER ADAMS

Member, Institution of Automobile Engineers
Author of "Motor-Car Mechanisms and Management"

ROLLA C. CARPENTER, M.M.E., LL.D.

Professor of Experimental Engineering, Sibley College, Cornell University
Author of "Internal Combustion Engines"

ROGER B. WHITMAN

Technical Director, The New York School of Automobile Engineers
Author of "Motor-Car Principles"

Authorities Consulted—Continued

CHARLES P. ROOT

Formerly Editor, *Motor Age*
Author of "Automobile Troubles, and How to Remedy Them"

W. HILBERT

Associate Member, Institute of Electrical Engineers
Author of "Electric Ignition for Motor Vehicles"

SIR HIRAM MAXIM

Member, American Society of Civil Engineers
British Association for the Advancement of Science
Chevalier Légion d'Honneur
Author of "Artificial and Natural Flight," etc.

SIGMUND KRAUSZ

Author of "Complete Automobile Record," "A B C of Motoring"

JOHN GEDDES McINTOSH

Lecturer on Manufacture and Application of Industrial Alcohol, at the Polytechnic Institute, London
Author of "Industrial Alcohol," etc.

FREDERICK GROVER, A.M., Inst.C.E., M.I.Mech.E.

Consulting Engineer
Author of "Modern Gas and Oil Engines"

FRANCIS B. CROCKER, M.E., Ph.D.

Head of Department of Electrical Engineering, Columbia University
Past President, American Institute of Electrical Engineers
Author of "Electric Lighting," Joint Author of "Management of Electrical Machinery"

A. HILDEBRANDT

Captain and Instructor in the Prussian Aeronautic Corps
Author of "Airships Past and Present"

T. HYLER WHITE

Associate Member, Institute of Mechanical Engineers
Author of "Petrol Motors and Motor Cars"

Authorities Consulted—Continued

ROBERT H. THURSTON, C.E., Ph.B., A.M., LL.D.

Director of Sibley College, Cornell University
Author of "Manual of the Steam Engine," "Manual of Steam Boilers," etc.

MAX PEMBERTON

Motoring Editor, *The London Sphere*
Author of "The Amateur Motorist"

HERMAN W. L. MOEDEBECK

Major and Battalions Kommandeur in Badischen Fussartillerie
Author of "Pocket-Book of Aeronautics"

EDWARD F. MILLER

Professor of Steam Engineering, Massachusetts Institute of Technology
Author of "Steam Boilers"

ALBERT L. CLOUGH

Author of "Operation, Care, and Repair of Automobiles"

W. F. DURAND

Author of "Motor Boats," etc.

PAUL N. HASLUCK

Editor, *Work* and *Building World*
Author of "Motorcycle Building"

JAMES E. HOMANS, A.M.

Author of "Self-Propelled Vehicles"

R. R. MECREDY

Editor, *The Encyclopedia of Motoring, Motor News,* etc.

S. R. BOTTONE

Author of "Ignition Devices," "Magnetos for Automobiles," etc.

LAMAR LYNDON, B.E., M.E.

Consulting Electrical Engineer
Associate Member, American Institute of Electrical Engineers
Author of "Storage Battery Engineering"

Courtesy of Detroit Electric Car Company, Detroit, Michigan

MITCHELL FIVE-PASSENGER TOURING CAR

Courtesy of Mitchell Motors Company, Inc., Racine, Wisconsin

Foreword

THE period of evolution of the automobile does not span many years, but the evolution has been none the less spectacular and complete. From a creature of sudden caprices and uncertain behavior, it has become today a well-behaved thoroughbred of known habits and perfect reliability. The driver no longer needs to carry war clothes in momentary expectation of a call to the front. He sits in his seat, starts his motor by pressing a button with his hand or foot, and probably for weeks on end will not need to do anything more serious than feed his animal gasoline or oil, screw up a few grease cups, and pump up a tire or two.

¶ And yet, the traveling along this road of reliability and mechanical perfection has not been easy, and the grades have not been negotiated or the heights reached without many trials and failures. The application of the internal-combustion motor, the electric motor, the storage battery, and the steam engine to the development of the modern types of mechanically propelled road carriages, has been a far-reaching engineering problem of great difficulty. Nevertheless, through the aid of the best scientific and mechanical minds in this and other countries, every detail has received the amount of attention necessary to make it as perfect as possible. Road troubles, except in connection with tires, have become almost negligible and even the inexperienced driver, who knows barely enough to keep to the road and shift gears properly, can venture on long touring trips without fear of getting stranded. The refinements in the ignition, starting, and lighting systems have added greatly to the pleasure in running the car. Altogether, the automobile as a whole has become standardized, and unless some unforeseen developments are brought about, future changes in either the gasoline or the electric automobile will be merely along the line of greater refinement of the mechanical and electrical devices used.

¶ Notwithstanding the high degree of reliability already spoken of, the cars, as they get older, will need the attention of the repair man. This is particularly true of the cars two and three seasons old. A special effort, therefore, has been made to furnish information which will be of value to the men whose duty it is to revive the faltering action of the motor and to take care of the other internal troubles in the machine.

¶ Special effort has been made to emphasize the treatment of the Electrical Equipment of Gasoline Cars, not only because it is in this direction that most of the improvements have lately taken place, but also because this department of automobile construction is least familiar to the repair men and others interested in the details of the automobile. A multitude of diagrams have been supplied showing the constructive features and wiring circuits of the principal systems. In addition to this instructive section, particular attention is called to the articles on Welding, Shop Information, and Garage Design and Equipment.

Table of Contents

VOLUME VI

*For page numbers, see foot of pages.
†For professional standing of authors, see list of Authors and Collaborators at front of volume.

TRACTOR WITH THREE-GANG PLOW IN ORCHARD
Courtesy of Bean Spray Pump Company, San Jose, California

HART-PARR FOUR-WHEEL TYPE TRACTOR
Courtesy of Hart-Parr Company Charles City, Iowa

FARQUHAR FOUR-WHEEL TYPE TRACTOR

Courtesy of A. B. Farquhar Company, Ltd., York, Pennsylvania

GASOLINE TRACTORS

PART I

INTRODUCTION

Relation of Tractor to Automobile. At first sight it appears to be rather a fortunate coincidence that the man to whom the tractor will prove of the greatest benefit is he who has found most advantage in the automobile—the progressive American farmer. The automobile has proved a veritable godsend to the farmer, and there is no question but that he has thoroughly mastered it. He appreciates that it is a piece of machinery and as such can only be kept in satisfactory operating condition by proper attention; and further, that even despite attention it is subject to breakdown at times. Having acquired this knowledge of an automobile by experience, the prospective purchaser of a tractor naturally feels perfectly competent to judge the merits and demerits of the various types offered and to give the one he buys whatever attention it may need to keep it operating satisfactorily. This is a mistake and has proved a more or less costly one to many farmers who have proceeded on such an assumption. The tractor is driven by a gasoline or kerosene engine, it has a gear set, clutch, and final drive—all counterparts of the automobile—but it is not an automobile any more than an aeroplane or a motorboat is, and the attention that will suffice to keep an automobile going will fall far short of what a tractor requires. Unlike an automobile, the tractor is always operating at full, or almost full, load. Moreover it operates for ten, twelve, or even eighteen hours a day under this load. Its requirements are those of the mogul freight engine rather than those of the high-speed passenger locomotive.

Need of Judgment in Selection of Tractor. Not every one can hope to operate a tractor satisfactorily, but the experience of those who have acquired the many thousand machines turned out in the last few years shows that, given proper judgment in the selection of a tractor for the work it is to perform and the right kind of attention to its needs, it will do all or more than is claimed for it. Buying a tractor may be likened in some respects to building a house. Many people never succeed in building just the house they want until they have made two or three attempts. This is equally true of tractor purchases; many farmers do not succeed the first time in buying the tractor they should have, but in the end the value of the experience gained usually offsets its cost.

CLASSES OF TRACTORS

Development of Tractor Industry. According to a recent issue of a directory of the industry one hundred and thirty-five different American manufacturers are building over two hundred models of tractors. This statement holds good only for the time at which it is written since both the number of manufacturers in the field and the number of models the old and the new entrants are turning out are constantly on the increase. The use of tractors on large farms dates back almost half a century, but up to less than ten years ago they were all of the steam-driven type. Their first cost as well as the expense of maintenance made them practical only on very large farms where skilled labor is constantly employed. This bit of history is mentioned merely to emphasize the infancy of the industry as it now exists, a factor that makes it exceedingly difficult to classify the product of all the manufacturers in the field and even harder for the prospective purchaser to make his selection of a machine. The business of building gasoline- and oil-driven tractors only dates back to about 1910, and for the first five years of its existence its progress was not very rapid. Consequently it is only during the last four years or so that most of the many manufacturers mentioned have entered the field in response to the great demand for tractors on the part of the farmers, caused by the acute shortage of farm labor and the corresponding increase in wages.

Lack of Standardization. When an industry comes into existence almost overnight, as in the present instance, every manufacturer proceeds along individual lines in the design of his machine with the result that the divergence in types is almost as noteworthy as the number competing. The tractor industry now finds itself in about the same position as did the automobile industry fifteen years earlier in that the machines differ widely in design and construction, horsepower ratings bear little relation to the dimensions or speed of the motor, and weights for the same horsepower are often far apart. There is accordingly an entire lack of standardization where any of the essentials are concerned though efforts to remedy this situation by the Society of Automotive Engineers are already well under way. It is scarcely to be expected, however, that the recommendations adopted can come into general use for two or three years at least. Meanwhile, many thousands of tractors are being turned out annually, and the prospective purchaser must make his selection of a machine from those offered, since conditions make it impossible to wait for the perfected tractor to be produced several years from now.

Types of Tractors. Regarded from the mechanical standpoint, the large number of machines now being built may be classified in groups according to some feature of design, such as the type of motor employed, the method of transmitting the power, the manner of securing traction, and the number of wheels, where the latter are used. For example, when classified according to type of motor, there would be a group consisting of those tractors using a slow-speed two-cylinder engine adapted from stationary-engine practice, and a second group of those employing a high-speed four- or six-cylinder motor designed along lines that have been made familiar on the automobile. When classified according to transmission of power, the tractors using a drive through a clutch, which are in the majority, would fall in one group and those employing a friction type of drive in another. On the basis of the method of obtaining traction we would have a group consisting of tractors employing wheels, also in the majority, and a group composed of the so-called *caterpillar,* or tracklaying, type and its numerous modifications. A subdivision of the class using wheels can be made to cover three- and four-wheel types since many machines differ chiefly in this respect. As a matter of fact, subdivisions of practically every one of these classes are possible. For instance, in some three-wheel machines there are two driving wheels, while in others but one is employed. These numerous differences are cited merely to point out the great range of variation that exists.

SELECTING TRACTOR

Work Done on Demonstration No Criterion. Involving, as it does, an investment larger than that of almost any other single farm machine, the selection of a tractor should be made the subject of as much study and investigation as the prospective buyer can possibly give. One of the commonest fallacies in tractor buying is to judge the merits of the machine by the class of *work* it does, the term "work" in this connection being applied almost entirely to plowing since the latter represents the heaviest service to which the tractor is put. It should be borne in mind that the tractor is nothing more than the motive power, and neither its reliability nor its value as a farm machine can be judged from the character of the plowing it does on a demonstration. Good or poor plowing depends entirely upon the plow itself and the methods used in its handling, so that a poor tractor properly hitched to the right type of plow and in the hands of a skilled operator will do better work than the best tractor that can be built will turn out when handled improperly. The method of hitching the plows to the tractor governs not only the quality of work turned out but likewise the amount of power consumed in doing it, granting that the right type of plow is being used for the soil under consideration. It would be just as sensible to judge the value of a team of horses by the character of the furrows they turned in plowing.

Financial Return. It has become customary to criticize American farming methods as compared with European solely upon the difference in production per acre, the fact that the application of intensive cultivation by hand labor to very small areas is accountable for the disparity being lost sight of entirely. American agricultural methods produce more per acre for each man employed than is grown anywhere else in the world, and this is due solely to the application of farm machinery to production on a larger scale than has ever been attempted abroad. This has a direct bearing on the purchase of a tractor, since the capital required for the latter must be invested for one of two reasons: either the tractor will enable its owner to cultivate the same number of acres more economically, or it will place him in a position to cultivate a greater number of acres with the same number of "hands."

The impression has been more or less general that the first of these two reasons, "It will do the work cheaper," is the chief one for purchasing a tractor. Investigations carried out by the Department of Agriculture, however, have shown that this reason is not valid. Taking into account the capital outlay required, the cost of operation, and the depreciation, and considering the average life of a tractor as seven or eight years, it has been found that plowing cannot be done any more cheaply with a tractor than with horses, but that the use of the tractor does enable the farmer to cultivate a substantially increased number of acres with the same number of men. Out of the large number of farms investigated, a majority of the owners found it necessary to increase their acreage after purchasing a tractor in order to use their machines most efficiently. In other words, the same crops could not be raised any more cheaply with the tractor than without it, but much larger crops could be raised by increasing the acreage under cultivation. This naturally applies more particularly to small farms, by which is meant those of 150 acres or less, taking the country as a whole, since what is considered a small farm in the Middle West would be thought quite the contrary in New England.

Size of Farm. It goes without saying that a tractor will not prove a profitable investment on farms of such a size that all the land available for cultivation may be as easily worked by horses in the time allowed, which classification would cover all farms having 100 acres or less of cultivable land since only a portion of the total acreage is open to cultivation on any farm. Many farmers consider the purchase of a tractor on the assumption that its excess capacity can be taken care of by doing "custom work," or plowing for neighbors. In a number of cases of this kind that were investigated the charge made for this work was not sufficient to leave a profit after deducting the cost of operation and the interest on the investment, so that the farmer would have been better off without undertaking this extra work. As a means of paying for the tractor when the owner's farm is not sufficiently large to absorb its full capacity, this practice did not show a profit that would warrant the investment in a tractor, since, as before stated, the charges were too low to cover the cost of operation, while increasing the rates to a point that would leave a profit would result in a falling off in the demand as the renter could do the same work for considerably less with horses.

Judging from the results of the investigations in question, it will not pay the owner of a 150-acre farm of which not more than 100 are cultivable to invest in a tractor unless he can add from 20 to 50 acres to that under cultivation. This, of course, is a general statement that may be subject to modification in numerous instances where specially favorable conditions make the use of a machine advantageous. But this statement as well as the preceding matter is intended chiefly to emphasize to the prospective purchaser of a tractor the fact that it is unwise to make the investment required in anticipation of doing the same amount of work much more economically than it can be performed with horses.

Size of Tractor. First cost is naturally the chief item considered in the purchase of a tractor, and in this connection true economy is to be found in the selection of a machine that is not only of good quality, properly designed and well built for the work it is to do, but that likewise has ample capacity to handle it without overloading. It will prove as expensive in the long run to pay for a good small machine that must be overloaded to do the work required as to buy a cheap machine of any size. In either case the repair bills and the time lost through delays at the height of the season are apt to make the buyer regret his choice, if, in fact, he is not led to condemn tractors altogether. In this connection, however, the skill and experience of the operator are factors which have a very important bearing on the successful use of the machine and largely govern the amount of time that it is out of service due to breakdowns. This is dwelt upon at greater length in later paragraphs.

Tests have demonstrated that at the maximum speed of plowing recommended for all tractors, that is, $2\frac{1}{3}$ to $2\frac{1}{2}$ miles per hour, a two-gang plow will not cover much more ground in a day of ten hours when drawn by a machine than when pulled by horses. In other words, the advantage of the tractor-drawn two-gang plow over horse work is so small that it usually does not pay to buy a machine whose *maximum capacity* is two plows. Whether it be a tractor or any other type of machine, it is not good practice to depend upon running it at its maximum capacity continuously.

The machine will not do as good work and it will be much more subject to frequent breakdown than where it has power in reserve to meet emergencies that will seriously overload a machine that is already working at its full output.

The number of plows that any given machine is capable of pulling depends upon so many other factors besides its power rating that it is often misleading to term a tractor a two-, three-, or four-plow machine, as the case may be. The depth of the furrow, the character and condition of the soil, and the method of hitching all influence this to such an extent that a machine capable of pulling three plows under favorable conditions might make a very poor job with two where the soil conditions were not so good or the plows were not properly hitched.

Margin of Safety Needed. It should be borne in mind that any machine will give the most satisfactory service and have the longest useful life when operated continuously at not more than 75 per cent of its rated capacity. Expense incident to delays as well as the cost of repairs will accordingly be minimized when a machine larger than is actually required is selected and is operated at less than its full capacity. Experienced tractor operators have proved this in many instances by investing in four-plow machines and pulling but three plows. It does not pay to load a machine to its limit since it cannot carry such a load continuously and give satisfactory service, so that in selecting a tractor the chief points to bear in mind are not to buy a lightly or cheaply built machine; and not to select a machine so small that it can only do the work required by working continuously at full load.

Power for Belt Work. While plowing constitutes more than one-half the work for which the tractor is required, it would pay few farmers to invest in a machine for that purpose alone. All tractors are designed to be used as stationary power plants as well, and one-third or more of the service demanded of them consists of driving other machines, such as threshers or ensilage cutters, or, as it is usually termed, belt work. Unless a machine has ample power for this, it will not be found satisfactory since there is usually a tendency under such conditions to load it to the stalling point and when a cutter has been "choked down," much valuable time is lost in getting it under way again.

A tractor that is not powerful enough to do all the work required of it is not likely to prove a satisfactory investment, though an error may also be made by going to the other extreme and selecting a machine of such a size that it is too expensive to operate on many of the jobs that a tractor of the proper size would perform economically.

Factors Governing Capacity. Why a machine that will pull three plows very satisfactorily under some conditions will with difficulty do good work with only two bottoms in other locations will be readily apparent from a consideration of the difference in drawbar pull required for plowing different soils. The average resistance of soils is given approximately in Table I.

While the figures in Table I have been drawn from experience, the draft of a tractor plow can only be approximated, since the condition of the plow itself and the method of hitching are of the greatest importance. The figures given are based upon the supposition that the plow is clean, sharp, and properly hitched so as to cut easily. When a plow is dull or does not scour well, the power required to draw it will be substantially increased. This is equally true when a plow is not leveled or is out of line in any way.

The draft likewise increases in proportion to the grade and the figures given are based upon plowing on level ground. For each 1 per cent rise in grade, that is, for each foot of vertical lift in each 100 feet of horizontal travel, 1 per cent of the combined weight of the tractor and the plows must be added to the draft. For example, assume a tractor weighing 5000 pounds and hauling four plows each weighing 250 pounds, making the total 6000 pounds: the maximum draft of the four plows in corn stubble, plowing 6 inches deep, would be 3200 pounds, to which it would be necessary to add 60 pounds for each 1 per cent increase in grade. Even on rolling prairie land, which is ordinarily thought of as being level, the dips and hollows often represent 10 per cent grades for short distances, and in this case they would necessitate adding 600 pounds to the draft required.

When planning to buy a tractor to do certain work, keep the figures given in the table in mind; consider the character of the soil, the grades, the depth of the furrow, and the horsepower rating of the machine desired—and it is always well to discount that

TABLE I

Average Resistance of Soils

Soil	Pounds per Square Inch	6 Inches Deep	8 Inches Deep
Sandy loam	4–6	600– 800	750– 950
Corn stubble	6	700– 800	900–1000
Wheat stubble	8	800– 900	1000–1100
Light clay	12	800–1200	1000–1400
Medium clay	14	900–1400	1200–1500
Heavy clay in good plowing condition	16	1600–2000	1800–2100
Sod or heavy clay, medium moisture	18	2500–3000	2700–3100
Gumbo—dry, hard	36	2600–3200	2800–3300

horsepower rating somewhat. It will also pay to keep these figures in mind when the over-enthusiastic salesman begins to make claims.

ANALYSIS OF TRACTOR MECHANISMS

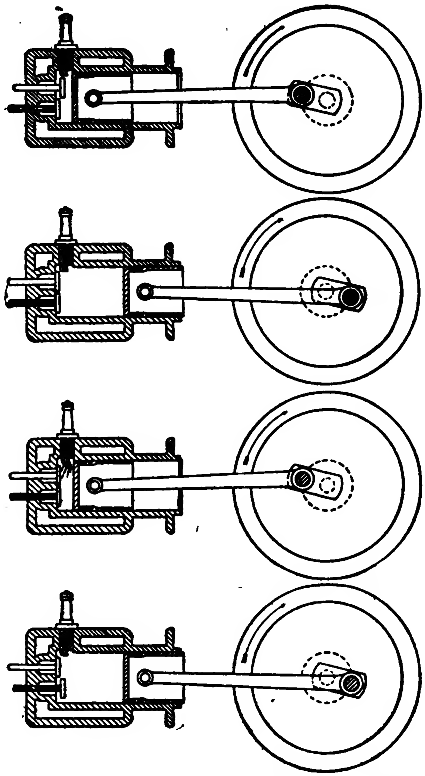
TRACTOR MOTORS

Steam Tractors vs. Internal-Combustion Tractors. Although tractors have been used in this country for almost half a century, they were all steam driven until less than ten years ago, so that the present widespread and rapidly increasing adoption of the tractor is due to the remarkable development of the internal-combustion motor, which, in turn, is largely the result of the great strides the automobile industry has made since 1900. The present work is accordingly confined to tractors with such motors since, although steam tractors will continue to be used on some of the very large farms on which they have been employed so long, they are not available to the average purchaser of a tractor and, at best, it will be only a matter of a comparatively few years before they will have been displaced by the internal-combustion type in most parts of the country.

Superiority of Four-Cycle Motor. The experience of the automobile manufacturer as well as that of the stationary oil-engine builder has demonstrated that of the several types of internal-combustion motors that may be used that based upon the so-called four-cycle method of operation combines the fewest drawbacks with the greatest number of advantages and is accordingly the most practical for general use. The two-cycle motor has never proved successful owing to its inefficiency where fuel consumption is concerned, while other types involve the use of excessive weights for the power generated.

Motor Parts. Assuming the motor to have but one cylinder, a four-cycle motor consists of a cylinder, inlet valve and exhaust valve, piston, piston rings, piston pin, connecting rod, crankshaft and bearings, flywheel, camshaft, valve springs and crankcase. Its accessories are a carburetor (or fuel-mixing device), magneto or other method of generating electric current, spark plug for igniting the fuel, lubricating system, cooling system, and the necessary piping for supplying lubricating oil and for conducting the cooling water between the cylinder jackets and the radiator, the fuel mixture from the carburetor to the combustion chamber of the cylinder, and the exhaust gases away from the latter after they have been burned. A circulating pump may or may not form a part of the cooling system according to the method of circulation employed. These auxiliaries, plus a fan to assist in the cooling of the water or oil in the radiator of the cooling system, complete the motor and the addition of any number of cylinders only involves the duplication of those parts directly attached to or working in the cylinder, such as valves, pistons, and connecting rods with, of course, the provision of an additional crankthrow on the crankshaft for each additional cylinder.

Four-Cycle Principle. *Intake Stroke.* The operation of the motor is based upon a cycle, or recurrence of operations, consisting of four distinct parts. Starting with the piston at the upper dead center, the first of these operations is the *intake*, or *suction*, *stroke*. The inlet valve has been opened through the revolution of the camshaft bringing the cam in contact with the valve tappet and raising the valve off its seat, Fig. 1. The piston is a gas-tight fit in the cylinder, being sealed by the piston rings, which press out against the cylinder walls, and by the presence of a film of lubricating oil between the piston and the cylinder. The downward travel of the piston accordingly creates a partial vacuum (negative pressure, or less than atmospheric) in the cylinder, and the atmospheric pressure (14.7 pounds at sea level), acting upon the liquid fuel in the carburetor, forces the liquid up through the spray nozzle of the carburetor and also draws a predetermined volume of air up through this spray, thus forming a fuel mixture which is forced into the cylinder. The action of the piston on this first part of the cycle is exactly the same as that of a pump in drawing water out of a well. The water is forced up into the pump, following the plunger owing to the decreased pressure in the pump barrel caused by the stroke of the plunger and to the outside pressure of the air on the surface of the water.



Figs. 1–4. Strokes of Four-Part Cycle: 1. Intake; 2. Compression; 3. Power; 4. Exhaust

Compression Stroke. When the piston reaches the limit of its travel, or lower dead center, the inlet valve closes and the piston in rising then compresses the fuel mixture against the head of the cylinder, the valves also being gas tight. This is the second part of the cycle, or the *compression stroke,* and gives to the fuel mixture what is known as the *initial compression.* This stroke has an important bearing on the power output of the motor since it renders the combustion of the fuel more rapid and complete and also increases the pressure developed when the charge is fired. The initial compression used in the average gasoline motor ranges from 50 to 80 pounds per square inch, and the higher it is, the more power the motor develops, other factors such as cylinder dimensions and number of cylinders being the same. In the case of gasoline, however, this initial pressure is limited to 90 pounds per square inch since the heat generated by compression above that point would cause the ignition of the mixture. In kerosene, alcohol, or low-grade fuel engines, it may be much higher, but in this case a compression release must be fitted to the engine in order that it may be turned over by hand for starting.

Power Stroke. The third part of the cycle begins with the firing of the charge by the passage of a spark at the plug, and the piston then starts downward on the *power stroke.* Just before the piston reaches the lower dead center on this stroke, the exhaust valve is lifted by the camshaft and the remaining pressure in the cylinder, which cannot be utilized for driving the piston, is allowed to escape. A very large part of the heat value of the fuel is wasted in this manner through the exhaust, but the drop from the very high pressure at the moment of ignition is so rapid that no advantage is to be gained from lengthening the stroke beyond a certain point in an attempt to utilize a greater percentage of the pressure.

Exhaust Stroke. The following upward movement of the piston is termed the *exhaust stroke* and serves to clear the cylinder of the remaining burned gases in preparation for the succeeding suction stroke, which recommences the cycle. Although it is one of the three idle strokes of the four-cycle method of operation, the exhaust stroke is quite as important as those which precede it since, unless the cylinder is swept clear of the burned gases of the previous explosion as completely as possible, a volume of dead gas is left to occupy space which should be filled with fresh fuel and the amount of power developed on succeeding strokes is reduced in proportion. This is one of the chief defects of the two-cycle method of operation, in which compression immediately follows the power stroke, there being no exhaust stroke or suction stroke. As a result, a considerable percentage of the cylinder space is always filled with burned gases and the time available for the power stroke is so short that part of the fresh gas escapes unburned. In the four-cycle method, upon the completion of the exhaust stroke, the exhaust valve closes and the inlet valve opens, beginning a new cycle. The relative positions of the piston and the valves during the compression, power, and exhaust strokes are shown in Figs. 2, 3, and 4.

Pressure and Temperature. While even the most skilled operator of a traction engine need not be conversant with the intricacies of its design nor with the scientific aspect of its operation, a knowledge of what goes on inside the cylinder will be found an aid to a clearer understanding of the engine itself and the principles on which it works. The internal-combustion motor is a heat engine pure and simple, and each part of its cycle is attended by an increase or decrease in pressure and temperature. One is a function of the other, a given degree of pressure resulting in an equivalent rise in temperature, and this fact is taken advantage of in determining the pressure and the temperature in the cylinder by means of an indicator, the use of which need not be described here since it is only used by designers in the shop.

Range of Pressure and Temperature. Some idea of the great range of pressure and temperature inside the cylinder during but two parts of the cycle, the compression and power strokes, may be gained by assuming that the motor is operating on a summer day with the surrounding temperature at 70° F. The temperature of the entering mixture will then be raised to approximately 100° F. or more through the use of hot air in forming the fuel mixture by taking the air supply from a "stove" attached to the exhaust manifold or by using exhaust gases direct from the engine and also through having a water jacket surrounding the intake manifold. Without these heating devices the mixture would be considerably cooler than the atmosphere since the conversion of the liquid fuel into a vapor is attended by the abstraction of heat from the air. Assuming that the engine has been running, the end of the previous exhaust stroke leaves the interior of the cylinder at a temperature of approximately 260° F. and the incoming mixture is further heated by contact with the cylinder walls and the piston head. At the moment of intake the pressure in the cylinder is slightly less than atmospheric. During the compression stroke this pressure is raised to 50–85 pounds, depending upon the amount of initial compression given, and the temperature rises to a point between 800° and 900° F. Upon the gases being ignited, their tremendous expansion in the confined space raises the pressure to 225–250 pounds per square inch with an increase in temperature ranging from 2500° to 4000° F., depending upon the character of the fuel used. This pressure decreases very rapidly as the piston moves outward on the power stroke, the so-called terminal pressure, that is, the pressure at the end of the stroke when the exhaust valve opens, reaching 40 to 50 pounds with a temperature of approximately 1000° F. The exhaust stroke lowers the pressure to approximately that of the surrounding atmosphere with a decrease in temperature that is governed to some extent by the length of time that the engine has been running.

Effect of High Temperature. The extreme range of temperatures inside the cylinder should impress upon the operator of a tractor engine the necessity for prompt attention if anything goes wrong. For example, in the presence of such great heat as is developed by the explosion it will be evident that failure of the lubrication or of the cooling system can cause serious damage in a very brief period. Pistons will score and scratch the cylinder walls, valves will warp, bearings will be burned out, and finally the pistons will bind hard and fast, all in the short space of a few minutes. In fact, five minutes will suffice to cause damage, the repairing of which will take a week and will represent a bill of three figures.

Grouping of Motor Parts. *Mechanical Group.* The parts necessary to a four-cycle motor, whether of one or several cylinders, have already been outlined. Upon studying these, it will be apparent that they may be divided into groups and that each group has as its object the carrying out of a certain function in the operation of the motor. The foundation of all the groups is naturally the chief mechanical group consisting of the cylinders, valves, pistons, connecting rods, crankshaft, camshaft, crankcase, and flywheel. The functions of this group are to provide a container in which the fuel may be compressed and ignited and moving parts against which the force of the explosion may act—first, to produce linear motion in the stroke of the piston and, second, to convert that motion into rotary motion at the crankshaft.

Auxiliary Groups. All the other groups really consist of auxiliaries, such as the carburetor, heating devices, and intake and exhaust manifolds, designed to mix the fuel with the proper proportion of air, warm it, conduct it to the cylinders, and lead it away from the latter after it has been burned. These parts constitute the second group, or fuel-supply system. The third group consists of the apparatus for igniting the fuel in the cylinders and is represented by the magneto (or other method of generating electric current), the spark plugs, the connecting cables, and any distributing or timing devices necessary when a battery instead of a magneto is employed. The fourth group is represented by the lubricating system, the function of which is to supply oil to all the moving parts; while the fifth group is the cooling system, consisting of the water jackets of the cylinders, the pump, the radiator, and the piping connections. On the traction engine there are further auxiliaries not necessary on an automobile engine, namely: the governor and the air cleaner. A large part of the work of the tractor consists in serving as a stationary power plant, and while doing belt work it is necessary that a steady engine speed be maintained under a wide range of load. Unless the engine were automatically governed under such conditions, it would stall when the load was increased and race when the load was relieved; and racing would be dangerous to the engine itself owing to the great stresses set up by the high speed. While not constituting a group in itself, the governor may be included in a further group consisting of the control system, in which the throttle and the spark levers represent the hand control, and the governor the automatic control of the engine.

Interrelation of Groups. It will be apparent upon a little study of these different groups, or systems, that all are equally essential to the operation of the motor and that precedence cannot be accorded to any one as compared with the others since the failure of any one would prevent the functioning of the rest. An understanding of the relations that these groups bear to one another will go a long way toward making clear the principles on which the engine operates and also the manner in which the different systems must work together in order that it may run satisfactorily. The interdependent functions of the groups are considered at some length in the following paragraphs.

Mechanical Group. Unless the pistons are free to move in the cylinders and the crankshaft and the connecting rods on their bearings, no movement can result. This free movement of the pistons and other working parts is entirely dependent upon the lubricating system maintaining a constant supply of oil on all contacting surfaces. But unless the cooling system continues to function properly, the fact that the lubricating system is working will not keep the motor running since the oil will be burned up on coming in contact with the cylinder walls owing to the high temperature inside the cylinder.

Fuel-Supply System. Air must be drawn through the carburetor and mixed with the spray of liquid fuel issuing from the carburetor nozzle, but this cannot be done unless the inlet valve of the cylinder opens just before or when the piston reaches upper dead center on the exhaust stroke, as otherwise there will be no difference in pressure between the inside and the outside of the carburetor and no suction will result. Nor will the admission of a charge to the cylinder be effective unless the inlet valve closes when the piston reaches or just after it passes lower dead center on the upward stroke as otherwise, instead of being compressed ready for firing, the fuel mixture would again be forced out of the cylinder.

Ignition System. Movement will naturally cease after the admission of a charge unless the electric spark takes place at the proper moment to fire that charge in order to produce the power, or third, stroke of the cycle. The entire failure of the spark will prevent further operation; its occurrence too early will stop the engine by driving the piston down in the reverse direction before it has completed its stroke on compression; and its occurrence too late will cause a substantial proportion of the power to be wasted although the motor will continue to operate. After the completion of the power stroke the mechanical system again enters since, unless the exhaust valve opens near the end of this stroke, the burned gases will remain in the cylinder and when the inlet valve opens, they will be blown back through the carburetor owing to the terminal pressure of 40 to 50 pounds per square inch remaining in the cylinder at the end of the power stroke just before the exhaust valve opens. Owing to the high temperature of these gases they may ignite the liquid fuel in the carburetor if blown back through it. This is known as a back fire, and while failure of the exhaust valve to operate is not as common a cause as either too lean or too rich a mixture, it is evident that back fire must invariably follow unless the exhaust valve does open.

Summary of Operation. Continued movement of the mechanical parts of the motor is dependent upon the working of the lubricating system. Lubrication fails unless the cooling system does its part to keep the temperature down to a point where the movement of the parts in contact is possible, as otherwise the oil is burned. Unless the inlet valve opens at the right time, the carburetor cannot supply a fuel mixture to the cylinder, while a failure of the electric spark to ignite this mixture at the proper moment renders the admission of the fuel supply useless. Failure of the exhaust valve to permit the escape of the burned gases from the cylinder stops further operation by preventing the admission of a fresh charge.

Value of Skilled Operator. It is necessary to take up each of these systems in detail and learn the principles upon which its operation is based in order to understand more clearly the manner in which they must co-operate to produce satisfactory running of the engine and also in order to recognize the symptoms at once when anything goes wrong and to know the remedy to apply to keep the engine going and avoid laying up the machine at the time when it is most needed. In the numerous investigations undertaken by the Department of Agriculture, some of which have been referred to, it was brought out in a most striking manner that in the majority of cases where repair bills were lowest and the most satisfactory service was obtained from the tractor, it was due in very large measure to the fact that a skilled operator was on the job.

It has not been a very uncommon thing in the past for manufacturers to advertise that their machines can be driven by a child. So can a big mogul freight locomotive be run by any boy with strength enough to pull the throttle, but no railroad company would entrust valuable machinery to the care of a boy even were the danger of collision entirely absent. A tractor cannot be run satisfactorily by a boy or a girl, nor can it be so run by a man unless he takes the trouble to acquaint himself with its principles of operation instead of trusting to luck and experience to acquire the necessary information haphazard. In other words, he must qualify as a skilled operative by familiarizing himself thoroughly with the sequence of operations responsible for the working of the motor and the principles upon which those operations are based.

VALVES AND VALVE TIMING

Placing of Valves. By referring to the description of the four-cycle method of operation, it will be seen that it is necessary to draw a fuel charge into the cylinder on one stroke, compress it on the second stroke, fire it on the third, and exhaust the burned gases on the fourth to complete the cycle. There must accordingly be valves to control the entrance and escape of the gases, and these valves must open and close at certain intervals with relation to the rest of the cycle. The placing of these valves depends upon the type of motor, of which there are three in general use, namely: the L-head motor, in which the valves are all on one side; the T-head motor, in which the inlet valves are placed on one side and the exhaust on the opposite side; and the valve-in-head type, in which the valves are located directly in the cylinder heads.

Valves in L-Head Motor. The L-head motor forming the power plant of the Fordson tractor is shown in Fig. 5 in phantom to bring out the details of the valves and valve-operating gear. In a motor of this type all the valves are placed on the same side of the motor so that in the line of eight valves an inlet and an exhaust alternate. The operation of the valves may be traced through their entire range of movement in this illustration by noting their positions in the different cylinders. Cylinder 2, for example, is on the first stroke of the cycle, the intake stroke. The inlet valve is accordingly open and the exhaust valve closed. Cylinder 1 is shown on the compression stroke, during which both valves remain closed. This is also true of the explosion stroke, as indicated by cylinder 3. On the fourth stroke of the cycle the exhaust valve opens to discharge the burned gases into the air, as shown by cylinder 4. (The cylinder numbers mentioned here refer to the cylinders counting from the forward end and not to the numerals shown on the illustration.)

Valve Details. The valves used on automobile and tractor motors are variously referred to as *mushroom* and *poppet* valves, the former name referring to their shape and the latter to their method of operation. The valve proper consists of a head and a stem, and as the valve is subjected to high temperatures, it is either made of cast iron welded to a steel stem or is a piece of nickel steel or other heat-resisting metal. Unless some expedient of this nature is employed, the valve heads are apt to warp under the terrific heat, this being particularly true of the exhaust valves. The stem passes down through a guide drilled and reamed in the cylinder casting itself, and below the point where it leaves this guide the stem is surrounded by a heavy helical spring. This spring is held against the guide at its upper end and against a washer at its lower end. A key passing through a slot in the valve stem itself holds this washer in place. The valve is accordingly held down on its seat by a strong spring, and it is the pull of this spring that returns it to its seat with a snap, or *pop*, after it has been opened. The inch or so of the valve stem extending below the spring washer contacts with the valve push rod when the latter is lifting the valve off its seat, but in order that the valve may come down squarely on its seat when closing, the valve stem and push rod should not be in contact normally. This distance, or clearance, that must exist between the valve stem and the valve push rod is not indicated in the illustration since, in this case, the valve push rod also acts to a certain extent as a lower guide, the valve stem entering its upper end for a short distance.

Camshaft and Timing Gear. At its lower end the valve push rod rides on a cam, and the position of this cam with relation to the camshaft determines the point at which the valve will open and close. There is, of course, a cam for each valve, and as their positions must remain absolutely fixed, they are usually drop-forged in one piece with the camshaft itself. While Fig. 5 shows all the details of the valves and valve gear of an L-head motor, it must be borne in mind that every manufacturer has his own designs and standards. For example, in most motors a cam follower is introduced between the valve push rod and the cam in order to minimize the friction. This usually takes the form of a fork which is in a guide of its own and has at its lower end a roller which rides on the face of the cam.

The inner end of the camshaft carries a gear known as the timing gear in that its position with relation to the smaller gear on the crankshaft, from which it is driven, determines the time at which all the valves open and close. In a T-head motor there are two camshafts and two timing gears, and there are also usually additional gears for driving the circulating pump and the magneto,

Fig. 5. Power Plant of Fordson Tractor
Courtesy of Henry Ford and Son, Inc., Dearborn, Michigan

which make the timing-gear end of the average motor look very complicated to the layman. In the motor shown in Fig. 5 there is but a single timing gear, and it also carries the ignition timing cam which determines the occurrence of the ignition spark in the different cylinders. This is marked *Comm. Roller* on the illustration. Just below the timing cam will also be noted zero marks on the time gears; these are check marks to enable the gears to be reassembled in the proper relation after a motor has been taken down for repairs. The gear on the crankshaft is but half the size of the camshaft gear since each cylinder has but one power stroke for every two revolutions. There are two power strokes per revolution in a four-cylinder motor, and the camshaft must accordingly be driven at half the speed of the crankshaft in such a motor.

Timing Valves. In a motor making 1000 r.p.m. (revolutions per minute), 2000 strokes or reciprocating movements of the pistons must take place in sixty seconds, so that the entire time consumed in making each stroke at this speed is three-hundredths second. A full realization of what an exceedingly short period this is in which to perform any mechanical operation should make it unnecessary to emphasize either the need for accurately timed valves to ensure an efficient running motor or the necessity of closely watching all parts of the valve gear to take up any lost motion caused by wear, since very little slack is required to cut down the effective opening of the valve. For example, assume the maximum lift of the valve from its seat to be $\frac{1}{4}$ inch plus the clearance of $\frac{1}{32}$ inch provided between the valve stem and the tappet to permit the valve to seat positively. Then if wear or lack of adjustment be permitted to increase this clearance to $\frac{1}{16}$ inch, the valve can only lift $\frac{7}{32}$ inch, so that the effective opening is reduced $12\frac{1}{2}$ per cent for every thirty-second of an inch lost motion between the valve tappet and the valve stem.

It is nothing unusual to see automobiles brought to the repair shop with so much clearance between their valve tappets and stems that the valves barely leave their seats when the cams come around. A tractor motor would not be of much service in this condition since it would not develop enough power to carry its load. If it were not for the fact that usually in driving an automobile only a very small fraction of its power is used it would be impossible to keep a motor running after it gets in such a condition. A knowledge of the principles of automobile operation will be an aid to the tractor operator but he will do well not to attempt to apply them literally to tractor handling since they fall far short of what is needed to keep a tractor running.

In designing a motor, both the contour, or outline, to be given the cams and their position on the camshaft are fixed, and the finished camshaft is a single piece of steel the cam faces of which have been ground to a high degree of precision. In timing a motor, it is accordingly only necessary to time the valves of one cylinder as the others must of necessity also be correct. This process is made very simple on the Fordson motor, since it is accomplished merely by the correct meshing of the timing gears. When the two zero marks on the driving and the driven gear coincide the camshaft is in the proper position to open the valves of all the cylinders in the correct order. This, of course, has nothing to do with the proper adjustment of the tappet clearance, which must be looked after at each valve.

Checking Valve Timing. A closer check is usually considered necessary than is afforded by the meshing of the timing gears just mentioned, and to provide this, the necessary data is marked on the flywheel of the motor while a reference point is also marked on the crankcase, Fig. 6. In the illustration, the line *U.D.C. 1 and 4* shown on the rim of the flywheel opposite the reference mrka on the crankcase indicates that that point represents upper dead center for the pistons of cylinders 1 and 4. The line *E.O. 2 and 3* indicates that when that line on the rim coincides with the reference mark, the exhaust valves of cylinders 2 and 3 open. Similarly, *E.C. 1 and 4* and *I.O. 1 and 4* represent, respectively, the exhaust closing and inlet opening points of cylinders 1 and 4, while *I.C. 2 and 3* gives the inlet closing point for cylinders 2 and 3. The rest of the points for the various cylinders are not shown.

Lead and Lag of Valve Movement. While the strong spring brings the valve down on its seat with a snap the moment the valve tappet rides off the cam, the valve cannot be opened in this manner. It must be lifted against the force of the spring, and as the time available for both its lifting and its closing again is so very short, it must begin to open somewhat before the moment when it is to be fully open. This *lead* is given to the inlet valves to a degree dependent upon the speed of the motor in order that a full charge of fuel mixture may be drawn into the cylinder on the intake stroke.

It is possible to start the opening of the inlet valve on the suction stroke before the exhaust valve has closed because of the fact that a gas, as well as a solid body, has *inertia.* Inertia is that property of all matter that tends to resist a change of state, whether that state be rest or movement. If a man runs full speed down a hallway and a door at the other end is suddenly closed, he crashes into the door because he cannot overcome his own inertia in time to stop. On the other hand, if, when standing quietly at the roadside, he attempts to board an automobile passing at twenty miles an hour simply by grasping the part nearest to him, the consequences are apt to be extremely unpleasant if his hold is good. If it is not good, he stays pretty much in the same place although his arm gets a severe wrench. In the same manner a gas possesses inertia, varying with its weight and velocity, or lack of it.

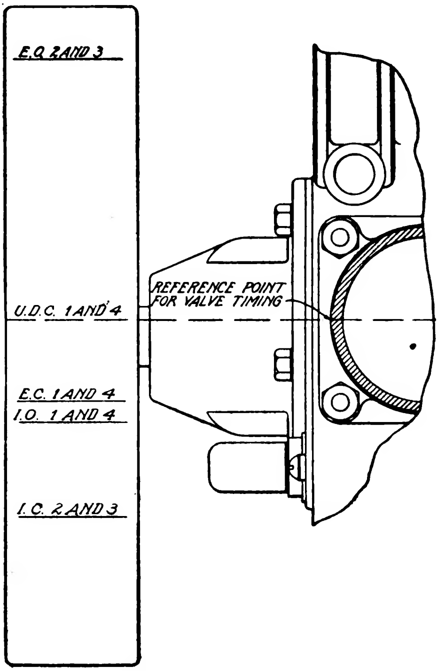


Fig. 6. Reference Marks for Valve Timing

When the gas is flowing out through the exhaust valve at a high rate of speed, since it has had almost the entire exhaust stroke in which to accelerate, the opening of the intake valve has no effect on its movement. Nor is there any risk of the incoming fresh charge passing through the cylinder and out the exhaust valve because its inertia makes it as hard to start as the high-speed exhaust is to stop and it cannot attain any speed until the piston is well down on the suction stroke. Then it in turn is hard to stop, so that it is possible to hold the inlet valve open after the piston has actually passed the lower dead center and started upward on the compression stroke. This delay is termed the *lag* given the valve closing, and in the case of the inlet valve it insures filling the cylinder with the fresh charge to the maximum extent as the fresh gas is rushing in at its highest speed just at that moment; and every fraction of a second, or of an inch on the stroke, that the valve can be kept open, the more efficient the motor will be.

Need of Closely Checking Valves. While not of the high-speed type as compared with automobile motors, which run up to 2000 r.p.m. or over, many tractor motors are high-speed types for the service they are designed to render since the tractor runs at a very considerable fraction of its load most of the time it is working while the automobile motor seldom carries over 20 per cent of its full load and then only for very brief periods. Many tractor motors are designed to deliver their rated output at 1000 r.p.m., and that is high speed for a motor which must carry 80 per cent of its maximum load for eight to ten hours a day. Wear of small parts such as valve tappets is apt to be rapid in such service, so that to keep such a motor up to a good degree of efficiency, the valve timing must be carefully checked and valve tappet clearances adjusted to $\frac{1}{32}$ inch at fairly frequent intervals. This is about the thickness of a visiting card. Some manufacturers supply a small metal gage for the purpose of testing this clearance, and it should be used often since under the continued vibration and jolting of a tractor adjustments are apt to shake loose.

Sixteen-Valve Engine. Particular attention has been called to the important influence that the rapid filling and emptying of the cylinders has on the efficiency of the motor, and mention has been made of the different expedients resorted to in order to increase this. The limit of efficiency in this respect is reached when single valves are used for the intake and the exhaust by placing both these valves directly in the cylinder head, so that neither the incoming nor the escaping gases have to go round any bends in entering or leaving the cylinder, while the combustion chamber of the latter is entirely free of pockets or dead spaces. To increase the efficiency still further, multiple valves are used, with the result that a larger effective area of opening is obtainable with a given cylinder head than could be secured by increasing the diameter of the single valves to the maximum permitted by that of the head. In other words, four valves are placed in the head with their centers located at the corners of a square, so that the greatest possible amount of space available in the circle represented by the combustion chamber is utilized for valve openings. Two of these valves are used for the intake, while the other two are employed for the exhaust.

Twin City Multiple-Valve Engine. In Fig. 7, which illustrates the Twin City tractor engine, the application of multiple valves to a valve-in-head type of motor is clearly shown. These valves have a clear diameter of 1½ inches and are operated by overhead rocker arms, each arm carrying two valves. The part sectional view at the left shows the intake side of the motor, while the end sectional view at the right illustrates the complete valve operating gear of both the intake and the exhaust valves.

Another unusual feature of this engine is the use of cylinder liners. The upper half of the crankcase and the cylinders themselves are cast in a single block. The liner is made with a flange which rests on a ground seat in the cylinder, so that when the liner is inserted, the upper face of the flange is flush with the upper surface of the cylinder casting and the cylinder head, when bolted on, holds it in place. This construction is clearly shown in the right-hand cylinder in the side elevation. These liners form the entire cylinder wall, so that the pistons do not come in contact with the cylinder castings at any point. The dimensions of this motor are 4¼ by 6 inches, and it is governed to run at 1000 r.p.m., at which speed it is rated at 20 hp.

FUEL SUPPLY SYSTEM

Operating Principle of Internal-Combustion Motor. The principle upon which the internal-combustion motor works is that of utilizing the great expansion of a volume of hydrocarbon vapor ignited when in intimate contact with a sufficient volume of oxygen to permit of extremely rapid combustion. In other words, an "explosion of gas," so to speak, is the driving force back of the piston. The various phases through which the gas passes in being drawn into the motor, compressed, fired, expanded, and exhausted have been referred to briefly in connection with the description of the four-cycle method of operation. Mention has also been made of the fact that the carburetor, while not strictly speaking a part of the motor proper, is a very important accessory. The purpose of the present section is to make clear how the fuel mixture of gas and air is obtained from the different liquid fuels employed.

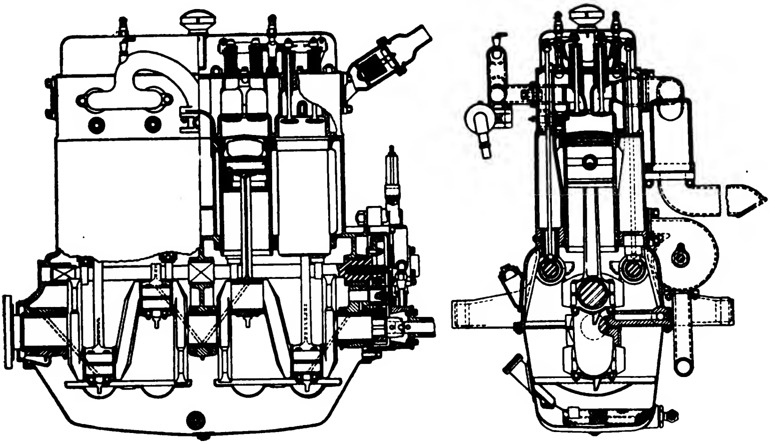


Fig. 7. Side and End Sectional Views of Twin City Sixteen-Valve Motor
Courtesy of Minneapolis Steel and Machinery Company, Minneapolis, Minnesota

Fuels Available. While there are a number of liquid hydrocarbons that may be employed as fuel in the motor, owing to their cost but very few of them are available for tractor operation. It is scarcely necessary to discuss what may be done with benzol, or alcohol, or any one of a number of other fuels since their present cost is prohibitive. The choice of a fuel is limited to petroleum and its derivatives, gasoline, kerosene, and distillate. Owing to the great demand for gasoline for other purposes its cost has reached a point where the difference between it and the cost of kerosene is more than sufficient to offset the disadvantages of the latter. Some farmers prefer to pay the higher price for gasoline because of the greater ease of operating the motor with this fuel, but they are greatly in the minority, and their plowing operations are generally on a comparatively small scale.

Petroleum as it comes from the ground is a heavy viscous liquid combining in one fluid practically the entire range of hydrocarbons (combinations of the gas hydrogen and carbon) all the way from that compound so light that it is evaporated by exposure to the atmosphere before the oil ever reaches the refinery to the heavy residue that is left after all the refining operations have been completed and that is suitable only for making arc-light carbons or for similar purposes. So far as their value as fuel for the internal-combustion motor is concerned, the only difference between any two of the hydrocarbons contained in petroleum lies in their evaporation points, that is, the temperatures at which the different liquids can be converted into vapor. The exceedingly volatile fraction that passes off into the air as an invisible vapor practically as soon as the oil is exposed to the atmosphere would make an ideal fuel; it would hardly be necessary to have a carburetor in its present form in order to handle such a fuel. But this highly volatile fraction forms such a very small percentage of the oil that running a motor on it would be equivalent to using perfumery essence at a dollar an ounce for the same purpose.

Products of Distillation. Up to within a few years ago the crude oil as it came from the well was subjected to a refining process which consisted chiefly of subjecting it to a gradually increasing range of temperatures so that the oil was broken up into its various constituent hydrocarbons, the latter being led off into separate vessels where the vapor was again condensed. For example, the first heat evaporated the naphtha, which was led off to its own condenser; then followed gasoline, which was in turn reconverted into a liquid in another condenser and was itself followed by kerosene, light lubricating oil, heavy lubricating oil, and so on down the scale. This process of refining, however, produced but 5 to 6 per cent of gasoline from the Pennsylvania and Ohio crude oil and so much less from the Texas and California oils that it was hardly worth while to attempt to make gasoline in this manner from them.

The great demand for gasoline led to the improvement of the process by the distillation of the oil under pressure as well as at a high temperature, so that in addition to the effect of the heat in breaking the heavy oil into its components, it was also actually "cracked" by the pressure and a much greater yield of the lighter fuel oils obtained. The Burton and the Rittmann are the two processes generally employed, and their products are sometimes referred to as "cracked oils." These methods produce a fuel that commonly passes under the name of gasoline, but which, owing to the much greater proportion of heavier oil that it contains, is a low-grade fuel compared with the gasoline of ten years ago. Kerosene is the next product, and then follow the various grades of lubricating oil.

Vaporizing Fuel. In order that a fuel may be used in the motor, it must first be converted into a vapor. The requirements of this process depend entirely upon the character of the liquid to be handled. In the case of the very volatile gasoline of which there appeared to be an unlimited supply when the automobile first appeared twenty-five years ago, it is only necessary to expose it to the air, so that the rudimentary carburetors employed on those first automobiles consisted in large part of a receptacle for a pool of gasoline over which the air was drawn to *carburet* it. This air picked up the vapor rising from the surface of the gasoline pool and with it formed an explosive mixture. The mixing process naturally could not be carried out with any speed, and it could not be depended upon to be uniform in its action. Gasoline evidently began to go down the scale very early, since the next step was to provide a heavy wick or similar surface to greatly increase the area exposed to the air current which was to be charged with the gasoline vapor. But gasoline of any grade that could be evaporated in this manner is now a thing of the past.

Spraying Necessary. When a liquid is not sufficiently volatile to evaporate when the surface of a pool of it is exposed to the air, the first step in causing it to evaporate is to break it up into a large number of globules and thus vastly increase the amount of surface exposed to the air. To break a liquid up in this manner, it is sprayed by being forced through a small orifice known as a jet, or nozzle. The different types of carburetor jets, or nozzles, ordinarily employed are illustrated in principle by Fig. 8.

The jet *A* is known as a fixed jet, in that it has no means of adjustment; *B* may be adjusted by means of the screw shown and is commonly referred to as a needle valve. A valve of this type is generally employed in the so-called mixers, which term is merely another name for a device that serves the purpose of the carburetor but is lacking in the refinements of construction of the automobile carburetor. Jet *C* is simply a variation of *B* in which the needle valve adjustment is made from above instead of below, while in *D* a cone takes the place of the needle but serves the same purpose, that is, so adjusting the orifice that the liquid will be broken up into a spray so fine as to be practically a mist. The fixed jet *A*, while used abroad to a greater extent than here, is now becoming more generally used in this country on account of its simplicity.

The principle of all the types is identical, namely, drawing the liquid through a fine orifice, with or without a baffle surface in the form of a needle or cone, so that the liquid, being under pressure, is sprayed out of the opening as a fine mist. The suction stroke, or descent of the piston in the first part of the cycle, supplies this pressure by decreasing the pressure in the cylinder so that the atmospheric pressure on the liquid in the carburetor forces it through the jet.

Mixing Gas and Air. As it comes out of the jet, or spray nozzle, the fuel is in an intermediate stage between liquid and vapor. To convert it into the latter, the descending piston also draws up past the spray nozzle of the carburetor a supply of air. The latter is given a whirling motion by the shape of the chamber it enters, with the result that it picks up the tiny globules or drops of gasoline and breaks them up further. With the volatile gasoline of earlier days this was all that was required to produce a true vapor, but with the lower grade fuel now common, and particularly with kerosene and distillate, the addition of heat is necessary. It is absolutely essential that the fuel mist and the air be thoroughly mixed for the double purpose of converting the fuel into a vapor and of bringing every particle of this vapor into direct contact with an equivalent particle of oxygen in the air, since it is oxygen that makes the rapid combustion of the fuel mixture possible.

Proportion of Air to Gas. Unless there is sufficient air, the result is a slow-burning, or *over rich,* mixture that produces a great deal of black smoke and causes the power of the engine to fall off. It also causes the familiar back fire that is so startling to the beginner. This occurs because the fuel is still burning in the cylinder when the inlet valve opens to admit a new charge and the latter is ignited and blown back through the carburetor instead of being taken into the cylinder. If there is too much air, the mixture is *thin,* or *poor.* In such a case the power falls off and the engine may miss in different cylinders, often jumping from one to another in an erratic manner. A back fire will also occur with a lean mixture since it is likewise slow-burning.

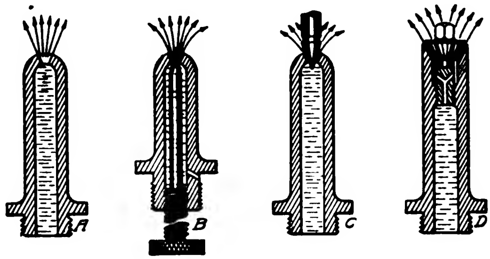


Fig. 8. Types of Carburetor Nozzles or Jets

To produce an explosive mixture requires the mixture of approximately ten to fourteen parts by volume of air to one of fuel vapor, the proportions naturally varying with the character of the fuel itself. But to produce an efficient explosive mixture in a given engine requires a carburetor that has either been specially designed for that particular motor or one that has been adjusted especially with a view to meeting the conditions imposed by that motor.

The amount of air needed for any given fuel or for any motor also varies largely with atmospheric conditions at the time and place in question. It is solely the oxygen content of the air that is of value in helping to burn the fuel mixture rapidly, and at times the air is denser than at others. The denser it is, the more oxygen it contains and the less of it is required to form a good explosive mixture. Just after sundown in spring and fall the air cools off very rapidly, and an automobile engine will run noticeably better at that time than in any other part of the day and for the same fuel consumption the amount of air used can be decreased. The contrary is true of high mountain districts where, owing to the altitude, the air is thinner and contains considerably less oxygen per cubic foot than at the sea level. In climbing from sea level to a height of several thousand feet, it is necessary to allow a greater proportion of air to maintain the given amount of oxygen required for the efficient combustion of the fuel. A tractor engine in Colorado would accordingly require a great deal more air to operate efficiently than would one working in Illinois, the same carburetor and the same fuel being used in both cases.

Details of Spraying Process. Since the difference between the pressure in the interior of the cylinder when the piston is going down on the suction stroke and that of the atmosphere (14.7 pounds per square inch at sea level) is not very great at the beginning of the stroke and as the time interval for charging the cylinder is very short, the spraying of the fuel into the incoming air must begin immediately. This is accomplished by carrying a small supply of the liquid fuel in the *float chamber* of the carburetor. A typical carburetor float chamber is illustrated at the left of Fig. 9, which shows a simple form of carburetor in section. The fuel enters from below through a needle valve, the needle of which passes through the hollow copper float. As the liquid rises in this chamber, the float rises with it and in so doing forces the needle down into its seat by means of the small weighted levers shown. The levers are attached to a collar on the spindle of the needle.

It will be noted that this float chamber communicates with the spray nozzle located in the *mixing chamber* just to the right of it. As a liquid always seeks its own level, the fuel rises to the same height in the spray nozzle as it does in the float chamber and the float is set to close the needle valve at a point where this fuel level is normally but a small fraction of an inch below the opening of the nozzle. The liquid is accordingly sprayed out of the nozzle under the influence of a difference in pressure of less than 1 pound to the square inch; that is, as soon as the pressure above the nozzle due to the suction stroke of the piston becomes less than that of the atmosphere on the supply of fuel in the float chamber, the liquid is forced out of the small opening.

This spray, or mist, is then carried upward through the carburetor and through the inlet valve into the cylinder by the current of air drawn in at the opening below the spray nozzle and extending to the right. Owing to the peculiar form given the chamber surrounding the spray nozzle (known as a Venturi tube), a whirling motion is imparted to the incoming air and its velocity is increased. The result is to mix the spray and air more thoroughly and to convert the mixture more nearly into a true vapor.

Effect of Increasing Speed. It is apparent that as the speed of the motor increases, the suction on the spray nozzle will become greater, and the interval between suction strokes, particularly in a motor having four or more cylinders, will be so short that the spraying action will be practically continuous. This tends to upset the balance of the mixture by causing an excess of the fuel spray so that the proper proportion of fuel to air is no longer maintained and the power output of the motor suffers correspondingly. To overcome this, means for supplying additional air are provided, usually in the form of an auxiliary air valve designed to be operated by the difference in pressure between the inside and the outside of the carburetor. In Fig. 9 an auxiliary air valve of this kind is shown in the upper part of the illustration. It consists of an opening in the carburetor body covered by a diaphragm, or plate, the latter normally keeping the opening closed by means of the spring shown. As the pressure inside the carburetor decreases below a certain point owing to the increasing speed of the motor, the atmospheric pressure on this diaphragm overcomes the spring and allows an additional supply of air to enter and combine with the mixture, which then passes off, through the opening shown at the right, to the intake manifold.

The carburetor shown in Fig. 9 is a single fixed-jet type with a simple auxiliary air valve, and it serves to illustrate the principles upon which practically all carburetors work, namely, spraying the liquid fuel in the form of a fine mist into an incoming current of air to which greater movement and increased velocity are imparted as it passes the spray nozzle. There are a great many different types of carburetors and an even greater number of different

ALLIS-CHALMERS FOUR-WHEEL TYPE TRACTOR
Courtesy of Allis-Chalmers Manufacturing Company, Milwaukee, Wisconsin

BETHLEHEM FOUR-WHEEL TRACTOR DESIGN, SHOWING SIMILARITY TO AUTOMOBILE PRACTICE

CLEVELAND TRACK LAYING TYPE TRACTOR
Courtesy of Cleveland Tractor Company, Cleveland, Ohio

TRUNDAAR TRACK-LAYING TRACTOR

makes, but all operate on these basic principles. In some instances two or more nozzles are used, the smaller being in action only while the motor is idling and the larger increasing the supply of fuel when the increased speed of the motor brings a greater pres-

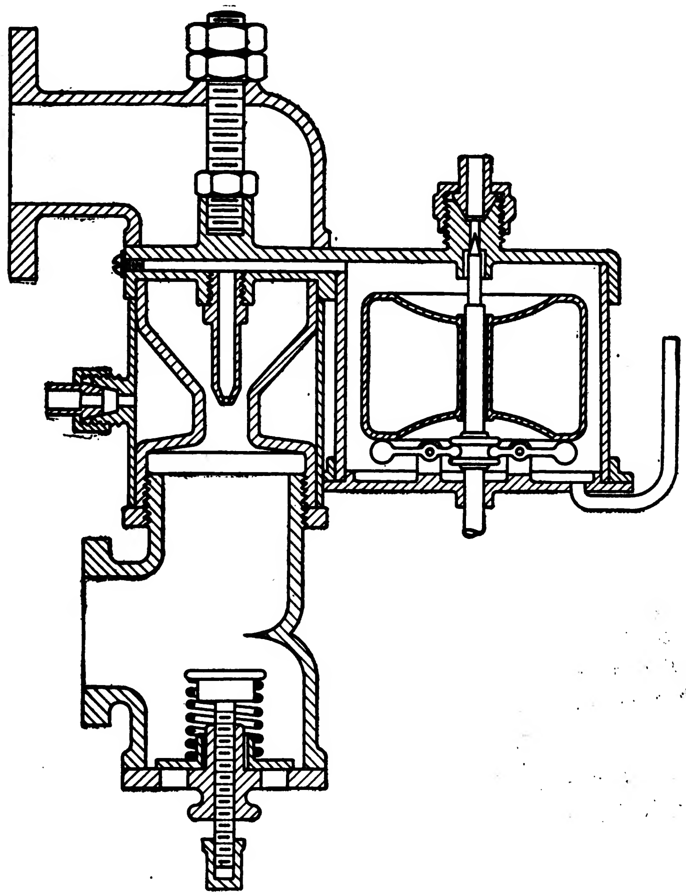


Fig. 9. Section of Typical Fixed-Jet Carburetor

sure to bear and causes them to spray. In this case the principle is that of altering the amount of fuel in the mixture in accordance with the speed, the air intake to the carburetor remaining fixed at all times, while in the single-jet type described above the air supply is increased with increasing speed. Still other types increase both the fuel and the air supply, a needle valve on the jet being connected with the auxiliary air valve, as in the Schebler carburetor shown in Fig. 10. The needle valve, or spray nozzle, is at *E*, and the needle is attached to a bell-crank lever, indicated by the dotted lines, which is attached at its other end to the spindle of the auxiliary air valve *A*. As the auxiliary air valve opens downward under the additional suction of increased motor speed, it lifts the needle *E* and permits a greater amount of fuel to spray through the jet at the same time that an increased supply of air enters through the valve *A*. While it is automatic in its action, this carburetor is also provided with a hand control, the connecting rod of which is attached at *B*. The movement of this adjustment is limited by the boss *D* coming against the stop *C*. When in this position, it is set for running and corresponds to the mark *AIR*, indicating that the full air supply is being given; at the other end the adjustment quadrant is marked *GAS*. This adjustment is used chiefly for starting. In this particular carburetor the float, which is not indicated in the illustration, surrounds the spray nozzle and consists of a shellacked cork ring.

Heating Requirements. The process of converting a liquid into a vapor is one in which considerable heat is rapidly absorbed from the surrounding air, so that the temperature of the resulting vapor is lowered. With the highly volatile gasoline used in early days no artificial heat was necessary to offset this under summer conditions, and the simple carburetors then in use were not provided with any heating devices. But when the car was run in cold weather, it was nothing unusual for the carburetor to become choked up with snow and ice caused by this refrigerating action of evaporation, and this also happened when aeroplanes first reached high levels. The lower the grade of fuel employed, the heavier it is and the higher its temperature of evaporation, so that heat is required even with gasoline fuel nowadays. Kerosene cannot be vaporized unless the temperature is raised very considerably above that of the surrounding atmosphere even on a hot summer day, since this fuel is not at all volatile and will not evaporate at any ordinary temperature.

Gasoline. For a carburetor handling gasoline only heat is ordinarily supplied by water-jacketing the mixture chamber, a small amount of hot water from the cooling system of the motor being circulated around this part of the carburetor. The water-jacket space and connection of the fixed-jet type of carburetor will be noted in Fig. 9. In addition, the main supply of air to the carburetor is heated by clamping a sheet-iron box or "stove" about the exhaust manifold and passing the air over this heated surface before conducting it to the carburetor through a flexible metal tube of large diameter.

Kerosene. While the arrangements mentioned work efficiently on the automobile using gasoline as a fuel, they would not prove

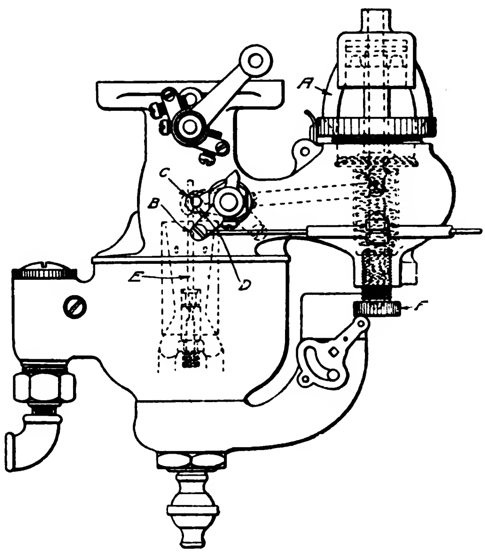


Fig. 10. Interconnected Air and Fuel Feed
Courtesy of Wheeler and Schebler, Indianapolis, Indiana

satisfactory for burning kerosene. A very high temperature is required to vaporize kerosene and the method of applying it is illustrated by the section of the Wilcox-Bennett kerosene carburetor, Fig. 11. The float chamber is shown at the lower left hand, while the mixing chamber, just to the right of it, is equipped with two needle valves. The lower of these is designed to admit water, which is required in the majority of engines using kerosene as a fuel. The kerosene needle valve is just above the water valve, and it will be noted that the mixing chamber above this valve is surrounded by a cast-iron radiator provided with fins. The function of this radiator is to absorb heat from the air passing over the exterior fins and to radiate it to the fuel mixture inside.

The passage in which this radiator is located is connected directly with a damper in the exhaust outlet of the motor, so that the exhaust gases may be passed directly through it and used to warm the air instead of merely utilizing some of the heat of the manifold for this purpose as is done in a gasoline carburetor. In other words, all or part of the exhaust of the motor is used for heating by shunting it through the carburetor instead of allowing it to escape through the muffler in the usual way. The method of accomplishing this in the Wilcox-Bennett carburetor is shown in Fig. 12 which also illustrates the connection of the air cleaner to the carburetor. The details of the radiator itself and the needle valves are shown by the part sectional view, Fig. 13, which illustrates these essentials of the carburetor in the no-load position at the left and in the full-load position at the right. By comparing the sectional views with the illustration of the complete carburetor, Fig. 14, a better idea of the relative positions of its essential parts can be had.

At the right in Fig. 14 there is a horn-shaped device surrounding the exhaust passage and connecting with the mixing chamber of the carburetor just below the needle valves. By referring to Fig. 11 or Fig. 13 again it is seen that the object of this device is to conduct heated air to the mixing chamber. This hot air is required when the motor is running slowly or under light load, as this represents a condition under which a kerosene burning motor will not ordinarily run satisfactorily since it is apt to cool off too much. The passage connecting this hot-air horn to the mixing chamber is designed to be opened and closed by a weighted valve, which is indicated in the drawing by heavy lines. It has already been explained that the suction of the motor varies with its speed and increases very markedly as the speed of the motor increases. At low speeds the force of gravity is more powerful than that of the motor suction, so that the weighted valve remains at the bottom and the hot-air passage stays open; when the motor speed increases sufficiently, the suction lifts this valve and holds it in a position to close the hot-air passage.

Air and Fuel Balanced. The Wilcox-Bennett kerosene carburetor is designed to be automatically controlled by the speed of the engine, the amount of fuel, air, and water admitted being dependent upon the suction, which varies almost directly as the speed.

Fig. 11. Section of Wilcox-Bennett Kerosene Carburetor, Shown at Full Speed Position
Courtesy of Wilcox-Bennett Carburetor Company, Minneapolis, Minnesota

It will be noted that the auxiliary air intake and its valve are at the upper left hand and also that this diaphragm valve is directly interconnected with the kerosene needle valve in the spray nozzle. A stand pipe is employed instead of one of the conventional forms of nozzle previously illustrated. The stand pipe consists of a tube whose entire circumference is drilled with a large number of fine holes, through which the fuel is drawn instead of through a single opening at the top. The lines to the right and the left of the kerosene needle in Fig. 11 indicate that the fuel is issuing from these openings. In this illustration are shown the essential parts of the carburetor in the position they assume at full speed: the diaphragm of the auxiliary air valve being depressed, so that there is a flow of cool air into the carburetor at this point; the kerosene needle valve is lifted well off its seat to supply the maximum amount

Fig. 12. Method of Employing Exhaust Gases in Wilcox-Bennett Carburetor
Courtesy of Wilcox-Bennett Carburetor Company, Minneapolis, Minnesota

of fuel; the hot-air intake below is closed; and the water intake, also governed by the weighted valve previously mentioned, is open.

It must be borne in mind that under the conditions given the exhaust of the motor is at its maximum both in volume and temperature, so that the kerosene mist, immediately after issuing from the standpipe and being whirled into the radiator chamber by the multi-bladed fan shown in Fig. 13, is at once subjected to a degree of heat reaching at times as high as 900° F. Since this is too hot for efficient combustion, before passing into the cylinder, the temperature of the fuel is lowered somewhat by the addition of the volume of air entering through the auxiliary air valve. The admission of water and its admixture with the fuel vapor in the form of steam serves to provide additional cooling, the necessity for which will depend upon the action of the motor.

Gasoline and Kerosene Carburetor. Since kerosene will not vaporize at ordinary temperatures, it is necessary to use gasoline for starting, the motor being run on this long enough to warm up sufficiently to permit the use of kerosene. The combination gasoline and kerosene vaporizer used on the Fordson tractor is illustrated in Fig. 15. Being designed especially for use on this one machine, it has been made much more compact than types which must be adapted to a number of different motors. Compactness

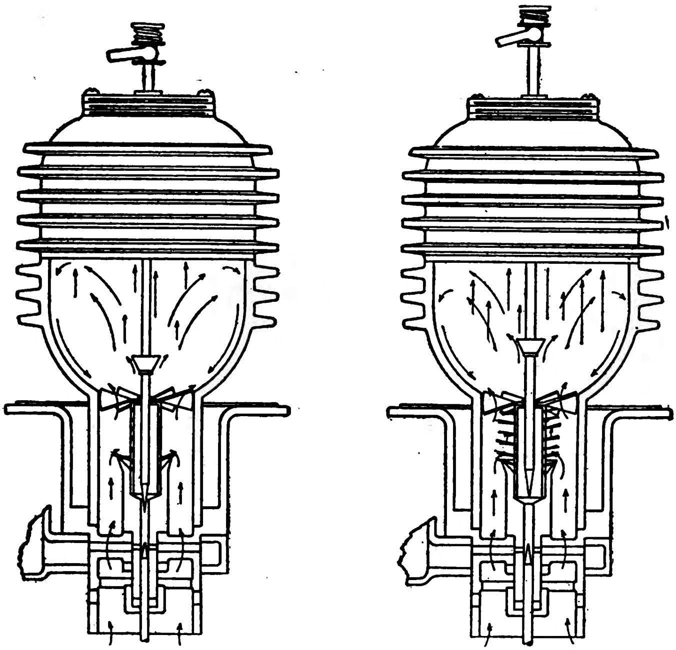


Fig. 13. Detail of Radiator, Wilcox-Bennett Carburetor
Courtesy of Wilcox-Bennett Carburetor Company, Minneapolis, Minnesota

has been obtained by combining the heating unit directly with the exhaust manifold, a shunt valve being provided to by-pass the hot gases as required.

The kerosene carburetor itself is shown at the lower left. It is of the conventional single-jet type, except that instead of being designed to produce a working fuel mixture in the carburetor proper it is only intended to make a heavy kerosene mist, with the result that only a small amount of air is drawn through it from the primary air tube. As shown by the black arrows inside the small white tube, Fig. 15, this rich mixture of kerosene and air is drawn through a heating coil in a chamber provided for that purpose in the exhaust manifold. From that point it passes to a mixing chamber above the inlet manifold, in which it is diluted to the proper consistency by the addition of air through the auxiliary air valve shown at the top of the illustration. This air valve is controlled in the usual way, that is, it varies its position with the speed of the motor itself.

Just below the mixing chamber are located the gasoline connection and passage, which are placed at this point since no heat is necessary for starting on gasoline and since the gasoline spray is converted into a fuel mixture in the same mixing chamber that is used for the kerosene. The gasoline vaporizing device is only in use for a minute or two when starting, the gasoline then being shut off. While gasoline is being used, the exhaust shunt lever is moved to the *ON* position, which permits all the exhaust gases to pass through the vapor-heating tube and gives the maximum heating effect. After the motor has been running on kerosene for a short time, the shunt lever is adjusted to suit the load conditions, the temperature of the mixture being lowered if the lever is moved toward the *OFF* position. When it is desired to run any motor idle on kerosene longer than momentarily, it is necessary to supply the maximum amount of heat and the ignition should also be retarded, as otherwise the plugs are apt to become badly sooted. No provision is made for supplying water directly with the fuel on the Fordson, but an air washer is used which serves the same purpose by moistening the main air supply.

Fig. 14. Assembled View, Wilcox-Bennett Carburetor
Courtesy of Wilcox-Bennett Carburetor Company, Minneapolis, Minnesota

Need for Cleaning Air. About fifteen years ago, when the automobile first began to assume such a degree of reliability where its ignition and carburetion mechanisms were concerned as to permit some degree of attention being given to ailments of other parts of the motor, carbon deposits were discovered on the pistons and in the combustion chamber. Ever since then there has been a great deal of discussion as to the conditions which cause these deposits and the methods of preventing them. A great deal of the discussion and most of the methods adopted have been misguided, if not entirely futile, since an analysis of these deposits made at an early day proved them to consist of road dirt and grit to the extent of 65 per cent or more, the balance being simply burned and partly burned lubricating oil, which serves as a binder and causes the mass to adhere to the cylinder head or piston. In addition to giving rise to these troublesome carbon deposits, which frequently accumulate to such an extent that they cause pounding or even preignition, the fine grit which composes a large part of the dirt drawn through the carburetor also causes the pistons and cylinders to wear very much more rapidly than they would were the air free of this foreign matter. Notwithstanding these discoveries, none of the numerous remedies proposed has ever taken the preventive form of cleaning the air before it is used.

Tractor Air Conditions Very Bad. There are several reasons why the troubles caused by dirt in the air have not assumed such proportions on the automobile that it has been considered necessary to use a preventive. Chief among these is the great improvement that has taken place in many thousands of miles of American roads, which have been made dustless in recent years. The general recourse to heated air taken from a small box, or stove, placed around a part of the exhaust manifold is another reason of equal importance, since this prevents the direct entrance to the carburetor of the air passing through the radiator. Before reaching the opening of the hot-air box on the exhaust manifold it must pass around various curves and strike different obstructions, which cause most of the heavier particles of dust to fall. Since the high speed of the machine permits it to run away from its own dust very effectively, it is only on very windy days, when the atmosphere is generally dust laden, that more than a very small amount finds its way through the radiator.

None of these advantages obtain in the case of tractor operation. Plowing must frequently be carried out under very dusty conditions, with the result that the entire machine operates in the midst of a cloud of dust from which it cannot escape. Under such conditions a large amount of dust and grit is drawn into the carburetor as the suction is very heavy owing to the motor operating under full load most of the time. Unless this intake of dirt is

Fig. 15. Holley Combination Gasoline and Kerosene Carburetor as Used on the Fordson Tractor
Courtesy of Henry Ford and Son, Inc., Dearborn, Michigan

guarded against, wear of the moving parts of the motor becomes excessive.

Since, as previously mentioned, approximately fourteen parts by weight of air to each part of liquid fuel are required to make an efficient burning mixture, the equivalent in volume of 10,000 gallons of air is needed for every gallon of fuel. In the case of a tractor burning 20 gallons of fuel in a day's work, a volume of air equal to 200,000 gallons must pass through the carburetor and cylinders in ten hours. The amount of dust that such a great volume of air can hold in suspension under the conditions of tractor operation makes the importance of thoroughly cleaning the air too apparent to call for any emphasis.

Types of Air Cleaners. *Air-Washer Type.* It is apparent that two or three different principles may be taken advantage of to remove dust and grit in suspension from a moving mass of air. The first of these to suggest itself is that of actually washing the air by passing it through a body of water, and a number of air cleaners are based on this idea. The action of the air in passing up through the water is indicated in Fig. 16, and it will be noted that in addition to dropping its dust and other foreign matter the air carries with it quite a percentage of moisture, so that the washing process is a further advantage in those motors that require considerable water to insure cool running when burning kerosene. When using gasoline, however, washing the air is apt to be quite the contrary since the excessive amount of water tends to cool the mixture too much to permit efficient operation. The air washer employed on the Fordson tractor is shown in section in Fig. 17. It consists of a water tank with a central intake tube and an air guide mounted on a float and surrounding the intake tube. The suction of the motor serves to draw air into the washer, and it is then deflected downward into the water by the air guide. In order that the air may pass through a considerable depth of water, the air guide is attached to the float shown so that the air will always enter the water at the same distance below the water level. The float keeps this distance constant by maintaining the outlet of the air guide at the same point at all times regardless of the amount of water in the bowl. The air guide mentioned also serves another purpose in that it serves to cut off the air supply when the water supply is allowed to fall so low that the float rests on the bottom of the bowl.

Centrifugal Type. Mention has already been made of the fact that in compelling the current of air drawn through the radiator of an automobile to pass around several obstructions most of the heavier grit is allowed to drop before the air can reach the carburetor intake. By purposely giving the current of air a whirling movement this effect can be accentuated by taking advantage of centrifugal force to throw the particles of dust to the outer edge of the container, where they drop into a receptacle. This is the principle upon which the air cleaner shown in Fig. 18 is based. By referring to the phantom view of the same air cleaner, Fig. 19, it is seen that after entering, the air is conducted through curved channels, from which it issues to again strike a large central cone, thus acquiring a whirling motion which tends to deposit on the sides of the cone all matter in suspension that is heavier than air. This matter then gravitates down the sides of the cone and finally drops off the edge into the glass receptacle placed below, which permits the operator to note the accumulation of dust and remove it in good season.

The same principle is also employed in connection with a receiving vessel, or dust collector, containing water. An air cleaner of this type is shown in Fig. 20, and a sectional view in Fig. 21. In the latter illustration the action of the air currents in entering and striking the central cone is more clearly indicated by the arrows. The air is first drawn into the outer casing and the spiral tubes at *A*. These tubes are set on the inner circumference of the casing, so that the action of the air causes the water to whirl rapidly and assume the position indicated by the dotted line, exactly as any liquid will do in a bowl when stirred in one direction very rapidly. The water, on striking against the lower projecting edges of the spiral tubes, is broken up into a fine spray through which the air passes in being cleaned. The washed air then rises and enters the opening *C* of the inner cleaner, where

Fig. 16. Sectional View of Parrett Wet-Type Air Cleaner
Courtesy of Parrett Tractor Company, Chicago Heights, Illinois

it is again subjected to a violent whirling. This further tends to throw down any particles of dust or water which may have been carried along with the air, the accumulation of dust being deposited at the bottom of the tube *B*. In a short time enough dirt collects to form a mud seal for this tube, so that if the operator forgets to renew the water supply, the cleaner will continue to operate as a dry type.

Felt Baffle Type. The third principle available in cleaning air is that of the dust screen, and the method of employing this is illustrated in Fig. 22, which shows the device in partial section. It consists of a cylinder of wire gauze on which felt is stretched. The air strikes this in entering, and the dust it contains is repelled by the felt while the air passes through and on to the carburetor by means of a connection with this inner chamber. The vibration of the motor as well as the force of the current of air itself tends to shake particles of dust off the felt and prevent their clogging it, the dust dropping out through the holes shown. In cold weather these holes may be closed to conserve the heat, and the dust then collects in the outer chamber until removed by hand.

Attention Required. Regardless of the type of air cleaner employed, the chief attention required is the frequent removal of the accumulation of dust, or mud in case an air washer is used. Neglect of this precaution simply makes conditions very much worse than they would be were no air cleaner employed, since the accumulation of dirt in the cleaner is apt to be drawn directly into the motor. Where an air washer is employed, the deposit of mud is converted into dust very quickly by the heat of the motor, though the partial shutting off of the air supply causes the motor to miss and lose power, thus providing a warning of the lack of water.

LUBRICATING SYSTEM

Effect of Temperature and Pressure. Where the lubricating system is concerned, as well as regards other essentials, the novice in tractor operation will do well not to rely on his automobile experience to carry him through without a slip that will result in serious damage. There can be no comparison whatever between the 30-hp. automobile motor that runs for ten hours a day and is seldom called upon to deliver 50 per cent of its rated power and

ange
r Supply
er
Air Supply
er

Cover
Guide
Air D
Filler
Wate
Float
Bowl
Gaske
Drain

Fig. 17. Air-Washer Type of Cleaner Used on Fordson Tractor
Courtesy of Henry Ford and Son, Inc., Dearborn, Michigan

the tractor engine of the same rating that is delivering 80 to 85 per cent of its rated output all day long.

The sole object of lubrication is to prevent moving surfaces from coming into actual rubbing contact of metal to metal, in other words, to maintain a film of lubricant between the two surfaces on which they may actually be said to float, though the film itself may be only a few thousandths of an inch in thickness.

Fig. 18. Wilcox-Bennett Fry-Type Air Cleaner
Courtesy of Wilcox-Bennett Carburetor Company, Minneapolis, Minnesota

Fig. 19. View Showing Method of Separating Dust from Air by Centrifugal Force
Courtesy of Wilcox-Bennett Carburetor Company, Minneapolis, Minnesota

The problem is accordingly the same in the automobile and the tractor engines, but the ease with which a film of lubricant may be maintained between moving surfaces depends upon the surrounding temperature and the pressure under which the surfaces move in contact. When the temperature of the circulating water is seldom allowed to exceed 165° F., as in an automobile motor running under but a fraction of its maximum load, the vaporizing point of the lubricating oil is seldom reached. But in a tractor engine running for hours at close to its full load the circulating water is seldom much below the boiling point at sea level, 212° F., and the conditions of operation are such that every part of the engine is very much hotter than this. Under the heavy load the pressure between the piston and the cylinder wall is much greater, and the oil tends to squeeze out much more rapidly, so that it must be renewed with far greater frequency than is necessary in an automobile engine.

Types of Lubricating Systems. *Splash System.* The earliest practical type of lubricating system used on the automobile engine was the splash system. The crankcase is filled with oil to a certain level, and the big ends of the connecting rods dip into it and splash it all over the interior of the motor. To keep up the sup-

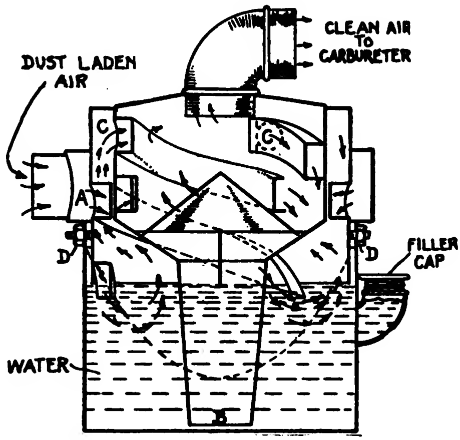


Fig. 20. Wilcox-Bennett Wet Type Air-Cleaner

Fig. 21. Method of Operation in Wilcox-Bennett Wet-Type Air Cleaner
Courtesy of Wilcox-Bennett Carburetor Company, Minneapolis, Minnesota

ply, 1 quart or more of oil is added at the beginning of a run, which results in having too much oil at the start and not enough at the finish. Moreover oil is not always oil so far as its lubricating properties are concerned, since they are burned out of it by high temperature. Therefore after a few days' steady use the oil becomes practically useless, and only the extra quart or two added to keep up the level serves as lubricant.

When the motor is run very cool, either with gasoline or kerosene, a certain proportion of the fuel mixture is condensed in the cylinders and finds its way past the pistons into the crankcase, thus thinning the oil out and further reducing its lubricating value. This is particularly true of kerosene, which has the further disadvantage under such conditions of washing the film of oil off the sides of the cylinder walls as it gravitates to the crankcase. One instance is cited in which a manufacturer agreed to deliver a tractor under its own power, but after a few hours running so much kerosene found its way into the crankcase that the main bearings were burned out and the tractor had to be towed back to the shop for repairs before ever reaching its prospective owner. In another case that illustrates the fallacy of depending upon automobile precedents a factory man was called to the assistance of a farmer who reported that the bearings of his motor had burned out before the end of the first week's work. When asked what he had done to lubricate the motor, the farmer said that he had added oil as often as he did on his Ford.

Modified Splash System. The simple splash system of lubrication is accordingly not practical on the tractor engine, though it is successfully employed on hundreds of thousands of automobile motors. A small percentage of the tractors now in use employ this system but as a rule it is improved by the addition of some means of constantly feeding fresh oil to the crankcase or of circulating it over the bearings and depending only upon the overflow from the latter to furnish splash lubrication. The cross-section of a Waukesha motor, Fig. 23, gives an excellent idea of how the dippers on the ends of the connecting rods distribute the oil to every part of the motor. Large receptacles over the main bearings are kept constantly filled, while the spray of oil thrown up reaches even to the valve stems. The crankcase is divided into compartments, as shown in Fig. 24, which illustration also shows the oil pan forming the bottom of the crankcase. The oil is raised by a small pump, forced through the wire gauze screen

Fig. 22. Orem Felt-Type Dry Air Cleaner

Fig. 23. Sectional End View of Waukesha Motor, Showing Operation and Interior Construction
Courtesy of Waukesha Motor Company, Waukesha, Wisconsin

S, and distributed to the different compartments of the bleeder tube, or pipe having openings *A*, *B*, *C*, and *D*. The overflow returns to the pump and is again distributed, so that this is what

Fig. 24. Crank Case Oil Pan, Showing Compartments and Bleeder Tube
Courtesy of Waukesha Motor Company, Waukesha, Wisconsin

Fig. 25. Diagram of Combination Force-Feed and Splash Lubrication
Courtesy of J. I. Case Plow Works, Racine, Wisconsin

may be termed a circulating-splash system of oiling. A gage on the crankcase shows the level of the oil. In some systems of this kind the stroke of the oil pump is regulated to feed the oil slowly and it remains in the crankcase until consumed.

Force-Feed Splash System. In the force-feed splash system reliance is not placed entirely upon the splash of oil in the crankcase to reach all surfaces in need of lubrication, but a supply of oil is forced directly to the main bearings, camshaft bearings, and timing gears, and the overflow from these points is allowed to collect in the crankcase and serve for splash lubrication for the pistons, piston pins, connecting rods, and cams. Copper tubes are usually placed on the sides of the connecting rods to lead the oil to the piston pins, and in some cases this oil is also relied upon to lubricate the

Fig. 26. Moline Circulating Pressure Force-Feed Lubrication

cylinder walls, since it is forced out of the hollow pin on to the cylinder. An indicator in sight of the operator shows whether the oil is being supplied by the force feed. The partial section of the Case engine, Fig. 25, illustrates the details of a system of this type.

Necessity for Discarding Used Oil. One of the chief drawbacks to all forms of splash systems of lubrication for the tractor is the difficulty of educating the farmer up to a realization of the saving that the constant renewal with fresh oil represents in repairs. Lubricating oil is the most expensive single item of supply for the tractor, regarded solely from the standpoint of its cost per gallon, and the farmer dislikes to throw it away no matter how long it has been used. Some tractor manufacturers recommend that the crankcase be drained at the end of every day's work, washed out, and refilled with fresh oil. When oil has been used, its structure is broken down by the high temperature. It is "cracked"—exactly as petroleum is in the pressure distillation process by which all petroleum fuels are produced nowadays—and it has lost its lubricating qualities. By taking a sample of oil

Fig. 27. Combination Force-Feed and Splash Lubrication. Detroit Fourteen-Lead Chain-Driven Oiler
Courtesy of Aultman-Taylor Machinery Company, Mansfield, Ohio

that has been used in the crankcase for several days and rubbing it between the fingers, the great difference between it and a sample of fresh oil will be noted. The average user does not like to drain the crankcase every day, and some practice the false economy of draining it but once a season. It will be found much cheaper at the end of a season's work to have bought plenty of good lubricating oil and used it but once, than to attempt to economize by using it over and over again. Repairs always cost far more than oil. The used oil may be employed to lubricate other parts of some machines, such as the track of a caterpillar tractor.

Pressure-Circulated Lubrication. Following automobile practice, some motors have the crankshaft drilled throughout its length and tubes connecting with this bore rising from the connecting rod bearings, so that the pressure generated by the pump causes the oil to flow over these bearings constantly, the cylinder walls being lubricated by the overflow through the piston pins.

Fig. 28. Force-Feed Oiler of Two-Cylinder Oil-Pull Engine
Courtesy of Advance-Rumely Thresher Company, Inc., Laporte, Indiana

In this system no dependence is placed on splash lubrication, and the connecting-rod big ends are not allowed to dip into the overflow, as shown by the section of the Moline motor, Fig. 26.

This system is also known as the dry-crankcase type in that the excess oil drops into a sump, or well, below the crankcase in which the pump is located, with the result that the entire supply is constantly kept in circulation. More than one pump is sometimes employed for this purpose, so that oil is drawn from different parts of the crankcase at the same time. The advantage of this method is that the location of the machine, as in climbing a hill, has no effect on the quantity of lubricating oil that reaches every part of the motor.

Fresh-Oil System. A very considerable percentage of all the tractors now in use follow steam-engine practice in lubrication by feeding only as much oil as is required by each bearing, so that

Fig. 29. Eccentric-Driven Force-Feed Oiler
Courtesy of Hart-Parr Company, Charles City, Iowa

the oil is consumed almost as fast as it is fed. This has the advantage of constantly renewing the lubricating film with fresh oil. To provide a factor of safety, however, the supply must actually be fed faster than it is used by the bearings in order that oil may accumulate in the crankcase, and unless this is drained off at frequent intervals, this system is open to the same objection as the ordinary splash system.

The supply of fresh oil for a system of this type is carried in an external reservoir which also serves as the lubricator, in that it is fitted with a number of small plunger pumps, one for each lead, or tube leading to the bearings. The lubricator is driven by a belt, chain, or rod (preferably the last named) from the camshaft of the motor, as shown in Fig. 27, which illustrates the Aultman-Taylor engine equipped with a fourteen-lead Detroit lubricator. Fig. 28 shows a similar lubricator on the Rumely two-cylinder motor, and Fig. 29 a Madison-Kipp lubricator on the Hart-Parr engine, an eccentric or crank and rod being employed to drive the lubricator pumps in both instances.

Frequent Attention Necessary. On an automobile, it is nothing unusual for grease cups to go an entire season without being refilled, and during that time they have only been turned down once or twice. How radically different is the attention required by a tractor may be appreciated from the instructions for oiling an International tractor. When doing belt work, the grease cup on the pulley must be turned down *every hour*. There are eleven bearings on the fuel and water pumps, camshaft, front wheels, rear axle, and clutch that require turning down *every two hours* that the tractor is running. On another group of ten bearings the grease cups must be turned down twice a day, while three others must be turned down once a day.

COOLING SYSTEM

Heat Efficiency of Motors. While the thermal, or heat, efficiency of the tractor motor is high as compared with that of a steam engine, in which it is difficult to utilize more than 8 per cent of the available heat of the coal, it is an unfortunate fact that a very large part of the heat available in gasoline or kerosene must also be wasted since no method that will utilize more of it has yet been discovered. Considering the fuel value of the entering charge as 100, about 40 per cent of this escapes through the exhaust valve at the end of the power stroke and during the succeeding exhaust stroke. An additional 35 per cent that cannot be utilized to drive the piston by its expansion must be absorbed and quickly dissipated or it will soon overheat the motor and bind the pistons hard and fast in the cylinders. Thus only 25 per cent of the real value of the fuel is converted into power. These are simply average percentages which may be made poorer or better by the type of engine, some simple steam engines working in the open in cold weather and poorly protected not showing an efficiency to exceed 3 or 4 per cent, while a condensing Corliss type

Fig. 30. Thermo-Syphon Cooling System of Fordson Tractor
Courtesy of Henry Ford and Son, Inc., Dearborn, Michigan

unit would reach 17 per cent and a modern type Diesel oil engine 35 per cent or better.

Types of Cooling Circulation. To carry the great amount of excess heat away from the cylinder heads and exhaust valve ports with sufficient rapidity to prevent these parts becoming overheated, a body of cool water is kept in direct contact with them and is replaced by fresh water as quickly as it can absorb the heat. This water is contained in the jackets—spaces cast in the cylinder walls and cylinder head for this purpose. The cool water is conducted to the lowest part of this water-jacket, passed up over the hottest parts of the cylinder, and then led to the radiator consisting of a bank or nest of tubes. These tubes are made of copper, which is an excellent conductor of heat as well as of electricity, and their cooling surface is greatly increased by surrounding them with thin copper fins which give up their heat to the air very readily. The movement of the water between the jackets and the radiator is termed the cooling circulation.

Thermo-Syphon Circulation. The circulation of the water may be effected by the difference in the temperature of the water itself or may be brought about by forcing the water through the piping at high speed by a pump. The first method is known as thermo-syphon circulation and its operation is illustrated by the view of the cooling system of the Fordson tractor, Fig. 30. The radiator is shown in section, while the flow of water through the connecting pipes and the cylinder jackets and head is indicated by the arrows. After passing downward through the radiator, the water issuing at the bottom is considerably cooler than that at the top of the cylinder jackets, which has been absorbing its charge of heat. As water gets hotter, it expands and becomes lighter, so that it tends to rise. The water in the cylinder head jacket accordingly flows toward the radiator and is replaced by fresh water rising through the cylinder jackets. The hotter the water gets, the faster it flows, its movement being controlled entirely by the difference in temperature between the water entering and the water leaving the system at the coolest and hottest points. It will be noted in the illustration how short and direct the connections are and how large their diameter is as compared with the connections on a motor on which a pump is employed to provide forced circulation of the cooling water, Fig. 31.

Forced Circulation. On the majority of tractors a forced type of circulation is employed. In this type the water is moved around through the cylinder jackets and to the radiator and back by means of a centrifugal pump driven from the camshaft or one of the other auxiliary shafts of the motor. The body of water carried, the size of the cylinder jackets, and the diameter of the connecting pipes may all be made much smaller than in systems where the water must move under the force of its own difference in temperature, as in the thermo-syphon system. But it is also apparent that the factor of safety is also somewhat lower in the forced circulation type than in the other. Any failure of the pump, fan, connections, or radiator must be detected and the engine

Fig. 31. Pump and Connections of Forced-Circulation Cooling System Used on Heider Tractor Engine
Courtesy of Rock Island Plow Company, Rock Island, Illinois

stopped at once if serious damage is to be avoided. With an engine that is designed to be run constantly under such a high percentage of its maximum load for a number of hours as the tractor engine, the cooling and lubricating systems are of the greatest importance. This is true particularly of the cooling system since any failure in it involves the lubrication system as well, as the moment the temperature rises beyond control, the lubricating oil is burned to carbon and the damage is done.

Protection of Radiator from Stresses. The tubular type of radiator is the most practical for tractor use owing to the necessity for withstanding constant vibration and also jolting and racking, and it is good practice to support the radiator on a flexible mounting so that these stresses cannot affect it directly. This refers particularly to the straining and racking due to the passage of the tractor over very uneven surfaces. To prevent damage from this cause, some radiators are mounted on a pin and trunnion, others have a three-point support, while still others are located at points on the frame where they will be subjected to the least stress from the twisting and bending due to rough going. In the illustrations in the section on motors the pumps and connections used on some of the machines are noticeable so that it is unnecessary to illustrate them here.

Automobile Experience Misleading. When first undertaking the management of a tractor, the average operator is very apt to be guided by his automobile experience and treat the heavier and slower-traveling machine in the same manner. This is apt to lead to serious errors as far as both the cooling and the lubrication are concerned. The tendency of most automobile engines is to run too cool to be efficient. In other words, if they could be run steadily at a higher temperature, less gasoline would be used and the smaller quantity passing through the cylinders would be employed more efficiently. But an automobile engine never runs steadily for any length of time and it is very seldom that more than a fraction of its normal power output is used at all. Except in pulling out of a mud hole or in climbing a very steep hill, it is rare for more than 25 per cent of the output of the motor to be needed in driving the car. Consequently its cooling system is very seldom called upon to work to capacity.

There are few cars built that could climb a two- or three-mile hill mainly on second or even third speed without starting the water to boiling very violently, and if the hill were five miles long, few would be able to get up without a stop on the way to cool off the motor. Compared with the level road service that an automobile is usually called upon to perform, the tractor, particularly when plowing, is performing the equivalent of mounting a steep hill on second or third, with the exception, however, that there is no summit to the hill and no opportunity to cool until the motor is shut down for the day. The cooling system accordingly calls for close attention, any sign of overheating being noted immediately and the engine shut down at once to remedy the trouble. Fan belts and pumps must constantly be kept at a high state of efficiency since slippage at the fan or a leaky pump gland will reduce the cooling ability of the system all out of proportion to the apparent importance of the defect. When working under a heavy load, such as plowing or driving a good-sized thresher, the engine cannot be shut down too quickly upon the first indication of any trouble with the cooling system as under such conditions only a few minutes are required to destroy the film of lubricating oil between the pistons and cylinders and then the damage is done.

With an automobile engine it is seldom necessary to add water to the cooling system even after a long run on a hot summer's day. A tractor cooling system, on the other hand, may need water several times a day, and this is particularly true of the thermo-syphon type of circulation since the water will not continue to circulate unless the entire system is filled to a certain level. The slower speed at which the water circulates in this type keeps it at a higher average temperature, so that evaporation is rapid. The manufacturers of the Fordson, for instance, recommend that the radiator always be filled before starting and replenished every time the machine is stopped for fuel or oil. As regards winter use, the same precautions apply as in the case of the automobile, that is, the radiator must either be drained upon stopping the motor or an anti-freezing solution used. Since the latter reduces the boiling point considerably, evaporation is even more rapid when running under full load on anything but very cold days, so that it is better practice to drain the system.

IGNITION SYSTEM

Importance of Ignition. It has been previously stated that precedence cannot be given to any of the systems upon which the operation of the motor depends since the failure of any one means the stopping of the motor. It will be found in practical service, however, that there are various degrees of importance as far as the order in which the failure of these systems may be responsible for stopping the motor is concerned. Considered from this point of view, the ignition system heads the list in that it is apt to be the cause of failure to operate more frequently than any of the others. There is no function of the motor, a knowledge of which is more important to the operator than familiarity with the principles involved in ignition, since without this knowledge it is always much more difficult to locate and remedy the trouble. Ignition breakdowns do not result in the serious damage that attends a failure of the cooling or the lubricating system, but they involve vexatious delays and the loss of much valuable time when the difficulty cannot be located quickly. The following brief review of electrical principles is confined wholly to those utilized in tractor operation, and they should be thoroughly mastered.

Electrical Principles

Electric Current. Electricity is one of nature's forces possessing many of the characteristics of light and heat plus a number that are peculiar to it alone. Like light and heat, it may be produced by artificial means in a number of different ways. The energy it represents may be utilized in different forms, such as current or as magnetism. For ignition purposes the electric current is either produced by a direct-current generator and chemically converted into another form in a storage battery from which it is taken for producing the spark required, or it is generated by a magneto, which is a simple form of alternating-current generator. Electric current may thus be direct or alternating, and in either case it possesses the property of being able to flow along or in a conductor. In the former case it flows in one direction around what is termed a circuit, the point at which it issues from the generator or battery being known as the positive, or +, pole, and the one to which it returns being the negative, or −, pole. The signs + and − are usually stamped on storage batteries to indicate what is known as the polarity of the battery, and they correspond to the north and the south poles of a magnet. Alternating current, on the other hand, pulsates, or alternates, first in one direction and then in the opposite, so that a pole which is positive at the beginning of an alternation becomes negative at its completion since the current then rises and flows in the opposite direction. A direct current is of uniform strength in addition to flowing in one direction, while an alternating current rises from zero to its maximum and then drops back to zero to rise again in the opposite direction. The majority of tractors are equipped with magnetos, which generate an alternating current, and from the character of such a current, as just outlined, the importance of properly timing the magneto to the engine may be appreciated since the current for producing the spark is only present when an alternation is approaching its maximum, or peak. If the magneto is improperly timed to the engine, no spark will occur at the plug.

Electrical Units. Electricity may be measured in units equivalent to the pressure and the rate of flow of any other form of energy and, carrying out the comparison, it also encounters resistance to its flow. The ampere is the electrical unit of quantity; the volt, that of force, or pressure; and the ohm, that of resistance. The electrical power unit is the watt, equal to the product of 1 ampere times 1 volt. The flow of an electric current may be compared directly to that of water under pressure in a pipe. The number of gallons delivered per minute is the equivalent of the amperes of current; the pressure under which it is delivered corresponds to the voltage of the current; and the resistance to flow represented by the friction of the water against the walls of the pipe corresponds to the resistance encountered by the current in a wire or other conductor. By increasing the pressure on the water, a greater volume is delivered in a given time. By increasing the voltage of an electric current, although no greater volume of current is delivered, the resulting power is correspondingly greater since electrical energy is represented by the product of the number of amperes times the voltage. Moreover when the pressure on the water is increased, a smaller proportion of the total head, or pressure, is lost in friction, and this is equally true of an electric current since the higher the voltage, the smaller the amount of electrical energy dissipated in the wire as resistance.

Conductors. The flow of an electric current is determined by the nature of the material comprising what is known as the circuit. Some materials are very good conductors, such as silver, copper, brass, and aluminum; others are poor conductors, such as iron, nickel, and alloys containing a high percentage of these metals; while still other materials, such as glass, porcelain, mica, rubber, wood, and stone, will not conduct the current at all when dry.

The latter are insulators and are used to prevent the passage of the current where this is not desired; for example, part of the spark plug is made of porcelain. The ability of a material to conduct electric current is determined by its size as well as by its nature. Given two pieces of wire of the same size, one of copper and the other of iron, the copper wire will conduct the current approximately thirty times easier than the iron. By increasing the iron wire to thirty times the size of the copper wire, both will then conduct the same current and voltage with the same amount of resistance. Iron and nickel are accordingly high resistance conductors, preventing the free flow of the current and converting a large part of the energy represented by the latter into heat,

Fig. 32. Simple Series Circuit Representing Ignition System of Single-Cylinder Motor. The Parallel Lines are Ground Return through the Motor

which explains why a piece of iron wire will not serve as well for a magneto or battery connection as the copper wire supplied by the manufacturer. In addition to the insulators already mentioned, no fabric such as silk, cotton, and wool will pass current when dry, while dry air is the best insulator known.

Circuits. It has already been mentioned that a current flows from the positive to the negative pole of the source of energy, but in order for it to do so there must be a complete circuit of conducting material between the two, a current of low voltage being considered in this connection. The presence of any insulators in the path of the current accordingly prevents its flow, and since air is one of the best insulators, any break in the current such as a parted wire or a loose connection admits air and interrupts the

BORING THREE-WHEEL TRACTOR WITH FORWARD DRIVE AND UNDERSLUNG PLOWS

HEAVY THREE-WHEEL TYPE OF TRACTOR

COMBINATION TRACK AND WHEEL TYPE TRACTOR
Courtesy of Bates Machine and Tractor Company, Joliet, Illinois

flow of current. If the material comprising the conducting path, or circuit, be of high resistance, the flow of current will be either greatly reduced or prevented altogether in the case of the low-tension currents employed in ignition. If a conductor of high resistance, such as a very small piece of wire, occurs in the circuit of a storage battery, it is likely to melt owing to the heat generated by its resistance.

Ignition Circuits. Ignition circuits are of but one kind, that is, series circuits in which all the pieces of apparatus, such as the magneto, the coil, and the plugs, form successive steps through which all the current must pass in order to complete the circuit. Simple forms of series circuits are illustrated in Figs. 32 and 33, which show a dry battery, coil, and plug used as a starting system

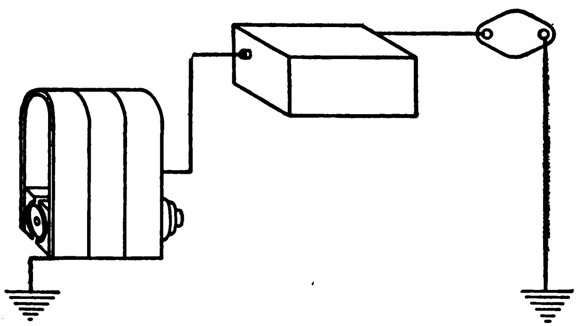


Fig. 33. Series Circuit Using Low-Tension Magneto for Single-Cylinder Ignition System

for a tractor and a low-tension magneto, coil, and plug constituting a complete ignition system. When a battery is employed for lighting to carry on night work as well as for ignition, two independent series circuits may be fed from the same source, the amount of current taken by each being determined by the resistance that it presents to the flow of the current. A multiple, or parallel, circuit is one in which lamps, motors, or other apparatus may be inserted at any point, each unit being connected to opposite sides of the circuit, so that any unit may draw current independently of the others. Connections may be taken at any point on opposite sides of such a circuit to form a branch circuit and the apparatus in the branch circuit connected in series, resulting in what is termed a multiple-series circuit.

Voltage and Amperage. The pressure under which the current flows is termed its voltage, and this may be determined either by the source of supply or by the presence of a transformer in the circuit. In the case of a battery the voltage depends upon the number of cells connected in series with one another, while the amperage, or volume of current, is measured by that of any one cell in the series. For example, dry cells deliver a current at 1½ volts and ordinarily average 15 amperes for short periods. A battery of four dry cells in series would thus produce a current of 15 amperes at 6 volts. If the cells were connected in multiple, that is, all the positives together and all the negatives together, the current would be increased but the voltage would be that of a single cell, so that there would be a current of 60 amperes at 1½ volts.

Storage Battery. In the case of a storage battery which delivers current at 2 volts per cell, the voltage required for ignition, that is, 6 volts, is obtained by connecting three cells in series, while the volume of current depends upon the capacity of the individual cells in the series, and this in turn is measured by their size. For ignition service cells of a battery are always connected in series, so that the positive of one cell must be connected to the negative of the next, and so on throughout the series, one terminal of the battery being positive and the other negative. Any cross connection in the series, such as the connection of the positive of one cell to the positive of the next, would cause one part of the battery to act against the remainder, with the result that no current would be delivered to the outside circuit.

Magneto. The voltage of the magneto or any other mechanical current-generating device is determined by the speed of its armature. The magneto illustrates the fact that electricity and magnetism are different forms of the same force in that one may be readily converted into the other. By moving a magnet close to a coil of wire, a current of electricity is *induced* in the wire, while if a coil of wire is placed about a bar of iron or steel and an electric current is then passed through the wire, the bar becomes magnetic. Steel retains a considerable percentage of the magnetism after the current ceases and is termed a permanent magnet. The fields of a magneto are formed of permanent magnets and supply the magnetism by means of which a current is generated when the wire on the armature is moved past their pole pieces, that is, their north and south poles. Therefore a magneto will generate a current at any speed, but the amount of current and the voltage under which it flows depend upon the speed with which the armature is revolved. The strength of a magnet is represented by imaginary lines passing from one pole to the other, and these are termed lines of force. The voltage of the magneto current is determined by the number of times per minute that the wires of the armature cut through the lines of force between the magnet poles.

Low- and High-Tension Currents. The foregoing brief explanation has been confined to what are known as low-voltage currents, the storage battery delivering current at 6 volts for ignition, while the magneto when running at full speed generates current at approximately 100 to 125 volts. Any current under 500 volts is usually referred to as a low-voltage current. In connection with the explanation of insulators it has been mentioned that the interposition of any insulating material in the circuit, and particularly a break or loose connection which creates an air gap, interrupts the flow of current. This is true of all low-voltage currents; all parts of the circuit must be not merely connected but in firm and positive contact, and the contact surfaces must be clean and bright since dirt is likewise an insulator. This is a principle frequently overlooked in the care of tractor and farm engines, which usually work in very dusty places; it is absolutely necessary to keep all connections clean and tight to insure the satisfactory working of the ignition system.

Since even a loose connection will interrupt the flow of current in a low-voltage circuit, it is not suitable for the production of a spark unless the terminals representing the positive and negative sides of the circuit are actually brought into contact and then separated. What is known as the low-tension system of ignition is employed on thousands of stationary farm engines and also on many tractors having low-speed engines. Most stationary engines are run at low speeds, ranging from 200 or less to 450 r.p.m., while few tractor engines run below 600 r.p.m. at normal speed and most of them operate at much higher speeds.

Types of Ignition Systems

Low-Tension Ignition. While dry cells may be employed for ignition with a stationary engine equipped with a hit-and-miss governor that cuts off the current except on the power strokes, they do not give satisfactory service and therefore a magneto is generally used. The magneto chosen is the simplest type and consists of nothing more than the field pieces, or permanent magnets, and a simple armature having a single winding. It may either be rotated or given a quick partial revolution by a rod and spring, but in any case it must be timed to the engine, so that the current in its armature is at the maximum value when the spark is to occur in the cylinder. While such a magneto produces ample current at a fair voltage it is not sufficient to produce a spark of the desired size for low-tension ignition, and therefore a spark coil is placed in the circuit.

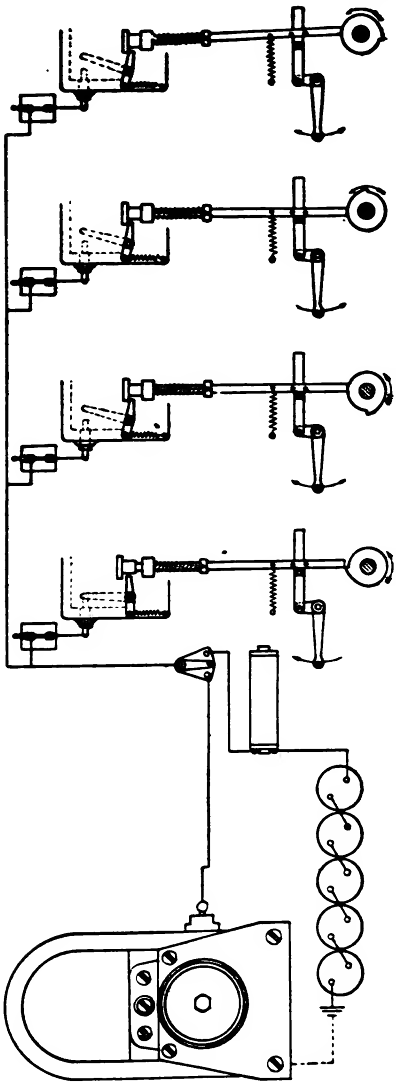


Fig. 34. Details of Low-Tension Ignition System

Spark Coil. The spark coil consists of a single winding of many layers of heavy insulated wire on a thick short core built up of fine iron wire that has been annealed until it is very soft, as in this condition it is capable of being magnetized and demagnetized very quickly. Such a coil acts on the principle of self-induction and produces a much hotter and larger spark than the magneto could unaided. Its working will be clear from Fig. 34, which shows a typical low-tension ignition system. Up to the time it is necessary for the spark to occur in the cylinder, the ignitor has its points in contact, so that the circuit is closed and current flows through the ignitor and the winding of the spark coil. Consequently the core of the coil is magnetized and stores up the equivalent of the current which magnetized it. When the circuit is broken by the sudden snapping of the ignitor, this magnetism is instantly reconverted into electric current and adds its force to that of the current in the winding, and a much hotter spark results at the contacts. In fact, this is really a flash instead of a spark and is usually termed an arc; and it is so hot that it burns the contact points away rapidly, which is one of the disadvantages of the low-tension system.

High-Tension Ignition. In high-tension ignition the ignitor of the low-tension system is replaced by a spark plug with fixed electrodes, or terminals, separated by an air gap. But in order that the current may bridge this gap, it is necessary to raise it to a high voltage. This ranges all the way from 10,000 to 30,000 volts, the higher voltage being necessary when the initial compression of the engine is high since a greater electrical tension is required to create a spark across a gap in compressed air than out in the open.

Induction Coil. In the brief reference given to elementary electrical principles it has been mentioned that when a coil of wire is passed before a magnet, a current of electricity is induced in the wire. This also occurs either when one coil of wire in circuit through which a current is flowing is moved close to another in which there is no current or, the two coils being stationary, when the current is suddenly broken in the first. This is the basic principle of the transformer, or induction coil. As in the case of the spark coil, the effect produced is greatly increased by using a heavy core of soft-iron wire. The character of the current induced in the second coil depends upon the relation that the windings of the latter bear to those of the coil in which the current, termed the primary current, is flowing. If both coils have the same number of turns in their windings, the induced, or secondary, current will be approximately the same in amperes and volts as the primary current. By increasing the number of turns in the secondary winding of the coil, the voltage of the induced current will be increased correspondingly. An induction coil accordingly consists of a comparatively few turns of heavy wire for the primary winding, which is closer to, though insulated from, the soft-iron core. The secondary coil consists of a great number of turns of very fine wire and surrounds the primary winding, but it must also be well insulated from the latter, as otherwise the high tension-current would tend to jump from the windings of one to the other. A coil in which this has occurred is said to be *punctured* and, as it is short-circuited, is useless for ignition until repaired.

Mechanisms to Make and Break Circuit. Where batteries are employed for ignition or the magneto generates a current which, though alternating in its nature, is of such high frequency as to be practically continuous, as on the Fordson tractor, the induction coil must be equipped with a vibrator to make and break the circuit since current is only induced in the secondary winding when the circuit is broken or the current rises and falls from zero to maximum and the reverse, as in an alternating current of lower frequency. In what is known as the modern battery system, employing a storage battery kept charged by a small direct-current generator, a primary contact breaker in connection with the distributor takes the place of the coil vibrator and but one coil is used.

Essential Parts of System. A high-tension system accordingly consists of a source of current, most often a magneto, a coil, a spark plug for each cylinder, and a distributor. The distributor always forms a part of the magneto and is driven by the magneto shaft, and in what is known as the true high-tension type of magneto the coil is also incorporated with it; that is, the magneto generates the primary low-tension current and also transforms it or steps it up to the required high voltage, the armature usually carrying both the primary and the secondary windings. Consequently with a high-tension magneto the complete ignition system consists of the magneto itself, the spark plugs, and the necessary connecting cables, so that the entire system is practically self-contained.

Condenser. A part of the high-tension system with which the operator is not likely to become acquainted unless something goes wrong with it is the condenser. In the form employed for ignition the condenser consists of alternate leaves of tinfoil and paraffined paper, the latter serving to insulate the sheets of tinfoil from one another. The tinfoil sheets are divided into two groups, which are connected to opposite sides of the contact breaker of the magneto, so that the condenser is in multiple with the breaker. (Magneto parts and construction are explained in detail in connection with the description of some of the standard makes employed for tractor ignition.) When parts in contact carrying current are suddenly separated, a flash, or arc, occurs owing to the tendency of the current to continue its flow across the break, as happens in a low-tension ignitor. This not only represents a loss of energy but tends to burn away the parts. To prevent this, a condenser is shunted about the contact, that is, connected in multiple with it. The current, instead of continuing across the gap in the form of an arc as the contacts open, flows into the condenser, which has the capacity to store a charge of electricity. Immediately upon the contact being made again so as to reclose the circuit, this stored charge flows back from the condenser into the circuit.

Safety Spark Gap. In the explanation of circuits mention has been made of the fact that a current divides or flows through different branches of a circuit in proportion to the resistance in those branches. In other words, it will always seek the path of least resistance. Consequently, if the air gap of a spark plug be made so large that it represents a resistance greater than the insulation of the windings of the coil, whether this coil be separate or on the armature of the magneto, the current will break down the insulation and short circuit the winding. The current burns away the electrodes of the spark plugs and the gap must be adjusted from time to time to correct this; at the most the gap should not exceed the thickness of a visiting card, or $\frac{1}{32}$ inch. As the gap widens, the spark becomes thinner and loses its heat value so that the ignition is less and less satisfactory. When at last the gap becomes so wide as to present a greater resistance than the coil insulation, the spark will jump across the safety spark gap provided to protect the coils. This gap is designed with an opening having a resistance that is considerably less than that of the coil insulation so as to allow an ample margin of safety for the coils. It is usually located under the arch of the magnets of a high-tension magneto and is mounted on the distributor of a modern battery ignition system. The occurrence of a spark across this gap is an indication that one or more of the spark plugs have been burned open too far, though this will usually be evident from the poor ignition resulting.

Low-Tension Magneto. Magneto ignition has proved the most dependable as well as the most enduring for tractor work since the excessive vibration and jolting make the use of the storage battery practically out of the question. Dry cells are of little value in any case for ignition, except where starting is concerned, and the necessity for them has been eliminated by the development of the impulse starter on the magneto, as described

Fig. 35. Inside and Outside Views of Low-Tension Ignition Plug Used on Oil-Pull Tractor

later. There are several types of magnetos in general use on the tractor and a brief reference is made to each of them.

On tractors employing low-speed horizontal engines, low-tension ignition is standard equipment. It has the advantage of being extremely simple and all its parts can be made amply strong enough to withstand the strenuous treatment of tractor service in the field. Its chief disadvantage is the more or less frequent necessity for attention to the ignitors, though the hot flash produced by the latter is better adapted to ignite low-grade fuels than the high-tension spark produced by a plug. The magneto employed with the low-tension system has but one winding and no contact breaker nor distributor. It is connected in a simple series circuit with a spark coil and the ignitors. The Bosch low-tension magneto is the type employed on the Rumely tractor.

In Fig. 35 are given two views of an ignitor, the view at the left showing the tripping mechanism outside the cylinder, while that at the right shows the details of the fixed and movable

Fig. 36. Tripping Mechanism of Low-Tension Ignitor, Electrodes in Contact before Sparking

electrodes between which the spark occurs when they are suddenly snapped apart. In Figs. 36 and 37 are shown the details of the tripping device, the former illustrating the mechanism with the electrodes in contact just before sparking.

Timing of Low-Tension System. Since the magneto is directly connected in a simple series circuit with each ignitor, it is evident that both the latter and the magneto itself must be timed to produce the spark at the proper moment for the explosion. The

Fig. 37. Low-Tension Ignitor Tripping Mechanism, Showing Adjustment Spacing

ignitor is tripped by a push rod and cam on the camshaft in exactly the same manner as the valves are operated, while the magneto itself is timed to the motor in much the same manner as is necessary in the case of a high-tension magneto. In the section on elementary electricity it has been explained how an alternating current rises from zero to maximum in one direction

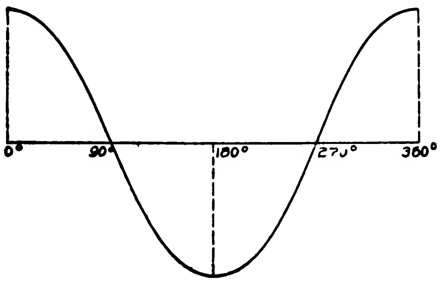


Fig. 38. Sine Wave Alternating Current as Generated by Magneto

and then subsides and rises again in the opposite direction. This is termed a sine-wave current and is illustrated by Fig. 38. The only part of this current that is of value for ignition is represented by the few degrees in the revolution of the armature that are indicated by the peaks of the alternations. In a simple magneto with an H armature, Fig. 39, this peak occurs at the point shown in the illustration, that is, the point when the core of the armature is entering the tunnel formed by the pole pieces attached to the field magnets at their lower ends.

In Fig. 39 the armature is turning to the left and has just left the right-hand pole piece by $\frac{1}{16}$ inch. From this point until

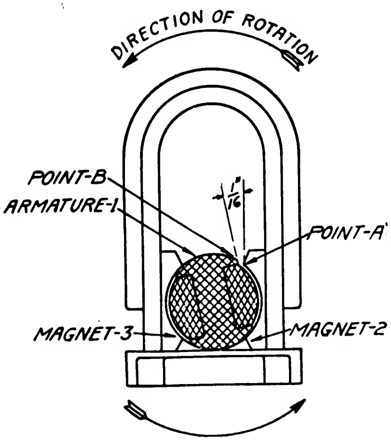


Fig. 39. Sparking Position of Armature

the center of the core of the armature is on a line with the upper part of the pole piece, the value of the current is close to the peak and is rising. The further revolution of the armature causes it to fall, and when the core reaches the lower part of the tunnel, it reverses and starts upward in the opposite direction. The armature of the magneto must accordingly be set so that it is in the position shown in the illustration when the ignitor is about to trip. This is not the maximum, as the armature cuts the greatest number of magnetic lines of force a few degrees further around and thus produces the current of the greatest value at that point. This setting allows for the necessary advance of the sparking time, which causes the latter to coincide with the point of maximum value just mentioned.

Causes of Trouble Few. There being only a current of very low voltage in any part of the system and only a single short wire being necessary to conduct this low-tension current to the ignitors, electrical troubles are rare with the low-tension system and are confined chiefly to failure of the ignitors, or make-and-break plugs, to spark owing to an accumulation of carbon, or soot, on the electrodes. Apart from this, any shortcomings of the system are apt to be purely mechanical rather than electrical. The tripping mechanism and springs must necessarily be light, but at the speeds at which they operate wear is more or less rapid, so that considerable attention is required to maintain them in efficient operating condition. This is the chief reason why the low-tension ignition is not applicable to the high-speed type of motor.

As before stated, most of the electrical difficulties experienced with the low-tension system involve the ignitors, or make-and-break plugs. Unless the fuel is being burned very efficiently by the engine, they short-circuit very quickly through a deposit of carbon, although this also occurs at regular intervals even where it is not possible to improve upon the running of the engine. Another cause of trouble is the sticking together of the electrodes by what is practically a form of electric welding. Carbon deposits must be scraped off carefully, electrode contact surfaces filed or scraped bright, and the remainder of the plug cleaned with kerosene. After a considerable time in service the mica insulation of these plugs may become so impregnated with carbon dust or a mixture of oil and carbon dust that it is impossible to prevent it short-circuiting, in which case it is necessary to replace the mica insulation. The plugs are the source of the trouble in about 85 per cent of the cases, but when they are in good condition, the magneto should be tested, first, to note whether it is generating or not and, second, to see whether it is properly timed to the engine. To provide sufficient current at a good voltage, the plug must snap, or *break,* just at the moment when the current in the armature of the magneto is close to the peak, Fig. 39. The maximum current and voltage are generated when the armature has turned a few degrees further.

Testing Low-Tension Magneto. To test the armature to find out whether it is generating or not, attach a short piece of copper wire to its terminal, place the bare end of this wire against the field magnet, and rotate the armature. Pull the wire away from time to time, and a good spark will follow if the magneto is in good order. If this proves to be the case and the spark still fails to occur at the plug, the position of the armature should be noted at the moment that the plug breaks, and if this does not correspond with the position shown in Fig. 39, the magneto should be retimed. The plug itself may be tested by taking it out and laying it on the cylinder. With the magneto running, the electrodes may be snapped apart. Should they fail to spark, all other parts of the system being in good working order, it is usually due to the insulation of the plug. A spare plug should be inserted and the insulation of the old one replaced as soon as the opportunity arises. By carrying spares, much valuable time in the field may be saved.

High-Tension Magnetos. *Two Types.* Two types of high-tension magnetos are employed for tractor ignition: one in which both windings are placed directly on the core of the H-type armature, so that the windings, core, and condenser rotate together; and the other, the so-called inductor type in which the winding is stationary while the rotor in two parts revolves on either side of it. The first type illustrates the elementary electrical principle that rotating a coil of wire through the lines of force of a magnetic field will induce a current in the wire. The current thus induced in the primary winding of the coil on the armature is transformed to one of high voltage by the secondary winding which is also on the armature. The gear shown at the right-hand end of the armature is for the purpose of driving the distributor disc, the function of which is explained later.

The rotor and winding of an inductor type of magneto, the K–W, are shown in Fig. 40, while a phantom view of the complete machine is given in Fig. 41. It will be noted in Fig. 40 that the rotor consists of two blocks of iron placed at right angles to one another with the winding between them. In Fig. 41 the condenser is at the left of the winding, while the contact box and the distributor of the magneto are at the right. The operation of the inductor type of magneto is based on the principle that rotating a magnet so that its lines of force cut the winding of a coil will induce a current in the latter. The magnet in this case is the rotor, the members of which form part of the magnetic circuit of the machine. They are most strongly magnetic when in the position at which the current of any magneto is at the maximum, as previously explained in connection with the low-tension magneto. The rotor takes its magnetism from the permanent magnets of the field in the same way that an ordinary horseshoe

Fig. 40. Rotor of K-W Inductor Motor
Courtesy of K-W Ignition Company, Cleveland, Ohio

magnet will render an iron nail magnetic as long as they are in contact.

High-Tension Circuit. The wiring of a true high-tension magneto, that is, one that has both the primary and the secondary windings embodied in the magneto itself, is almost as simple as that of the low-tension type already described; in the high-tension system one wire is necessary for each plug and in the low-tension system a single cable connected to a busbar in contact with all the ignitors is needed. But in the high-tension system these wires carry current at very high voltage and the slightest defect in the insulation or the presence of dampness is apt to permit this high-tension current to leak away, usually without giving any sign of its escape.

The primary circuit of a high-tension system consists of the primary winding on the armature, whether stationary or rotating, the condenser, and the contact breaker. The secondary circuit consists of the secondary winding (whether located on the armature of the magneto itself in the form of a coil placed under the arch of the magnets in the magneto or placed independently of the magneto), the distributor, the cables leading to each of the spark plugs, and the safety spark gap. It will be noted that each case represents but one side of a circuit. The other side is grounded, that is, the current returns through the metal of the magneto in the primary circuit and through that of the motor

Fig. 41. Phantom View of Complete K-W Inductor Magneto
Courtesy of K-W Ignition Company, Cleveland, Ohio

and the magneto in the secondary. Thus a spark plug with a cable attached completes the circuit when it is screwed into the cylinder.

Contact Breaker. Regardless of detailed differences in their construction or design, all high-tension magnetos operate on the same principles, and in every case the contact breaker is the part of the magneto on which its continued operation depends. In Fig. 42 is shown a complete high-tension ignition system consisting of a K–W magneto and its connections for a four-cylinder motor. The contact breaker details are plainly shown just below the distributor of the magneto: *C* is a cam carried on the end of the magneto armature shaft; *R* is a roller carried at the center of a hinged arm which is pivoted at its right-hand end and is designed to minimize wear on the cam. At its left-hand end this same hinged arm carries a platinum contact point designed to make contact with a similar point that is held stationary, but is adjustable for wear. The hinged arm and the stationary contact point are attached to the contact breaker box *A*, which may be turned through a partial revolution in either direction to advance or retard the time of sparking.

The circuit through the primary winding on the armature is completed when the contact points *P* are together, and it will be

MAGNETO

Fig. 42. Ignition Circuit of Four-Cylinder Motor
Courtesy of K-W Ignition Company, Cleveland, Ohio

noted that they are in contact with each other as long as the cam *C* is horizontal, so that current is flowing in this circuit. When the cam *C* turns so that it becomes vertical, it corresponds to the position of maximum current in the armature winding and the circuit is suddenly opened at that moment. This breaking of the current provides the impulse necessary to induce the maximum current and voltage in the secondary winding. At the same moment that the contact breaker opens, provided the motor is designed to turn to the right, or clockwise, the distributor contact *B* is passing close to *S*, which is the terminal representing the spark plug of cylinder 1. If it is a left-handed motor, the distributor contact *B* will be at the sparking point for cylinder 4 at *S'*. There is accordingly a path open for the high-tension current to the spark plug. As the distributor is driven directly from the armature of the magneto by gearing, Fig. 43, the distributor contact is at a point corresponding to the cylinder that is to be fired each time the contact breaker opens.

Firing Order. While these points on the distributor are numbered consecutively from 1 to 4, the cylinders of a four-cylinder motor cannot be fired in that order since the cranks of a four-cylinder four-cycle motor are spaced at 180°. In other words, there are two in one plane and the other two are in the plane

Fig. 43. Distributor End of K-W Magneto
Courtesy of K-W Ignition Company, Cleveland, Ohio

opposite, or half a revolution away. Consequently, cylinders in the same plane cannot follow one another in firing. This is made plain in the circuit diagram, Fig. 42. From this illustration it is evident that cylinders 1 and 4 have their cranks in the same plane, so that the cylinder to fire after cylinder 1 must be either 2 or 3. It will also be noted that contact 3 of the distributor corresponds to cylinder 4 of the motor, so that the firing order of this motor is 1, 2, 4, 3. The firing order most commonly adopted for four-cylinder motors is 1, 3, 4, 2 since this produces a somewhat better impulse balance by distributing the successive explosions among cylinders at equidistant points on the crankshaft. In checking up the ignition or making any repairs it is important to know what the firing order of the motor is, and this will usually be found stamped on it in some conspicuous place.

Care of Magneto. Since modern high-tension magnetos have their shafts mounted on ball-bearings, they require very little oil and that only at infrequent intervals. A few drops once a week in the case of some and once in two weeks with others is all that is necessary so far as lubrication is concerned.

The contact breaker is the most important part of the magneto and is the one that should be looked to first whenever the magneto fails to deliver a spark at the plugs, all other essentials of the system being in good condition. Long continued operation at full load is apt to burn the contact points away to such an extent that they do not come together when the cam is in the horizontal position. Or they become so pitted and covered with oxidizing material, which insulates them, that the current cannot pass even though they make contact. The contact points should be kept true and bright with a very fine thin file or with a strip of fine sandpaper, taking care to remove all traces of dust from the contact box by cleaning it out with gasoline or kerosene. Since the points are made of very expensive material, when they are trued up no more metal should be removed than is necessary to bring the surfaces squarely together. Much better service will be obtained from the magneto if this operation is carried out at frequent intervals, say once a month when the tractor is being used steadily, instead of waiting until the points get in such a condition that the magneto will not operate at all. If the contact points burn away very rapidly, it is an indication that the condenser has broken down and should be replaced. This is usually a job that must be referred to the magneto manufacturer. Apart from the attention required by the contact breaker, the only care that it is necessary to give the magneto is to keep it clean and well-oiled and see that its connections are always tight.

Spark Plugs. Regardless of how well every other part of the ignition system is working, a spark will not occur in the cylinder unless the spark plugs are in good condition. The spark plug is the business end of the entire system since its failure will render useless the perfect functioning of every other part. As will be noted in the sectional view, Fig. 44, a spark plug consists of two electrodes with a gap between them across which the current must jump in order to ignite the fuel in the cylinder. One of these electrodes is the outer shell of the spark plug itself and completes the circuit through the *ground return* when it is screwed into the cylinder head. The other, or central electrode, is connected directly with one of the points on the high-tension distributor of the magneto, so that the path of the current is down through this central electrode, across the gap to form the spark and back through the body of the motor to the magneto, which is also grounded by being bolted to the motor.

Importance of Insulation. No spark plug can be any better than the insulation which separates the two electrodes since the entire operation of the plug depends upon its preventing the escape of the current before reaching the gap. Like any other force under pressure, electricity will always seek the line of least resistance, and as compressed air has a higher electrical resistance than any solid insulator, the slightest leak in the insulation will open a path for the current and no spark will occur at the gap.

Fig. 44. Sectional View of a Spark Plug

Heat, vibration, hot oil, and soot are all enemies of the insulation, and under their combined attack it is bound to break down sooner or later. Soot, or carbon, which is an excellent conductor of electricity, is the commonest cause of spark-plug failure, but it does not necessarily put the plug out of commission for good. It is particularly difficult to prevent the accumulation of carbon on the ends of the plugs in an engine burning kerosene, but a good cleaning with a fine wire brush and plenty of gasoline is usually all that is necessary to restore them to service.

Common Plug Troubles. Apart from the difficulty of short-circuiting due to carbon collecting on the ends of the plugs, the commonest causes of trouble are due to a hidden breakdown of the insulation and to the burning away of the electrode points, so that the resistance of the gap becomes too great for the current to bridge. Porcelain is one of the best insulators known for the purpose, but it is difficult to make a porcelain that will withstand the intense heat and the vibration indefinitely, particularly as the material is already under stress due to the screwing down of the gasket nut of the plug in order to make it gas tight. When it becomes intensely hot, the vibration and pounding are apt to open fine invisible cracks in the body of the porcelain. The carbon is forced into these and forms a conducting path for the current. As this carbon cannot be cleaned out, the plug is useless until a new porcelain has been inserted.

In the same manner, the hot oil carrying a considerable percentage of carbon particles is forced into the mica insulation of a plug until it becomes so impregnated with this conducting material that it will no longer spark. Only the replacement of the electrode and its insulator will cure the trouble. Failure to spark due to the electrode points having been burned too far apart sometimes makes itself apparent by the current visibly passing over the outside of the plug. That is, instead of jumping the gap inside the cylinder, the current finds a path of less resistance across the surface of the insulator. This will sometimes occur when a plug gets extremely hot, even though the points are properly spaced, and since water is a good conductor, it will always take place if the slightest amount of moisture is allowed to fall on the porcelain of the plugs. Dirty oil will also provide a conducting path. When the electrode points have burned too far apart and no indication is visible at the plug itself, the spark will be noticed jumping the safety spark gap on the magneto.

Under the continued heavy service of a tractor engine that is being used for plowing ten hours a day and six days a week, it will be nothing unusual to have to adjust the spark plug points two or three times a week, particularly where cheap plugs are used, since the electrodes are of common iron and burn away very quickly. It is poor economy to buy cheap spark plugs, though it is not so great a sin as to buy cheap lubricating oil. The latter besides damaging the motor in other ways will cause added trouble with spark plugs of any kind owing to the excessive amount of carbon that accumulates in the cylinders. Leakage of compression through the plugs must be prevented by turning down the nut at the base of the porcelain to seat it on the gasket, but this must be done carefully or the porcelain will break.

Wiring. Moisture and oil are also enemies of the insulation of the high-tension cables that connect the distributor terminals of the magneto with the plugs. These cables must be kept clean and dry and their terminals at both ends must be kept tight with the cables in a position where they do not come into contact with one another or with the body of the engine as far as possible since despite the thickness of the rubber and the cotton insulation the high-voltage current will find a path through it at the slightest opportunity. When the cables have become soaked with oil and dirt, it is better to discard them and replace them with an entire new set as the value of the insulation has been destroyed to a large extent.

In order to make the cables flexible, they are made up of a large number of fine copper wires stranded together. When the cables become frayed at the ends next to the plug terminals, particularly, it is nothing unusual for one or more of these very fine strands of copper to project against the body of the plug or some other metal and thus cause a short-circuit that is not noticeable. Both ends of the cables should be well taped at the terminals to prevent this. Contact with any moving parts must be avoided as even a slight amount of wear on the insulation will lower its resistance to a point where the current will find a path through it. This is particularly true of cuts that penetrate both the cotton and the rubber, but which may be so small as to be imperceptible. Despite their size the current will leak through them if the cables come in contact with any metal parts since almost any path of this kind will present less resistance than does the gap of the spark plug, especially when the latter has been burned open too far.

Magneto Impulse Starter. Owing to the fact that it is not found practical in the majority of instances to carry a storage battery on a tractor, while the average tractor motor cannot be cranked fast enough by hand to start it with the ordinary magneto, an attachment has been designed for the latter by means of which it may be caused to generate sufficient current for a hot spark regardless of the speed of the engine. This is known as an impulse starter. It consists of a spring mechanism, which, when the engine is cranked, is automatically released, causing the magneto armature to turn through a partial revolution much more rapidly than the crankshaft.

Bosch. The details of the Bosch impulse starter are shown in Fig. 45, while Fig. 46 illustrates the magneto complete as equipped with the starter. Referring to the detail view Fig. 45, it will be noted that a dish-shaped flange is attached to the armature shaft and that this flange carries two cams on its periphery. In the view at the right is shown the crossbar member which forms an integral part of the starter driving shaft. The squared ends of this bar fit the openings of the flange mentioned. This bar *floats* on the helical springs shown, which are held in a circular recess and are secured to the starter shaft, which is also the main driv-

Fig. 45. Details of Bosch Impulse Starter
Courtesy of American Bosch Magneto Corporation, Springfield, Massachusetts

ing shaft, as is made clear in the assembled view of the magneto. The operation of this starter is controlled by a latch forming part of the external engagement lever, which is shown projecting upward. When it is not desired to operate the impulse starter, this latch is held away from the cams by a trigger. Releasing the trigger drops the latch, and the starter, or coupling shaft, is revolved, causing the spring to be compressed. Since the crossbar is held stationary, the armature does not revolve. By moving the small lever to the *release* position, the springs are freed and they give a rapid partial turn to the magneto armature. When the engine speed exceeds 150 r.p.m., the speed at which the cams strike the lever is sufficient to cause it to fly up out of the position where it is held by the trigger, so that the magneto operates in the usual manner. For starting large engines, it is customary to prime the cylinders with gasoline; the impulse starter lever is then moved over to the *engaged* position and let go. The engine is cranked to bring the piston in a cylinder that is about to fire a few degrees beyond the upper dead center on the firing stroke, and then the starter lever is pushed to the release position, causing a spark to occur in the cylinder under compression. To facilitate starting in this manner, a check mark may be made on the flywheel to indicate the starting position.

Eisemann. In Fig. 47 is illustrated the mechanism of the Eisemann magneto impulse starter, in which a spiral spring is employed as the driving element. For greater clearness, this

Fig. 46. Bosch Magneto Equipped with Impulse Starter
Courtesy of American Bosch Magneto Corporation, Springfield, Massachusetts

spring is indicated by dotted lines. The spring *S* is attached to the members *H* and *C*, the former being the housing attached to the magneto shaft and the latter the driving member; *B* is a fixed bar which is mounted on the base of the magneto; and *T* is a floating member, or trigger. When the motor is cranked slowly, the trigger *T* drops by gravity, engaging the bar *B* and temporarily preventing the rotation of the housing *H*. Since *C* is driven by the engine, cranking causes it to compress the spring, or wind it up, until the cam on *C* strikes the wedge *W*. This forces the trigger upward until it slips off the lower bar, thus releasing the housing *H* and causing the spring to give the armature a sharp partial turn. The right-hand illustration shows the relation of the members after the spring has been released and the magneto starter is in its normal running position. Stops are provided on the housing and the outer part of the driver *C* to prevent the armature from being turned past the position it must maintain to be properly timed to the engine. To hold the starter out of operation while the engine is running, *T* is heavily counterbalanced and as a result the action of centrifugal force on it draws the part *T* further in until the detent on it, shown just above the trigger

Fig. 47. Impulse Starter on Eisemann Magneto
Courtesy of Eisemann Magneto Company, Brooklyn, New York

itself, enters the notch *N* in the driving member *C*, where it is held as long as the magneto runs at its normal speed. As this notch provides a positive drive for the magneto independently of the spring, the starter acts merely as a coupling when running.

TYPES OF MOTORS

Wide Range of Types. When gasoline-driven tractors were first placed on the market with a view to providing a machine that could be more widely used than the steam tractor, they consisted of little more than a single-cylinder stationary gasoline engine on wheels. While tractor design has advanced considerably since that time, it is still a long way from having reached any standard as far as the power plant is concerned. Meanwhile, the automobile engine has undergone tremendous improvement, while its manufacture is now carried out on a scale that was not dreamed of fifteen years ago. As a result, the tractor engine has been developed under the influence of two widely separated standards, first, that of the stationary engine builder and second, that of the automobile engine manufacturer. There is, consequently, a wide

Fig. 48. Two-Cylinder Horizontal Motor Used on 20–40 Oil-Pull Tractor
Courtesy of Advance-Rumely Thresher Company, Inc., Laporte, Indiana

Fig. 49. Interior of Crank Case, Oil-Pull Motor
Courtesy of Advance-Rumely Thresher Company, Inc., Laporte, Indiana

range of engine types used for tractor propulsion. At one end of this range there is the descendant of the original stationary engine, made more compact and with additional cylinders to provide the needed extra power without excessive weight, while at the other extreme there is the light, high-speed, multi-cylinder motor, which to all intents and purposes is practically an automobile engine.

Horizontal Engine. *Oil-Pull.* To a large extent the horizontal engine is an outgrowth of stationary engine practice. A representative example is illustrated in Fig. 48, which shows the 20–40 Oil-Pull engine. The cylinders are cast with separable heads and the valves, located in the latter, are operated by rocker arms. The carburetor, or fuel mixer, the magneto, the force-feed oiler, and the circulating pump are all placed on top of the motor for

Fig. 50. Section of Eagle Two-Cylinder Horizontal Motor
Courtesy of Eagle Manufacturing Company, Appleton, Wisconsin

greater accessibility. Since splash lubrication cannot be used owing to the position of the cylinders, force-feed oilers with leads directly to each of the bearings are commonly used on this type of engine. In Fig. 49, is shown a head-on view of the same motor with the crankcase removed, showing the crankshaft and bearings, the camshaft and timing gears. The magneto, the circulating pump, and the force-feed oiler are also driven by the gears. In this engine the cylinders are slightly offset to reduce the pressure on the cylinder walls during the firing stroke.

Eagle. A clearer idea of the internal details of this type of engine is obtainable from the sectional view, Fig. 50, showing an

Fig. 51. Avery Two-Cylinder Horizontal Opposed Motor
Courtesy of Avery Company, Peoria, Illinois

Eagle two-cylinder motor. The upper cylinder has been sectioned through the center line of the piston, showing the piston pin and the inside of the valve cages, while the lower one illustrates the complete piston with its rings and the removable valve cages in the cylinder head. Whether it be horizontal or vertical, one of the advantages of the valve-in-head type of motor is the ease with which the valves may be kept in condition, grinding-in being an operation that must be carried out at frequent intervals on a tractor engine.

Horizontal-Opposed Avery. The horizontal opposed type was largely used on automobiles for several years during the early period of their development in this country. It provides better impulse and mechanical balance than the two-cylinder type in which

Fig. 52. Engine of Holt Caterpillar Tractor
Courtesy of Holt Manufacturing Company, Inc., Peoria, Illinois

Fig. 53. Parts of Tracklayer Tractor Engine
Courtesy of C. L. Best Gas Tractor Company, San Leandro, California

the cylinders are placed side by side and is accordingly freer from vibration. In Fig. 51 is illustrated the Avéry two-cylinder motor of this type, which is also built with four cylinders in the larger sizes. A novel feature of the Avery motor that overcomes the disadvantage to which this type was subject on the automobile is

Fig. 54. Automobile Type Engine of Parrett Tractor
Courtesy of Parrett Tractor Company, Chicago Heights, Illinois

the use of removable cylinder liners. Owing to the weight of the piston resting on the lower half of the cylinder wall the latter wore out of round more rapidly than would the cylinders of a vertical engine in the same service. This destroyed the compression and involved the reboring of the cylinders and the fitting of oversize pistons. The Avery cylinder liners are cast of harder metal than the cylinders themselves and may be given a part turn from time to time so as to distribute the wear over the entire wall, while the liner itself may be replaced readily.

Vertical Motors. *Holt and Tracklayer.* All the horizontal motors described are specially designed for tractor service by the manufacturers of the tractors themselves and produced in their own shops. With comparatively few exceptions, most of the vertical types of tractor motors are the products of the various large

Fig. 55. Section of Moline Four-Cylinder Motor
Courtesy of Moline Plow Company, Moline, Illinois

automobile motor factories and are designed along lines that closely follow practice in the automobile field. One of these exceptions is the Holt motor shown in Fig. 52, while another of very similar design is the power plant of the Tracklayer tractor. Some of the construction details of this motor are shown in Fig. 53, which illustrates a cylinder casting, cylinder head with valves, piston, piston pin, and the cylinder head and manifold gaskets. Both of these motors are specially designed and built for tractor service and are of the slow-speed type best adapted for carrying a large percentage of their maximum load continuously.

Parrett. The Parrett motor shown in Fig. 54, while also designed for this service, follows automobile practice more closely. It is shown with the cylinder head casting and the crankcase oil pan removed to illustrate the accessibility thus obtained. Its smaller size and greater compactness is accounted for by the fact that it is a high-speed type, designed to produce its normal rated output at 1000 r.p.m.

Moline. Another motor of this class is the Moline, which is shown in longitudinal section in Fig. 55 and in cross-section in Fig. 56. These illustrations are taken from the Moline instruction book and the identification figures serve to make clear the functions of the various parts of a motor. From *1* to *5* in Fig. 55 they refer to the lubricating system, as follows: *1*, oil level in crankcase; *2*, suction pipe to oil pump; *3*, oil pump; *4*, oil conduit drilled through the crankshaft; and *5*, oil lead to crankpin bearings. Numbers *6* and *7* are the driving pinion and gear of the timing gear; *8*, a bevel gear for the belt pulley of the tractor; *9*, a valve tappet; *10*, the valve mechanism chamber; and *11*, the oil cap filler and *breather*. The latter admits air to the crankcase and is a necessary feature of all motors but is usually located directly on the crankcase itself. It is one of the points that must be carefully guarded against the entrance of dust and grit to the interior of the motor.

Fig. 56. Cross-Section of Moline Motor
Courtesy of Moline Plow Company, Moline, Illinois

In Fig. 56 *1* is the oil screen; *2*, the suction pipe to the oil pump; *3*, the oil hole to the crankpin bearing; *4*, the crankshaft;

5, the crankpin; *6*, the combustion chamber of one cylinder; *7*, a valve; *8*, the valve spring; *9*, the rocker arm of the valve linkage; and *11*, the rocker arm stud; *10* is the intake passage. The details of the crankshaft and piston assembly are shown in Fig. 57, in which *1* is the oil outlet hole from the drilled crankshaft at the forward crankshaft bearing; *2*, the oil intake hole at the rear

Fig. 57. Crankshaft and Piston Assembly of Moline Motor

crankshaft bearing; *3*, a series of threads designed to work the oil backward into the crankcase and prevent its entrance into the clutch housing; *5*, the helical half-time gear for driving the camshaft and auxiliaries; and *6*, the bevel pinion for driving the belt pulley. The bolts for fastening the flywheel to the crankshaft flange are identified by *4*.

FORDSON TRACTOR BEING USED FOR BELT WORK
Courtesy of Henry Ford and Son, Inc., Dearborn, Michigan

GASOLINE TRACTORS

PART II

CONTROL SYSTEM

ENGINE GOVERNORS

Need of Governors. *Plowing.* In order that a tractor may be operated most economically, it must be capable of one-man control since, in plowing, conditions are continually encountered where the driver's attention must be centered on the management of the plows and the steering of the machine to the exclusion of everything else. Moreover the demands upon the engine are continually varying even when the soil conditions are apparently uniform for long stretches. Stones, roots, and extra heavy patches of sod all impose considerable extra load on the engine that can be met satisfactorily only by an automatically controlled throttle if a uniform plowing speed is to be maintained.

Belt Work. A far greater load variation is encountered in belt work than in plowing, as in the former the engine may be running practically idle at one moment and be almost choked down by overloading the next, whereas in the latter there is always a load on the engine and therefore the danger of racing is absent. Irregular speed under changing load, racing of the idle engine, and tardy opening of the throttle to meet the increased load, all of which are unavoidable with hand control, represent conditions of operation which not only reduce production at the machine being driven but are very bad for the engine itself as they result in overheating, prevent proper lubrication, and, not infrequently, result in burned-out bearings. In any case the provision of a governor on the engine releases a hand for other and more productive labor. The majority of tractors go into service in the hands of an unskilled operator, and unless there is a governor on the engine, his course of instruction is likely to be marked by the occurrence of more or less damage that automatic control would prevent.

Centrifugal Governors. Despite almost innumerable attempts to displace it, the centrifugal principle first taken advantage of more than a century ago to control the speed of a steam engine is still in almost universal use for this purpose. Most tractor engines are equipped with what is commonly termed a fly-ball governor, though the details of the mechanism and the character of the throttle valve it is employed to control differ more or less. In its simplest form such a governor consists of two weights on the end of oppositely placed arms which are pivoted on a spindle connected to the throttle valve, either directly or through suitable linkage, so that any movement of the weights is communicated directly to the throttle. On a stationary engine the governor may

Fig. 58. Simplex Engine Governor
Courtesy of Duplex Engine Governor Company, Brooklyn, New York

be placed upright and is not subjected to vibration or jolting, so that gravity alone may be depended upon to keep the weights in their normal position, but on the tractor springs are usually employed, and the governor may then be placed in any position. When running below a certain speed, either gravity or the pull of the spring is sufficiently strong to keep the weights together against the shaft or close to it. But as the speed increases, centrifugal force acts on the weights and tends to make them assume a position at right angles to the shaft. The faster the engine runs, the closer the weights approach to this position, but as their movement brings about a proportionate closing of the throttle, the engine is not given an opportunity to increase its speed. A well-balanced governor of this type will operate so sensitively that there will be practically no perceptible change in speed between idling and full load. So far as the tractor is concerned, centrifugal governors are of two general types, those that are an integral part of the design of the engine and are built right into it and those that are in the nature of auxiliary devices designed to be attached to the inlet manifold between the carburetor and the intake valves.

Auxiliary Types. The Simplex governor, shown in Fig. 58, and the Pierce, illustrated in Fig. 59, are examples of governors designed to be adapted to any make of motor, the only modification necessary depending upon the details of the drive, since the governor must be driven directly from the motor itself. In the

Fig. 59. Section of Pierce Engine Governor
Courtesy of Pierce Governor Company, Anderson, Indiana

Simplex the governor weights, which are housed in the casing just under and to the left of the oil plug shown, operate a grid valve the openings of which appear in the intake manifold flange at the left. The driving attachment, designed in this instance for a flexible shaft drive, appears at the right. Fig. 60 shows the attachment of a Simplex governor to a Continental motor, the drive in this case consisting of a solid shaft and bevel gears operating from the camshaft. The governor is set for the maximum speed to which the motor on which it is mounted is best adapted and is then sealed, as shown at the left end. As the governor mechanism runs in a bath of oil, it requires no attention except to replenish the oil from time to time.

Fig. 60. Installation of Simplex Governor on Continental Motor of Bullock Tractor
Courtesy of Bullock Tractor Company, Chicago, Illinois

Fig. 61. Installation of Pierce Governor on Buda Motor
Courtesy of Pierce Governor Company, Anderson, Indiana

The Pierce governor, which is shown in horizontal section, operates a conventional butterfly type of throttle valve such as is used in the majority of carburetors. This valve is shown at the left, while the weights and the driving attachment are at the right. Between the two is the spring against which the centrifugal force of the revolving weights must act to close the throttle. Just above

Fig. 62. Built-In Governor of Creeping-Grip Tractor
Courtesy of Bullock Tractor Company, Chicago, Illinois

the left-hand end of this spring will be noted a screw adjustment by means of which the speed for which the governor is set may be altered. Increasing the tension of the spring by screwing this in permits an increase in the speed of the motor since the weights must then revolve at a higher speed in order to overcome the pull of the spring. This is the principle upon which the adjustment of all centrifugal governors is based. One method of attaching the Pierce governor is illustrated in Fig. 61, which shows it mounted on a Buda motor and driven through bevel gearing from the camshaft.

Built-In Types. The part sectional end view of the engine of the Creeping Grip tractor, Fig. 62, illustrates an excellent example of a built-in governor. This is driven from a transverse shaft which takes its power through helical cut gearing from the timing gear of the motor, the same shaft also serving as the magneto drive. In expanding, the revolving weights draw in the sliding shaft shown, which is linked to a bell-crank lever at its outer end. The lever is attached to the throttle, which will be noted just to the right of the carburetor. This bell-crank lever is also attached by linkage to a dash pot to prevent the governor from "hunting," or "surging," as it is

Fig. 63. Governor and Magnetic Unit of Creeping-Grip Tractor Motor
Courtesy of Bullock Tractor Company, Chicago, Illinois

Fig. 64. Emerson-Brantingham Motor, Showing Governor
Courtesy of Emerson-Brantingham Company, Rockford, Illinois

variously termed, that is, fluctuating violently over a wide speed range. This governor is designed to control the speed of the motor between a minimum and a maximum of 400 to 700 r.p.m. and is adjustable by means of the hand lever shown in Fig. 63, which illustrates the combined governor and magneto unit before attachment to the motor.

In Fig. 64, which shows the complete power plant of the Emerson-Brantingham 12–20 tractor, is illustrated another type of built-in governor, the details of which are clearly shown. This governor is driven by a belt and is of the usual steam-engine type in which the weights are carried on leaf springs, the movement being transmitted to the throttle through the linkage shown.

TRACTOR CLUTCHES

Functions of Clutches. Since the internal combustion motor cannot be started under load and will stall if the load be applied too suddenly, even though the engine is developing its full power, it is necessary to employ a means of picking up the load gradually as well as of connecting or disconnecting the motor from the load as desired. This means is the clutch; and clutch problems on the tractor are the same in kind but greater in degree than those encountered on the automobile since the load to be started is so much greater. An automobile need start its own weight only and in doing so it encounters but slight rolling resistance, whereas the tractor must not only get a very much greater weight under way but in starting it must overcome the far greater resistance represented by the plows or other load and also that of the ground itself.

As a general rule the types of clutches employed on tractors are the same as those used on automobiles, but they are given a considerably increased area of contact surfaces and these surfaces are held together under much higher spring pressures in order to carry the heavier load. Regardless of its type, the principle of the friction clutch is based upon holding the driving surface (directly connected to the motor) and the driven surface (directly connected to the transmission or speed reduction gear) in contact under a pressure per square inch that is greater than that exerted by the engine in carrying the load. When the pressure required to carry the load exceeds that exerted by the clutch spring, the contact surfaces slide upon one another and the clutch is said to *slip.* Unless this slipping took place, some one of the links in the transmission between the wheels or tracks and the engine would have to give way or the engine itself would be stalled by the load. It is accordingly the function of the clutch to slip, first, to insure gradual engagement in picking up the load and, second, to prevent damage to the transmission or the motor when the load becomes excessive. The latter function, however, is more important in theory than in practice since an excessive load almost

Fig. 65. Transmission Unit of Illinois Tractor Showing Multiple-Disc Clutch
Courtesy of Illinois Tractor Company, Bloomington, Illinois

invariably stalls the motor before the clutch begins to slip, unless its surfaces have become glazed through wear or its spring has weakened.

Types of Clutches. In practically every case the flywheel of the motor itself forms the driving member of the clutch. The driven member may be a cone faced with asbestos-wire fabric, a plate faced with similar friction fabric, or a contracting band similarly faced which is mounted so as to contact with the rim of the flywheel itself or with that of a smaller drum attached to the flywheel; or friction-faced shoes may be arranged to expand against the inner face of the flywheel. The moving force in every case is the clutch spring. In the order mentioned, these types are known as the cone, plate, contracting-band, and expanding-band, or expanding-shoe, clutches. Where a greater contact area is desired than is afforded by the diameter of the flywheel, a series of plates or discs is employed. These plates are divided into two groups, one of which is carried on spindles or bolts attached to

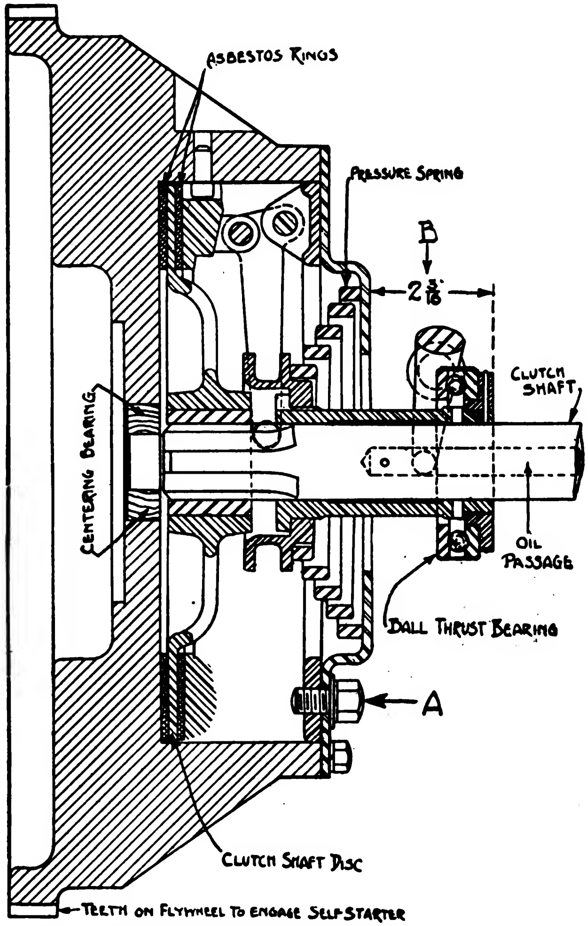


Fig. 66. Section of Dry-Plate Clutch As Used on Moline Tractor
Courtesy of Moline Plow Company, Moline, Illinois

the flywheel and forms the driving member, while the second group is similarly mounted on members attached to the clutch shaft and forms the driven member. When in engagement, the two groups are pressed together by the clutch spring in the same manner as in other types of clutches. This clutch is known as the multiple-disc type, and in some instances it operates in a bath of lubricating oil, the latter being squeezed from between the plates as they come in contact, thus ensuring gradual engagement. In Fig. 65 is shown the multiple-disc clutch of the Illinois tractor, the clutch being the small group of plates shown at one end of the transmission unit.

Plate Type. The sectional diagram, Fig. 66, not only serves to illustrate the details of the dry-plate clutch but also makes clear the principles of clutch operation. This is the Borg and Beck clutch as used on the Moline tractor. One of the asbestos

Fig. 67. Main Clutch of Holt Caterpillar Tractor
Courtesy of Holt Manufacturing Company, Inc., Peoria, Illinois

rings shown is attached to the flywheel, while the second ring is carried on the driven clutch member, while between the two is the clutch disc, which is a ring or disc of steel also attached to the clutch shaft. By means of the collar and toggle levers which multiply the force exerted by the spring, this clutch disc is clamped between the two asbestos rings when the clutch is engaged. The backward pressure, or reaction of the spring, is taken on the ball thrust bearing shown, this being an essential of all types of cone or plate clutches since otherwise this back pressure of the spring would cause considerable frictional resistance to the revolution of the clutch shaft. The screw marked *A* is an adjustment to maintain the distance *B* indicated, this distance being necessary for the complete release of the clutch when disengaged.

Expanding-Shoe Type. The Lauson tractor clutch affords an example of the expanding-shoe type which calls for very little

Fig. 68. Friction Transmission of Heider Tractor
Courtesy of Rock Island Plow Company, Rock Island, Illinois

explanation. Against the inner face of the flywheel are two pivoted shoes which are counterbalanced. These shoes are faced with asbestos brake lining and are designed to be held in contact with the inner face of the flywheel rim by means of the toggle mechanism shown. The spring has the same location as in other types of clutches, while its purpose, like that of other clutches, is to hold the clutch friction surfaces together under a pressure greater than that exerted by the engine in driving the tractor under load. The main clutch of the Holt caterpillar tractor is of a similar type, Fig. 67.

Contracting-Band Clutch. Neither the contracting-band nor the cone clutch calls for much description. The contracting-band clutch is practically a duplicate of the usual brake mechanism in which a friction-lined band is pressed against a revolving drum to bring the latter to a stop. In the case of such a clutch the object is to bring the contracting band to a stop on the drum, which is

Fig. 69. Bevel Friction Transmission of Square Turn Tractor
Courtesy of Square Turn Tractor Company, Norfolk, Nebraska

the flywheel, so that both the band and the flywheel revolve together, this really being the only difference between the brake and the clutch mechanism. The contracting band is attached to the clutch shaft, or driven member, and when in operation, revolves with it, thus carrying the load. This clutch is used in connection with a planetary type of transmission and is accordingly familiar through its employment on many thousand Fords.

Cone Clutch. In the cone clutch the inner face of the flywheel is turned to a bevel of approximately 30 degrees to form the driving member into which a cone-shaped member with the same bevel and lined with asbestos or other friction facing is pressed by the spring. Owing to the necessarily limited area of friction contact in this type of clutch, a high spring pressure is necessary where a heavy load must be transmitted.

On the automobile this spring pressure is very much less than on the tractor owing to the slight resistance encountered by the machine in starting, so that the clutch may readily be disengaged with the foot through the medium of a short lever and pedal, but on any tractor except a very light one the effort required to do this would be excessive. The usual method of clutch operation on the tractor is accordingly by means of a long hand lever provided with a ratchet or locking detent, so that the clutch may be held out of engagement. Since it does not benefit the spring to keep it compressed, the clutch should not be locked out of engagement any longer than is necessary to shift the transmission gears to neutral, when the clutch should again be allowed to engage. Holding the clutch out of engagement overnight or while the tractor is standing in the field subjects the clutch spring to abuse and will soon result in weakening it to the point where the clutch slips whenever any extra load comes on it.

Friction Drive. While all the types of clutches mentioned are, in a sense, a friction drive in that friction is depended upon to transmit the power, the so-called friction drive is one in which the load transmitting members revolve independently of one another except for a single point, or line, of contact. This is made clear by the illustration of the friction transmission of the Heider tractor, Fig. 68. The flywheel is the driving member, as usual, but in this case its entire outer rim is covered with a special friction facing consisting of hard fiber. The flywheel rotates between two large steel discs, either one of which may be pressed against it. In this instance the left-hand disc is used for forward movement and the right-hand disc for backing, or reverse. It is also apparent that the point at which the flywheel makes contact with the disc determines the speed at which the latter and the tractor itself are driven.

In the position shown the tractor speed will be the lowest provided, since the flywheel is in contact with the outer edge of the disc, so that the relation of the two is that of a small gear to a large one and the speed of the latter is reduced. As the flywheel moves toward the center of the driven disc, the relationship between the two becomes that of driving and driven gears which approach closer and closer to the same size, so that the speed of the driven member is increased. This movement of the flywheel is accomplished by mounting the motor itself on slides on the frame and moving it backward or forward by means of a large hand lever. The direction of movement of the tractor depends upon which disc is pressed against the flywheel.

Both Wheels Forward *Both Wheels Reversed* *Left Wheel Forward*

Right Wheel Reversed

Fig. 70. Details of Operation of Bevel Friction Transmission
Courtesy of Square Turn Tractor Company, Norfolk, Nebraska

Bevel Friction Drive. The form of friction drive employed on the Square Turn tractor is shown in Fig. 69. In this drive the principle is exactly the same as already outlined, except that friction-faced (fiber) conical members take the place of the flywheel as the driving member and corresponding cones of iron are the driven members. The design is also modified to permit of driving either rear wheel independently or both in different directions at the same time in order to turn short corners. The small diagrams showing the different relations in which the driving and driven members may be placed, Fig. 70, explain the operations much better than a description. A separate hand lever controls each of the driven discs, or traction members. Moving both of them forward drives the machine ahead through both driving wheels; pulling them back reverses the movement; and each may be used independently, so that one drives forward while the other is backing, thus turning the machine as if on a pivot.

TRACTOR TRANSMISSIONS

Speed vs. Weight. The power generated in an engine, whether by the expansion of steam or that of the ignited gases in an oil engine, is converted into mechanical energy by applying it to the movement of weight, and the power itself is represented by the extent of that weight and the number of times per minute that it is moved. Hence, for a given power the slower the speed at which the engine runs, the heavier must be the weight moved since it is set into movement a smaller number of times per minute. By increasing the speed, or number of impulses per minute, the weight moved can be correspondingly reduced. This fact explains why 25 hp. may be generated by a single cylinder stationary gas engine running at 250 r.p.m. or by a four-cylinder motor running at 1000 r.p.m. and why one motor is scarcely more than one-eighth the size of the other, although their power output is the same. The single cylinder engine will weigh 2 tons or more and will have flywheels of large diameter weighing more than the total weight of the smaller engine, but both move the same amount of weight per minute.

Automobile Practice. On the automobile the object of the designer is to keep the total weight down as much as possible consistent with reliability, so that light high-speed motors running up to 2000 r.p.m. or higher are employed. Such motors are practical for automobile use because the speed ratio between the driving and driven members—the motor and the rear wheels—is not excessive despite the high speed of the motor.

Tractor Practice. But on the tractor, where the maximum speed in plowing cannot exceed three miles per hour and is preferably less than that (2⅓ miles per hour is recommended by the Society of Automotive Engineers and most tractors are designed to plow at 2½ miles per hour), the higher the speed of the motor, the greater the number of steps required in the gear reduction, and each step represents a loss of power in friction as well as additional parts to wear out. Since the tractor is not subject to the same weight limitations as the automobile, there is no advantage in employing a light high-speed motor. Generally speaking, the slower the speed of the motor consistent with the avoidance of excessive weight, the better adapted it is to tractor use. The slow-speed motor running at 450 to 750 r.p.m. also has the further advantage of subjecting its moving parts to less rapid wear in service and, other things being equal, should require less attention to keep in satisfactory running condition.

Function of Transmission. In the section on tractor motors it has been pointed out that the types in general use belong to two distinct classes: those which have developed with the stationary engine as a basis; and those that are an outgrowth of automobile practice. In either case the engine will only develop its normal rated power when allowed to run steadily at a rate close to its maximum speed. A gear reduction must accordingly be interposed between the motor and the driving members of the tractor; the speed of the motor determines how great this reduction must be, while the space and the limit of weight available determine what form it will take. Whether consisting of a compact unit such as is used on the automobile or of large pinions and gears occupying the entire space between the frame members of the tractor, this speed reducing mechanism is usually termed the transmission. This name includes everything between the clutch and the final application of the power to the wheels or the tracks, which is termed the final drive.

Wide Range of Types. Since tractor motors differ so widely, there is naturally a correspondingly wide range of types of transmissions, the latter varying all the way from what is practically a duplicate of the gear train used on heavy steam tractors, or road rollers, to the light and compact gear box used on high-speed automobiles. A few illustrations of typical examples of each class will suffice to give an idea of how widely this feature of the tractor varies on different designs. In comparing these, it should be borne in mind that while increased width of gear face affords a larger wearing surface to carry the load and large gear diameter means fewer steps in the reduction, these advantages may be offset by the exposure of the gears to dirt and mud.

The great differences in size and weight, in many cases where the same amount of power is to be transmitted, are accounted for by a similarly great difference in the character of the materials used. Small pinions and gears running at high speeds must be made of alloy steels, hardened and toughened by heat treatment, and must be run in a bath of oil. Large broad-faced gears, on the other hand, may be made of steel castings or even cast iron, and it is the usual practice to run them to a great extent without protection.

Speeds. Since the speed range of the average farm tractor is necessarily very low, its requirements are usually covered by the provision of but two forward speeds and one reverse. A few machines are provided with three speed transmissions, but this is the exception and is due to the use of either a high-speed motor or an automobile-type transmission. On low gear, which is equivalent to a forward speed of about one mile per hour, the speed reduction between the motor and the driving wheels of the tractor may range all the way from 40–1 to 80–1, that is, the motor makes 80 revolutions to a single turn of the driving wheels in the second case mentioned. Such a great difference between the motor speed and that of the machine itself necessitates a number of gear reductions, each one of which involves a power loss in itself and also presents an extra wearing surface that needs replacement sooner or later. Generally speaking, the lower the speed of the motor consistent with the avoidance of excessive weight, the less loss there will be in the transmission of the power to the rear wheels or tracks, as the case may be. The point below which it does not pay to reduce the motor speed appears to line between 400 and 500 r.p.m., as beyond that the weight increases all out of proportion to the advantage gained, while the upper limit lies between 700 and 800 r.p.m.; that is, a low-speed motor would govern between these limits, say 450 to 750 r.p.m., and its transmission would be designed to take care of the difference between 750 r.p.m. and the number of turns per minute made by the driving wheels, which would depend upon their diameter.

A high-speed motor, on the other hand, would run at 1000 to 1200 r.p.m. and its power would fall off very rapidly the moment its speed dropped below 800 r.p.m. To avoid an excessive number of gear reductions, the driving wheels of a tractor equipped with a high-speed motor would usually be made comparatively small,

Fig. 71. Friction Drive of the Port Huron 12-25 H.P. Farm Tractor
Courtesy of Port Huron Engine and Thresher Company, Port Huron, Michigan

which is a disadvantage since such a tractor is constantly climbing the grade formed by its small wheels sinking into soft earth, or depressions, and is accordingly expending a large fraction of its

Fig. 72. Plan View of Avery Transmission
Courtesy of Avery Company, Peoria, Illinois

power in lifting itself rather than in driving ahead. It does not necessarily follow that a tractor equipped with a high-speed motor always has small driving wheels, since the reduction in speed required may be taken care of in the final drive.

Heavy Types. Those transmissions which, as already mentioned, represent a continuance of the practice followed for years on heavy steam tractors and road rollers are known as heavy types. Such a transmission is shown in Fig. 71, which gives a plan view of the Port Huron 12–25 friction-driven tractor. It also affords an example of a tractor with a comparatively high-speed engine equipped with large driving wheels. There are three gear reductions in all: the first will be noted at the left; the second is from this transverse shaft to a central gear on a shorter transverse shaft which also carries two small pinions meshing with the bull

Fig. 73. Transmission and Differential of 75 HP. Tracklayer Tractor
Courtesy of C. L. Best Gas Tractor Company, San Leandro, California

gears. Ordinarily the bull gears are attached directly to the driving wheels, but in that location it is difficult to protect them, while in the present design they are completely encased.

Since a tractor must make very short turns and both wheels must be driven when going straight ahead, a differential is indispensable. When rounding a short turn, it will be evident that the wheel on the outside of the curve must travel a much greater distance than that on the inside and that if both were driven at an equal speed, one would be forced to slip and impose a heavy strain on the machine. If the ground condition were such that the wheel would not slip, rounding the turn would be difficult.

In the Port Huron tractor illustrated the differential is located in the second transverse shaft which carries the pinions meshing with the bull gears. As changes in speed are effected through the friction drive, the gears of this transmission are constantly in mesh.

The Avery transmission shown in Fig. 72, is another example of the heavy type, the illustration showing the relation of the horizontal motor to the transmission. The two forward speed reductions are represented by the two pinions of different sizes carried directly on the crankshaft of the motor, while the reverse speed is the pinion just forward of these. The transverse shaft just under the rear end of the motor embodies the differential the housing of which will be noted at the right. This shaft also carries the pinions meshing with the bull gears. The complete power plant is carried on a sliding frame, and the different speed changes are effected by moving the motor so as to bring the different pinions into mesh with the large gear carrying the differential.

Fig. 74. Cotta Automobile Transmission of Dog-Clutch Type As Used on Four-Drive Tractor
Courtesy of Cotta Transmission Company, Rockford, Illinois

Intermediate Types. Between the heavy types just described and what is practically a motor-truck transmission, there are a number of transmissions that conform to some degree with automobile gear-box practice but are built on much heavier lines, for example, the transmission of the Best 75 hp. tracklayer type tractor shown in Fig. 73. Sliding gears are employed for the speed changes, and a bevel pinion and driving gear on the counter-shaft which incorporates the differential, the internal bevel gear of which shows plainly in the illustration. A typical automobile-type transmission is the Cotta, Fig. 74, as used on the Four Drive tractor.

Fig. 75. Transmission and Spring Drive Differential of 16-30 Oil-Pull Tractor
Courtesy of Advance-Rumely Thresher Company, Inc., Laporte, Indiana

Fig. 76. Transmission of Turner Tractor
Courtesy of Turner Manufacturing Company, Port Washington, Wisconsin

A clearer view of the details of the mechanism of a differential is shown in Fig. 75, which illustrates the Rumely 16–30 transmission. One of the features of this differential is the use of a series of eight springs for taking up the shock of starting which will be noted just inside the large gear. Upon engaging the clutch, these springs must first be compressed before the load falls upon the gear teeth, thus cushioning the latter. Other similar transmissions are the Turner, Fig. 76, the Hart-Parr, Fig. 77, and the Nilson, Fig. 78.

Fig. 77. Transmission of Hart-Parr Tractor
Courtesy of Hart-Parr Company, Charles City, Iowa

Special Types. In Fig. 79 is shown a plan view of the transmission of the Twin City 25–45 tractor, a feature of which is the use of toothed, or *dog*, clutches, the details of which are clearly shown. This view also shows the contracting-band clutch used on this machine. The dome just to the right of and forward of the flywheel houses the engine governor. Automobile practice is closely approached in the Yuba transmission, Fig. 80, and in the Holt caterpillar transmission, the gear box of the 10-ton Holt

Fig. 78. Transmission of Nilson Tractor
Courtesy of Nilson Tractor Company

Fig. 79. Contracting-Band Clutch and Transmission of Twin City Tractor
Courtesy of Minneapolis Steel and Machinery Company, Minneapolis, Minnesota

Fig. 80. Dual Automobile Type Transmission of Yuba Tractor
Courtesy of Yuba Manufacturing Company, Marysville, California

Fig. 81. Transmission of 10-Ton Holt Caterpillar
Courtesy of Holt Manufacturing Company, Inc., Peoria, Illinois

tractor being shown in Fig. 81. Both these types are of the selective sliding-gear type generally used in automobiles, the Yuba

Fig. 82. Worm Drive of Sandusky Tractor
Courtesy of Dauck Manufacturing Company, Sandusky, Ohio

Fig. 83. Transmission of Huber Light Four Tractor
Courtesy of Huber Manufacturing Company, Marion, Ohio

transmission clearly showing the individual clutches which are used in the tracklaying machine to enable the operator to drive either track separately when turning. A feature taken directly from automobile practice is the use of the worm drive, Fig. 82. The Huber, Fig. 83, is a type that is in a class by itself. Its details and method of operation are clearly indicated in the illustration.

Final Drive. As in the case of the automobile there is a further speed reduction between the engine and rear wheels in the final drive, but as the speed reduction between the tractor engine and its driving members, whether the latter be wheels or tracks, is so great, this cannot take the form of a small pair of bevel

Fig. 84. Sectional View of Emerson-Brantingham Company Transmission, Showing Oil Level
Courtesy of Emerson-Brantingham Company, Rockford, Illinois

gears. The usual method is to employ bull gears, or internal gear rings of large diameter which are bolted to the driving wheels and with which small pinions on the ends of the transverse shafts of the change-speed gear mesh. In some instances automobile practice is followed by using a live axle. This is a combination of a sliding change-speed gear of the selective type with a planetary gear. The sectional view of the Emerson-Brantingham transmission, Fig. 84, clearly shows the relation of the selective sliding gears and the oil level necessary for lubrication.

Fig. 85. Details of Final Drive, or Track of Holt Caterpillar Tractor
Courtesy of Holt Manufacturing Company, Inc., Peoria, Illinois

Fig. 86. Final Drive of C. L. Best Tracklayer Tractor
Courtesy of C. L. Best Gas Tractor Company, San Leandro, California

Fig. 87. Details of Final Drive of Yuba Ball-Tread Tractor
Courtesy of Yuba Manufacturing Company, Marysville, California

Final drive in tracklaying machines is usually through large sprockets on the ends of the transverse shaft, these sprockets meshing in the track itself. The track runs on rollers or balls and passes around an idler at the end of the tread, this idler being made adjustable so as to vary the tension on the continuous track. The details of the Holt caterpillar, the Best tracklayer, and the Yuba ball-tread machines of this type are shown in Figs. 85, 86, and 87, which make the principles of operation so clear that further explanation is unnecessary.

Only a brief mention has been made of a few of the different types of transmissions and final drives employed on tractors, there being so many that it would be out of the question to attempt to describe all of them, particularly since not a few have numerous special features. The foregoing examples, however, cover the principles employed in practically all tractor transmissions and suffice to make clear the manner in which these principles are applied.

TRACTOR OPERATION

GENERAL INSTRUCTIONS

Tractors Different in Design but Alike in Care Required. In the foregoing pages an attempt has been made to outline briefly the principles of tractor operation with just sufficient references to actual types to make the text clear. At the present stage of development it is hardly possible to select any one manufacturer's product as typical of tractor design in general or as embodying throughout those features of design which are most likely to become standardized during the next five years of development. There are so many different makes on the market and frequently so many models of each make that it would require a volume larger than the present one merely to give a brief description of all of them. Consequently, no extended descriptions of any tractors are given here.

While designs and details of construction differ so widely and so frequently, all oil or gas engine tractors are based on certain underlying principles and all call for the same kind of care. The remainder of this article is accordingly devoted to an outline of the methods of handling tractors in service with a view to pointing out clearly just the kind of care the machine needs to keep it running efficiently. To facilitate reference, this information is put in the form of questions and answers grouped under the particular subjects which they cover.

Degree of Care Necessary. Before taking up the detailed consideration of tractor operation it is well to revert for a moment to the comparison between the automobile and the tractor in order to emphasize the great difference in the conditions of operation of the two. It is a great mistake for the owner or operator of a tractor to conclude that because he can keep his car running for weeks at a time and subject it to the severest kind of service without being called upon to give it more than passing attention at infrequent intervals, the same amount of care will suffice to keep the tractor running equally well. The most severe service to which an automobile can be subjected is trifling compared to what a tractor must undergo in plowing ten hours a day. No comparison between the two is possible. The attention demanded in running a tractor is really only comparable to that required by a marine engine which is run steadily at full power.

It is naturally impracticable to employ more than one man to run the average tractor so that the single operator must assume the combined tasks of the oiler, engine-room attendant, and engineer on watch in the engine room of a steamer. He must see that every part is constantly lubricated, must watch all moving parts in sight from time to time and keep all his senses on the alert all the time to detect the first indications of overheating or faulty operation as evidenced by the sounds produced.

Parts Giving Most Trouble. Over two thousand tractor owners sent in reports in answer to a questionnaire forwarded to them by the Department of Agriculture. In answer to the question "What part of your tractor gives you most trouble?" more than seven hundred mentioned some part of the motor and of that number considerably over one-half gave the ignition as the chief source of delay. A leading tractor manufacturer substantiates this by stating in his instruction book that the motor is responsible for fully 75 per cent of all tractor troubles and that

70 per cent of the motor trouble is due to the ignition. A resumé of the answers sent in to the questionnaire follows:

Magnetos	299	Cylinders and pistons	61
Spark plugs	110	Clutch	59
Gears	108	Valves and springs	43
Carburetor	104	Lubrication	29
Bearings	80	Starting	28

The figures given in each case represent the number of tractor owners who gave the part in question as the chief cause of their troubles in operation. These figures do not, however, give any idea of the relative importance of the parts as sources of trouble. Failure of the magneto, or even of a spark plug, brings the tractor to a halt, but the trouble may usually be remedied in a very short time and no damage is caused, whereas a breakdown due to faulty lubrication, or to the failure of the cooling system, which is not mentioned at all, will usually involve the loss of anywhere from a day to a week besides a heavy repair bill.

Supply of Spares Necessary. The cost of an ample supply of spare parts is small compared with the time that is saved when the part most needed is right at hand and can be installed without delay, so that a number of spares of the most necessary parts should be considered part of the investment and be bought at the same time as the machine. Unless it be an ocean-going steamer, there is hardly another piece of machinery that performs such strenuous service so far from a repair and supply base as does the tractor. It would be just as foolish for the chief engineer of a steamer to leave port without any spare parts in the storeroom and still expect to arrive at his destination, regardless of what happened, as it is for a farmer to purchase a tractor and expect to get through his first, second, or any other season of plowing or threshing without vexatious delays unless he has on hand spares of the parts most frequently needed.

Manufacturer's Service Poor. While it would not be just to generalize by saying that the service rendered the purchaser by every manufacturer of tractors is poor, this is true in many cases and must always remain so for the farmer who is located miles from the nearest dealer representing the factory. It is nothing unusual to waste from half a day to a day, telephoning and waiting for a part to be sent out or driving in for it. The dealer may be off for the day in some other part of the county, making a demonstration or closing a sale, and there may be no one in his place of business to render the desired service. Meanwhile, the machine is standing idle. There are few replacements that the experienced driver of a tractor cannot make without other assistance than that provided by the usual farm shop, so that if the parts are on hand little time will be lost in getting the machine under way again.

Parts Needed. While the make of the tractor in question will determine the character of many of the spares that should be carried by its owner, there are some that are needed with all makes. These are valves, valve springs, and small parts needed in connection with the valves, ignitors, or make-and-break plugs for low-tension ignition systems, also ignitor trip rods, or rather the small parts which compose the fittings of the rod rather than the rod itself, since the latter is not subjected to wear. Spare connecting cables cut to length and fitted with terminals, whether for high- or low-tension systems, will often be found valuable. Extra fan belts and spark plugs should hardly be called spare parts in this connection since they are absolute necessities at comparatively short intervals. Hose connections between the motor and the radiator are also in the same class. Where a motor is equipped with die-cast main bearings or connecting-rod bearings, a spare set will often prove to be worth many times its cost in the saving of plowing or threshing time, since even well-attended machines do suffer breakdowns from burnt-out bearings at times. Extra piston rings as well as an extra piston and a connecting rod are likely to be called for sooner or later. The magneto is a pretty expensive piece of equipment and, moreover, it is usually so reliable that it will continue to work season after season without giving any trouble. But when it does break down, it is sometimes beyond the ability of the tractor operator to make the repair. Where two or more tractors are operated on a farm and the same magneto is standard on all of them, it would pay to invest in a spare, though at any time but the height of the season the laying up of one tractor would probably not cause any trouble.

The foregoing discussion has been confined to enumerating motor parts or accessories that should be carried as spares since they are common to practically all motors. So far as the rest of the machine is concerned, the owner must either learn from experience what parts are likely to wear out rapidly and need replacement at short intervals, or he must depend upon the manufacturer's representative to give him this information. Naturally, the maker and his salesmen do not wish to give the impression that any of the machine's parts will need replacement in a short time, and in a good many instances they are as much in the dark as the purchaser is, since it may be that the model has just been placed on the market and there has been no opportunity to learn its weak points in actual service.

Both the time spent in getting information of this kind and the money invested in the necessary spare parts will return very substantial dividends when the occasion arises to use the parts. There are some parts that may never be used, such as a steering knuckle. Get the manufacturer's representative to give you a frank opinion. Point out your position, when isolated, and do not content yourself with his first recommendations. Insist on finding out what are the weak parts of every important unit. The factory man has a good line on this by the extent of the demand for certain replacement parts. It will usually be found a paying investment to purchase a stock of almost all of them rather than take chances on getting the particular part most needed at a time when the tractor is worth a good many dollars an hour to you.

LUBRICATION

MOTOR LUBRICATION

Q. What grade of lubricating oil should be used for a slow-speed tractor motor; for a high-speed type?

A. Every responsible tractor manufacturer goes to considerable expense to determine just what grade of lubricating oil is best adapted to his own engines. His investigation covers everything from a chemical analysis and flash test of every grade of oil recommended for his use to actual tests in service extending over considerable periods of time. The tractor owner should accordingly never use anything but the oil recommended by the manufacturer.

Q. In a motor having any form of splash lubrication, that is, one in which part of the supply is carried in the crankcase pan, how often should the oil be drained from the crankcase?

A. The recommendations of different tractor manufacturers range all the way from every day to once in two weeks, many giving one week as the maximum period of time the same oil should be used.

Q. How often should the oil in a circulating system be completely replaced with a fresh supply?

A. It should be replaced at the intervals given above for a splash system since the service demanded of the lubricant is the same.

Q. Does oil lose its lubricating qualities through use, and how can this be determined?

A. High temperature and pressure completely change the character of lubricating oil and destroy its lubricating qualities. The lubricating quality of an oil depends upon its viscosity, that is, its *body*, upon which depends its ability to hold apart surfaces under pressure by a film of lubricant. Dip the finger ends in some old oil from the crankcase and rub together under pressure. The oil will have a thin watery feeling and the finger tips may be pressed into close contact through it. Try the same experiment with some fresh oil, and it will be noted that a sliding film is formed between the fingers despite the greatest pressure that can be put upon them to squeeze it out.

Q. What influence has the effect of high temperature and pressure on the length of time during which the oil should be allowed to remain in the crankcase?

A. Both the temperature and the pressure conditions differ widely in different engines so that in some the oil literally *wears out* much faster than in others and should accordingly be replaced oftener. The tractor manufacturer has learned from experience the proper period of time for his motors, and his recommendation is based on a desire to avoid having his customer pay for the same experience.

Q. Next to labor and fuel, lubricating oil is the most expensive item of tractor maintenance. Is it really economy to

replace what appears to be good oil as often as the tractor manufacturer recommends it?

A. The cost of repairs due to a single breakdown from failure of the lubrication would usually buy anywhere from one to five or more 50-gallon barrels of oil, without taking into account the loss of time due to the tractor being out of service. It is the highest form of economy to follow the maker's instructions in this respect; if these are to discard the oil at the end of every day's service, it will be found far cheaper in the end to do so. Many tractor owners do not regard it as necessary to clean out the crankcase more than once or twice a season, but instead of saving oil they are simply running up repair bills.

Q. What other causes tend to destroy the lubricating quality of the oil?

A. Another cause is leakage of the fuel past the pistons so that the supply of oil in the crankcase is thinned out by the gasoline or kerosene. This is particularly true of kerosene, especially if the motor be run at a low temperature so that the kerosene vapor condenses into a liquid. The admixture of carbon and dirt with the oil also tends to destroy its lubricating quality. Compare the color of oil that has been used for some time with fresh oil; the difference is due entirely to the foreign matter that has become mixed with it.

Q. What attention does a force-feed lubricator require?

A. The sight feeds should be watched frequently to note whether oil is constantly passing through them or not. To make certain of this, dirt should be wiped from the glasses at least once a day. While this type of lubrication has the great advantage of constantly feeding fresh oil to the bearings almost as fast as it is consumed, its factor of safety is not so high as that of the splash or circulating type. In other words, failure of the part is apt to follow immediately upon a stopping of the feed since it usually receives no lubrication from any other source. The lubricator must accordingly be watched closely and the engine stopped at once if any of the feeds has become clogged.

Q. How often should such a lubricator be supplied with fresh oil?

A. The maker's instructions may be followed but a still better practice is to get into the habit of keeping the lubricator constantly filled; that is, of filling it twice or oftener a day, if necessary, rather than waiting until the supply runs low. A gage glass on the side of the lubricator shows the amount in it. The plunger pumps which force the oil to the bearings will always work better when there is an ample supply.

Q. What other precautions should be taken with a force-feed lubricator?

A. When it is driven by a belt, close watch should be kept on the belt to see that it does not become too loose, since any slackening of the belt slows down the pumps and supplies less oil to the bearings.

Q. How often should a force-feed lubricator be cleaned out?

A. Two or three times a season should ordinarily be ample, but this will depend to some extent upon the care that is exercised in handling the supply of oil itself. Unless the oil supply is kept in a covered oil tank, more or less dust and other foreign matter is bound to find its way into it. The presence of dirt in the oil will make itself apparent by clouding the inside of the sight-feed glasses, making them difficult to read. Oil having visible foreign matter, such as small specks of grit, short ends of straw, or chaff, in it should never be put into the lubricator without straining, as it is liable to clog the pump valves.

Q. How is a force-feed lubricator cleaned out?

A. By disconnecting the leads and flushing it out thoroughly with gasoline or kerosene. The leads should be disconnected at both ends and also flushed out, blowing through them to see that they are clear from end to end.

Q. Are some of these leads more apt to clog up than others?

A. Those that supply oil to the pistons are most likely to clog owing to an accumulation of carbon in the ends opening into the cylinder. They should be taken off at shorter intervals and all carbon removed in the tube itself as well as in the opening through which the oil passes through the cylinder wall.

Q. What attention does a circulating system require?

A. A circulating system requires replenishing of the entire supply after washing out at intervals, as directed in the manufacturer's instructions; examination at short intervals of the oil pump; and frequent washing off of the oil pump screen. Keep the sight-feed glasses clean and shut down immediately if an oil stream fails to appear in any of them (some tractors have but one, others several).

Q. What general precautions should be observed in cleaning out a lubricating system of any type and in handling oil?

A. Always avoid the use of waste or rags from which lint will detach itself in wiping out the crankcase or any part of the system, since these threads will invariably clog an oil pump or feeder tubes. All cans or other vessels used in handling oil should be kept covered to prevent dust falling in them and should be wiped clean before using. Dust is simply fine grit, and its presence in the oil converts it into a grinding compound which will quickly cut away bearing surfaces.

Q. What other lubrication does the motor require?

A. This will depend entirely on the type of motor. Where it has overhead valves as used on many tractor motors, the rocker arm spindles and pin should be oiled at least once or twice a day with a hand oiler. This applies as well to any other external moving parts not lubricated by the oiling system of the motor. The grease cups on the fan and on the pump should be turned down at least once a day. Some tractors are equipped with gravity oilers for this purpose.

CONTROL SYSTEM LUBRICATION

Q. How is the clutch lubricated?

A. On some tractors it is enclosed in the same housing as the motor and runs in a bath of oil. Where it is not housed in, grease cups are usually provided on the clutch, and these should be turned down at least once a day. No oil should be allowed to fall on the facing, as this would reduce the holding power of the clutch and cause it to slip.

Q. What attention is required to keep the transmission properly lubricated?

A. When the transmission is of the enclosed type, running in oil, it should be kept filled to the height given in the maker's instructions and with the grade of lubricant recommended. Don't attempt to use cup grease, or a home-made compound of grease and oil or graphite, as the different materials will separate, nor should heavy steam cylinder oil be used, since it contains animal fats and will become acid, attacking the steel faces of the gears. The pressure between the gear teeth in a transmission is very high so that the oil *wears out* in time and should be replaced at intervals of two to three months. Watch the transmission housing for leaks and renew felt washers or other provision for preventing leaks.

Q. How are open transmission gears lubricated?

A. Where gears are run without a housing, they are not intended to be lubricated and care should be taken to see that no oil or grease gets on them as it will hold dirt and grit and cause the teeth to wear out much faster. The gears should be kept free of mud and dirt, but an oily rag or waste should never be used for this purpose. This also applies to the bull pinion and gear except where completely housed in.

Q. What attention is required to lubricate other moving parts of the tractor?

A. Grease cups are usually provided on all other moving parts, and they should be turned down as instructed by the maker. In some instances the directions are to screw these cups down as often as twice a day; in others, once an hour.

ENGINE PARTS

ENGINE BEARINGS

Q. How long will motor bearings run without developing sufficient play to require adjustment?

A. This will depend largely upon the motor itself and the service demanded of the tractor. If it is being run constantly with an overload, they will need attention much sooner than when the machine is not called upon to carry more than 75 per cent of its load for the greater part of the time. In any case the bearings should be examined at least once a week; some makers recommend that they be tested for looseness as often as twice a week when in constant service.

Q. How can the bearings be tested for looseness?

A. They should always be examined just after the motor has been shut down and is still hot; the amount of play will be greater when all the parts are cold but some of this will be taken up by the thickened oil film then present and their condition cannot be determined as satisfactorily. The connecting-rod bearings are the first to show signs of looseness. Take the handhole covers off the crankcase and turn the motor until two of the connecting-rod ends are close to the openings. If there is much play, it will be evident upon grasping the connecting rod and attempting to lift it, but this amount would usually cause a knock in operation. Take a small bar and pry the bearing upward from below, keeping the other hand on the rod to detect any movement. Do not confuse the side play of the bearing with looseness of the bearing itself as a small amount of side movement is allowed on all connecting-rod bearings. Apply this test to the other two connecting rods also. A bar may also be used to detect any looseness of the main or crankshaft bearings.

Q. Will it do any harm to allow a certain amount of play in these bearings?

A. Nothing will be apt to run up a big repair bill quicker than running the motor with the bearings too loose. Every reversal of movement pounds the crankshaft and in time will cause crystallization of the steel with consequent breakage of the shaft. The resulting vibration is also detrimental to every other part of the motor.

Q. How are the bearings adjusted when a test reveals play in them?

A. Most motor bearings are provided with shims, that is, small strips of metal placed between the halves of the bearing and through which the bolts pass to hold the bearing together. Take off one or more shims on each side of the bearing and screw down the nuts again tightly. To obtain a proper adjustment, you must be able to set up these nuts as far as they will go without binding the shaft. Open the pet cocks or the compression release, where one is provided on the engine, and try the adjustment by cranking the motor by hand. It will be very difficult to turn the motor over if the bearings are too tight. They should be adjusted so that the motor turns easily, indicating that there is sufficient space between the bearing halves and the shaft to permit the formation of an oil film between them. The shaft should be tested for play, as already described, to prevent making the adjustment too loose.

Q. When a bearing is too tight, is it good practice to ease off the nuts and let the shaft run that way?

A. A bearing is not properly adjusted unless the nuts can be set up hard on the bearing caps, all adjustments being made by removing or re-inserting shims, or laminations of metal only a few thousandths of an inch thick. One or two shims should be removed from each side at a time and the adjustment tested. Care must always be taken to see that the bearing cap is replaced on the bearing from which it was taken and that it is *put back in the same way.*

Q. Is it ever necessary to adjust the piston-pin, or wrist-pin, bearing?

A. This is the bearing which holds the upper end of the connecting rod in the piston and if the motor is properly lubricated with clean oil, it will seldom require any attention. In some motors the pin is held fast in the sides of the piston and the connecting rod moves on it, and shims are provided on the connecting-rod bearing for adjustment. In others the upper end of the connecting rod is clamped fast to the pin, and the pin moves in bronze bushings in the sides of the piston or bears directly on the piston walls. Allowing the big-end connecting-rod bearings and the crankshaft bearings to become too loose so that the motor knocks is the chief cause of lost motion in the wrist-pin bearing. Where the pin bears in the piston walls this may wear the holes out of round so that they have to be rebored and bushed to make a good bearing.

Q. When the connecting rod or crankshaft bearings of a motor require adjustment at frequent intervals, what is the cause of the trouble?

A. The cause is faulty lubrication: failure to clean out the crankcase at the proper intervals, with the result that the oil loses its lubricating qualities and the dirt that becomes mixed with it cuts away the bearing surfaces.

Q. Where bearings have become worn to the point where it is no longer possible to adjust them properly, is it practical for the average operator of a tractor to replace them with new bearings?

A. It is not practical unless he has had experience in the work, since it requires accurate lining up and scraping in of the bearings to a close fit. Unless this is carried out properly, such heavy stresses will be imposed on the crankshaft that it will break sooner or later. Therefore it is poor economy to attempt this repair without actually having had experience in making it; it is one of those things that cannot be learned from an instruction book. It is necessary to see it done in the shop more than once and the first attempt should be made under the supervision of one who has had experience.

VALVES

Q. What attention is required to keep the valves in good operating condition?

A. The valve stems must be lubricated one or more times a day, except on motors provided with special means for doing this automatically. The clearance between the valve tappet and push rod, or between the end of the rocker arm and the valve stem, depending upon the type of motor, must be adjusted at frequent intervals and the valves themselves must be ground as often as is necessary to keep them tight.

Q. Why is adjustment of the clearance necessary, and what should this be?

A. The constant hammering of the tappet or rocker arm against the valve stem tends to increase this clearance as well as to wear away the parts, thus increasing the distance. The greater this distance is the less the valve will lift when operated, so that less fuel is admitted on the intake stroke and some of the exhaust gases are left in the cylinder on the exhaust stroke, thus cutting down the power. This clearance should be just sufficient to allow the valve to close completely under the pull of its spring when the tappet or rocker arm is released by the cam. It should be tested and adjusted with the motor hot, since, if made very close when cold, the expansion of the parts is apt to prevent the valve from closing properly. An ordinary visiting card or a piece of tin plate makes a good gage; it should be possible to slip this between the tappet and stem easily. In any case the clearance should not exceed $\frac{1}{32}$ inch.

Q. How often should the valves be ground?

A. When a tractor is being used ten hours a day and six days a week, they will doubtless require grinding once every four to six weeks, depending more or less on the motor itself; some motors run very much hotter than others and in some the provision for cooling the exhaust valve is inadequate, so that more frequent attention is necessary.

Q. How may the valves be tested for leakage without taking the motor down?

A. Turn the motor over by hand about one-third of a revolution, until two of the pistons are within an inch or two of the upper dead center. At this point the pressure in the cylinder that is then on the compression stroke should be highest. Hold the piston up against this pressure, just exerting sufficient pull to cause the piston to move if the compression leaks away. In a motor that is in good condition, there should be no perceptible movement due to leakage in the course of two or three minutes, and if the pull of the hand is slackened, the piston should tend to push the starting crank down again under the influence of the pressure in the cylinder. Apply the test to each cylinder in turn and any difference in the compression-holding power of the different cylinders will be noticeable.

Q. When the usual adjustment of the clearance does not correct a loose and noisy valve action, what is apt to be the cause of the trouble?

A. The pin of the cam roller has probably worn so that there is considerable lost motion between the roller and the pin on which it turns. The only remedy is to replace the roller and pin or maybe the tappet complete. Any lost motion at this point permits the roller to move upward the distance represented by the wear before the tappet itself can lift. While the play at any one point may be very small, when it is increased by an equivalent amount at two or three other points, the total is sufficient to reduce the effective valve opening considerably, with a corresponding decrease in the power. When new parts are not readily obtainable, this condition may be remedied by boring out the holes of the cam roller and the rocker lever and fitting them with bushings.

Q. When grinding valves, is it necessary to continue the operation until the entire valve and seat have taken on a polish?

A. No; the operation may be considered complete when both the valve and the seat are smooth all around and completely free from any sign of pitting. A polished surface may give a little closer fit, but the difference is not enough to compensate for the time necessary to produce it. The grinding operation should always be finished by the use of the fine grinding compound.

Q. In case a motor has been allowed to run until the valve seats have become very badly pitted, is it necessary to cut these down by grinding alone?

A. No; a valve-seat reaming tool should be employed for cutting away the metal until the pitting has almost disappeared, and the remainder of the operation should then be carried out by grinding in the usual manner. No more metal than necessary should be removed with the reamer as cutting too deep will simply shorten the life of the cylinder casting. Valves are made in two standard tapers, 45 degrees and 60 degrees, and care must be taken to see that the angle of the reamer blades corresponds to that of the valve seat before beginning to cut.

Q. Is there any way of testing the tightness of the valves before putting them back into the motor?

A. When the valves are in cages, they may be tested by pouring some gasoline into the cage and noting whether it leaks past the valve or not.

Q. Does a rapid loss of compression under such a test always definitely indicate that the valves are at fault?

A. No; the piston rings may be worn or the lubrication may be poor, so that there is not a good compression seal in the cylinder. To definitely ascertain the trouble, take out the spark plugs and pour an ounce or two of heavy cylinder oil into each cylinder. Turn the motor over fifteen to twenty times with the plugs out to work this oil down on the pistons, replace the spark plugs and repeat the test as first described. Failure to hold compression will then mean poorly seating valves almost invariably, since, with a fresh oil seal, even loose piston rings will hold compression when the motor is being turned over by hand. The necessity for putting in this oil indicates that the oil in the crankcase or the circulating system needs renewing. This test for loss of compression should be carried out with the motor cold.

Q. What is the best method of grinding the valves?

A. With a valve-in-head type of motor, take the valve cages over to the bench so that there is no risk of getting any of the grinding compound into the cylinders. Use nothing but the specially prepared grinding compound designed for this purpose; ordinary emery and oil should never be employed as it will score the valve and its seat. When a special valve grinder is not at hand, a screw driver bit in an ordinary brace makes the best grinding tool. Smear some of the compound on the valve, drop it on its seat and turn it first one way and then the other, making about a quarter turn in each direction without exerting much pressure. When the compound has been squeezed out, put in more and continue the operation, repeating this for fifteen to twenty minutes. Wash the valve and seat off with kerosene and examine to see if all signs of pitting have been removed and the valve has a bright uniform band around its entire circumference. The presence of any breaks in this ring indicates low spots and calls for further grinding. Never turn the valve completely around when grinding, making only a quarter turn, since the complete turn will score the seat. Be careful to flush off every trace of the grinding compound with kerosene when through to prevent any trace of it getting into the cylinder. Otherwise, the engine will be ruined. Where the valves cannot be taken away from the motor for grinding, the greatest care must be exercised to prevent any of the compound from getting into the cylinders or down into the valve guides.

Q. Why is it necessary to grind the valves at such short intervals?

A. The exhaust valves in particular are subjected to exceedingly high temperatures that pit the metal face of the valve. Once this pitting starts, it proceeds rapidly and if the valves are allowed to run too long without grinding, these pits in the valve face will be so deep that new valves will be necessary. They will also be deep in the valve seat with the result that a correspondingly longer time is required to grind them out. By grinding at the proper intervals, only fifteen to twenty minutes will be required for each valve, whereas if they are allowed to run too long, it may take an hour or more to get each valve and its seat into proper condition again. The motor will also run very much better and deliver more power if the valves are kept in good condition.

Q. What is the cause of a valve leaking very badly at times?

A. Hard particles of carbon from the cylinder may lodge in the pitted face of the seat or valve and prevent it from closing tightly. Even though the valve be held off its seat only a few thousandths of an inch, it cannot hold any compression.

Q. What is the cause of a valve binding so that it will not operate?

A. Worn valve guides will sometimes permit sufficient side play to cause the valve stem to become bent. Lack of lubrication and an accumulation of dirt and carbon in the valve guide will cause the valve stem to expand to a point where it binds hard and fast in the guide.

Q. What causes a valve head to warp so that the valve must be replaced?

A. It may be caused by overheating of the motor due to partial failure of the cooling system, such as may be caused by a slipping fan belt, trouble with the circulating pump, shortage of water in the system, or the clogging of some of the pipes or the radiator. An accumulation of sediment or scale in the jackets or the radiator may have the same effect.

Q. Do valve springs ever need replacement?

A. In the course of a season's use, the temper may be drawn sufficiently to make the valve action sluggish, particularly in a motor that runs very hot, but ordinarily the valve springs do not often need replacement.

Q. Is it ever necessary to check the valve timing of the engine?

A. It is never necessary except in reassembling the engine after it has been taken down. Since the camshafts are made with the cams integral, no relative movement of the cams is possible and it is only necessary to time one cylinder. Most engines have reference points by which the valve timing may be checked when reassembling the engine.

PISTONS

Q. What attention do the pistons require?

A. The piston rings will wear to such a degree that the pistons no longer hold the compression and there is a substantial falling off in the power.

Q. How often should it be necessary to replace the piston rings?

A. This will depend entirely upon the care that is taken to keep dirt out of the lubricating oil and to prevent its entrance to the motor through the carburetor. If the oil is handled carelessly, containers being allowed to stand uncovered and a film of dust settling on them, or if the carburetor is not provided with an air cleaner, a great deal of grit will find its way into the motor and will grind the piston rings down rapidly and also the bearings.

Q. How may the pistons be tested for tightness?

A. The valves being in good condition, preferably recently ground, the test may be made as previously described for testing the valves; or, with the handhole plates off the crankcase, have an assistant turn the motor over slowly and note whether there is any sound of air blowing down past the pistons into the crankcase. Put a few ounces of fresh oil into each cylinder through the spark plug openings, replace the plugs, and repeat the test. Loss of compression may be due entirely to poor lubrication. Drain the crankcase, wash out with kerosene, and replenish the oil supply; and test in the same manner.

Q. Is wear of the piston rings the only cause for loss of compression, aside from pitted valves?

A. An accumulation of carbon under the piston rings may be holding the piston ring joints apart or the latter may have all worked into line so that the pressure is escaping through them. If, with good tight valves, there is still a loss of compression after putting fresh oil into the cylinders, it is an indication that the piston rings need attention.

Q. Does the compression fail in all the cylinders equally, or is one of the cylinders likely to be worse than the rest?

A. The wear is likely to be uneven, so that one or two of the cylinders will be found very much worse than the rest. Sometimes only one cylinder will fail to hold compression. Test in the same manner as described for the valves, pulling the crank up very slowly to note the resistance offered by each piston in turn as it comes up on the compression stroke. It may be found much easier to move one of the pistons than the others. When this is the case, it will be necessary to fit new rings on that piston.

Q. How are new piston rings fitted?

A. Oversize piston rings are supplied for this purpose. They are slightly larger (a few thousandths of an inch) than those originally supplied with the motor in order to compensate for the wear of the cylinder. Take the old rings off by inserting thin strips of steel (old table-knife blades or discarded hack saws are excellent for the purpose) at three or four points around the piston and under the ring. Scrape and wash out all carbon and gummed oil in the slots. Do not use a file for this purpose. First try the new rings by fitting them in the cylinder, which operation will show how much will have to be taken off to allow them to enter the bore. They must be small enough to insert an inch or two into the cylinder, since it is turned somewhat larger for a short distance at the end. If the rings are too large, take a few cuts with a fine file across the faces of the joint, being careful to keep the surfaces square and parallel. Very little must be taken off each time and the ring tried in the cylinder again. The job must be carried out with painstaking care as unless it is properly done the new rings will be no better than the old ones. When they have been properly fitted, use the same strips to place them on the piston, care being taken not to spring the rings out of round in putting them on.

Q. When fitting rings in the cylinder as a preliminary to putting them on the piston, should the break come together for a good fit?

A. No; allowance must be made for the lengthwise expansion of the ring due to the high temperature, and this allowance must be greater for the top ring than for the lower ones as it becomes hotter. Depending upon the diameter of the cylinder, it is customary to allow $\frac{20}{1000}$ to $\frac{30}{1000}$ inch between the ends of the topmost ring and $\frac{10}{1000}$ to $\frac{15}{1000}$ inch for the other two. Bearing shims are often stamped with the thickness in thousandths of an inch and may be used as a gage. Unless this allowance is made, the expansion of the ring will cause it to bind against the cylinder wall and may cause scoring.

Q. Must the piston ring be a tight fit in the piston slot?

A. Allowance for expansion must also be made here. After scraping the piston slots free of carbon and washing them out with kerosene so that they are perfectly clean, insert the ring and see that it turns freely in the slot. A piece of coated catalog paper has a thickness of $\frac{4}{1000}$ to $\frac{5}{1000}$ inch and it should be possible to insert a piece of this paper between the ring and the slot. If the rings are too tight they will bind on the piston and cause damage as mentioned above. Unless they can be moved freely in the slots, they will have to be made smaller by taking metal off the bottom edge of the ring. Smear some valve grinding compound on a flat metal plate or a smooth piece of hardwood plank and rotate the ring in this under pressure with the hand. Be sure to wash off all traces of the grinding compound before trying on the piston again.

Q. Do the pistons themselves ever have to be replaced?

A. The same condition that causes rapid wear of the piston rings, that is, dirt in the lubricating oil, will also cause equally rapid wear of the pistons. When this wear amounts to $\frac{15}{1000}$ to $\frac{20}{1000}$ inch, the piston will rock on the piston pin in the cylinder and produce a distinctive noise, known as *piston slap,* which cannot be traced to any other cause. At first, it is likely to be attributed to a loose bearing, and as it increases it will greatly resemble a bearing knock. When one piston reaches this stage, it is better to replace all of them with oversize pistons. The cylinders should be examined carefully for scoring and tested to see if they have worn out of round as it may be necessary to rebore them or to replace the cylinder casting to make a good job of it.

Q. Can the pistons be tested for looseness without taking the motor down when a knock cannot be traced to any other cause?

A. The amount of wear that will cause considerable piston slapping is so small that it would be difficult to detect it without having the cylinder and piston on a bench where the fit can be examined closely. The average driver would never attribute the loud knocking caused by a loose piston to the apparently slight amount of play that is revealed when the piston is examined.

Q. What causes besides dirt in the lubricating oil will bring about rapid wear of the pistons or scoring of the cylinders?

A. Other causes are the use of a poor grade of oil, using the same oil too long, or any other condition that results in inefficient lubrication, such as overheating due to partial failure of the cooling system. Unless there is a good oil film between the piston and the cylinder, the metal comes into actual contact and scoring follows. Too thin an oil will be burned away by the heat of the explosion as fast as the film is formed on the cylinder, while too heavy an oil may not reach the upper end of the cylinder bore owing to failure to pass the piston rings. Worn piston rings will permit particles of carbon from the combustion chamber to work between the piston and the cylinder wall. Partial failure of the lubrication system, such as the clogging of an oil lead in a force-feed system, the clogging of the screen or of the pump in a circulating system, or an insufficient supply of oil in a splash system, will result in scoring.

Cylinder scoring may be due to the piston ring binding owing to failure to allow for expansion in fitting or to the piston sticking owing to an accumulation of carbon under it. The wrist pin may become loose and move endways so that it scrapes against the cylinder wall; or in assembling the piston and connecting rod, the wrist pin may be so placed that it presses the piston unevenly against one side of the cylinder. Carelessness in valve grinding that results in some of the compound getting into the cylinder will cause serious scoring sooner than almost anything else.

CARBURETOR

Q. What attention does the carburetor need?

A. It should be drained at frequent intervals to remove the accumulation of sediment. Care should be taken to prevent dirt from getting into the fuel, and the latter should be strained as it is poured into the tank. In making needle-valve adjustments, the needle must never be screwed down hard on its seat, since this is likely to turn a shoulder on it so that proper adjustments cannot be made with it.

Q. When the carburetor floods, what is the usual cause of the trouble?

A. The usual cause is dirt lodging under the needle valve in the float chamber. Where a hollow copper float is used, it may have sprung a leak, causing it to sink.

Q. How should the carburetor be adjusted to give the maximum power with the most economical fuel consumption?

A. Definite instructions covering every make of carburetor cannot be given, but the same principles can be applied to all. With the motor running, cut down the fuel supply gradually until the motor begins to run irregularly or to miss. The fuel mixture is thus made leaner, and in some cases the motor will back fire through the carburetor when the mixture becomes too lean. When the point of adjustment has been found at which the motor is not getting sufficient fuel, turn back slightly until just enough fuel is being supplied to permit it to idle regularly. This is termed the low-speed adjustment and some carburetors have no other, that is, only the fuel supply can be regulated. Others have a high-speed adjustment as well; this controls the air supply and takes the form of an adjustable auxiliary air valve. Speed the motor up and release the tension of the auxiliary air valve spring until the point is reached where too much air is being admitted and the mixture again becomes too lean. Then turn back slowly until as much air is being admitted as is possible without causing irregular operation.

Q. Does the working of any other part of the motor influence the carburetor adjustment?

A. Unless all other parts of the motor are in good working condition, it will be found impossible to make a satisfactory carburetor adjustment. Valves in need of grinding, excessive clearance between valve tappets and stems or rocker arms, worn piston rings or pistons, and worn valve guides will all influence the adjustment of the carburetor. Air drawn in through worn valve guides, a leaky intake manifold, or a leak at the throttle valve of the carburetor will weaken the mixture and make it too lean, so that the motor loses power and overheats. With the motor running, take a squirt can and put some gasoline on the intake manifold gaskets and around the valve stems and note whether it is drawn in or not. New gaskets will remedy trouble of this nature at the manifold. Whenever the manifold has to be taken down, it is always better to replace the gaskets, since it is difficult to make used gaskets tight.

Q. The float valve and needle adjustment being in good condition, what is the cause of the trouble when a regular flow of fuel cannot be obtained at the nozzle in the mixing chamber?

A. The supply line may be partially clogged or the vent hole in the top of the carburetor may be stopped up. This is a small opening designed to admit air in order that there may be atmospheric pressure on the fuel in the float chamber. If this clogs up, a partial vacuum is formed. In a gravity system the air vent on the tank may have become stopped up and the fuel will not flow to the carburetor owing to the lack of atmospheric pressure on top of the supply. In a pressure or a vacuum tank supply system the trouble may be with the pump, or with loose joints, or with the tank itself.

Q. When difficulty is experienced in making a satisfactory low-speed adjustment, what is likely to be the cause?

A. The needle valve may have been forced down on its seat so that a burr or ring has been formed on the needle. The latter should be taken out and repointed.

Q. Is an air cleaner indispensable in connection with a tractor carburetor?

A. It will save its cost and the time required to attend to it many times over. Without it, pistons, rings, and bearings will grind out very rapidly, and trouble will be experienced with accumulations of carbon, more than half of which will be nothing more nor less than dirt drawn in through the carburetor.

Q. What attention does the air cleaner require?

A. Frequent cleaning is the only attention needed. When the cleaner is of the dry-air type, the engine should always be shut down before emptying it. If it is a washer type, see that it is constantly supplied with plenty of water. Clean out either type twice a day or oftener, if necessary, rather than wait until it is full. Analyses of carbon accumulations taken from automobile cylinders have shown them to consist of 65 per cent, or more, of road dirt.

Q. How can an over-rich mixture be detected?

A. Note the color of the exhaust from the muffler. The presence of black smoke indicates that too much fuel is being fed; blue smoke, too much lubricating oil; and grayish-white smoke, poor combustion of kerosene usually due to an excess of water. An over-rich mixture, particularly when kerosene is being used, will cut the lubricating oil from the cylinder walls and cause scoring unless remedied.

Q. What is the object of feeding water with the fuel?

A. To assist in keeping the temperature of the engine down to the proper point for satisfactory working. The steam generated rapidly absorbs a great deal of the heat and has the further advantage of preventing the formation of carbon in the cylinders. It also causes better combustion, particularly in the case of kerosene.

Q. Should water be fed with the fuel regardless of the grade of oil employed?

A. Little or no water is necessary when using gasoline, but the majority of motors will not operate satisfactorily on kerosene without it.

Q. Is there any danger of feeding too much water, particularly when the motor is running very hot and appears to need it?

A. Excess water fed with the fuel is liable to lower the temperature to the point at which kerosene recondenses to a liquid; in such a case considerable of it works its way past the pistons and down into the crankcase. This destroys the film of lubricant on the cylinder walls and is liable to cause damage, not alone to the cylinders themselves but likewise to the bearings; thinning the oil in the crankcase destroys its lubricating qualities. If the motor appears to be getting too hot, the trouble should be remedied by locating the fault in the cooling or the lubricating system and not by attempting to overcome it by increasing the amount of water fed.

Q. What indication is there of excessive water in the fuel?

A. A grayish white smoke will appear at the exhaust indicating that the kerosene is not being completely burned in the cylinders. Cut down the water supply very gradually until the smoke disappears, the motor being kept running at a good speed, since if run too slowly on kerosene the combustion of the latter will not be complete owing to the drop in temperature.

Q. Are all tractor motors provided with hand-controlled apparatus for feeding water?

A. No; some carburetors are designed to feed water automatically as it is needed, while in others the use of a wet air cleaner is depended upon to supply the proper amount of water required.

Q. Where hand control is provided, should the water be fed as long as the engine is running?

A. It is better to shut it off five minutes or so before the motor is to be stopped, and the fuel should be switched from kerosene to gasoline at the same time, as this will leave the motor in better condition and facilitate restarting.

Q. What precautions should be taken with the water supplied for this purpose?

A. Clean rain water should be used, and it is well to strain it through two or three thicknesses of cloth to prevent the entrance of any dirt.

COOLING SYSTEM

Q. When the engine overheats despite the fact that the cooling system is working properly, what is the cause of the trouble?

A. It may be due either to an over-rich or an over-lean mixture. In either case combustion is slow instead of taking the form of the explosion required to produce the maximum power. The mixture continues to burn throughout the stroke and in the exhaust passages and muffler. Flame issuing from the exhaust is an indication of this condition. The ignition may be retarded too far and bring about the same condition.

Q. What are some of the causes of failure of the cooling system?

A. Among the causes are the following: insufficient water supply; fan belt slipping; pump running too slow when driven by a belt; insufficient lubrication; leaks in radiator or at pump packing permitting water to escape or air to enter; and clogging of radiator, circulating pipes, or water jackets with an accumulation of sediment. The cooling system should be drained at frequent intervals and flushed out with clean water. An accumulation of carbon in the cylinders will also cause the engine to overheat and if allowed to become very bad, will cause preignition, which imposes very heavy stresses on all moving parts of the engine.

Q. When hard water has to be used in the cooling system and scale forms, how can this be removed?

A. A strong soda solution made by adding several pounds of common washing soda to enough boiling water to fill the system should be used for a day or so in place of ordinary water. The system should then be drained and flushed out. The use of rain water will prevent the formation of scale. Particles of iron rust in the water when the system is flushed should not be confused with scale; these will always be found, even if the system is drained every day.

Q. Do the flexible-hose connections ever cause any trouble?

A. The inner plies of the hose sometimes become detached owing to the high temperature of the cooling water and either partially or wholly clog the passage. The passage is liable to become wholly clogged with the pump type of circulation owing to the much smaller diameter of the hose used. To guard against trouble of this nature, use nothing but the hose connections supplied by the manufacturers as replacements since this hose is specially made to withstand hot water. Ordinary hose will disintegrate rapidly when employed for this purpose and should never be so used except to tide over an emergency, being replaced with a new connection as soon as possible.

Q. Is partial or total failure of the cooling system the only cause of overheating?

A. No; there are numerous other causes of overheating. The motor may be run with the ignition retarded; the lubrication may not be efficient; or carbon may have accumulated in the combustion chambers, as pointed out in a previous answer.

Q. How can carbon be prevented from accumulating in the motor?

A. After the motor has been shut down for the day and is very hot, take out the spark plugs, turn the motor over by hand until all the pistons are at approximately the same height, and pour into each cylinder about an ounce of kerosene, letting it stand this way over night. Do not use more than this amount of kerosene (a tablespoon will hold about an ounce) on the theory that if a little does good, more will do better, since more kerosene will cut the lubricating film off the cylinder walls and thin the oil in the crankcase.

Q. How can the fan belt be kept in good condition?

A. Make adjustments only when the motor is hot and do not put any more tension on the belt than is necessary to prevent slipping. A belt that is set up too tightly will wear very quickly besides imposing undue stresses on the pulley bearings. Keep the leather soft by applying neatsfoot oil from time to time.

Q. How often should the radiator and cooling system be drained?

A. Two or three times a season are sufficient in summer if clean rain water is being used and it is strained before being put into the radiator. In winter it will be found better practice to drain the entire system every night rather than to depend upon an anti-freezing solution, since the latter lowers the boiling point of the water to such an extent that it is likely to boil away. In any case, if alcohol is used in the anti-freezing solution, it is likely to boil out of the water, so that the latter cannot be left in over night with safety. Some tractors are cooled by oil, and in cold weather it is necessary to thin this oil with kerosene before it will circulate freely.

Q. When it is discovered that a considerable quantity of the water has boiled away and the motor is very hot, is it good practice to fill up with cold water immediately?

A. This should not be done, particularly in winter, as the fresh supply is likely to be very cold and the sudden contraction would impose severe stresses on the radiator joints, starting leaks.

Q. What attention does the pump of a circulating system require?

A. See that the glands are kept tight. The appearance of a drop of water at the gland indicates the beginning of a slow leak. Give the gland nut a partial turn to tighten it; if water still appears, it will be necessary to repack the stuffing box. Use oil-soaked cotton wick or graphite packing.

HORSEPOWER RATINGS

Q. Why are tractors rated as 10–20, 16–30, etc., always giving two horsepower ratings?

A. Tractors are designed to be used for belt as well as for field work. In doing the latter, the tractor must use a substantial percentage of its power to move itself. The lower rating accordingly expresses the amount of power available for plowing. When standing, as in performing belt work, the only losses are caused by whatever transmission gearing is interposed between the engine and the belt pulley, so that almost the entire output of the power plant is available for driving other machinery.

Q. What constitutes an overload, and why do all manufacturers warn the tractor user so strongly against subjecting the machine to overloads?

A. Considerable confusion exists as to the meaning of the term horsepower. For a few minutes, as in pulling out of a hole, a heavy draft horse is capable of exerting 600 to 800 pounds drawbar pull, which is the equivalent of more than 1 hp., but the same horse cannot exert much more than an average of 100 pounds drawbar pull at a speed of three miles an hour in hauling a load all day. The fact that a tractor having a field rating of 16 hp. may be pulled out of a bad place by three heavy horses does not indicate that the team is capable of doing as much work as the machine. The animals can only exert this much power for a very short period. The tractor will generate an amount of power at the drawbar equivalent to fourteen or fifteen horses at the usual plowing speed and will keep it up all day. A load such as twelve horses could haul all day would represent the practical working maximum for such a machine. A heavier load than this, apart from emergencies which call for all the power the machine can produce for only a very short period, would represent an overload for that tractor. In other words, the tractor should not be steadily subjected to a load amounting to more than 75 per cent of its capacity. Manufacturers warn tractor owners against overloading their machines because tractors will wear out very quickly under the excessive strain and will not give satisfactory service during the machine's greatly reduced useful life. Regardless of the plow rating of the tractor, as for instance, three-plow or four-plow, the number of plows used should depend upon the nature of the soil. When the latter is very heavy, or the plowing has to be done on an up grade, fewer plows should be used. More and better work will be done by not subjecting the tractor to any greater load than it can pull without exerting more than 75 per cent of its power.

ENGINE TROUBLES

FAILURE TO START

Q. What are some of the commoner causes of failure to start?

A. Over 95 per cent of all failures to start are due to either lack of fuel or lack of the spark to ignite it. Part of the remaining 5 per cent are due to the failure of the two to come together at the right time, while the rest may be put down to faults having no connection with either the carburetor or the magneto.

Q. Does lack of fuel in this connection mean an empty tank and nothing more?

A. While a great deal of energy has been expended to no good purpose in trying to start an engine that was connected to an empty gasoline tank, lack of fuel implies a great deal more than that. It does not do much good to have a full tank unless the fuel is actually getting into the cylinders every time the engine turns over. There may be a stoppage between the tank and the carburetor or between the latter and the cylinders. A plugged air vent either at the tank or at the carburetor will prevent the liquid fuel from reaching the carburetor nozzle. A stopped-up carburetor nozzle will not vaporize any fuel, while a broken throttle connection which leaves the throttle closed will not permit any spray from an open nozzle to reach the motor, or at least not enough to render starting easy. Air leaks at the carburetor, the manifold, or the valve stems will weaken the mixture considerably.

Q. Is it not as hard to start with too much fuel as with too little?

A. Flooding the cylinders makes starting very difficult, and when this has occurred, the only remedy is to shut off the supply entirely and crank the motor for a few minutes to clean out the cylinders. Priming too freely is a bad practice, since the liquid gasoline cuts the lubricating oil from the cylinder walls and destroys the compression to such an extent that in an old engine it is next to impossible to start even though the fuel and the spark come together in the right place at the right time. This is one of the unspecified causes responsible for part of the 5 per cent of the failures to start mentioned previously. There will be a weak explosion every time a cylinder should fire, but not enough power will be produced to cause the engine to take up its cycle and run.

Q. When the cylinders have been flooded by over-priming with gasoline, what should be done?

A. Close the throttle and open the air valve or choker, so that no gasoline is drawn through the carburetor. Take out the spark plugs and put 2 or 3 ounces of heavy cylinder oil into each cylinder. Replace the plugs and turn the motor over for two or three minutes with the ignition off.

Q. Has the position of the throttle lever any effect on the fuel supply at starting?

A. Some engines can only be started readily with the throttle at a certain position, usually not more than one-third open and sometimes considerably less. On a cold morning opening the throttle too far is liable to allow too much gasoline in liquid form to find its way into the cylinders, so that the effect is the same as that of over-priming or flooding.

Q. How should an engine be primed?

A. Gasoline should be carried in a squirt can for this purpose and not more than a teaspoonful should be squirted into each cylinder through the pet cocks. If the engine does not start after priming two or three times, look for some other cause of fuel or ignition failure. If the engine starts and only turns over a few times and then stops, the cause is likely to be lack of fuel as indicated by the fact that it ran on what was injected into the cylinders. In priming the float in the carburetor is also depressed by means of a button or lever provided for the purpose. This floods the carburetor and causes the gasoline to overflow through the nozzle into the mixing chamber. The moment any gasoline leaks out of the carburetor, the float should be released, since otherwise the cylinders will be flooded. Never prime the carburetor just as the engine is starting, as this will produce an over-rich mixture and probably cause a pop back which may ignite the gasoline in the carburetor.

Q. Is water in the gasoline a frequent cause of failure to start?

A. It may not be a very frequent cause, but the occurrence of any water in the gasoline will make it difficult to start the motor. Being heavier than gasoline the water sinks to the bottom of the tank and there may be enough of it to partly fill the carburetor. The remedy is to drain the carburetor, taking out a half-pint or so.

Q. What effect does the use of kerosene as fuel have on the starting of the motor?

A. It has no effect, if the matter is properly handled. At least five minutes before the engine is to be stopped the kerosene should always be shut off and the engine allowed to run on gasoline so that all traces of kerosene will be cleaned out of the cylinders and the manifold. If this has not been done, it will take considerable cranking to start the engine, and it may also be necessary to inject 2 or 3 ounces of fresh oil into each cylinder to renew the compression seal since the kerosene condenses in the cylinders as soon as they get cold and then runs down past the pistons into the crankcase.

Q. Will an adjustment of the mixture make starting any easier?

A. The actual adjustment of the carburetor itself should never be disturbed for starting purposes, as, if this is done, either the carburetor will seldom be properly adjusted for efficient running or a great deal of time will be spent unnecessarily in making adjustments. Moreover the carburetor parts will soon wear badly and make efficient adjustment impossible. Most carburetors are provided with a *choker* which, when closed, causes all the air to be drawn past the nozzle, thus increasing the suction and giving a rich mixture. This should be closed for starting and opened the moment the motor gets under way. Ordinarily the running mixture is too lean to make starting easy.

Q. What are the commoner causes of failure to start through ignition trouble?

A. Among the causes are the following: a ground or short-circuit in the wiring; points of plugs burned too far apart; moisture on the distributor of the magneto; failure of the contact points in the breaker box of the magneto to separate when the cam strikes the hinged lever; impulse starter of magneto stuck or spring broken; putting plug cables on wrong plugs when a change has been made just before attempting to start; badly sooted plugs; spark lever advanced too far; and loose connections, particularly where a separate coil is used with the magneto.

Q. What simple test can be made to determine whether the spark is occurring in each cylinder at the proper time?

A. Take out the plugs, leaving the cables attached to them, and lay the plugs on the cylinder head. Then turn the motor over slowly and note whether or not the sparks occur at the plugs in the proper sequence. Note whether there is a strong blast of air from one of the spark plug holes each time the motor is turned over; if not, pour an ounce or two of fresh oil into each cylinder. The failure to start may be due to lack of compression.

Q. If, when the spark plugs are thus placed, no spark occurs at them, where should the trouble be sought?

A. Take off the cover of the contact breaker of the magneto; have an assistant turn the motor over slowly, and note whether the points of the contact breaker separate twice per revolution (four-cylinder motor). If they do separate, note whether the faces of the contact points are clean and square. If they are blackened or pitted, clean and true them up with a very fine file or a strip of fine sandpaper, and then so adjust them that they come together firmly when the cam is horizontal and do not separate more than $\frac{1}{64}$ inch when the cam is vertical. By giving the motor a sharp turn beyond a compression point a spark will be noted between the points; or the impulse starter may be used and the result noted.

Q. Assuming that a spark takes place between the contact points of the magneto, but none occurs at any of the spark plugs, where should the trouble be sought?

A. Open up the distributor of the magneto and wipe it free of any moisture or dirt that may have accumulated on it. Turn the motor over and note whether the distributor brush revolves as it should. Adjust all the spark plug gaps to not more than $\frac{1}{32}$ inch; see that the plugs are properly cleaned and that they are lying on their sides on the cylinder heads, so that only their bodies come in contact with the metal. If they are so placed that the central electrodes are touching, the current will pass through them without causing a spark, since there are then no gaps for it to jump. In case none of these tests produces a spark at the plugs, there is more than likely to be some internal trouble with the magneto, though this is of comparatively rare occurrence.

Q. When the impulse starter fails to operate, what is likely to be the cause of the trouble?

A. Either the mechanism has become gummed up with oil and dirt or the spring has broken. Cleaning out the impulse starter with gasoline and re-oiling will remove the former cause.

Q. When the engine fails to start after having been primed once or twice and cranked several times, in what order should the cause of the trouble be sought?

A. This will depend largely upon weather conditions. In very cold weather it is quite likely that nothing but the low temperature is the cause of difficulty in starting. Results will usually follow continued cranking, as this warms the engine up somewhat and makes it turn over easier, with the result that the first weak explosions may cause it to take up its cycle. In warm weather, if a start does not follow several attempts at cranking, test the ignition first and then the fuel supply, applying the different tests already outlined and in about the order given.

Q. Are there any other points in the ignition system that are likely to be responsible for failure to start?

A. If, when turning over, the motor produces a spark at the contact breaker but none at the plugs, investigate the magneto switch. It may have become broken or its connections may be faulty. See that it is in the right position, since many tractor motors can only be stopped by short-circuiting the magneto by means of the switch. In case the switch is in the *STOP* position, no spark will occur at the plugs. On some tractors the spark-advance lever takes the place of the switch; by fully retarding it the magneto is short-circuited, and the motor cannot be started.

Q. Do the magnets of the magneto lose so much of their strength that no current is produced?

A. In time, the heat and vibration are liable to weaken the magneto, but this is far from being a common source of trouble. If, after making the tests mentioned, no spark is produced, take off the distributor plate of the magneto and rest a screwdriver blade on the gear casing so that its end comes within $\frac{1}{8}$ inch of the collector ring. Turn the motor over, and note whether a spark jumps this gap. A $\frac{1}{8}$-inch spark at this point will indicate that there is no falling off in the power of the magneto. If a spark cannot be produced in this way, there is something wrong with the magneto itself, and it should be sent to the manufacturer for repairs. Ordinarily remagnetization is only necessary if the magneto has been taken apart and the magnets allowed to stand without a "keeper," or piece of soft iron across their ends, or if they have been removed from the magneto and reassembled in the wrong way.

Q. When the contact points have become so badly pitted and burned away that they cannot be properly adjusted after cleaning and trueing up, what should be done?

A. One or both of the contacts should be replaced and adjusted properly. The magneto manufacturer usually supplies a special wrench for this purpose, one end of it serving as a gage for the proper gap between them. The lock nut of the movable point should always be screwed down firmly after the adjustment has been made or it will back off owing to the vibration.

Q. Are there any connections on the magneto which are likely to become short-circuited or grounded?

A. When the wire is brought out through the side of the magneto, the insulation may become so worn that the metal touches the side of the opening, causing a short-circuit. In the inductor types of magneto, such as the Remy and K–W, this is most likely to occur at the grounding screw where the wire is fastened to the side of the magneto. In shuttle-wound types, such as the Eisemann, Kingston, and Bosch, the break may be at the point where the wire is fastened to the armature or where it is fastened to the collector ring.

Q. Can the contact breaker become short-circuited?

A. Metallic dust or filings will be liable to cause this; the remedy is to clean out the inside of the box with gasoline. Whenever an adjustment is made, the contact points must always be redressed so as to come together squarely. For this purpose use only the small file supplied by the manufacturer, and take off just as little of the platinum as possible, since it is worth considerably more than gold.

Q. How can the contact-breaker box be tested for a short-circuit?

A. Remove it from the magneto, place a piece of paper between the points, and then hold the box within $\frac{1}{8}$ inch of the shaft while the magneto is turned over with the other hand. No spark should occur; if it does, it indicates that the insulation of the adjustable contact point is poor and should be replaced. The test should then be repeated with the paper removed so that the points are in contact; a spark should then occur when the armature is turned over, the breaker box being held within $\frac{1}{8}$ inch or less.

Q. Does oil getting on the parts injure the magneto in any way?

A. If allowed to get between the contact points in the breaker box, it will insulate them. On the shuttle-wound types of magneto there is a collector ring and brush, and allowing any oil to get on them will prevent the operation of the magneto altogether. Oil usually carries more or less dirt with it, and if allowed to get on the distributor, it is liable to cause leakage of the high-tension current, so that no spark occurs at the plugs.

Q. How often should the contact points of the magneto need attention?

A. This will depend more or less on the particular type of magneto and the engine, but they should be inspected at least once every thirty days while the tractor is in service steadily and trued up with the sandpaper or special file whenever the slightest irregularity of their surfaces is evident. Taking off a little at frequent intervals will keep the points in much better condition and will save the costly platinum, since once the points start to pit this process proceeds very rapidly. Emery should never be used on the points.

Q. Is excess oil in the motor ever a cause of failure to start?

A. When there is so much oil in the motor that considerable of it finds its way into the combustion chambers, it will collect on the spark plug points and insulate them, if unburned, or short-circuit them, if carbonized. The fact that the motor apparently ran satisfactorily just before being shut down the last time is not conclusive evidence that the spark plugs are in good condition. The magneto generates a high voltage when running at full speed, and the motor will often continue to operate in spite of poor conditions whereas it cannot be started again, once it has become cold, without first remedying the faults.

Q. What is the commonest cause of failure to start a motor equipped with low-tension ignition?

A. Dirty plugs, or ignitors, are probably the most frequent cause. As in the case of the high-tension spark plugs just mentioned, the engine may continue to run with the plugs in poor condition, but once it has been shut down and allowed to become cold, the magneto will not produce a spark at the dirty plugs at the low speed at which the engine is cranked. Whenever an engine with this type of ignition is difficult to start, the first thing to do is to examine the plugs. Give them a thorough cleaning with gasoline and a wire brush, taking out the moving contact to remove any soot that has been forced into the bearing. These plugs may be tested by laying on the cylinder head, contacts up, and snapping the contact with a small piece of wood while an assistant turns the motor over so that the magneto is generating.

Q. What other attention do these plugs require?

A. The contact points burn away rapidly and need frequent dressing up to keep their contact faces from becoming pitted. They should be trued up in the same manner as directed for the magneto breaker-box contact points, and while the material is not so expensive, no more than necessary should be taken off. The operation should be repeated at frequent intervals to keep the plugs in good condition.

Q. How may the low-tension magneto be tested to find out whether it is generating or not?

A. Place a screwdriver blade against the single terminal of the magneto and hold the end against some metal part of the motor while the motor is cranked. Move the tip of the screw-driver over the metal while maintaining contact with the terminal at the other end and sparks will be noted at the tip. A similar test may be made by disconnecting the cable leading from the coil. Rub the metal terminal of this cable over different adjacent parts of the motor so that contact is made and broken while the engine is being cranked, and much larger sparks will be noted.

Q. If, after making tests successfully, no spark is obtainable at the ignitor plug itself, what is the cause of the trouble?

A. The plug is likely to be at fault. Oil that has been used for any time carries in solution a considerable percentage of carbon in a finely divided state. When hot, this oil is thin and is forced into the insulation of the plug, short-circuiting it, though apparently there is nothing wrong with it. The only remedy is to renew the insulation of the plug.

Q. Though a test of the ignitors shows them to be in good working condition, the motor still fails to start and examination shows every other part to be working properly, so that the fault is evidently with the ignition, what is the cause?

A. Either some part of the ignitor tripping mechanism has failed, so that the contacts do not separate, or the timing has become deranged, so that the separation takes place at the wrong moment. In the latter case the spark is occurring in the cylinder, but it is taking place either too soon or too late to fire the charge. Check up the timing of the ignitor mechanism in accordance with the maker's instruction book.

Q. How can the dry cells ordinarily used for starting with low-tension ignition be tested?

A. A pocket ammeter, or so-called battery tester, should be used for this purpose. Hold the tips on the cells only long enough to allow the instrument needle to come to rest, since the ammeter represents a dead short-circuit on the battery and will run it down very quickly. If the reading of the ammeter shows less than 10 amperes, the batteries are of no further use for starting purposes and should be renewed. Any other method of testing will only show whether the battery is actually dead or not, and dry cells may make a fairly large spark through the coil but will give a reading of only 2 to 3 amperes on the instrument and will fail to ignite the charge in the cylinder. Batteries when this low give out very quickly. If the switch has been left on the battery side inadvertently, give the cells ten to fifteen minutes to recuperate and then test again.

Q. What is likely to go wrong with the wiring of a low-tension system?

A. About the only thing that can happen to this wiring is a loose connection at the magneto, at the ground on the motor, at the ignitor connection, or at the switch. The switch itself may become short-circuited and thus prevent any current from reaching the plugs.

Q. Does the tripping mechanism of a low-tension system require frequent attention?

A. The trip-rod mechanism should be inspected from time to time to see that it is working normally, as the vibration is likely to knock it out of adjustment. The springs should be replaced whenever they show any signs of weakening.

RUNNING TROUBLES

Q. What causes the engine to emit smoke?

A. Among the causes are the following: an over-rich mixture caused by faulty adjustment of the carburetor; and flooding of the carburetor due to a leaking metal float or a water-logged cork float. In either of these cases the smoke will be black. Oil getting into the combustion chambers in excess, caused by feeding too much oil or by broken or stuck piston rings, will produce a blue smoke. Feeding an excessive amount of water when burning kerosene or running the engine too cold will produce a white or gray smoke, indicating that the kerosene is not being entirely consumed.

Q. What is the cause of back firing through the carburetor?

A. A slow-burning fuel mixture is being fed, that is, one either too lean or too rich, usually the former, so that there is still flame in the cylinder when the valve opens. At times this will occur to such an extent that the flame issues from the exhaust pipe at the end of the muffler. This is an indication that the mixture is too rich, since it is still burning after being exhausted from the cylinder. One of the valves may not be closing properly;

it may be held off its seat slightly by an accumulation of carbon, or its stem may have become bent, so that the spring cannot close it. When the ignition has been dismantled, reassembling the cables on the wrong plugs so as to alter the firing order will cause a back fire, but in this case the engine cannot be started. An air trap in the fuel line or partial clogging of the latter will also cause this at times.

Q. What are the commoner causes of missing?

A. The most frequent cause is a defective spark plug. Owing to the heat and the vibration the porcelain of a plug will break, but the cracks will be so small that they are invisible. The pressure forces carbon-laden oil into these cracks and the plug becomes short-circuited, though apparently in good order. Test by short-circuiting the plugs in turn with a wooden-handled screwdriver. When short-circuiting a plug causes no perceptible difference in the running of the engine, replace it. Pitted and badly worn contact points in the magneto breaker box will also cause irregular running. (See the directions given under Failure to Start.) Missing may also be caused by the fuel mixture being too rich or too lean, partial stoppage of the fuel line, water in the gasoline, defective insulation or loose connections, carbon dust on the distributor plate of the magneto, or a sticking valve.

Q. In what other ways may spark plugs fail besides the porcelain cracking?

A. Very frequently the electrodes burn too far apart, so that the current is unable to jump the gap, or if it does, the spark is weak and irregular. Plugs become foul through an accumulation of soot in them, and to clean a badly sooted plug out thoroughly, it may be necessary to take it apart. The insulation of a mica plug will fail in time through the hot oil and carbon being driven into it under pressure, and the only remedy is to replace the insulator. Leakage around the gasket sometimes occurs, and when it is not sufficient to cause a hissing noise, it will be indicated by the porcelain of the plug becoming very dirty. Squirt a little oil on the porcelain when the engine is running and bubbles will form at the gasket if the plug is leaking. Cheap plugs are made with iron electrodes, and the latter burn away so fast that it may be necessary to adjust the gap once a day.

Q. What is the cause of preignition?

A. Usually an accumulation of carbon in the combustion chamber. This carbon deposit often takes the form of small cones which become incandescent when the engine is running under full load so that the fresh mixture is ignited the moment it enters the cylinder. When running on kerosene, the piston head may become so hot as to produce the same result. In either case, preignition will be evidenced by a heavy pounding and the engine should be stopped at once as this imposes a very heavy stress on all the moving parts. Increasing the amount of water fed with the fuel will remedy it when it is due to overheated pistons and the use of kerosene. Otherwise, the engine will have to be cleaned out to remove the carbon.

Q. How can the accumulation of carbon be prevented?

A. By using only the grade of oil recommended by the manufacturer of the tractor; cleaning it out and putting in a fresh supply as often as directed; keeping the piston rings in good condition, so that an excessive amount of oil cannot find its way into the combustion chambers; and keeping the carburetor properly adjusted, so that too rich a mixture is not used. Feed the proper amount of water when burning kerosene. In spite of these precautions, more or less carbon will always accumulate in the cylinders. This amount can be kept down to a minimum by pouring a few ounces of kerosene into each cylinder at the end of a day's run when the engine is still very hot and leaving this in the cylinders over night. Before starting up in the morning, the compression seal should be renewed by putting a few ounces of fresh oil into each cylinder.

Q. When the engine fires regularly but the explosions are so weak that very little power is produced, what is the cause of the trouble?

A. Some of the commoner causes are as follows: spark plug points burned too far apart; excessive clearance at the valve stem tappets or rocker arms, so that only a fraction of the fuel required is being admitted; valves in need of grinding; poor compression caused by oil not being renewed at sufficiently short intervals; broken or stuck piston rings; leaks around spark plugs; use of a fuel mixture that is too lean or too rich, so that slow burning results instead of an explosion; a weakened or broken valve spring; clogging of the passages of the muffler with carbon; or any obstruction in the exhaust piping.

Q. What causes the engine to run regularly for a time and then to misfire badly?

A. This may be caused by switching to kerosene before the engine has run long enough on gasoline to become thoroughly warmed up; a valve with a bent stem that operates properly at times and then sticks during a few revolutions; air leaks around the valve stems or in the intake manifold; dirt in the carburetor, so that the nozzle is partly clogged at times and free at others; defective insulation or a loose connection which interrupts the circuit from time to time owing to the vibration of the engine, causing it to change position; water in the gasoline; carbon on the distributor plate of the magneto; or faulty spark plugs which will permit the engine to run regularly when idling but which will fail the moment the load is applied. A spark plug with fine cracks in the porcelain will fail under load owing to the greatly increased pressure in the cylinder, but will often spark regularly when the engine is running without load. A loose connection or weak spot in the insulation is the most puzzling of these causes since it is often the most difficult to find.

Q. What causes the engine to stop suddenly?

A. This is generally due to a failure of the ignition, owing to a break in the circuit caused by a connection dropping off, the switch suddenly opening under the vibration, or some part of the wiring becoming short-circuited. Clogging of the fuel line or of the carburetor nozzle or an empty tank will also result in the engine stopping. Where the stoppage is due to failure of the fuel supply from any cause, the engine will not usually come to as sudden a stop as when the ignition fails. The contacts in the breaker box of the magneto may have stuck together. If the cooling or the lubricating system fails, it will also take more time to bring the engine to a stop and there will be noises that give ample evidence of the cause of the trouble. The engine should be shut off the moment these noises occur for otherwise it will be forcibly stopped by the binding of the pistons, thus putting the engine out of commission.

ENGINE NOISES

Q. How are the different engine noises that signify trouble in the operation of the motor characterized?

A. Experienced motor mechanics give a different term to each one of several distinct classes of noise indicating faulty operation, such as knock, hammer, pound, and slap, and to the ear that is familiar with them each can be distinguished.

Q. What do these different noises signify to the experienced ear?

A. A knock is the first indication of looseness in a bearing, usually a connecting-rod big end, and the sound is generally that of a sharp metallic blow. When it is allowed to develop or when looseness in the crankshaft bearings develops, the sound becomes louder but not so sharp and is more aptly described as hammering, owing to its similarity to the blow of a sledge. Pounding is caused by preignition and by overheating and is so violent as to rack the whole motor very badly. Slap is the result of worn pistons, the skirts or lower ends of which are banged against the cylinder walls every time the motor fires. The noise produced is very similar to that of a knock and is often mistaken for the latter, though an experienced mechanic will seldom go wrong on this. In addition to the noises mentioned, there is another that is readily distinguished by the experienced ear, and that is the clatter caused by a loose valve motion, indicating that an excessive amount of clearance has been allowed to develop between the valve tappets and stems or in the rocker arms. To the inexperienced ear all strange noises will be *knocks* and it may seem to be drawing too fine distinctions to differentiate between knocking, hammering, and pounding, but familiarity with a motor will enable the operator not only to make these distinctions but to know as well what causes the different noises.

Q. Which of these noises calls for immediate attention on the part of the operator to prevent damage to the motor?

A. A very good rule to follow is to shut the motor down the moment any of these noises is heard and correct the trouble, but those that call for immediate attention to prevent serious damage are hammering and pounding. The first indicates a very loose bearing, which may result in a broken crankshaft if allowed to run a moment longer than necessary, while pounding not only imposes exceedingly heavy stresses on every part of the motor but may also be the first sign of failure of either the cooling or the lubricating system. The cause may be nothing more serious than lack of sufficient water when burning kerosene or the fact that the spark lever may be advanced too far.

GOVERNOR

Q. What causes the engine to race when the load is thrown off?

A. The governor needs adjustment, or the connection between it and the throttle has parted.

Q. What attention does the governor ordinarily need?

A. This depends largely upon the type of governor. Some are housed in and the lubrication provided for by filling the housing with oil; such a governor needs very little attention, except to adjust it when it permits the engine to idle too fast. An adjusting screw is provided for this purpose. With the engine running, turn the screw gradually until the engine slows down to a point where it idles satisfactorily. The governor spring weakens in time, and the adjustment is provided to permit of increasing the tension. Apart from this, the only regular attention required by those types which are not automatically lubricated is to oil the bearings at regular intervals and see that the connecting linkage is in good order.

CLUTCH AND TRANSMISSION

Q. What provision is made for taking up wear in the clutch?

A. The friction surface, which is usually asbestos on a wire foundation, should be replaced when worn sufficiently to require it. After considerable service the spring pressure may let up sufficiently to cause unsatisfactory operation of the clutch. An adjustment is provided for increasing the tension of the spring, and this should be tightened just enough to make the clutch hold under load; but it is not good practice to attempt to make up for a badly worn friction facing by increasing the tension of the spring. Replace the facing first. This, of course, does not apply to the type employing metal to metal contact surfaces. Apart from this, the chief attention required is lubrication, which should be carried out in accordance with the manufacturer's instructions, some clutch mechanisms calling for oil as much as two or three times a day.

Q. Is it good practice to let the machine stand with the clutch out of engagement?

A. No; as it only weakens the clutch spring and shortens its life. Whenever the machine is to stand more than a few moments, the gears should be shifted to neutral and the clutch allowed to engage. It is particularly bad practice to let the machine stand over night with the clutch out of engagement.

Q. Are a worn friction facing and a weak spring the only causes of a slipping clutch?

A. Allowing oil or grease to fall on the friction faces of the clutch will cause it to slip badly.

Q. What attention does the transmission require?

A. Maintain the oil level as indicated in the manufacturer's instructions and use only the oil called for by the latter. Drain as often as instructed, and wash out with gasoline or kerosene before refilling. This is usually two to three times a season, though some types may require it oftener. When the case has been cleaned out, inspect the gear teeth carefully for breaks, and see that any chips or foreign matter are removed. By filtering the old oil through several thicknesses of cloth, it may be used for other farm machines which do not require the same high degree of lubrication as the tractor.

Q. Does the differential require any special form of attention?

A. The differential is frequently combined with the transmission, so that it is lubricated by the same supply of oil. Where it is separate from the transmission, the attention required is the same as that just mentioned for the transmission.

HOUSING TRACTOR

Q. Does it pay to build a special shelter for a tractor?

A. It will undoubtedly be found a good investment, since the cost of a building large enough to shelter the tractor and provide a working bench beside it will usually be less than the added depreciation incurred by leaving it exposed to the weather.

Q. When the tractor is put up for the season, what attention should be given it?

A. Before putting the machine away for the winter, the valves should be ground, the bearings adjusted, the valve mechanism and the magneto overhauled, the oil drained from the crankcase and the transmission, and the latter washed out and provided with a fresh supply of oil. Wash the cylinders and pistons by putting a pint or more of gasoline in each cylinder and running the motor for half a minute. Then put a pint of fresh oil in each cylinder and turn the motor over by hand a few times to spread it over the surfaces; otherwise, the cylinders and pistons may rust. Coat all exposed parts with grease and cover the machine with a tarpaulin or old canvas. Make a list of all replacement parts necessary and order them at the time the machine is put away in order that they may be installed during the winter.

STANDARD UNITED STATES ARMY TRUCK
Courtesy of The White Company, Cleveland, Ohio

COMMERCIAL VEHICLES

INTRODUCTION

Development of Field. While the development of the commercial car was slow at first owing to the numerous shortcomings of early types, it has advanced with wonderful rapidity during the past few years and bids fair to supersede, in a comparatively short time, the use of the horse-drawn vehicle for business purposes, not only in the large cities but also on the farm. As in the case of the pleasure car, Europe led in the development of the automobile for transportation purposes, chiefly with military necessities in view, as without power-driven vehicles it would be impossible to move the enormous food and ammunition supplies required by an army of present-day proportions. However, American manufacturers have advanced so rapidly in the production of commercial cars during the past few years that in 1916 the registration of New York City alone showed a greater number of these vehicles than were reported by the census of 1915 for the whole German Empire and more than half the number reported in service in Great Britain during the same period.

Scope of the "Commercial Vehicle". It is important to know the reasons for the revolution which is now in active progress, as well as to become familiar with the prevailing practices in America and abroad in the construction, operation, and maintenance of that large and varied class of automobiles employed exclusively for business purposes. Regardless of type, class, or method of propulsion, these are commonly referred to as "commercial vehicles". This classification embraces not only motor delivery wagons and trucks for the transportation of merchandise, but also taxicabs, omnibuses, sight-seeing vehicles, motor road trains, farm tractors, emergency repair or tower wagons for street-railway service, and also vehicles for special municipal service—ambulances, patrol wagons, fire engines, street-sprinkling and garbage-removal wagons, and the like. In fact, it may be said that any automobile not devoted to pleasure is a commercial vehicle, and, as was to be expected, the first types of these vehicles were merely pleasure cars transformed to suit the needs of the occasion. To a certain extent, this still continues to be the case.

Standard Design. Whether it be electric-, steam-, or gasoline-driven, the general design of the motive power, as well as that of its transmission to the driving wheels, is practically the same in the commercial vehicle as it is in the pleasure car, except that the chain drive has now almost disappeared on the latter, and all the component parts—bearings, frames, axles, steering gear, and compensating mechanism—are the same. In other words, the chassis in both cases is composed of similar members. For the sake of brevity in the present treatise, it is assumed at the outset that the reader has become familiar with motor-car engineering so far as it relates to pleasure-car construction; that he understands, from previous study and the actual handling of machines, the *theory* of the operation of the internal-combustion engine; that he is conversant with the distinguishing characteristics of the several types of engines as well as with their advantages and limitations; and that he is acquainted with the types of transmission systems ordinarily employed on pleasure cars—in brief, that he understands any reference to component parts, to their functions, and to their relation to one another, without the necessity of explanation.

In common with the pleasure car, the commercial vehicle is capable of traveling at various speeds wherever road conditions will permit it to go. Both comprise in a single entity a wheeled vehicle suitable for transportation purposes, fitted with an independent, self-contained power plant, and both present the same engineering problems so far as they relate to the construction of the motor, its control, and the transmission of its power to the road wheels, the design of the running gear, and the control of the vehicle itself. Divergence in practice is encountered with the consideration of the purposes for which each vehicle is designed. The pleasure car is not intended to be a very efficient vehicle. Its carrying capacity bears a comparatively insignificant ratio to its total weight, and, usually, the car is not designed to work under the same severe and continued conditions of service that are the first requirements of the commercial vehicle It must be capable of high speed with its maximum load of passengers and must combine reliability with endurance to an extent sufficient to meet the demands of its owner when on pleasure bent.

Classification. In order to make the subject as clear as possible and to facilitate reference on the part of the student, industrial motor vehicles as a whole have been classified, first, by their motive power; and second, by the uses for which they are intended. Thus there are, today, in the order of their relative importance:

Motive Power	Electric vehicles Gasoline-driven vehicles Gas-electric vehicles Steam vehicles
Types of Vehicles	Industrial electric trucks Delivery wagons Trucks, vans, and similar freight carriers Passenger vehicles—stages, busses, taxicabs, sight-seeing cars, etc. Municipal vehicles—patrol wagons, ambulances, fire apparatus, garbage-removal wagons, street sprinklers, etc. Special types—railway tower wagons, emergency repair wagons, farm tractors, road trains, etc.

This classification has been made advisedly, for, though kerosene and alcohol are being experimented with as fuels for the internal-combustion engine and particularly for commercial purposes, by far the greater majority of types marketed at present are driven by gasoline fuel.

Each of the foregoing principal divisions is susceptible of further subdivision, but this is neither necessary nor desirable. Commercial motor vehicles are now built for almost every conceivable purpose involving freight hauling or the transportation of passengers and include many special uses, such as hauling huge reels of telephone cable and drawing the cable through the underground conduits, transporting and hoisting safes and pianos, delivering coal with special dumping wagons, and the like. They differ only in the special equipment with which they are provided for the service in view, and, as their construction otherwise is the same, it would only lead to confusion to attempt to consider them separately.

ELECTRIC VEHICLES

Range of Use. Owing to the general recognition of its simplicity and economy, which has been brought about by a co-operative propaganda fostered by the electric lighting and power companies, the growth of the use of the electric commercial vehicles during the past few years has been little short of phenomenal. One New York firm alone uses nearly 350 electric delivery wagons, several have nearly 100, while no fewer than forty-five have "fleets" of 10 cars or more. All told, there are several thousand electric vehicles in New York City and more than 100 garages and charging stations, while the demand for current has been so great that the minimum for charging batteries has recently been reduced to $10 per month. Current is supplied at a preferred rate under special contract, which calls for the charging of the batteries during those hours of the night when the load on the central stations is lowest.

Advantages of the Electric Type. *Simplicity.* One of the chief advantages of the electric vehicle, when judged from the purely commercial point of view, is its great simplicity, which, to a very large extent, solves the labor question that has proved such a deterrent to the adoption of the gasoline vehicle for commercial service. As the duties of the driver of an electric vehicle do not extend beyond its actual starting, stopping, and guidance while under way, anyone who has been accostumed to the use of horses can master its operation in the course of a few hours. This also appears to be equally true of men who have never driven any type of vehicle previous to their taking the wheel or steering tiller of an electric. Apart from the actual mechanical control of the vehicle, the driver's only other care is to keep informed as to the state of charge of the battery by watching the voltmeter, in order to prevent running the car with the batteries exhausted, as this is very detrimental to their continued usefulness. However, as the batteries of most commercial vehicles are charged every twenty-four hours and the car run is planned to lie within its traveling radius on a single charge, with a factor of safety allowed in addition, this is not a very onerous duty. The further requirement of noting the current consumption on starting and running, as indicated by the ammeter, in order that any defect in the operation of the running gear of the car may be detected and remedied, is also a very simple one, so that an unskilled driver is available at a correspondingly lower charge for labor cost in the operation of the vehicle. The adoption of the ampere-hour meter showing the actual consumption of battery energy has simplified the task of the driver still further.

Efficiency and Long Life. Broadly speaking, short runs with many stops are the province of the electric, so that probably 80 per cent of all average city deliveries come within its economic field. Its labor cost is much lower than that of the gasoline car, since an unskilled hand can operate it efficiently, while one man at the garage can take care of nearly twice as many electrics as of gasoline cars. The electric is easier on tires, owing to its reduced speed, insurance rates are lower, and its depreciation can be figured on a much more favorable basis, as it has been shown to have an average effective life of ten years. The fact that all its moving parts revolve has a most important influence on its low maintenance cost and reliability, many electric trucks showing an average of 297 days in service of the 300 working days in a year.

Power Efficiency. The amount of power available on a single charge of the batteries without unduly increasing the weight is so limited that in the design of the electric great care must be taken to eliminate friction and other sources of power loss at every possible point. This is further necessitated by the gradually decreasing efficiency of the batteries with age. Starting with 80 per cent when new, the efficiency may drop rapidly to 50 per cent or below unless the batteries are properly maintained, which is likewise true of the transmission efficiency of the running gear of the vehicle; so that while unskilled labor may be employed for the operation of the vehicles this is not the case where their maintenance is concerned. Power losses due to the tires are also an important factor, and as the pneumatic tire can very seldom be considered for commercial service, the same degree of efficiency is not obtainable from the business electric wagon as from the pleasure type employing the same motive power. Road conditions must also be considered—despite the fact that electrics are employed almost exclusively for city or near-by suburban service—as mud, snow, and ice in winter, and poor pavements at any time cause an increase in the current consumption.

ELECTRIC DELIVERY WAGON

General Specifications. Whether considered from the point of view of design and construction or from that of operation, the electric delivery wagon is, without doubt, the simplest vehicle in the commercial field. As already mentioned, its operation may be mastered in a comparatively short time, either by the ex-horsedriver or by a person who has never had any experience in the control of a vehicle, so that the labor cost—always an item of importance in this field—may be materially reduced without fear of the equipment suffering in consequence. It is usually customary with manufacturers of these vehicles to adopt a standard form of design, which is employed throughout in every size listed by the same maker, the only differences being those of dimension, load capacity of the vehicle, and capacity of the battery to take care of the increased weight.

Package delivery wagons and express wagons of the electric type have a useful load capacity ranging from 1000 to 2000 pounds, though a very few of less than 1000 pounds' capacity were employed at first. The 40-mile run is standard and is based on an average speed of 10 to 20 miles an hour, including stops, as the necessity for frequently stopping and re-starting the car in delivery service has an important bearing on the mileage of which the car is capable on a single charge. The latter is naturally figured on the maximum efficiency of the car as a whole, so that in practice this is seldom fully realized, owing to the deterioration of the batteries in service.

Design. The electric has progressed through the stages represented by the angle-iron frame, the armored wood frame, and the modifications of the two as employed on gasoline cars to the now generally current type of pressed-steel frame. This frame has the advantage of being extremely strong for its weight. It is composed of side and transverse members produced in hydraulic presses directly from steel plates of about $\frac{5}{16}$-inch thickness, these members being riveted together and further reinforced by gussets at the corners. On account of the height of the vehicle, the frames are made perfectly rectangular and without either a drop or narrowing forward.

The types of suspension employed also show the same variations as are to be found in the gasoline-driven cars, some of the smaller electrics having the full elliptic springs ordinarily employed on wagons, while intermediate and heavy vehicles have either straight semi-elliptic springs front and rear or a half-platform type of suspension in the rear. A study of the Baker and General Vehicle types of delivery wagons and trucks will show how closely they approach, as a whole, to what is considered general practice in the automobile field.

Because of the heavy loads carried and of the fact that solid tires are used, the entire running gear has to be planned on a very liberal scale. This is likewise true of the springs. While it is desirable that the latter afford as much protection to the mechanism as possible, sufficient stability to carry the load is of more importance than flexibility, as the comparatively slow speeds do not occasion the violent shocks met with in the pleasure car.

MOTIVE POWER

Type of Motor. As already mentioned, the motive power of the majority of smaller electric vehicles consists of a single motor, and, in several makes, such as the Waverley, G.V., G.M.C., and Detroit, this practice extends to heavy units, with a corresponding increase in the efficiency of the vehicle as a whole. In order to keep down the weight as well as the space occupied, these motors are very small for their power output, and consequently have to be wound for high rotative speeds. They are usually of the series type of the General Electric or the Westinghouse make and are designed to carry heavy overloads for short periods, to enable the car to pull out of a bad place, to start with full load on a heavy grade, or to meet similar emergencies, the motor, under such conditions, delivering an amount of power greatly in excess of its normal rating.

Motor Suspension with Chain Drive. Since the use of spur-gear drives has decreased, the motor is usually suspended from the frame by means of transverse members riveted to the side rails and is placed near, or slightly forward of, the center of the chassis, in order to give the best distribution of weight. This is an advantage not obtainable when the motors are hung from the rear axle or too close to it. In view of the high speed at which the motors run—1800 to 2000 r.p.m. or more—a reduction in two stages is necessary to avoid the employment of excessively large sprockets. The first step is from the motor to a countershaft by means of a single silent chain of the Morse or the Renold type, the motor being suspended in such a manner that it may be moved a short distance one way or the other to permit the adjusting of this chain to the proper tension, Fig. 1. The large sprocket on the countershaft, which serves to cut down the speed in the proportion of about 1 to 5, also embodies a differential, or compensating, gear of the usual bevel or spur type, thus making it possible to employ a solid one-piece axle instead of weakening the latter by inserting the balance gear in it. This is an important feature, as the rear axle must bear 60 to 70 per cent of the total weight of both the car and the load. From the countershaft, chains are run to each of the driving wheels. The relative positions of the countershaft and the rear axle are maintained by heavy adjustable radius rods, attached forward to the outer ends of the countershaft and, at the rear, to the axle. These rods take the stress of the drive off the

Fig. 1. Motor Suspension and Silent-Chain Drive on Baker Trucks

springs and counteract the tendency of the chains to draw the rear axle toward the countershaft, under the pull of the motor.

Motor Suspension with Shaft Drive. On light delivery wagons of the shaft-driven type, three methods of motor suspension may be noted. In the first method, the motor is placed just forward of the rear axle, its housing being practically integral with that of the axle. Either a worm drive permitting of a single-speed reduction or a two-speed gear through spur gears is employed. As the motor moves with the axle and their relations are fixed, flexible joints are not required. A modification of the first method consists in placing the motor under the car at about the center and mounting it on a flexible suspension so that it can move under stress without disturbing its alignment; while the third method provides for taking such stresses on universal and slip joints interposed between the motor and the rear axle.

Fig. 2. Chassis of 4000-Pound G. V. Electric Delivery Wagon

The relative locations of the various essentials of a delivery wagon of the single-motor side-chain-drive type are clearly shown in Fig. 2 that illustrates a G.V. chassis of 4000 pounds' capacity, this being the same except for the difference in size.

Worm-Gear Transmission. While the power is transmitted through a combination-chain drive, i.e., silent chain for the first reduction and roller chains for the final drive, on the majority of delivery wagons, the practice of utilizing the worm drive, which has recently been adopted on the pleasure cars, has also been taken up in this field on the light vehicles. An example of this is represented by

Fig. 3. Rear Axle of Commercial Electric Delivery Wagon

the G.V. 1000-pound delivery wagon, equipped with a single motor driving through a propeller shaft having two universals and with a David Brown (British) type of worm-gear rear axle. On machines of this class, it is customary to mount the motor on a flexible support, which permits it to adapt itself to variations in the angularity of the propeller shaft, thus reducing the load imposed on the universal joints and, at the same time, avoiding the effects of torsional stresses on the motor. As the location of the motor is such as to prevent the suspension of the battery below the frame in the usual cradle, it is carried forward under a bonnet, or hood, and the wheel-base of

Fig. 4. G.M.C. Chassis with Combination Shaft and Chain Drive

the chassis correspondingly lengthened. This is not the case with the Commercial worm-driven delivery wagon, as in this instance the motor is placed almost directly on the rear axle, as shown in Fig. 3, thus eliminating the propeller shaft and the necessity for universal joints. The spring suspension of the motor will be noted protruding above its forward end.

Fig. 5. Motor, Drive Shaft, and Jackshaft Assembly for G.M.C. Electric Wagon

Shaft and Chain Transmission. The G.M.C. (General Motors Company) electric embodies a combination of shaft and chain drive, as shown by the chassis, Fig. 4. This drive incorporates an ingenious

Fig. 6. Details of Motor Mounting, Brake, and Drive, G.M.C. Electric Delivery Wagon

feature consisting of the use of a spring steel shaft, as shown by the detail view, Fig. 5. The design of these cars, as shown by the chassis, is standard for all capacities ranging from a 1000-pound delivery

Fig. 7. Chassis of Waverley 5-Ton Electric Truck, Showing Battery Installation

wagon up to a 6-ton truck, and, in each case, the section of this shaft is calculated to transmit the power necessary, with a predetermined degree of flexure in starting, which serves to cushion the mechanism as well as the tires. The pin attachment at the motor and the bevel-gear-driven countershaft eliminate the necessity for universal joints in this member while still permitting a rigid mounting of the motor on its sub-frame. As will be noted in Fig. 6, which shows the details of the complete drive, this sub-frame is carried in bearings on a tubular transverse member, thus allowing for relative movement in a longitudinal plane, the shaft itself compensating for torsional stresses.

Unit-Wheel Drives. Mention has already been made of the abandonment of two-motor drives on comparatively light cars, as well as the successful employment of a single motor on vehicles up to 5 tons' capacity, as in the case of the Waverley 5-ton chassis,

Fig. 8. Two-Motor Axle with Spur-Gear Drive, Commercial 2-Ton Truck

Fig. 7. The Commercial electric is an exception to this in that it shows the successful employment of two motors on cars as small as one-ton capacity. The rear axle of this car is a complete self-contained unit, as will be seen upon referring to Fig. 8 illustrating the drive of a 2-ton Commercial. The form of mounting employed is clear in the illustration, while Fig. 9 shows the details of the gear reduction between the motor and the driving wheel. This concern also makes a four-wheel drive, which is employed on vehicles of 3½ to 7 tons' capacity. On these machines, both front and rear axles are alike. One of them is illustrated in Fig. 10, in which it will be noted that the motor and the driving wheel are an integral unit pivoted in

the axle to permit of utilizing all four wheels for steering. The speed reduction in this instance is simply a double spur-gear train meshing with an internal gear cut on a drum in the rear wheel.

Couple-Gear Truck Drive. A particularly ingenious example of the ease and directness with which electricity lends itself to special

Fig. 9. View of Spur-Gear Reduction of Commercial Electric Drive

forms of construction is to be found in the drive of the Couple-Gear truck, so called because all four wheels are not only driven by electric

Fig. 10. Two-Motor Axle of Four-Wheel Drive of Commercial Heavy Trucks

motors but are utilized for steering purposes. These vehicles are built as straight electrics, using a storage battery as the source of current; and as gas-electric vehicles, a gasoline engine and generator forming the power plant, the remainder of the design and construction being the same in both cases. Fig. 11 illustrates the detail of the axle design employed, each wheel being carried on a steering

Fig. 11. Couple-Gear Axle for Unit-Wheel Drive

spindle, and all four wheels coupled to act in unison, permitting the car to turn in a very short radius. The parts shown on the right-hand spindle in the illustration are the fields of the motor, the wind-

Fig. 12. Dismounted Couple-Gear Truck Wheel, Showing Motor Parts

ings being just visible in the armature tunnel. They are made in this form, as the motor is practically a part of the wheel.

The motor is built directly into the wheel, as will be apparent from the illustration of a dismounted wheel shown in Fig. 12. The motor is of bipolar type, designed with flat fields in order that it may fit within the wheel without unduly increasing its section, and is held by its attachment to the axle. The wheel accordingly revolves about the motor, being driven by the two small pinions which are noticeable on opposite ends of the armature shaft and which mesh with the circular racks attached to the periphery of the wheel. The brushes are carried in a yoke bolted to the outer half of the field casting, so

Fig. 13. Walker Electric Chassis, Showing Combined Motor Axle

that the removal of the latter makes everything accessible. The cables for the motor current are led through the hollow axle. Apart from this feature and the employment of a four-wheel steer, the vehicle itself follows more or less conventional lines.

Balanced Drive. The transmission on the Walker cars, known as a "balanced drive", is another radical departure from current practice in this respect. These cars are built in capacities ranging from 750 to 7000 pounds and have been in successful service for a number of years. As will be noted in Fig. 13, a single motor is employed, and it is built practically as an integral part of the rear axle, the housings of which form the fields. The armature of the motor is at right angles to the driving wheels, and its shaft is extended both ways to form the drive. At the outer ends, this shaft carries small spur pinions which mesh with two large gears. The latter,

Fig. 14. Details of Walker Electric Wheel Drive

in turn, mesh with an internal gear bolted to the inner face of the steel rims of the driving wheels themselves. The detail of this is made plain in Fig. 14, showing one of the wheels with the outer protecting disc removed. It will be apparent that this constitutes not only an unusually compact motor unit and transmission, having the great advantage of being always in direct line with its drive, but that it likewise dispenses with a differential, as the wheels themselves are balance gears.

CURRENT AND CURRENT CONTROL

Battery Equipment. As the motors commonly employed are wound to take current at 80 to 85 volts, the battery consists of 44 cells, divided into three or four groups of cells held in separate oak boxes, or "trays", as they are termed, to facilitate handling. This voltage is standard, regardless of the size of the vehicle, the latter being compensated for by changing the capacity of the battery. Thus, for light delivery wagons, each cell contains three positive and four negative plates of medium size, giving an 85-ampere-hour discharge capacity, while a 1000-pound wagon is equipped with a battery having nine-plate cells with a capacity of 112 ampere hours; a 2000-pound wagon, eleven-plate cells of larger dimensions, giving 140 ampere hours; and so on in accordance with the size of the vehicle and the load it is designed to carry. Most electric vehicles have the battery underslung, i.e., carried in a cradle supported from the frame of the chassis. The cradle is enclosed in a battery box for protection against mud and water and has hinged doors at the ends through which the battery may be introduced or removed. By this arrangement, the weight of the battery, which is the heaviest single item in the entire construction, is distributed evenly between the forward and rear wheels, which leaves the entire floor space of the wagon available for the load. In special types, such as the G.V. 1000-pound worm-driven delivery wagon, the usual practice in the pleasure-car method of carrying the battery under a hood forward is followed. All the wiring between the battery, controller, and motor is carried beneath the floor and is protected from injury by running it through iron conduits.

Controller. In the case of delivery wagons and light trucks, the controller itself is placed either beneath the seat or under the footboards and is similar in construction to those employed on street cars, but much smaller in size, owing to the low voltage and comparatively small amount of current to be handled. It is operated by a small hand lever and usually provides four speeds ahead and two reverse, all of which are obtainable by moving the same lever, although a special lock, or catch, must first be operated before the vehicle can be moved backward. This usually takes the form of a pedal, or kick plate, which may be depressed with the heel and must frequently be held down while reversing. When released, it automatically returns the controller to the ahead position, in order to prevent the vehicle from being backed inadvertently.

Departures from the usual method of placing the controller are to be found in some of the medium-capacity vehicles, such as the Baker, in which the controller is located on the steering column just below the footboards; in the Urban, it is placed in a special dash compartment, the lever being on the steering wheel. This compartment also contains the ampere-hour meter, a type of instrument which records in watt hours the amount of power drawn from the battery and, at the same time, indicates the available amount remaining at any time. Ampere-hour meters are coming more and more into general use on both pleasure and commercial electrics, and a detailed description of the instrument and its use is given in connection with electric pleasure cars. In service, this dash compartment is protected by an aluminum plate through which the dial of the meter appears. On the Commercial, the controller is mounted directly on the steering column and is operated by a second smaller wheel, Fig. 15. The controller itself is thus above the footboards, and by the removal of the protective housing shown becomes very accessible. In cases where it is necessary to provide for handling heavy currents, a railway type of controller is employed.

Fig. 15. Commercial Electric Controller on Steering Column

A novel controller installation that gives instant accessibility is found on the G.M.C., as shown in Fig. 16. The controller proper, as well as all wiring terminals, fuses, and meters are mounted under a short hood, the resistance being suspended just beneath the controller, while the charging receptacle is below the center of the bumper. This view illustrates the forward side of the dash, while Fig. 17 shows the side facing the driver. The connection between the control lever over the steering wheel and the controller is through a shaft and a bevel gearing, as shown in Fig. 16. In the illustrations, this lever is

Fig. 16. Controller Installation of G.M.C. Electric Delivery Wagon

at the neutral position, successive movement from this point forward giving five speeds ahead and two reverse speeds backward. The

Fig. 17. Simple Control of G.M.C. Electric

G.V. control is equally compact, being mounted in a steel box forming the driver's seat, as shown in Fig. 18. The safety switch and the plug connection for an inspection lamp are seen on the outside at the left. Inside are, first, the switch connections, then the fuses, and, next, the fingers of the controller. At the upper right hand (driver's left) is the control lever, while just visible below the box is the resistance.

Safety Devices. In view of the fact that the average driver of an electric delivery wagon or a truck is either a graduate from the reins or has had no experience in handling vehicles at all, it has become customary to provide safety devices which, to a large extent,

Fig. 18. Controller Box of G. V. Electric Delivery Wagon

prevent accidents that might otherwise result from this lack of experience.

Cut-Out Switch Connected to Brake. The brake is usually interconnected with a cut-out switch which automatically shuts off the power independently of the controller simply by the application of the former. While the brakes are sufficiently powerful to stop the machine even with the current on, forgetting to shut off the current would either blow out the fuses or result disastrously to the motor.

Circuit-Breaker and Hand Switch. A circuit-breaker is provided on some cars to obviate the necessity for frequent replacing of the fuses, this being the usual practice in street railway and other electric work. Frequently, a hand-operated cut-out switch is also installed to permit of inspecting or working on the controller without the necessity of disconnecting the battery, as a failure to do so where no switch is provided is apt to result in painful burns, owing to the large amount of current.

Charging Circuit-Breaker. Another safeguard is an automatically operated circuit-breaker to protect the battery from being overcharged. This is used in connection with the Sangamo ampere-hour meter, which is described under the head of "Meters". Unlike the Anderson device described previously, which can be employed only where connection can be had to the field coils of the generator, this circuit-breaker operates exactly the same as the circuit-breaker in a generating station, which opens the line when an excess amount of current passes through it, except that in this case its operation is not controlled by the number of ampere turns on the circuit-breaker itself, but by a trip switch actuated by the ampere-hour meter when its dial records that the battery is fully charged.

Devices to Prevent Accidental Starting or Tampering. Devices are provided to prevent the accidental starting of the vehicle when not anticipated by the driver; also to guard against tampering by the ubiquitous small boy. On the G.V. 1000-pound worm-driven delivery wagon, for example, the emergency brake cannot be locked on except when the "running switch" is in either the neutral or the charging position, and cannot be released until thrown into the running position. Moreover, this switch can be thrown to the running position only when the controller is at the "off" point, or neutral position. The interconnection of the brakes and the controller "throw-off" allows the driver to use both hands for steering, in an emergency and, at the same time, to cut off the power and apply both brakes with his feet. This emergency-brake lock compels the driver to turn off the current by throwing the running switch to neutral when leaving the car; it also prevents the brake from being released by an unauthorized person, as the driver can take the switch handle with him. As the brake cannot be released until the switch is thrown on, the driver is reminded of that fact. The running-switch lock prevents the accidental starting of the vehicle, which might happen if the controller had been tampered with during the driver's absence, and if, upon his return, he threw the running switch on without first looking at the controller handle.

Brakes. Owing to the comparatively low speeds, the braking equipment in the earlier designs usually consisted of a single set of drums attached to the driving wheels. Against the inner faces of these steel drums bronze shoes were expanded by means of a pedal and the usual brake rigging beneath the car. As was the case in practically all early chain-driven cars, the braking drums carried the driving sprockets on their outer faces.

But in this, as in many other essentials, practice has been improved along the lines followed in the gasoline car. It is now customary to employ two sets of brakes, one for regular service and one for emergencies. Usually, both sets of brakes are carried in drums on the driving wheels, either side by side or concentrically, a friction facing of asbestos on a woven-wire foundation being employed. In some cases, the service brake operates on a drum carried on the armature shaft of the motor.

Tires. While solid rubber tires are most generally employed, they are not necessarily so, as pneumatic tires are to be preferred where the merchandise to be carried is of a light or fragile nature or where speed is one of the chief features of the delivery service. They not only reduce the liability to breakage, but also lessen the cost of maintaining the vehicle in repair. However, as there are comparatively few branches of commercial service in which the pneumatic tire is economically practicable, its use is very limited. The solid tires employed vary in size from two to four inches, and for weights in excess of the capacity of the latter, they are used in twin form on the rear wheels.

SPECIAL FORMS OF THE ELECTRIC

Electric Tractors. The huge street-cleaning or garbage-removal truck, shown in Fig. 19, is drawn by a 5-ton G.V. electric tractor, the combination being along lines somewhat similar to the front-driven electrics adopted by the Paris street-cleaning department for the same purpose, except that the latter have a two-wheel tractor and are fitted with a specially designed covered steel body. One use of the electric tractor built along the lines just referred to is shown by the Couple-Gear propelled steam fire engine, Fig. 20. Part of the battery is carried on the frame and the remainder is suspended beneath it, the power consisting of two Couple-Gear motor wheels

Fig. 19. Five-Ton G. V. Electric Tractor Hauling Garbage Wagon

mounted on steering spindles and operated by a street-railway type of controller which will be noted at the left of the driver. The entire power plant is a complete unit, which is bolted directly to the engine without further alteration than the removal of its front truck.

Fig. 20. Couple-Gear Tractor Drawing Steam Fire Engine

Industrial Trucks. One of the most important developments of the past few years has been the widespread adoption of the so-called industrial truck. In a broad sense, the term represents a classification rather than a type, as there are several different types of chassis built for this purpose. Probably the first of these to be placed in service was the Lansden dock truck, designed for handling cargo on steamship piers. In addition to this, there are baggage and mail trucks for use in railway depots, also truck cranes and tractor trucks, and it will be apparent that they are designed for service where no other form of power than electricity would be either convenient or permitted. The battery truck crane, the baggage truck, and the tractor trucks are merely modifications of the simple freight truck, their functions varying somewhat in each case. The baggage truck has a field of its own in the handling of baggage and mail, some being of the drop-frame and double-platform type and others having the battery and mechanism placed below the loading platform, which is made of railway-car height.

The simple industrial, or freight, truck is built in sizes and capacities suitable for moving loads on piers, in freight sheds, warehouses, factories, and industrial establishments generally. Its short wheelbase permits it to pass through congested spaces, going backward or forward with the same facility, while it is capable of ascending gradients of 10 to 25 per cent. On piers and at railway terminals it can deliver its load on the deck of a vessel or in a box car. The capacity of such trucks seldom exceeds 2000 pounds, this figure being found the practical limit for trucks capable of the widest range of action. The loading space of a truck of this capacity is 28 square feet, while the total area required for movement is only 34 square feet, the machine having an extreme width of 4 feet and an extreme length of 8 feet, so that an industrial truck can be operated wherever a hand truck can go, while the former will ascend grades impossible to the latter.

Fig. 21 shows a standard G.V. 2000-pound industrial truck, of which there are several hundred in use. Both the battery and the driving mechanism are suspended below the platform, which has rounded corners and is extended to protect the mechanism at every point. Its speed on hard level surfaces is 7 miles per hour; its average radius, 25 miles on one charge of the battery, the current consumption for a full charge amounting to 6 to 8 kilowatt hours. For grades up to 10 per cent, only one motor is employed. When equipped with two motors, each rear wheel is driven by an individual motor geared to a housed spur gear fastened to the wheel. A spring-returned controller is used, the operating lever returning to neutral when released by the driver. The brake is also spring-operated and is normally set, so that in order to run the car the driver must keep the brake pedal depressed. A further safety precaution is an automatic cut-off

Fig. 21. G.V. One-Ton Industrial Truck Handling Freight

switch connected with the brake, so that in releasing the pedal of the latter the power is cut off automatically. In addition to this pedal, two operating handles are provided, one for the controller and the other for steering, the truck being capable of turning around in a 7-foot radius. In general freight-shifting service, the hauls averaging from 200 to 800 feet, each truck displaces from four to six men with hand trucks. The efficiency of these trucks is frequently increased by using them in connection with trailers and large numbers are employed in factories for transporting material from one department to another.

ELECTRIC TRUCKS

Classification. There is little, if any, difference in design between delivery wagons and trucks, the frames, axles, wheels, springs, and transmission simply being made heavier in proportion to the great increase in load to be carried, while there is a corresponding difference in the power of the motor or motors and in the size of the chains or other essentials of the transmission. As already mentioned, some makes, such as the Walker, adhere to the single-motor power plant even in sizes up to 2 and 3½ tons' capacity, and the G.V., Lansden, Waverly, and G.M.C., up to 5 and 6 tons, on the score of increased economy and higher efficiency, while others, such as the Commercial, employ two motors on vehicles as small as the 4000-pound size and four motors on larger trucks.

Next to the delivery wagon, in which electric power has scored a great success, trucks of 2-ton and 3-ton capacity are the most common forms of electric vehicles—though the 5-ton size has come into general use for brewery service—several hundred being run by brewers in New York, while one St. Louis company has nearly a hundred. Electric trucks of 6- and 7-ton capacity are also built. In order to obtain the increase in load-carrying capacity, the size of the motor must naturally be enlarged, with a corresponding increase in the power consumption, which calls for a very much larger battery. In order that the capacity of the battery may be sufficient to give the vehicle a practical radius of travel on a single charge without unduly adding to the weight, the speed is reduced, so that electric trucks of 2-ton capacity usually have an average speed of 8 to 10 miles an hour; 3-ton trucks, 6 to 9 miles an hour; while 5-ton trucks seldom exceed 7 miles an hour.

Characteristics of Chassis. The electrics listed by the General Vehicle Company afford an excellent example of a standard design of chassis applied to cars ranging from 1000 pounds up to 5 tons' capacity, the intermediate sizes being 2000 pounds, 2 tons, and 3½ tons. Naturally, the first two are delivery wagons and are capable of traveling 45 miles on a single charge of the battery at a maximum speed of 12 and 10 miles per hour, respectively. The 2-ton wagon, while capable of the same mileage, has a maximum speed of but 9 miles per hour. This is further reduced to 8 miles per hour for the 3½-ton truck, which has a radius of 40 miles on a charge, while the

5-ton truck travels only 7 miles an hour as a maximum and has an extreme radius of 35 miles on a charge. In every case, only a single

Fig. 22. Rear View of G.V. 4000-Pound Chassis

motor is used, and as the design in all other respects is also standard for all sizes, a description of the 4000-pound wagon will suffice.

Fig. 23. General Electric Motor

With the exception of the use of a single-motor drive, a large number of the parts employed are practically the same as those used in other makes of electrics. The foundation of the entire car consists of a pressed-steel frame, to which are directly riveted the cradle for

Fig. 24. Rear Axle of G.V. 2-Ton Truck

carrying the battery, the spring hangers, and the supports for the countershaft bearings.

A view of the complete chassis will be found in Fig. 2. The view is taken from above and illustrates every essential except the battery. At the rear are the semi-elliptic springs, the solid-steel axle, artillery wheels with solid rubber tires and large driven sprockets, driving chains, the single motor suspended from a transverse tubular member on the frame, the enclosed silent-chain drive from the motor to the countershaft, the wiring in conduits from the controller to the motor, and the countershaft with its radius rods to equalize and maintain its distance from the rear axle. These rods also serve to

Fig. 25. Front Axle of G.V. 2-Ton Truck

take the stresses of driving off the rear springs. Just in front of the countershaft is the steel cradle for the battery trays; at the left, that is, at the front of the truck, is the steering gear, forward axle, springs, and wheels.

An excellent view of the entire bottom construction, which gives a clear idea of the arrangement of the power and the drive, is shown in Fig. 22, while the essentials comprising it are shown in detail in Figs. 23, 24, and 25. Fig. 23 is a G.E. multipolar, ironclad motor. Fig. 24 shows the rear axle, while the forward axle and its steering attachments are shown in Fig. 25. A 44-cell storage battery furnishes current at 85 volts, the motor being wound to operate economically at this voltage. The battery is in sectional form, in crates of such weight and size as to permit of easy removal or of replacement from either side of the vehicle. It is so arranged that it may be recharged without disturbing it; but, where two batteries are employed, a charged set may be easily and quickly substituted for the exhausted battery.

The controller is of the continuous-torque type which will permit of changing the motor speeds by degrees without interrupting the power between any of the steps. This gives a gradual and steady acceleration, without the jerk and strain so detrimental to the life and efficiency of every part of the vehicle. The motor is designed along the lines which have proved so successful in street-railway work. It has a very heavy shaft as well as a simple and durable brush rigging and is wound to show not only a high efficiency but also a high capacity for overload. The armature shaft, which is carried on annular ball bearings that tend to greatly increase the efficiency of the motor as a whole, is suspended on a transverse bar pivoted to the side members of the frame forward of the rear axle. This pivoted suspension keeps the motor shaft parallel with the countershaft throughout the entire range of chain adjustment and permits the use of an efficient silent-chain drive, which, as will be noticed in Fig. 2, is enclosed in an aluminum housing.

The countershaft is housed in and is carried on four taper-roller bearings inside the tube, the latter being held in self-aligning ball sleeves in hangers riveted to the sides of the frame. The two short driving shafts are connected by a spur differential and carry at their outer ends small sprockets for the roller chains to drive the rear wheels, the entire countershaft being a complete unit. It is driven by a silent chain of ample width running over a small pinion on the motor and over the gear of the differential. Altogether, this is a very efficient form of truck.

GASOLINE VEHICLES

GASOLINE DELIVERY WAGONS

Classification Limits. It will be found on a brief examination of the subject that this is a far more comprehensive heading than would appear at first sight, as it includes everything from the little three-wheeler up to the type known as the "light truck", but which is, in reality, also a delivery wagon with an open platform, or stake type of body. The range of carrying capacity is from one to two hundred

Fig. 26. Autocar Two-Cylinder Delivery Wagon

pounds up to one ton, or slightly more, as many delivery wagons and light trucks are built with a load capacity of 2500 pounds or even 3000 pounds.

Autocar. The Autocar delivery wagon, Fig. 26, affords an excellent example of a vehicle designed especially for the most severe business conditions. The motor is of the two-cylinder, horizontal, opposed, four-cycle type, the cylinder dimensions being $4\frac{3}{4}$-inch bore by $4\frac{1}{2}$-inch stroke, and is rated at 18 horsepower. The crankshaft is mounted on imported annular ball bearings, which not only add greatly to the efficiency of the motor as a whole, but do away with the attention necessary to adjust plain bearings. This construction, which is far more expensive than plain bearings, also reduces the number of parts which are subject to damage should the driver neglect to provide sufficient oil. The lubrication system is entirely automatic in operation. Two flywheels are carried on the crankshaft, the forward one having its blades cast staggered so as to set up a strong current of air, thus eliminating the necessity of a belt- or gear-driven fan, while the rear flywheel carries the clutch. The importance of providing ample weight in the balance wheel is something to which insufficient attention has been devoted in the past, its influence upon the starting ability and the smooth-running qualities of the vehicle being extremely marked, especially where a two-cylinder motor is employed. Both flywheels on the Autocar motor are counter-weighted, and this, supplemented by a careful balance of all the reciprocating parts, makes an extremely smooth- and quiet-running motor with unusual starting and grade-climbing ability for its size.

The crankcase is split horizontally into two sections, the lower half carrying the cylinders, crankshaft, camshaft, and water pump, while the upper half carries the push-rod guides, the magneto, the oiler, and a gear for driving the water pump. The magneto and oiler are both driven through bevel gears and short shafts, reducing the possibility of failure in these two highly important essentials—ignition and lubrication—to a minimum. The upper section of the crankcase is readily removable, carrying its parts with it and thus giving access to the crankpin bearings without the necessity of dismantling the motor. A Bosch magneto with a fixed firing point is employed, thus taking this element of control out of the hands of the driver. Lubrication is by a force-feed oiler delivering oil through a sight feed to the crankcase, from which the pistons, crankpins, and main bearings are lubricated by splash. Both the magneto and the lubricator are simply attached to the crankcase by wing nuts so that they may be removed without the aid of tools. A hydraulic speed regulator, connected in the circulation circuit of the cooling water, controls a throttle placed in the intake manifold between the carburetor and the cylinders, limiting the speed of the motor to 1400 r.p.m. and that of the vehicle to 18 to 20 miles per hour.

A patented floating-ring clutch, which has been developed on the same make of pleasure cars and used for a number of years, constitutes the first step in the transmission. It consists of a bronze floating ring, lined with cork inserts on its inner face, and is mounted on four keys on the inside of the rim of the rear flywheel, thus rotating with the latter. Two cast-iron rings, adapted to clamp the bronze ring when the clutch is engaged, are mounted on the clutchshaft which extends into the transmission case. Engagement is accomplished by a sliding trunnion and four toggle links, the motion of which is checked by a dashpot and a plunger. This insures gradual automatic action, entirely free from jerk, regardless of the care exercised by the driver. The addition of small springs to the floating ring eliminates all noise, whether the clutch be engaged or not.

Fig. 27. Autocar Double-Reduction Floating Rear Axle

Fig. 28. Rear View of Autocar Delivery Wagon

The transmission housing is all in one piece, except its cover plate, and has been so designed that all the shafts and gears may be removed without disturbing the housing itself. The shafts are large and are

Fig. 29. Autocar Engine and Transmission Mounted on Separate Sub-Frame

carried on adjustable roller bearings, while the gears have broad faces and heavy teeth. Three speeds forward and one reverse, operating progressively, are provided, lubrication being obtained by covering the shafts and gears with a bath of semi-fluid oil.

Fig. 30. Autocar Engine and Transmission—Plan View

Both front and rear axles have been designed especially to meet the requirements of the heavy service imposed upon them in carrying the load on solid rubber tires. The front axle is of the tubular type, with extra heavy yokes for the steering spindles, which are made integral with the spring saddles. Adjustable roller bearings are employed in the wheel hubs. The rear axle is of the full floating type, with a double-gear reduction. A bevel pinion at the end of the propeller shaft meshes with a large bevel gear on a short transverse shaft, from which the drive is transmitted to the differential case by means of a pair of substantial spur gears, the method of mounting them being shown by Fig. 27. The complete axle, as well as the spring suspension, the brakes, and other details are shown in the rear view, Fig. 28.

One of the chief features of advantage on the Autocar delivery wagon is the mounting of the complete motor and transmission, barring the rear axle, on an independent sub-frame, as shown in Figs.

Fig. 31. Plan View of White Delivery Wagon Chassis

29 and 30. An illustration of the complete chassis would show every part of the power plant to be accessible by lifting the bonnet, while the complete unit, as shown separately, may be removed from the chassis and replaced by another. The rear view of the chassis, Fig. 28, shows the relative location of all the essential parts, including the gasoline tank, which is placed transversely on the main frame directly under the driver's seat. The frame is of pressed steel, perfectly rectangular and heavily reinforced. Two sets of brakes act on drums attached to the driving wheels, while the suspension consists of double-elliptic springs in the rear and semi-elliptic springs placed forward directly under the motor.

White. This may be regarded as a representative standard design, as will be evident from the photo of the chassis, Fig. 31, showing that it differs from heavier-capacity vehicles of the same make only in being shaft-driven and having lighter dimensions. It is built in 1500- and 3000-pound sizes, the chassis illustrated being of the latter capacity. Single rear tires are usually fitted on the smaller car, and pneumatics are frequently employed to take advantage of the higher speed thus made possible, an example of this practice being illustrated by Fig. 32. Apart from the difference in dimensions and tire equipment, both sizes are the same, each being equipped with a $3\frac{3}{4}$- by $5\frac{1}{2}$-inch motor, the cylinders of which are cast in one piece,

Fig. 32. White Delivery Wagon with Light Top Body and Pneumatic Tires

with the intake and exhaust passages integral. This motor is rated at 30 horsepower and fitted with a compression release for starting. A single-nozzle water-jacketed carburetor supplied with hot air from a jacket on the exhaust pipe, a high-tension magneto for ignition, and a gear-driven centrifugal water pump comprise its auxiliaries.

GASOLINE TRUCKS

Load Efficiency Increases with Size. It will be apparent that above the 2-ton size the load efficiency increases, as, once a certain point is reached, additions to the weight caused by increasing the dimensions of the load-carrying space and adding to the power of the motor are disproportionately small as compared with the increase in load capacity. For example, one truck of 3-ton capacity has a chassis weighing only 4500 pounds, which tips the scales at 5200 pounds completely fitted, or "all on"; on the other hand, another chassis for the same nominal carrying capacity, i.e., 3 tons, weighs 6000 pounds. However, as no standard for rating the load-carrying capacity of gasoline trucks has ever been attempted, and one maker's 5-ton truck is sometimes no larger than the 3-ton truck of another, it is often difficult to make comparisons that will be fair on a basis of catalogue weights alone.

MOTOR DETAILS

Design

Both the design and construction of internal-combustion motors for commercial use are along lines similar to those employed on pleasure automobiles except as modified by the requirements of the more severe service. This necessitates a higher factor of safety throughout, such as increased provision for lubrication and cooling; extra large bearing surfaces, which must be readily accessible for adjustment, except, of course, where antifriction bearings are employed; increased crankshaft dimensions; broad gear faces; and a considerably increased weight of flywheel in order that the motor may develop as high a torque as possible at low speeds. The greater amount of weight in the rim of the flywheel also eliminates motor vibration to a considerable extent and makes the engine run much more smoothly. Such variations of design as are usual in the pleasure-car motors are to be found in the commercial type; in fact, where a manufacturer builds both types, the same lines are followed in each case, the only practical difference being in the dimensions and speeds. It will be necessary, accordingly, to refer to only a few of the more representative makes.

Long Stroke, Low Speed. Generally speaking, a commercial motor is of the long-stroke low-speed type, some idea of the proportions being obtainable by the dimensions of the White and the Pierce-Arrow motors for 5-ton trucks. The former has a $4\frac{1}{4}$-inch bore by a $6\frac{3}{4}$-inch stroke, while the latter measures $4\frac{7}{8}$ by 6 inches. Similar small variations in dimensions are to be noted in practically every make, in conformity with the varying standards of compression and volumetric requirements adopted by their designers. This will be apparent by a comparison of a few makes, such as the Locomobile, 5 by 6 inches; G.V. and Mercedes, 4.25 by 5.9 inches; Peerless and Kelly, 4½ by 6½ inches; Vulcan, 4¾ by 5½ inches. No increase is made in motor dimensions above the 5-ton size, the extra carrying capacity being gained by higher gear reductions and lower speeds, the Vulcan motor mentioned being employed on both the 5- and 7-ton sizes of that make. These motors are variously rated at 35 to 40 horsepower,

Fig. 33. Peerless 5-Ton Motor, T-Head Type

viz, Vulcan, 36 horsepower; White, 40; Kelly, 38.5; Peerless, 32.4; Pierce-Arrow, 38.

Causes of Variations in Ratings. The variation in the ratings is due to a number of causes, although one of the chief reasons is the differences in the practice followed, i.e., in some cases, the power stated is the maximum indicated horsepower based on the dimensions and worked out by the S.A.E. formula of $\frac{D \times N}{2.5}$, in which D is the bore, N the number of cylinders, and 2.5 an arbitrary constant derived from taking the speed characteristics of a large number of motors and striking an average representing a piston speed of 1000 feet per minute. In other cases, it is the result of actual brake tests

Fig. 34. White 40-Horsepower Block-Type Motor for 5-Ton Truck

Fig. 35. Pierce-Arrow Motor for 5-Ton Truck

and is accordingly based on the maximum r.p.m. rate of the motor; while in still others it is the power which the motor is capable of developing at the speed at which it is controlled by the governor, usually 800 to 1000 r.p.m., to give the best service from the truck of the capacity for which it is designed. For instance, the rating of the Kelly motor is based on a speed of 900 r.p.m., while that of the Peerless, Fig. 33, of the same dimensions, is its indicated horsepower figured according to the above formula. The White motor, Fig. 34, is an example of the L-head type; while the Pierce-Arrow, Fig. 35, like the Peerless already mentioned, is of the T-head type.

Accessories

Ignition. In every department of commercial-car practice, the designer aims to make the operation of the machine as nearly automatic as possible and to that extent to relieve the driver of any opportunity to exercise his discretion. The usual practice is to employ a magneto fitted with an automatic spark-timing device. This operates on the principle of the centrifugal governor and is controlled entirely by the speed of the motor, so that when the motor is stopped the spark timing is fully retarded and there is no danger from a "back-kick" as is the case where this precaution is inadvertently overlooked. As the motor speed increases, the occurrence of the spark in the cylinders is automatically advanced to correspond, thus relieving the driver of this important function and preventing the abuse of the motor in unskilled hands. The same slight differences in detail as found on the pleasure type are also found in the ignition systems of commercial cars.

Carburetors. Carburetors also are the same both in principle and construction as on the pleasure cars, except in instances where they have been specially designed for commercial service, in which case the modification applies to the construction. In view of the very general custom in this country of leaving the design of auxiliaries to the accessory manufacturer, the number of these instances is very small, so that in the majority of cases the carburetor manufacturer sells the same carburetor for either type of vehicle. To permit of the efficient utilization of lower-grade fuels, ample provision is usually made for heating the carburetor by a large warm-water jacket and a supply of hot air taken from a collector located on the exhaust pipe.

Cooling Systems. The so-called direct system, in which air is relied upon to keep the cylinder walls of the motor at a temperature that will permit of efficient operation without danger of seizing, was never attempted on commercial vehicles except in the lighter sizes. Most of these were light delivery wagons, although one make of 3-ton trucks employed a blower system for several years. However, air as the cooling agent without an intermediary in the form of a water circulation has been definitely abandoned on the commercial car. Both the principles and the operation are the same as on pleasure cars, due allowance being made for the more severe service by increasing the size of the pump, the section of the cylinder jackets, the area of radiating surface, and the diameter of the connections.

Radiator Construction. The radiator is the most vulnerable part of the truck, and precautions are therefore taken to protect it from injury. In order to be proof against the constant vibration and jolting, the gilled-tube type of radiator is employed in the majority of instances. Accidental damage is usually provided against by extending the frame and equipping it with a bumper, and further protection is sometimes afforded by mounting a heavy wire screen in front of it. This is done more frequently on honeycomb, or cellular, radiators, as they are liable to suffer severely when prodded with the steel-shod pole of a horse-drawn truck, and are difficult and expensive to repair. In the case of the gilled-tube type, only those tubes actually struck are likely to be damaged and they will frequently bend without rupture, while often nothing more serious happens than the bending and derangement of the cooling fins with which each tube is surrounded. These tubes are placed vertically and, in the case of the Reo 2-ton truck radiator, Fig. 36, are made demountable, so that a damaged tube may be easily replaced in a short time without the necessity for making any soldered repairs. It will be noted that each pair of tubes is held in place by a bolted yoke, so that upon loosening the yoke they may be lifted out. This illustration also clearly shows the flat copper tubes, which are placed with their narrow edges facing the air current, as well as the copper radiating fins attached to them. The upper and lower parts of the radiator are hollow castings, which form tanks, the sides merely providing a support and spacer for the tubes. The usual construction consists of a removable tank, which forms the top and bottom chambers, with a bank of gilled tubes having their ends expanded and soldered into perforated plates, the solder playing an unimportant part, as such joints cannot be relied upon where there is much vibration.

Unless properly provided against, one of the chief sources of injury to the radiator arises out of the twisting of the frame under torsional stresses. Flexible joints between the radiator and motor are accordingly necessary to take care of relative movement, and it is common practice, both in this country and abroad, to employ rubber hose for this purpose. By reason of the heavy loads carried and the use of solid tires, this precaution is not sufficient to guard the radiator against the effects of vibration and road shocks, so that it is usually mounted on some kind of spring suspension. This spring suspension usually consists of a pair of helical springs, one on either side, so that the radiator has no solid connection with its support. In some instances, the radiator is hung on a pair of trunnions, similar to a gun mounting, but this form, while providing ample allowance for movement, does not cushion it against shocks. Still another method consists in mounting the radiator on an extension of the motor, the motor itself being carried on a three-point support, so that the radiator and motor move together; but, unless provided with some form of spring buffer between them, this type suffers from the same disadvantage as the one just mentioned. Figs. 37 and 38 show some typical methods of radiator protection.

Fig. 36. Reo Demountable-Section Gilled-Tube Radiator

Fans. In every case, the radiator is supplemented by a fan driven at high speed, and, in view of the slow travel of the heavier trucks, the proper working of the cooling system depends upon the efficiency of the fan, since the speed of the vehicle cannot force a strong draft of air through the radiator as it does in a touring car. Thus, the fan is a very important part of the cooling system on a slow-moving vehicle, as it must provide an ample draft, no matter how low the road speed may be, otherwise the engine is liable to heat beyond the point where the oil begins to lose its lubricating qualities. An inefficient fan allows excessive heating every time it is necessary to climb a long hill.

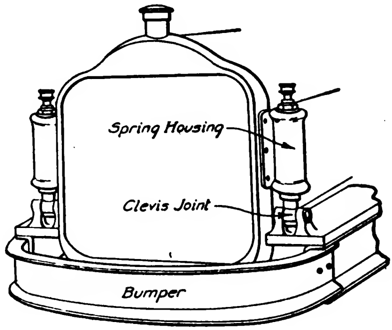


Fig. 37. White Radiator Mounting, Providing Spring Cushioning and Relative Movement through Clevises

Circulating Apparatus. In the majority of cases, the cooling water is circulated by a pump on commercial-car motors, though many heavy trucks, such as the Kelly-Springfield, have thermosiphon circulation. This pump is of the centrifugal type and is capable of delivering a much greater volume of water than are those employed on pleasure-car motors of corresponding power, owing to the reduced road speeds of trucks. These pumps vary more or less in design, but are based almost without exception on the centrifugal principle, as the latter is the only one which will permit of a thermosiphon circulation through it in case the impeller ceases to revolve. A stoppage of the gear type of pump also stops the circulation at once.

Lubrication. Granting that an excess can be prevented from reaching the combustion chambers of the cylinders, it is axiomatic that the power plant of a motor truck cannot have too much oil. In commercial service, the demands upon the lubricating system are quite as severe as they are upon the cooling system, and the failure of one usually involves the failure of the other in a short time. Hence, a greater amount of oil must be provided and every precaution taken to insure its reaching the bearings. Except for the increase in the quantity of

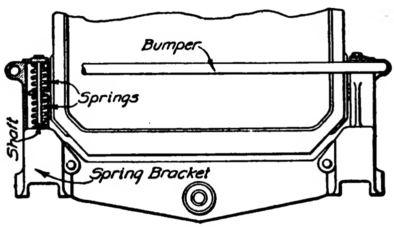


Fig. 38. Spring Hangers Combined with Front Hanger Bracket

lubricant, this does not differ in any way from the requirements of the pleasure car. Consequently, the systems employed are practically the same in both cases. The White lubrication system shown in Fig. 39 illustrates a typical sight-feed system.

Motor Governors

Of the two chief evils that beset the motor truck in the hands of the untrained driver—speeding and overloading—the former is the more destructive, as the driver who will overload his truck will also run at excessive speeds, and, with a heavy load, this is severe punishment for the entire mechanism. The practice became so common in the early days of the motor truck—nearly all drivers

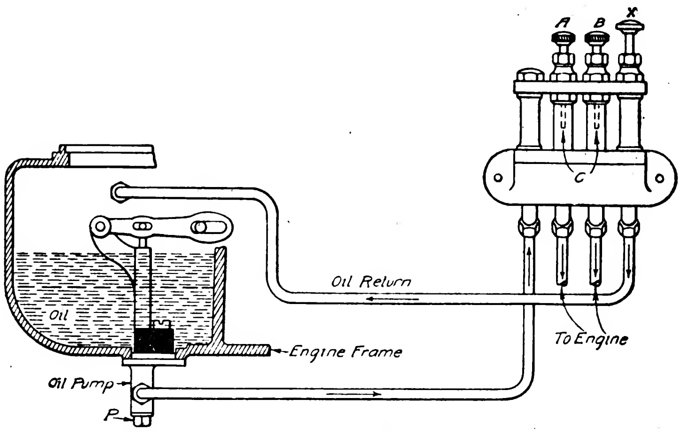


Fig. 39. Sight-Feed (Drop) Lubricating System as Used on White Trucks

then being graduates from the pleasure-car field—that it has now become customary to govern the speed of the motor. The governor itself is usually sealed to prevent its being tampered with by the driver.

General Characteristics. The most generally accepted type is that of the usual centrifugal governor attached directly to the motor and operating a butterfly valve in the intake manifold between the regular carburetor throttle and the valve ports. Owing to the high motor speeds and the slight amount of movement necessary, the governor is very small and compact, so that it will frequently be found incorporated in the crankcase at the end of the camshaft. A variation from this is a drive taken from an outside auxiliary, such as the magneto shaft or water-pump shaft. In either case, the speed of the governor is always directly proportional to that of the motor itself and bears no relation to that of the vehicle. This is a disadvantage at times, as in pulling through a heavy road on low speed when the maximum power of which the motor is capable is required.

Controlling Car Speed. An improvement on this practice has been the adoption of a vehicle "speed controller" which, while acting on the motor itself in the same manner as the usual motor governor, is controlled directly by the speed of the car and bears no relation to that of the engine. With this type, the motor is free to run at any speed at which the hand-operated throttle will supply it with fuel, so long as the speed of travel does not exceed that for which the governor, or controller, is set. So far as the motor is concerned, it is not directly governed and may be speeded up to any extent necessary to pull the car through heavy going or out of a ditch, as the controller does not come into action while the car is moving slowly. Practically, the only disadvantage of this type is the fact that it does not prevent the motor from racing, as does the former, when the load is suddenly removed, with the throttle open. The vehicle speed controller is driven either from one of the front wheels or from a shaft of the transmission, as its operation depends entirely upon the speed of the car. In addition to the centrifugal method of speed control, the hydraulic principle is also employed. It will be apparent that as the motor speed increases the circulation of the water, as driven by the pump, does likewise, and there is a corresponding rise in pressure in the cooling circulation. This rise in pressure is utilized to act on a large diaphragm connected with a plunger attached to a butterfly valve. A description of some of the governors in use will make clear the method of taking advantage of the different principles of operation.

Centrifugal Type. In Fig. 40 is illustrated a typical centrifugal governor designed for attachment to one of the auxiliary shafts, as will be noted by the driving gears at the bottom. As the revolving weights tend to spread against the compression of the helical spring surrounding the spindle on which they revolve, they push up a yoke to which a shaft directly connected with the throttle valve is attached. As in the case of the steam engine, this valve is entirely independent of the hand-operated valve which may thus be left all the way open. The details of construction of the Pierce governor are shown by the sectional view, Fig. 41, in which the weights are at the right. As the triangular weights open under the centrifugal force generated, they push the rod forward, and, as this rod has a rack cut on it

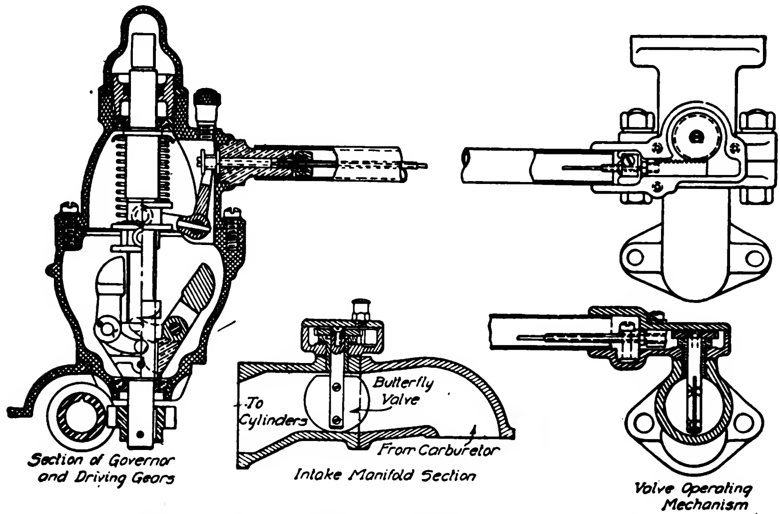


Fig. 40. Sectional Diagrams of Centrifugal Type of Governor

that meshes with a pinion on the butterfly valve, this action tends to close the valve. A spring keeps this rod pressed against the spindle on which the weights are mounted, but is not connected with the spindle in any way. As is true of all governors in this service,

Fig. 41. Sectional View of Pierce Centrifugal Motor Governor

a speed adjustment and a method of sealing it against tampering are provided.

Hydraulic Type. An example of the hydraulic type of governor is shown in section in Fig. 42, while the application of this form of governor is illustrated by the Reo 2-ton truck motor, Fig. 43. As will be seen in the section, this type consists of a water chamber, diaphragm, spring, and operating lever; the operating mechanism

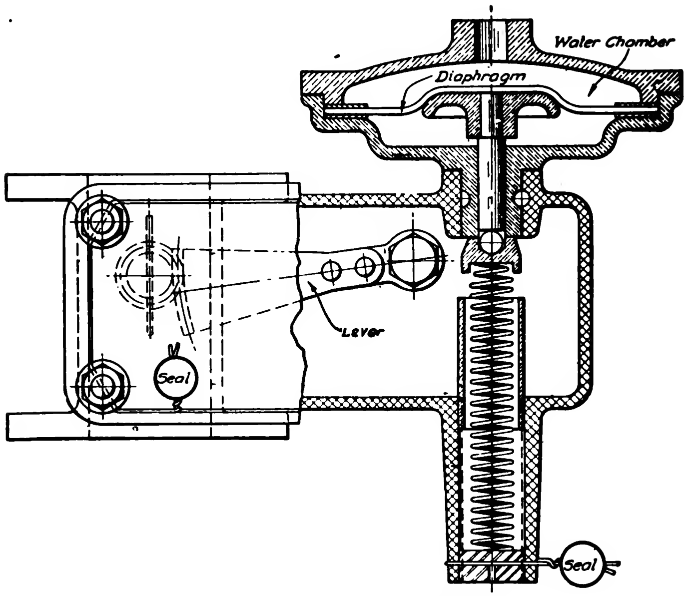


Fig. 42. Hydraulic Type of Governor

being combined with the governor proper results in a simple and compact unit which requires only one connection. This connection is led from the circulating system on the cold-water side, as will be noted in Fig. 43, in order to bring it close to the pump. As the speed of the pump increases, the pressure increases, and the diaphragm is forced down against the spring, carrying with it the lever operating the valve

Fig. 43. Hydraulic Governor as Installed on Reo 2-Ton Truck Motor

through a rack and a pinion. As the pressure decreases, the spring returns the diaphragm, and with it the valve, to its normal position. The water chamber, operating-lever housing, and the spring-retaining plug are sealed so that the adjustment cannot be varied without disturbing one of these seals. In this, as well as in the centrifugal type where the adjustment is effected by altering the tension of a spring, it will be obvious that the spring could readily be screwed up so tightly that no speed of which the motor was capable would have any effect on the governor, thus practically cutting out its action altogether.

POWER TRANSMISSION DETAILS

Clutch and Transmission

Clutches. *Cone Type.* A comparison of the specifications of a number of representative makes of trucks reveals a variation in clutch design about equivalent to what would be found on an equal number of pleasure cars, except that a greater number of instances of the leather-faced cone occur in the trucks. This is the oldest type employed on the automobile and is likewise the simplest in construction, which probably accounts for its more general retention in the commercial field. What is termed the *direct* conical type, in which the leather-faced cone engages by moving forward into the corresponding wedge-shaped recess of the flywheel, is in more general use than the *indirect,* or *internal,* cone in which the male member moves backward into engagement. An example of the latter type is found on the Peerless trucks, while the Garford, Kelly, Vulcan, Mais, and Pierce are representative of the former. In the case of the Pierce, the cone operates in an oil bath, the others running dry, as is more often the case.

Multiple-Disc Type. The Packard and Autocar in this country and the De Dion in France have long been fitted with a three-plate type, the Albion (British) having a single-plate form of clutch in the heavier sizes. Multiple-disc clutches are found on the Locomobile, the Mack, and the Reo, and other American makes.

Transmission. Owing to the great reduction in speed necessary between the motor and the driving wheels, transmission plays a more important part on the commercial vehicle than it does on the pleasure car. On the latter, its services can be dispensed with in an emergency, as the car can be started on the direct drive in case of accident to the intermediate speeds, but this would manifestly be impossible on a heavily loaded truck. In this connection, it is to be noted that the term "transmission" has come to signify the "change-speed gearset" alone, doubtless owing to the awkwardness of the latter appellation, and does not apply to the transmission of the power from the motor to the rear or front wheels or to all four, as the case may be.

Sliding-Gear Type. In the majority of instances, the sliding-gear type of transmission is employed for commercial work, in which the gears are actually slid into engagement with each other to effect the various ratios of driving and driven members. This type is

Fig. 44. Type of Transmission Employed on White Shaft-Driven Trucks

practically universal on the pleasure car, so that only a brief reference to it is necessary here. On almost all except the lighter vehicles, it provides four forward speeds, the others having but three speeds and reverse. Fig. 44 shows the White transmission as employed with a shaft drive. Owing to the controlling connections being absent, this has been inadvertently photographed with both the first, or lowest speed, and the direct, or highest speed, engaged. The large gear at the left, shown in engagement with its corresponding gear on the layshaft, gives the first speed. By moving it forward until the gear just ahead, with which it is integral, meshes with the next gear to the right on the layshaft, the second speed is obtained. Moving the single gear at the right back until it meshes with the right-hand gear of the pair on the layshaft gives third speed. For fourth speed, or direct drive, this same gear is moved forward, its forward face being cut in the form of a dog clutch that engages a similar gear permanently attached to the clutchshaft. This is unusual, as the dog clutch is generally formed of a smaller diameter extension on the hub of the direct-drive gear. The two gears at the extreme right-hand end are permanently engaged and serve to drive the layshaft. By moving the largest gear to the extreme left, the reverse is engaged, this being effected through an intermediate pinion, or idler, part of which is just visible below the main shaft at that point. The moving members slide on splines cut on the main shaft, the sliding being sometimes effected by making the main shaft of square section.

Fig. 45. Peerless Transmission and Countershaft

A similar transmission, combined with a bevel drive and spur-gear differential on a jackshaft for side-chain final drive, is that of the Peerless, Fig. 45. This is shown engaged on the direct drive, so the dog clutch is not visible. The material used in the housing is usually aluminum, sometimes cast iron, and, in the case of the Locomobile, manganese bronze. Annular ball bearings are employed in many instances, the bearings themselves being apparent in the White transmission and their mountings in the Peerless. Taper roller bearings are also employed for the same purpose. Operation is almost invariably by the selective method, the gear lever being shifted across through a gate to pick up one or the other of the sliding members shown. The control lever of the White, which is mounted directly on the transmission housing, is shown in Fig. 46. This lever is more often mounted at the side in a fixture also carrying the emergency-brake lever, as on the Pierce. On this truck, only three forward speeds are provided.

Mack Transmission. The Mack transmission, Fig. 47, is a selectively operated type in which the gears of the various speeds are always in mesh, small clutches being designed to slide in either direction on the squared main shaft, engaging the particular speed desired. These clutches are practically small gears which mesh

Fig. 46. Completely Assembled White Transmission, Showing Control Lever

with internal-gear members attached to the driving members. They will be noted lying between the driving gears on the main shaft, in the illustration. The gear housing in this case is of phosphor bronze.

Use of "Dog" Clutches. A variation of the Mack type of transmission employs what are known as "dog" clutches, probably from the fact that they apparently *bite* into one another, being cut with a comparatively small number of heavy teeth on their end faces. These teeth, if they can be properly so-called, are of heavy section and are cut with an easy angle which insures ready engagement. This will be noted in the direct-drive engagement of the White gearset. The dog-clutch type of gearset has been employed more in Great Britain than in this country. Its great advantages are that the driving gears are constantly in mesh and that the dog clutches can be engaged without particular attention being paid to the speed at which the two shafts are revolving, as is necessary with the sliding-gear type. The details of a transmission of this kind, as well as

Fig. 47. Mack Transmission Used on Manhattan Trucks

of the method of operation, are clearly shown in Fig. 48, which is a Cotta transmission designed for use on worm-driven trucks. As shown in the illustration, the first, or low, speed is engaged, the clutch on the layshaft at the lower right-hand corner being in mesh with its counterpart on the large, or low-speed, gear. The clutch-shaft being at the right-hand end of the gear box, as shown, the drive is then through the pinion on it, the large gear below, with which it is in mesh, and then through the layshaft and the pair of gears at the left-hand end, these gears being fastened to their respective shafts. The other gears, with the exception of the clutchshaft pinion previously mentioned, are free to rotate on their shafts and are permanently in mesh. However, the male members of the individual clutches, while free to slide on the shafts, must turn with them, so that when engaged they "pick up" the various gears corresponding to the different speeds.

Silent-Chain Transmission. Another form of transmission, which has been used to a greater or less extent abroad, but which has found little favor here, is the silent-chain type. This is along similar lines to the Mack transmission illustrated, except that roller chains take the place of the permanently meshed gears, dog clutches being engaged to pick up the latter according to the speed desired.

Final Drive

Until a few years ago, there was a sharp line of demarcation between the pleasure car and the commercial vehicle where the

Fig. 48. Cotta Individual (Dog) Clutch Transmission Designed for Worm-Driven Trucks

important final drive was concerned. Practically all pleasure cars were shaft-driven, and, to the same extent, commercial cars were chain-driven. The tendency that has manifested itself in the interim makes it apparent that the history made in the development of the pleasure car is apt to repeat itself in commercial-car development. In other words, chain-driven trucks were largely in the majority a few years ago, but the recent advances made in live-axle construction have had a marked effect and their adoption has now reached such a scale that, barring something unforeseen, the chain on the truck will soon disappear as it has from the touring car.

Classification. As at present employed, there are four general classes of final drive on commercial cars. In the order of their age and present comparative importance, these are: first, the double side-chain from a centrally located countershaft carrying the differential and the bevel drive, and usually combined with the gearset, or transmission, so called; second, the worm drive, which differs from the bevel-gear type only by the substitution of a worm and a worm wheel for the bevel gear and the pinion; third, the double-reduction live axle, in which a bevel-gear drive is employed in connection with a second reduction in speed through the spur gears; fourth, the so-called internal-drive rear axle, in which the first reduction is through the conventional bevel gear and the second is by means of a small spur pinion meshing with an internal gear cut on the inner face of a drum attached to the driving wheel. It may occasion some surprise to note in this connection that the worm drive is mentioned as being second in point of seniority, and further that no mention is made of the standard bevel-gear live axle. In the first place, the use of the worm on automobiles dates back to its employment on the Lanchester pleasure cars in 1898 and its adoption on the Dennis busses in London in 1903, on which it has been regularly used ever since. No mention is made of the standard bevel-gear axle here, since the latter is only adapted for use on light cars. The higher speeds at which these vehicles run do not necessitate the employment of extremely high reduction ratios, so that a live axle of this type may be employed without having to make the bevel gear of a size that would seriously reduce road clearance, on the one hand; or a bevel pinion that would exceed the mechanical limitations of this form of drive, on the other. It is rarely employed, however, on vehicles of more than 1½ tons' capacity, and the ease with which the entire speed reduction necessary may be carried out in a single step by means of a worm gear will doubtless make the straight bevel type obsolete on commercial vehicles within the next few years.

Side-Chain Drive. Until the introduction in this country, at a comparatively recent date, of the worm drive, some form of double-reduction gearing has been used on all heavy motor trucks. The form most commonly used has been the double side-chain final drive, in which the primary gear reduction is obtained by means of a bevel gear driving the jackshaft and a secondary reduction in the chains and sprockets. This type of drive, utilizing roller chains, has been used on nearly all heavy motor trucks since the inception of the commercial vehicle. With but one or two exceptions, on all these trucks of American manufacture no attempt has been made to house the chains in, and they run exposed to dirt, mud, and water.

Standard Types. A typical American side-chain drive for trucks of medium capacity is shown in Fig. 49, which illustrates a Timken unit. Except for the provision of brakes and sprockets at its outer ends instead of wheels, the countershaft, or jackshaft, is practically

Fig. 49. Timken Standard Jackshaft for Side-Chain Drive

a bevel-gear live axle. The rear axle is what is known as a "dead" axle in that it has no moving parts other than the wheels which revolve on bearings mounted on it. The two wheels are kept at a predetermined distance apart, and their parallelism is preserved by two distance, or radius, rods. A little consideration will make it plain that the thrust of repulsion against the ground of the driving wheels must be taken up on the vehicle before the latter can move, otherwise the rear axle would tend to travel forward independently until checked by the springs, which would then take the driving effort.

This is frequently done on pleasure cars, and makes a flexible power transmission which is easy on the mechansim and the tires, but which is not practical with the heavy loads handled on trucks. Hence, the radius rods are employed to transmit this strain to the frame of the car, but, at the same time, they must provide for a certain amount of relative movement in both a vertical as well as a horizontal plane, besides affording a certain amount of flexibility.

Radius and Torque Rods. Fig. 50, which represents a well-worked-out radius-rod design, illustrates how these various requirements are met. Starting at the right-hand end of the rod which is attached to the rear axle, it will be seen that this design consists of a connecting-rod type of bearing that permits movement in a vertical plane, as this bearing is held on a tubular section of the axle and

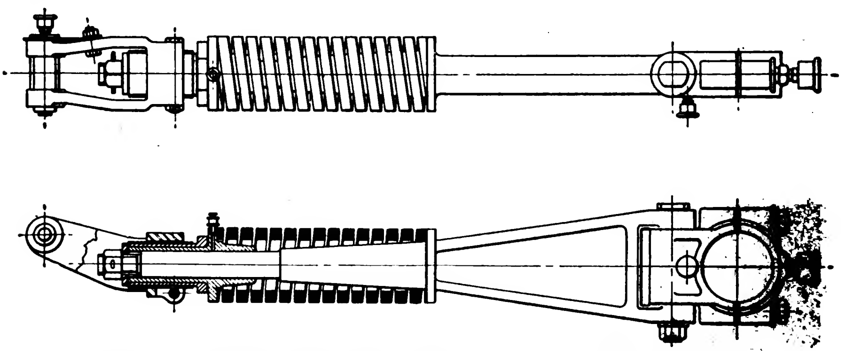


Fig. 50. Flexible Universally Jointed Radius Rod for Double Side-Chain Drive

is kept well lubricated. Just forward of the bearing is a heavy spindle which pivots the rest of the rod on the rear bearing, so that ample provision is made for lateral movement. The rod proper is in two parts held together by the compression of a heavy helical spring, which relieves the mechanism and tires of the initial thrust of starting, and also prevents shocks to the rear axle reaching the frame via the radius rod. Further provision for movement in a vertical plane is made by the attachment of the forward end of the rod to the frame, which forms a pivoted yoke. The threaded portion and the locked collar, noticed at the forward end, allow for adjustment in the length of the rod, this adjustment being provided for in the spring rod by the nut shown inside the yoke at the forward end. On shaft-driven cars, a torque rod is employed to take this thrust and also to take up the twisting effort, or "torque," of the propeller shaft.

Speed Reduction. The rear axle proper is simply a drop forging of I-beam section representing the strongest and lightest cross-section for a beam. It is forged integral with the pads, or saddles, for attaching the springs and is machined to receive the wheel bearings and the bearings of the radius rods which complete its construction. The driving sprockets are bolted to the pressed-steel or cast-steel brake drums and the latter are in turn bolted to the wood artillery wheels. On trucks of two to seven tons' capacity, the speed reduction between the motor and the rear wheels ranges all the way from 7 to 1 to 14 or 15 to 1. The first step in the reduction is carried out in

Fig. 51. Rear of Packard 5-Ton Chassis, Showing Size of Driving Sprockets

the bevel-gear drive of the countershaft and rarely exceeds 4 or 5 to 1, as the use of a larger bevel would involve the use of a cumbersome and weighty housing. The remaining reduction is accomplished by the difference in the driving and driven sprockets. How great this second reduction may be can be seen from Fig. 51, which is a rear view of a standard design of side-chain-driven heavy truck, the Packard. A study of this illustration will make clear several of the details of axle, spring, brake, and radius-rod construction described in previous paragraphs.

Worm Drive. The worm gear was tried tentatively on steam traction engines in England as early as 1850, but it was not until

1898, when it was applied to the driving of the Lanchester car, that it was seriously taken up for this purpose. The Lanchester worm is a peculiar variation of the more familiar Hindley type and is placed under the wheel to insure lubrication. An illustration of this worm gear will be found in the section devoted to the transmission of electric pleasure vehicles, as worm gears of this type are imported from England for use on the Detroit electric cars. The first rear-axle motor-truck drive of the worm type was a 3½-ton Dennis bus

Fig. 52. Phantom View of Pierce Worm-Driven Rear Axle

and quite a number of worm-driven Dennis busses have been in service in London for several years. Dennis was also the first to running in London. This was first put in service in 1903 and, though its introduction met with considerable opposition, it proved a success, mount the worm over the wheel, producing the so-called "overhead" type, which feature also came in for much criticism owing to its alleged failure to provide lubrication. It will be perfectly obvious that with the worm-wheel housing only partly full of oil this criticism would be unfounded, as the wheel acts as an excellent conveyor to carry the oil up to the worm. Eight years' use in London without failure of lubrication bears out this statement.

Development. The London General Omnibus Company was the first to design and manufacture on a large scale a new type of worm-gear axle in which the worm gear was mounted on a separate assembly. This design has superseded others until now, with some modification, it is accepted practice. The worm and the wheel are mounted in a very rigid block and, with their bearings, housings, etc., form a complete unenclosed transmission unit, as seen in Fig. 52, which is a phantom view of the worm gear employed on the

Fig. 53. Chassis of Pierce 5-Ton Worm-Driven Truck

Pierce trucks, the makers of the latter having been the pioneers in introducing this type into the United States. This unit is dropped into the bowl-shaped rear-axle housing and bolted in place. This mounting lends itself readily to accurate machining, every part being open and easily accessible. This is also true of the unit as a whole where inspection, adjustment, and repair are concerned. This housing is of heavy construction and, as it is rigid, prevents road shocks or stresses, other than those coming through the driving axles, from disturbing the alignment of the worm gear. The housings of the driving shafts, or axles, are tubular, and the shafts themselves are assembled through the tubes into the squared sockets in the differential. This makes a very accessible assembly as, by pulling out the driving axles and disconnecting the universal joint, the worm unit can be lifted out of its housing. The socket, with several keyways in it extending forward from the worm proper, is for the reception of the splined end of the propeller shaft from the gearset. This keyed socket is the slip end of the rear universal joint in the shaft line and is designed to prevent relative movement of rear axle and of gear set from imposing excessive stresses on the propeller shaft.

The driving thrust and the torque are taken on a short heavy torque rod, which will be noted extending forward from the rear-axle housing just below the universal joint. This is a heavy drop forging and, as will be clear, is mounted on a heavy spindle at the axle housing, allowing for movement in a horizontal plane; while at its forward end, which is made in the form of a yoke, it is carried on a horizontal pin permitting a vertical movement to compensate for variations in the vertical distance between the axle and frame caused by the compression and recoil of the springs. Its location is made clear in the chassis view, Fig. 53.

Fig. 54 shows the form of mounting adopted by the Timken Company for the David Brown type of worm drive which they manufacture. This is the same as that employed on the Pierce trucks, but both the method of mounting and the bearings differ. The Timken Company use their own taper roller bearings, while the Pierce Company use annular ball bearings. The worm is of the so-called straight type, meaning that it is of uniform diameter throughout its length as distinguished from the "hourglass" type.

Standard Types of Worm Gears. In the straight type, the worm is cylindrical through its entire length, and the worm wheel into which it meshes is concave. In the hourglass type, both worm and worm wheel are concave. The advantage claimed for the latter form is the greater area of engagement, thus spreading the driving strain over a greater number of teeth and reducing the pressure on the surface of both. On this type, however, there is only one position in which the worm and the worm wheel can be located with respect to each other in order to take advantage of this greater area of contact, while on the straight type it is necessary only to locate the worm correctly, with respect to the worm wheel, in one direction, since the worm is cylindrical and uniform in diameter throughout its entire length. The straight type is therefore much less liable to damage through misalignment. With the hourglass type, a slight misplacement in any direction is liable to prove fatal, so that the chances of trouble in practical operation are greatly reduced in the straight type.

Efficiency of Worm Gears. In an elaborate test of three different types of worm gears (by types in this connection being meant

Fig. 54. David Brown Type of Worm Gear as Mounted on Timken Axle

differences in tooth form and pitch) made at the Brown and Sharpe plant to determine which form was best adapted to automobile use, efficiencies ranging from 90.2 to 95.5 were obtained on the first speed, 91.3 to 93.4 per cent on the second speed, and 90.1 to 97.6 per cent on the direct drive. The results obtained with a bevel-gear-drive test made for comparison were 91.4 to 96.6 per cent on first speed, 94.5 to 99.3 on second, and 94.0 to 99.2 on direct drive. So far as the life of the worm is concerned, mileage records obtained on commercial cars range from 40,000 to 110,000 miles, the lower figure being considered only fair for a well-made straight type of worm; while, on pleasure cars, three years of constant service was not thought at all unusual.

Double-Reduction Live Axle. As sufficient drop in speed cannot be had with a bevel gear through a single reduction without making the driven bevel gear of impracticable proportions, thus involving excessive weight in the rear-axle housing and a dangerous lack of clearance between the latter and the ground, an intermediate spur reduction is introduced just forward of the bevel gears. One method of accomplishing this is illustrated by Fig. 55, which shows the extra speed reduction combined in the same housing as the differential and the bevel drive, an extra cover plate making it accessible. It will be noted that helical-cut gears are employed

Fig. 55. White Differential, Showing Second-Reduction Gear

instead of the straight-spur type, this form of tooth giving greater bearing surface, closer engagement, i.e., less backlash, or lost motion, between the gears and far less noise in running. Another form of double-reduction axle is the special type developed on the Autocar delivery wagon and illustrated in connection with the description of that vehicle.

Internal Gear-Driven Axle. The internal gear-driven type of axle is another form of final drive that has been introduced in this country after a long and successful record abroad. Like the worm gear, it aspires to the honor of replacing the side chains and, like that form, also has already made considerable progress in this direction. In principle, this form of drive consists of making the driving axles independent of, and external to, the rear axle proper, which, in this case, is of the "dead" type, usually a solid section, such as a square or an I-beam forging. Its function is merely to carry the weight of the car, although it also is made to serve both as a support and as a reinforcement for the live axle. In the case of the Mercedes (German) trucks, on which it has been used since 1900, the driving axle is placed forward of the dead axle. At their outer ends, the shafts of the latter carry small spur pinions which mesh with large internal gears cut on rings attached to drums on the rear wheels. One of these wheels and the driving pinion on the end of the live shaft are illustrated in Fig. 56, which shows this construction as carried out on an American-built replica of the German truck in question.

This same form of axle has been employed also for a number of years in Paris by the builders of the De Dion cars for their commercial types, chiefly busses. In this case, the live axle is carried above

Fig. 56. Mercedes (German) Internal Gear Drive, Showing Principle of Action and Assembled Rear Wheel

its support. More than a hundred of these busses have been in service in New York for several years and, as more are ordered from time to time to meet the increasing requirements, it must be concluded that they have been satisfactory. The builders of the Mais trucks were doubtless the pioneers in the commercial use of this form of axle in this country, and the Mais internal gear-driven rear axle is probably the form in which this type is most generally used. In this case, the driving axle is placed forward of the dead axle. Upon comparing the size of the driving pinion at the rear wheel with the internal gear, it will be apparent that a very large gear reduction is conveniently obtainable by this method without in any way interfering with the road clearance of the vehicle. The first reduction consists, of course, in every case, of the conventional bevel-gear drive, but, as will be noted from the part sectional views of the Torbensen and Garford types of internal gear-driven axles, as shown in Figs. 57 and 58, there is very little reduction between the bevel pinion and its gear. This decreases the amount of leverage the pinion has to exert and conse-

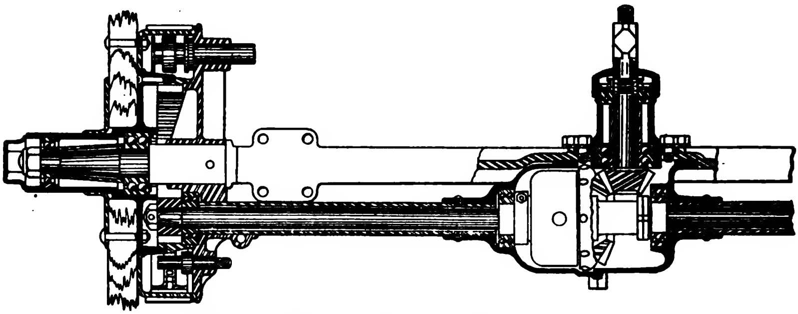


Fig. 57. Torbensen Internal Gear-Driven Rear Axle

quently decreases the tooth pressure in proportion. In the Torbensen axle, the live member, or countershaft, is placed to the rear of the I-beam supporting member, while in the Garford this is reversed. On the Jeffery "Quad", it is placed directly over the wheel support, as

Fig. 58. Garford Internal Gear-Driven Rear Axle

shown by Fig. 59, which illustrates the driving pinion and the wheel with its internal gear. As this truck steers, drives, and brakes on all four wheels, a universal joint is placed directly behind the pinion. Fig. 60 shows the wheel and its gear ready for mounting. A somewhat similar design is found on the Christie front-drive tractor for fire apparatus, with the added distinction that on this machine only the rim of the driving wheel revolves and is carried on a ball bearing which is practically the size of the wheel itself. On the Jeffery, the wheel revolves on the two taper roller bearings shown.

Differential Lock. The function of the differential, balance gear, or compensating gear, as it is variously called, is naturally the same on the commercial vehicle as it is on the pleasure car, i.e., that of permitting one wheel to run free in rounding a turn so that it may travel the greater distance represented by the outside circle in the same time that the inner takes to traverse its orbit; but the differential has the unfortunate drawback of not permitting any power to reach one of the driving wheels in case it is held while the other is free. This frequently occurs where the truck settles into a ditch or extra deep rut in a soft road, leaving the other wheel more or less in the air. Under such conditions the entire power goes to the free wheel, making the problem of extricating the machine from this predicament much more difficult. To overcome this disadvantage of the balance gear, it is customary to provide a differential lock. One form of this lock is illustrated in Fig. 61. On the right-hand side a four-jaw clutch is keyed to the drive shaft, but is left free to slide into mesh with its corresponding member on the differential housing to permit of locking the differential gears. This clutch is operated through a suitable linkage from the driver's seat. By locking the differential, the sunken wheel will pull itself out if the truck is capable of exerting the necessary power.

Fig. 59. Jeffery Rear-Axle Driving Mechanism and Bearings

Front Drives. *Early Development.* One of the earliest applications of power proposed for road locomotion was the attachment of a self-contained power unit to existing horse-drawn vehicles, and a number of different types of such units were built in Europe in the early days of the industry. For some reason, none of them developed to the point of a commercial success. The front-wheel drive, which seems to have been discarded almost entirely for some years, has recently come to the fore again and has been developed very successfully for fire apparatus, on which both mechanical and electrical methods of transmission have been utilized.

Fig. 60. Jeffery Wheel with Internal Gear Ready for Mounting on Axle

Electric Front Drive. The electric front drive has been utilized in numerous lines of business, more particularly for brewery and municipal service, for several years; the Couple-Gear type of electric motor wheel, previously described in the section on the transmission of power on electric cars, was employed for this purpose. In some instances, a single power wheel is used to haul a dump cart or similar slow-moving vehicle; or a unit, comprising a storage battery, controller, steering gear, axle, and two of these power wheels, is permanently coupled to a truck in place of the axle and wheels used when drawn by horses.

The power to drive these motors may be supplied by the current from a storage battery or from a gasoline-electric generator. The

Fig. 61. Bevel-Driven Commercial-Car Axle Fitted with Differential Lock

Fig. 62. Electric Front Drive Using Couple-Gear Motor Wheels

dynamo supplies the power directly to the wheel motors through a three-point controller, there being no other intermediate electric member. This controller is fitted with two forward speeds and a single reverse, the speed and amount of power utilized being controlled chiefly by means of the spark lever and the throttle of the gasoline motor in the conventional manner. Fig. 62 illustrates a fire engine gasoline-electric tractor using Couple-Gear drive.

Four-Wheel Drives. To meet the requirements of military service, a truck must be able to travel "wherever a team of mules can haul a load". Consequently, like that useful quadruped, it must be equipped with power-transmitting members at all four points of contact with the ground. While the conventional type of truck with one or the other of the standard forms of transmission driving only two rear wheels has proved eminently satisfactory for service wherever a solid roadbed or its equivalent is to be found, it is of little use off the beaten track. Ditches, soft ground, sand, and mud, which do not even embarrass the army mule or, for that matter, the average team of farm horses, render the average motor truck absolutely helpless. To be able to extricate itself from bogs and ditches, it is necessary to be able to "git up and git" on all fours.

To take advantage to the full extent of this form of transmission, the majority of four-wheel-driven cars both drive and steer through all the wheels. Accomplishing this presents no particular mechanical difficulties. Three forms of drive have been developed for this purpose; one in which the power is transmitted through bevel gears mounted on the steering knuckle, while a second employs the internal-gear type of drive using universal joints on the driving shafts just back of the wheels. The third type drives directly to the hubs of the wheels through hollow steering knuckles. This last type presents the simplest layout and was one of the first to be developed in this country on a commercial scale, having been built for several years by the Four Wheel Drive Automobile Company.

This transmission is a simple modification of the three-speed individual-clutch type transmitting the power through a broad silent chain to a parallel shaft placed at the left to clear the engine. This can be seen more clearly in the photograph of the chassis, Fig. 63. This chain also serves as the first reduction in the speed, the second being through the conventional form of bevel gears at the rear and front axles. Each of these bevel-gear drives incorporates a differential for balancing the tractive effort at the wheels, while a third differential centrally placed on the parallel driving shaft balances the amount of power transmitted to each pair of wheels. This third differential is built in the large sprocket of the silent-chain drive and is provided with a locking device controlled by the driver. A brake

Fig. 63. Chassis of Four-Wheel Drive Truck

drum is mounted on the parallel shaft on either side of the main differential. These transmission brakes are for regular service, the emergency brakes being mounted in drums on the rear wheels.

Fig. 64. Chassis of Jeffery "Quad", Showing Four-Wheel Drive

Owing to their location, the former retard all four wheels simultaneously. There are, of course, four universal joints. Steering is accomplished by means of the front wheels only, so that the rear axle is of the conventional full-floating construction.

Jeffery "Quad". This truck is representative of the second class, or internal gear-driven type mentioned, and has been developed particularly to meet the United States Army requirements. The motor is a four-cylinder block-cast type with L-head cylinders rated at 32 horsepower and is fitted with duplex ignition, i.e., using

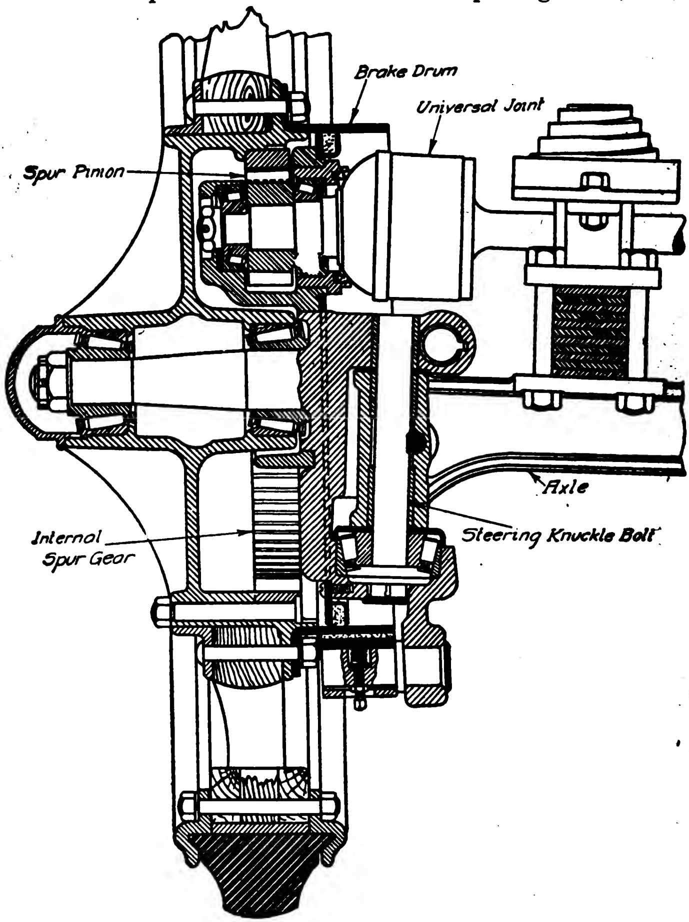


Fig. 65. Sectional View of Jeffery Front-Wheel Drive
Courtesy of Horseless Age

two sets of spark plugs simultaneously. The motor is offset to the right side of the frame and mounted on a three-point suspension, as shown by the plan view of the chassis, Fig. 64. The drive is by shaft to a centrally placed four-speed selectively operated gearset of the sliding-gear type, but the latter differs from the conventional form of this type of gearset in that it has no direct drive. The propeller shafts are gear driven from the layshaft of the transmission, this construction bringing the forward one sufficiently to one side to clear the motor. Three differentials are employed, one on each axle and one in the gear box, all being of the Wayne gearless type. Both axles are "dead" and are fitted with steering knuckles. The transverse driving shafts at either end are placed above the axles and springs and have universal joints just inside of the wheels and directly over their steering pivots, as shown by the sectional view, Fig. 65. The driving pinion is supported from the steering knuckles between two taper roller bearings and drives an internal gear mounted in the enlarged wheel hub. Bolted to this large hub and the wheel itself is

Fig. 66. Chassis of Jeffery "Quad"

a pressed-steel drum for an external brake, a dust-excluding felt packing being fitted between the drum and the gear ring. The ability of the four-wheel drive to extricate itself from heavy mud and sand with the same amount of power is due to the tendency of the front wheels to climb over obstacles and, at the same time, assist in the propulsion of the weight. Enclosed wheels are employed to cut down the resistance, Fig. 66.

Electric Transmission

Advantages. The practice of utilizing electricity for power distribution in manufacturing plants was already well established before the advent of the automobile on a commercial scale, and attempts were made at an early day to utilize its advantages for transmitting the power on the latter. Despite the numerous difficulties met with at the outset in the application of the sliding-gear transmission, the employment of electricity has never become as general as its advantages would appear to warrant. A great amount of experimental work, however, has been done, and numerous different systems evolved. Probably the only example of the consistent employment of electric transmission at the present date is to be found in its use on gasoline-electric-railway motor cars, of which quite a number are in service. As the limitation of weight, one of the most important factors to be considered on the automobile, is lacking in this application, it can hardly be said to represent an exact parallel.

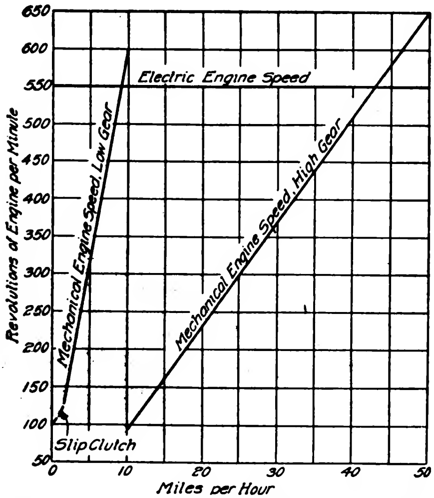


Fig. 67. Curves Showing Variations of Engine Speed for Gasoline-Electric Transmission

One of the chief advantages of the employment of electric transmission is the possibility of running the gasoline motor constantly at its normal speed, at which it develops its rated output most economically and with a minimum wear. The sharp contrast between the speed variations required of the gasoline motor employed with a mechanical transmission and with one of the electrical type is shown by the curves in Fig. 67. With the electric transmission, the gasoline motor speed remains constant from the time of starting right up to 50 miles an hour.

Several Systems. To those familar with electric practice it will be plain that several methods of utilizing electricity for the transmission of the power on an automobile are available. In general, however, they may be divided roughly into three divisions. The first of these is simply a replica of that commonly employed in manufacturing plants, i.e., mechanical energy as produced by an engine is converted into electrical power, transmitted to an electric motor at a distance, and there reconverted into mechanical energy. This double conversion naturally entails a loss of efficiency; but, in manufacturing practice, this is considerably less than where the power is directly transmitted from the engine to the tool at which it is to be used, and the efficiency increases with an increase in the distance between the two.

The second system involves the conversion of mechanical into chemical energy in the storage battery, from which the current is drawn to operate electric motors in the usual way, Fig. 68. This is really a self-contained electric in that it carries its own charging plant, with the further advantage, however, that the excess capacity of the generator is always available for driving the vehicle. Or, to put it

Fig. 68. Couple-Gear Gasoline-Electric System

the other way around, the greater part of the current from the gasoline motor electric-generator unit is employed for running the car, and the excess current utilized for charging the storage battery, which is then said to be "floated on the line."

The third system is based on the principle employed in the cradle type of electric dynamometer, in which an electric generator is so mounted that its field may revolve in response to the drag exerted on it by the armature, this tendency being counteracted by a balance lever attached to the field. By means of weights placed on this lever, the effort exerted may be accurately weighed, and the power developed by the prime mover driving the generator may be calculated within close limits.

DETAILS OF CHASSIS AND RUNNING GEAR

Springs

The problem of providing a form of spring suspension that will not be overstiff when the car is empty and still provide sufficient holding powers to withstand rough road work with a full load, which the designer of the touring car has had to face, is aggravated a hundredfold on heavy trucks. Between the "load" and "no load" points of the pleasure car, there is a comparatively small range. When a touring car weighing 4000 pounds, all on, has its full load of seven passengers averaging 150 pounds each, their combined weight represents only 25 per cent of the weight of the vehicle itself, but when a 5-ton truck, weighing slightly over five tons when empty—say 11,000 pounds—receives its full load of five tons plus anywhere from 10,000 to 14,000 pounds, the increase, instead of being from 0 to 25 per cent, is from 0 to 100 per cent plus. There is also the far greater tendency to side sway, owing to the height at which the load is ordinarily carried.

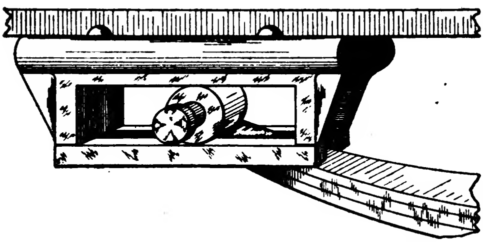


Fig. 69. Principle of the Compensating Spring Support Employed on Heavy Trucks

Semi-Elliptic Usual Type. As it permits keeping the center of gravity down, gives less recoil under heavy shock, and is less subject to lateral stresses, the flat semi-elliptic type of spring is almost universally employed on commercial vehicles, from a delivery wagon up to a 7-ton truck. By delivery wagon in this connection is meant the type specially designed for commercial service and not the converted touring-car type in which pleasure-car standards remain unaltered, and the high three-quarter elliptic spring at the rear is not uncommon.

It will be apparent, however, that no form of spring suspension would be sufficient in itself to cover such an extended range of loading as that mentioned and still give even a fair approximation to efficiency at either extreme. Maximum carrying ability is the chief thing to be provided, and using springs that will do this alone would be an easy matter; but the problem is to guard against the maximum stresses to which the springs will be subjected under heavy loads and still have a suspension that will prevent the motor and driving mechanism of the truck from being pounded to pieces when the vehicle is running without a load. To achieve this, it is customary to employ rocking shackles at one end and some form of sliding, or compensating, support at the other, although in numerous instances the springs are shackled at both ends in the same manner. As the driving strain is practically always taken on radius, or distance, rods in the case of side-chain-driven cars, and on torque rods on cars of the shaft-driven type, there is ample altitude for variation in this respect.

Principle of Compensating Support. The sketch, Fig. 69, illustrates the principle upon which all compensating supports for the springs is based. Of course, this applies only to the rear-wheel springs, which are usually called upon to bear anywhere from 60 to 85 per cent of the useful load. The front springs are usually pinned to the dropped dumb ends of the frame forward and shackled to brackets at their rear ends. The front end of a rear spring is shown by the illustration. Given a suspension sufficiently stiff to withstand the maximum load of which the truck is capable, it will be apparent that when empty the body will be lifted and the sliding end of the spring will be against the right-hand end of the support. The spring is then under its minimum compression and will respond more readily to shock.

Brakes

Usual Types. In as much as the greater loads carried far more than offset the lower speeds at which commercial cars travel as compared with the pleasure type, there can be no comparison of the braking requirements of the two. This is particularly the case in as much as the greatest strain does not come on the brakes because of the infrequent necessity for stopping suddenly but on account of their continued use in holding the loaded truck back on long hills. Commercial-car brake design naturally varies with the type of vehicle and likewise with its carrying capacity. On light delivery wagons, the type employed is the same as used on touring cars, viz, internal-expanding and external-contracting asbestos-fabric-lined shoes in pressed-steel drums on the rear wheels. In some instances, the practice, usually confined to the higher-priced pleasure cars, of placing the two sets of brakes side by side so that they contact on the same drum and can be enclosed against the entry of dirt and water, is also found. An example of the first type mentioned is shown in Fig. 70, which illustrates a Timken worm-driven rear axle. The brakes on the Reo chassis are shown in Fig. 71.

Braking All Wheels. Considerable discussion has arisen from time to time regarding the advisability of braking on all four wheels;

Fig. 70. Timken Worm-Driven Rear Axle, Showing Brakes

but, prior to the advent of the four-wheel drive, this was tried in only a comparatively few instances. In addition to providing greater retarding power, the advantage of eliminating the tendency to skid has also been attributed to the front-wheel brake. When all four

Fig. 71. Brake Detail, Reo 2-Ton Chassis

wheels are driven, brakes are applied to all simultaneously, the braking effort at each wheel being equalized by a compensating device. On the Jeffery "Quad", these brakes are applied directly to the wheels themselves and consist of a simple and well-worked-out internal-expanding cam-actuated type, as shown by Fig. 72.

TRAILERS

Utilizing Excess Power. Trucks, like all other motor vehicles, must necessarily be equipped with power plants capable of successfully meeting exceptionally severe conditions imposed by heavy grades and by muddy, sandy, and snowy road surfaces, as well as the normally easy grade and road conditions encountered by the average truck during a very large proportion of its service. Hence, there is a large reserve power-plant capacity idle for a great part of the time. From the economic standpoint, it is a wasteful condition for a truck with sufficient power to handle a ten-ton load on smooth

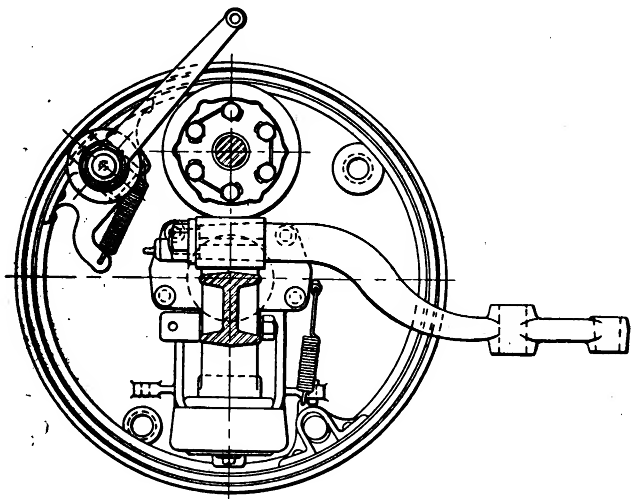


Fig. 72. Internal Expanding Cam-Actuated Type of Brake Employed on the Jeffery "Quad"

level roads to be restricted to the five-ton load which its structural parts permit. This applies proportionately to all sizes of commercial vehicles, from the very lightest up, and it accounts for the widespread use to which trailers are being put.

Two-Wheel Types. For light- and medium-capacity service, trailers can be made with only two wheels, thus keeping the wheelbase of the double unit down and permitting of much higher speeds. Trailers designed for use in connection with the lightest types of delivery wagons, such as the Ford, or for the thousands of ex-touring cars that are spending the second period of their existence in a commercial rôle, usually carry a load of about 400 pounds. They are made to fit any standard make of automobile, a special bracket being fitted to the rear of the frame of the car. Connection is made by means of a tongue fitted with a swiveling pin and locked with a thumb nut, so that the trailer may be attached or detached quickly without using tools; the pin in question, together with the fact that the trailer has only a single axle, allows for universal relative movement between it and the towing car.

Four-Wheel Types. It is in the employment of what is practically a second truck, where its carrying capacity is concerned, that the use of the trailer shows the greatest operating economy, and

Fig. 73. Troy Trailer for Motor Trucks

specially designed vehicles have been developed for this purpose. The builders of the Troy wagons have evolved a special type of trailer for the motor truck, as shown in Fig. 73.

Troy Trailer. It will be noted upon referring to the illustration, Fig. 73, previously mentioned, that the construction of the Troy trailer is along very similar lines to those generally followed in motor-truck construction. In fact, the trailer is practically a motor truck without power and, as it is subjected to even heavier loading and more severe strains than the latter, is built accordingly.

Both sets of wheels are designed to steer and are controlled by the drawbars at each end of the trailer, the cross-connecting rod of the steering gear being attached to the under side of the drawbar near its rear end. As the drawbar follows its towing truck around corners, it also serves to swerve the front wheels of the trailer in the same direction.

RAULANG ELECTRIC COACH

Courtesy of The Baker R. and L. Company, Cleveland, Ohio

ELECTRIC AUTOMOBILES

PART I

Introduction. The essentials of the electric automobile are few in number and simple in construction. They are, first, the storage battery, or source of power; second, the electric motor, forming the medium through which the current is transformed into mechanical energy; and, third, the drive, or means by which the power of the motor is in turn applied to the propulsion of the vehicle. There are, naturally, differences in design and in the details by which the power produced at the electrical end is applied to driving the machine. Where these differences are of sufficient importance, they are described in detail, and illustrations of the vehicles and their component parts are given, thus making it easy to distinguish them.

FUNDAMENTAL FEATURES OF THE ELECTRIC

THE STORAGE BATTERY

There is probably no other single electrical device in general use about which there is so much popular misconception as the storage battery, or accumulator, as it is more technically known. It does not in itself create a current of electricity—as does a primary battery, such as the familiar dry cell, in which chemical processes actually generate a current of electricity—and for this reason the storage cell is called a secondary battery. The word *storage* in connection with this type is really a misnomer, as the process by which it absorbs and re-delivers electricity is not one of storage in any sense of the word, but consists of chemical conversion and reconversion upon a reversal of the conditions. As is the case with electric vehicles, there are numerous different forms of storage batteries, for many of which special advantages are claimed; but in general all lead-plate batteries are very much alike, and a description of one will make clear the principles upon which all are based. Theoretically, the principle of the Edison battery is also the same, i.e., that of a chemical reaction upon the passage of the charging current through the cell and a reconversion upon a reversal of the conditions, but it differs so radically in practice that a detailed description of its construction is given.

CONSTRUCTION AND ACTION OF TYPICAL CELL

General Description. In order to obtain an understanding of just how these processes are carried on, it is necessary to become familiar with the internal action of the cell on receiving and discharging a current and, for this purpose, it is essential to delve into chemistry somewhat. Before taking up this subject, it may be well to mention that *a battery is composed of a group of cells, each of which*

Fig. 1. Typical Battery Plates

is a complete and self-contained unit, though the term battery is indiscriminately applied to both. In a description of its working, a cell is naturally referred to, as all are alike. *A cell consists of two sets of lead grids with pockets so cast in them that what is known as the "active material" may be securely held even in case of severe jolting and vibration.* When filled with the active material, these grids are called plates and are divided into two groups, one positive or + (plus) in character, and the other negative or − (minus), of which typical illustrations are given in Fig. 1. As it is necessary, in order to obtain maximum efficiency, to oppose a surface of negative capacity to each surface of a positive nature, every storage cell will be found to have one more negative than positive plate. It is possible to distinguish them in this manner, where other indications are lacking, but as it is most essential that they be known, the terminals or connections of the groups are plainly marked by the makers either by the plus and minus signs or in some other equally plain manner, such as painting the positive terminal red. These groups of plates are known as electrodes and are inserted in a jar containing a solution termed the *electrolyte,* which consists of water and sulphuric acid. Fig. 2 shows a sectional view of a small cell.

Electrolyte. The solution in which the elements of the storage battery are immersed, or electrolyte, as it is termed, consists of pure sulphuric acid and distilled, or other pure, water. Concentrated sulphuric acid is a heavy oily liquid having a specific gravity of about 1.835. A battery will not operate if the acid is too strong, and it is therefore diluted with sufficient water to bring it about 1.275 for a fully charged cell. While a battery is being discharged, the electrolyte becomes weaker as part of the acid is combined in the plates in producing the current. This weakening of the electrolyte causes the specific gravity to drop 100 to 150 points during the complete discharge. During the charge, this acid is returned to the electrolyte, thus increasing its strength until it again reaches the normal gravity. There being no loss of acid, it is never necessary during the normal service of a battery to add any acid to the cells.

Fig. 2. Assembled Storage Cell

Unless acid is actually known to have been lost out of a cell, none should ever be added during the entire life of the battery.

When the cells have been allowed to gas too freely, for reasons that are explained later, there is more or less spray of acid through the vent holes, but the amount of acid lost in this way is so small as to be entirely negligible. The gravity of the electrolyte need not necessarily be exact, as in a fully charged battery a range of from 1.250 to 1.300 is permissible.

Purity of Acid and Water. Both the acid and the water used in making electrolyte should be chemically pure to a certain standard. This is the same standard of purity in acid as is usually sold in drug stores as "C P" (chemically pure), or by the chemical manufacturers as "battery acid". In this connection, the expression "chemically pure" acid is sometimes confused with acid of full strength, approximately 1.835 sp.gr., and at the same time chemically pure. If this chemically pure acid of full strength be mixed with distilled water, the mixture will still be chemically pure but not of full strength. On the other hand, if a small quantity of some impurity be introduced into the acid, it would not materially reduce the strength, but the acid would no longer be chemically pure.

Determination of Strength of Acid. The usual method of determining the strength of electrolyte is by taking its specific gravity, this method being possible because of the fact that sulphuric acid is heavier than water. Therefore, the greater the proportion of acid contained in the electrolyte, the heavier the solution or the higher its gravity. By specific gravity is meant the relative weight of any substance compared with distilled water as a basis. Pure water, therefore, is considered to have a gravity of 1. An equal volume of chemically pure sulphuric acid weighs 1.835 pounds. It, therefore, has a specific gravity of 1.835 and is referred to as "eighteen thirty-five". As it is customary to carry the gravity readings out to three decimal places, the gravity of water, which is 1, is written 1.000 and is spoken of as "one thousand". These specific gravity readings are usually taken by means of a hydrometer, shown in Fig. 3, and discussed on page 8.

Temperature Correction. Since the electrolyte, like other substances, expands when heated, its specific gravity is affected by a change in temperature. If electrolyte has a certain specific gravity at 70° F. and is then heated, the heat will cause the electrolyte to expand, and although the actual strength of the solution will be the same as before heating, yet the expansion will cause it to have a lower specific gravity, the difference amounting to approximately one point (.001) for each three degrees rise in temperature. For instance, if electrolyte has a reading of 1.270 at 70° F. and the temperature be raised to 73° F., this increase in temperature will expand the electrolyte sufficiently to drop its gravity from 1.275 to 1.274. On the other

TABLE I

Sulphuric-Acid Solutions*

Based on one part acid of 1.835 sp. gr. at 60° F.

Specific Gravity of Solution (70° F.)	Parts of Water to One Part Acid		Percentage of Sulphuric Acid in Solution
	By Volume	By Weight	
1.100	9.8	5.4	14.65
1.110	8.8	4.84	16.
1.120	8.	4.4	17.4
1.130	7.28	3.98	18.8
1.140	6.68	3.63	20.1
1.150	6.15	3.35	21.4
1.160	5.7	3.11	22.7
1.170	5.3	2.9	24.
1.180	4.95	2.7	25.2
1.190	4.62	2.52	26.5
1.200	4.33	2.36	27.7
1.210	4.07	2.22	29.
1.220	3.84	2.09	30.2
1.230	3.6	1.97	31.4
1.240	3.4	1.86	32.5
1.250	3.22	1.76	33.7
1.260	3.05	1.66	35.
1.270	2.9	1.57	36.1
1.280	2.75	1.49	37.3
1.290	2.6	1.41	38.5
1.300	2.47	1.34	39.65
1.320	2.24	1.22	42.
1.340	2.04	1.11	44.1
1.360	1.86	1.01	46.3
1.380	1.7	.92	48.4
1.400	1.56	.84	50.5
1.450	1.25	.68	55.5
1.500	1.	.55	60.15
1.550	.8	.44	64.6
1.600	.639	.348	69.12
1.650	.497	.27	73.32
1.700	.369	.201	77.6
1.750	.248	.135	82.1
1.800	.1192	.0646	87.5
1.835	0.	0.	93.19

* Courtesy of *Electric Storage Battery Co.*

hand, if the temperature had dropped to 67° F., this would have caused the gravity of the electrolyte to rise to 1.276. Since change of temperature does not alter the strength of the electrolyte but merely changes its specific gravity, the gravity reading should be corrected one point for every three degrees change in temperature. For convenience, 70° F. is considered normal and is the point from which corrections are made. This refers to the temperature of the electrolyte itself and not to that of the surrounding air. Table I shows the parts of water by volume, the parts of water by weight, and the percentage of acid to water to produce different specific gravities.

Replacing Evaporation or Other Losses. The electrolyte, or solution, in the cell consists of a mixture of sulphuric acid and water; the sulphuric acid does not evaporate, but the water does. When the level of the electrolyte becomes low, it is due under normal conditions to the evaporation of water, and this loss should be replaced with water only. There being no loss of acid, it is never necessary during normal service to add any acid to a battery. Of course, if a jar is upset and acid spilled, or if a jar breaks and the acid leaks out, it must be replaced. Care should be taken to see that the cells do not become flooded with water when washing the car; this is apt to short-circuit them across the lead connectors and if it enters the cells to disturb the specific gravity of the electrolyte.

Unless acid is actually known to be lost out of a cell, none should ever be added during the entire life of a battery. The amount of acid lost in the form of spray due to the gassing of the cells is so small that it may be neglected. Only distilled water or other water of approved purity should be used for replacing evaporation. Most natural waters contain impurities, some of which are chemically injurious to the batteries, while others are not. Any water to be regularly used in a garage for battery purposes without distillation should be submitted to the battery manufacturer for approval.

It is necessary that the plates and separators be covered with electrolyte at all times. When adding water, cover the plates about ½ inch. Do not put in more than this amount on the theory that if a little is good more is better, since cells that are over-full tend to slop while the car is running and will also be apt to lose electrolyte while charging, as gassing raises the level of the solution in the cells. Replace evaporation every five to fifteen days, depending upon the conditions of service. The best time for adding water is just before a charge. This may be done most conveniently with the aid of a syringe of the type ordinarily used with a hydrometer. Keeping the cells filled to the proper level with electrolyte is quite as important as not allowing them to stand discharged for any length of time.

Adjusting the Specific Gravity. The best indication of the condition of a storage cell at any time is the specific gravity of its electrolyte and the treatment to be given should always be governed by the latter. The electrolyte of a fully charged cell of the vehicle type when first put into service should have a specific gravity of 1.270 to 1.280. Although this will change somewhat with age, the battery will continue to give good service between the limits of 1.250 and 1.300. If the gravity should ever rise above 1.300, it should be lowered promptly by replacing some of the electrolyte with pure water. Low gravity in a cell is usually caused by acid being combined in the plates through lack of charge; although, if a jar has been upset and acid spilled, or the jar is leaking, no amount of charging will bring its specific gravity up to the proper point. A decreasing specific gravity in the electrolyte throughout the cells of an entire battery is an indication that sediment is accumulating in the bottom of the jars and that the battery requires washing. This is true, of course, only when the low reading is *not due to insufficient charging.*

Before attempting to raise the specific gravity of any cell by adding acid, charge the battery until certain that a maximum gravity has been reached or, in other words, that no acid is still combined with the plates in the cell. For example, if the electrolyte in a cell should be adjusted to 1.275 when 50 points of acid still remain in the plates, the gravity would rise to 1.325 if the cell were subsequently charged to its maximum.

To adjust the specific gravity to its proper value (1.270 to 1.280), first bring the battery to its true maximum, which can be assured only by charging until there is no further rise in gravity during a period of at least twenty-four hours of continuous charging at about one-half the normal finishing rate. If, after this, the specific gravity is too high, remove electrolyte down to the level of the plates with the syringe and replace with pure water to ½ inch over the plates; if the specific gravity is too low, replace with 1.300 electrolyte, adding it in small quantities to prevent bringing about the opposite condition.

When much adjustment is necessary and facilities are available, as should be the case in a garage handling many electric vehicles, it is good practice to pour the electrolyte out of the cells into a glazed earthenware vessel or a lead-lined tank, and to raise or lower the specific gravity of this electrolyte as conditions demand. About one-third of the electrolyte is held in the plates and the separators and cannot be poured out, and this should be allowed for in estimating the proper gravity before refilling the cells. In cases where there is a wide variation between different cells, further adjustment may be necessary.

Hydrometer and Its Use. The specific gravity of a liquid is tested by means of an instrument, termed a *hydrometer*, consisting of a weighted glass tube having an appropriate scale. The depth to which this instrument sinks in the liquid to be tested shows its specific gravity by the reading of the scale at the level of the liquid. Fig. 3 shows the several types of hydrometers, while beside each is an enlarged view of the scale. The Type V-1 is more commonly used with electric vehicle batteries, and Type S-1 with starting and lighting batteries. Type M is employed in the battery rooms of central stations where more exact readings are required.

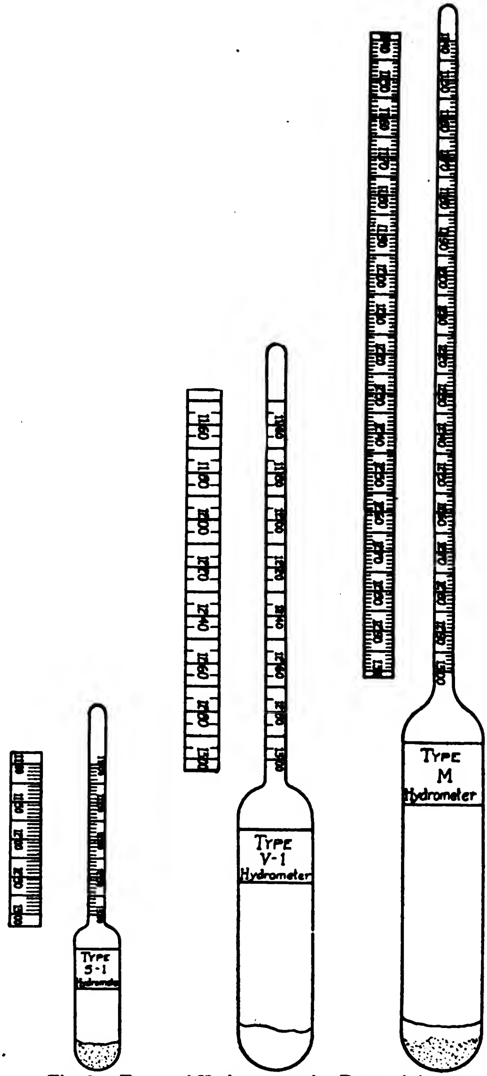


Fig. 3. Types of Hydrometers for Determining Specific Gravity

Where only occasional readings are taken a testing set, such as that shown in Fig. 54, Part II, will serve all purposes, the acid being transferred from the cell to the glass tube by means of the syringe, putting in just sufficient to float the hydrometer clear of the bottom. For constant use in connection with either vehicle or starting and lighting batteries, the type shown in Fig. 53, Part II, is most practical. The readings may be made more rapidly, and there is no danger of spilling acid on the tops of the cells or on the hands. To prevent the hydrometer from sticking to the sides of the barrel, it is necessary to hold it vertically to take the reading. As some of the cells on certain makes of cars are not so situated that the test can be made in this way, the soft-rubber plug in the bottom of the glass barrel is in the form of a trap so that when sufficient acid has been drawn into the barrel, the hydrometer nozzle can be removed from the vent hole of the cell and held in a vertical position, and the acid will not run out. The acid should be immediately *returned to the same cell.*

Failure to replace the acid withdrawn for a test in the same cell from which it was taken is apt to cause trouble. For example, if acid is taken from one cell, and, after making the reading, it is replaced in another cell, the result is that the amount of acid taken from the first cell is later replaced with water, making the electrolyte that much weaker, and *vice versa.* As soon as sufficient electrolyte has been drawn into the barrel, care being taken to see that the instrument is not sticking to the sides of the latter, note *underneath the level* of the liquid the graduation on the stem of the hydrometer.

For the convenience of the tester, a thermometer has been designed with a special scale opposite the mercury column. This scale corresponds to the temperature scale and indicates at a glance the correction required for the temperature reading. See Fig. 4. Opposite 70° it will be noted that the scale reads zero; above this the correction is plus and below it minus. In making readings, however, it is not customary to note a temperature correction for each, but simply to record the temperature at which the tests are made, and if the variation is sufficient to make the correction important, this is done after all have been taken. The necessary temperature corrections for the specific gravity are given from 30° to 100° F. in Table III, Part II, but in this case the rated specific gravity for various stages of charge is based on a temperature of 80° F.

A hydrometer test, however, cannot always be considered as conclusive evidence of the condition of a cell. The hydrometer alone may sometimes be a very unreliable guide as to the charged or discharged condition of a cell. For example, if electrolyte or acid had just previously been added to the cell without the knowledge of the tester, the hydrometer reading would apparently show the battery to be fully charged when the reverse might be the case. Consequently, voltage tests must be used in addition as, in the instance just cited, the voltmeter would give an indication directly opposite to that of the hydrometer. Under average conditions, however, the hydrometer alone will closely indicate the state of charge, though it is not to be relied upon in all cases. When there is not enough electrolyte in the cell to make it possible to use the hydrometer for a test, add enough distilled water to restore the normal level and then charge for at least one hour before making the test, as, when recently added, the water will remain at the top of the cell, and the reading thus taken will be valueless. Charging the battery mixes the water thoroughly with the acid of the electrolyte.

Specific gravity readings between 1.275 and 1.300 indicate that the battery is fully charged; between 1.200 and 1.225 that the battery is more than half discharged; between 1.150 and 1.200 that the battery is nearing a fully discharged condition and must be recharged very shortly, as otherwise serious damage will result; below 1.150 that the battery is exhausted and must be recharged immediately.

Variations in Readings. Where the specific gravity in any cell tests more than 25 points lower than the average of the others in the battery, it is an indication that this cell is out of order. Dependence should not be placed, however, on a single reading where there is any question as to the specific gravity. Take several readings and average them. Variations in cell readings may be due to short-circuits inside the cell; putting too much water in the cell, causing loss of electrolyte through overflowing; or to loss of electrolyte caused by a cracked, or leaky, jar. Short-circuits may result from a broken separator or from an accumulation of sediment in the bottom of the jar reaching the plates.

When first testing the cells, low specific gravity in one or more of them may often be equalized by charging, during which frequent readings should be taken at short intervals. If the specific gravity in any of the cells does not rise to 1.260 after the other cell readings indicate that the battery is fully charged, it is an indication that the low cell is in need of internal adjustment, and it must be dismantled in accordance with the instructions given under that head. See also instructions under "Renewal of an Element" for the method of remedying the trouble.

Quite a substantial percentage of battery troubles—and this is particularly the case with starting-system batteries that are usually neglected until they give out—may be traced to letting the electrolyte get too low in the jars. The effect of this is to weaken the battery, thus causing it to discharge more readily and frequently resulting in harmful sulphating of the plates and injury to the separators. When the latter occurs, it permits the plates to come into contact and causes an internal short-circuit. The importance of always maintaining the level of the electrolyte ½ inch above the tops of the plates by frequent addition of distilled water to bring it up will be evident from this. If, after the occurrence of low cells, the battery does not regain its full efficiency after one or two days, it is an indication that sulphating has taken place, and the remedy as given under that heading should be applied without delay, as letting a battery go without attention in this condition will ruin it.

One of the most frequent causes for low electrolyte in a cell is the presence of a cracked, or leaky, jar, and if one of the cells requires more frequent addition of water to maintain the level of its electrolyte, it is an indication that it is leaking. Unless the jar is replaced immediately, the cell itself will be ruined, and it may cause serious damage to the remainder of the battery. Jars are often broken, owing to the hold-downs becoming loose and allowing the battery to jolt around, or it may be due to freezing. The presence of a frozen cell in a battery shows that it has been allowed to stand in an undercharged condition in cold weather, as a fully charged cell will not freeze except at very low temperatures.

Frozen Cells. In some cases the cells may freeze without cracking the jars. This will be indicated by a great falling off in the efficiency of the cells that have suffered this injury or by a totally discharged condition, which cannot be remedied by continuous charging. In other words, the battery is "dead", and the plates are worthless except as scrap lead. In all cases where cells have been frozen, whether the jar has cracked or not, the plates must be replaced at once. It must always be borne in mind that low temperatures seriously affect the efficiency of the storage battery and this should be taken into consideration when making hydrometer tests in cold weather. The readings will not be the same in winter as they are in summer for the same condition of charge.

Process of Charging. *Precautions Regarding Electrolyte.* To charge, direct current is passed through the cells in the direction opposite to that of discharge. This current passing through the cells in the reverse direction reverses the chemical action which took place in the cells during the discharge. During the latter the acid of the electrolyte penetrates the active material and combines with it, filling its pores with lead sulphate and causing the electrolyte to become weaker. Reversing the current through this sulphate in the plates restores the active material to its original condition and returns the acid to the electrolyte. This is why the battery manufacturer lays such stress on his instructions *never to add acid to the electrolyte to bring up the specific gravity.* Low gravity indicates that a large proportion of the acid is combined with the active material of the plates, and that when the cells are recharged this acid will be returned to the electrolyte; thus any addition will represent an excess.

During the charge the electrolyte gradually becomes stronger, as the sulphate in the plates decreases until no more sulphate remains and all the acid has been returned to the electrolyte, when it will be of the same strength as before the discharge, and the same acid will be ready to be used over again in the next discharge. Since there is no loss of acid, none should ever be added to the electrolyte. The acid absorbed by the plates during the discharge is driven from the plates by the charging current and restored to the electrolyte during the charge. *This is the whole object of charging.*

Charging Rate and Time of Charge. In charging there are only two factors to be considered, rate in amperes, and time. The rate in amperes is limited by the state of discharge. When the cells are fully discharged, in which condition the plates contain the maximum amount of sulphate, the charging current can be utilized at the highest rate.

Gassing. As the charge progresses and the amount of sulphate in the plates decreases, they can no longer absorb current at the same rate, and the charge must be reduced. This becomes necessary when the cells begin to give off hydrogen gas. This is termed *gassing* and is an important feature of the process of recharging, since *gassing shows at any time whether or not the charging rate is too high.* Passing current through a cell will always be followed by a reaction in the cell; just what this reaction will be depends upon the condition of the cell at the time. In any case the current will always follow the path of least resistance and will accordingly always do the easiest thing first. When the cell is in a discharged state, the easiest thing is to decompose the lead sulphate. As there is a comparatively large amount of lead sulphate in a fully discharged cell, a correspondingly large amount of current can be used in charging. But as the amount of sulphate progressively decreases with the charge, a point is reached at which there is no longer sufficient sulphate remaining to ultilize all the current that is passing through the cell.

The excess current will then begin to do the next easiest thing, which is to decompose the water of the electrolyte and produce gas. Therefore, when the cells begin to gas freely, it indicates that current is being passed through them at too high a rate, and the charge should be reduced sufficiently to stop the gassing. As the charge is continued at the lower rate, the remaining sulphate will continue to decrease in amount until there is no longer sufficient to utilize the smaller amount of current, and the cells will again begin to gas. The charge should be reduced each time the gassing begins. When the cells begin to gas freely at a very low charging rate, it indicates that there is practically no sulphate remaining, so that even this small amount of current cannot be utilized, and the charge is complete.

Discharge. The action of the cell on discharge is briefly as follows: When the cell is connected up to discharge, the current is produced by the acid in the electrolyte combining with the lead of the porous parts of the plates, termed the *active material* which, as already mentioned, consists of lead peroxide in the positive plates and metallic lead in a spongy form in the negative plates. When the sulphuric acid in the electrolyte combines with the lead in the active material, a compound, lead sulphate, is formed. This is formed in the same way that sulphuric acid dropped on the copper wiring, or terminals, forms copper sulphate, or acid dropped on the iron work of the car forms iron sulphate. In cases of this kind it will always be noted that an amount of sulphate is formed out of all proportion to the quantity of metal eaten away. In the same manner, the sulphuric acid of the electrolyte combines with lead in the plates forming lead sulphate which, on account of its increased volume, fills the pores of the active material.

As the discharge progresses, the electrolyte becomes weaker in proportion to the amount of acid absorbed by the active material of the plates in the formation of lead sulphate, a compound of acid and lead. This lead sulphate continues to increase in quantity and bulk, filling the pores of the plates, and, as these pores are stopped up by the sulphate, the free circulation of the acid through the plates is retarded. Since the acid cannot reach the active material in the plates fast enough to maintain the normal action, the battery becomes less active, as is evidenced by a rapid drop in voltage. Experiences show that at the normal discharge rate, the voltage will begin to drop very rapidly soon after reaching 1.8 volts per cell.

During a normal discharge, the amount of acid used from the electrolyte will cause the gravity to drop 100 to 150 points. Thus, if the gravity of a fully charged cell is 1.275, it will, at the end of the discharge, be between 1.175 and 1.125, depending on the type of cell. The battery should never be allowed to drop below this point, but should immediately be placed on charge.

Efficiency of Storage Cell. About 20 per cent of the energy employed in charging the cell is lost in the process, so that the efficiency of the storage cell in good condition is approximately 80 per cent, this representing the available output of the fully charged cell. By abuse or neglect this percentage of efficiency may fall so low that the figures given will be almost reversed, from which the necessity for properly looking after the battery may be appreciated, particularly when it is expressed in terms of miles per charge and the reduced capacity may mean stranding at quite a distance from a source of current.

Sulphating. The conversion of the active material into lead sulphate, which takes place during the discharge of the cells, is a normal reaction and as such occasions no damage. If, however, the cells are allowed to stand for any length of time in a discharged condition, the sulphate not only continues to increase in amount but becomes *hard* and white, and the presence of white spots on the plates is an indication that the cells have been neglected. In this condition, the plates have lost their porosity to a considerable extent and it is correspondingly more difficult to force the charging current through the active material. This is the abnormal condition usually referred to as *sulphated*.

Continued and persistent charging at a low rate will restore practically any condition of sulphate, the time necessary being in proportion to the degree to which the condition has been allowed to extend. It is entirely a question of time, since a higher rate will only produce gassing and high temperature, the low rate being all that the cells in this condition are capable of using.

Time Necessary to Restore a Sulphated Battery. The additional length of time necessary to restore a sulphated battery is illustrated by the following test:

Preventing Sulphating. In ordinary charging, there is usually not sufficient time to continue the charge until absolutely all the sulphate has been converted. To prevent the small amount of sulphate remaining from increasing and getting hard, an *equalizing charge* should be given at frequent intervals. Some makers recommend doing this once a week, others every fortnight, and still others once a month. This equalizing charge is an extra long charge at a low rate, whereby no more current than can be absorbed by the amount of sulphate remaining is passed through the cells.

A battery was charged to the maximum, and the gravity regulated to exactly 1.275, with the electrolyte just one-half inch above the tops of the plates, this height being carefully marked. The battery was then discharged and recharged to 1.275 at the normal rate in each case. The specific gravity changed from 1.265 to 1.275 during the last hour and a half of the charge. During the following twelve weeks the battery was charged and discharged daily, each charge being only to 1.265, thus leaving 10 points of acid still in the plate. At the end of the twelve weeks the charge was continued, to determine the time required to regain the 10 points and thus restore the specific gravity to the original 1.275. Eleven hours were needed, as compared with the hour and a half needed at first.

The test further illustrates why it is necessary to give a battery an occasional overcharge, or equalizing charge, to prevent it becoming sulphated. Had the battery in question been charged daily to its maximum of 1.275 and discharged to the same extent during the twelve weeks, nine and a half hours of the last charge would have been saved. It is neither necessary nor desirable, however, to carry every charge to its absolute maximum. The weekly equalizing charge is better practice.

Restoring a Sulphated Battery. It has become more or less common to suspect the battery of being sulphated every time it fails to give the mileage the user thinks it should give on an electric vehicle, or to have the capacity for starting that, in the driver's estimation, it should have, on a gasoline car. But if the sediment has not been allowed to reach the bottom of the plates, and if the level of the electrolyte over the plates has been properly maintained by replacing evaporation with distilled water, the battery can be sulphated only because it has not been properly charged, or because acid has been added to the electrolyte. An individual cell may become sulphated through an internal short-circuit, or by drying out as might be caused by failure to replace evaporation with water, or failure to properly replace a broken jar.

Sulphate Tests. To determine whether a battery is sulphated when it is known that it does not require cleaning, it is advisable to remove it from the car, give it the ordinary equalizing charge, and discharge it at the normal rate. If it gives its rated capacity, the reason for short mileage should be looked for elsewhere in the electric vehicle, or in the other essentials of the starting and lighting system on a gasoline car. (The removal of the battery refers to an electric vehicle and not to a starting and lighting battery.) If the rated capacity is not obtained on this discharge, recharge in the usual way. When the battery is considered fully charged, take and record a hydrometer reading of each cell and the temperature of one cell. Charge the battery at a rate as near one-half its normal rate as the charging apparatus will permit. If the temperature reaches 100° F., reduce the current or temporarily interrupt the charge not to exceed this temperature.

Treatment for Sulphates. A battery is sulphated only when acid is retained in the plates. When the specific gravity of the electrolyte has reached a maximum, it shows that there is no more sulphate to be acted upon, since during the charge the electrolyte receives acid from no other source. Hydrometer readings should be recorded at intervals sufficiently frequent (four to six hours apart) to determine if the specific gravity is rising or if it has reached its maximum. Continue the charge, recording the readings, until there has been no further rise in any cell during a period of at least twelve hours. Maintain the level of the electrolyte at a constant height by adding pure water after each reading with the hydrometer. (If water were added just before taking hydrometer readings, the water would not have time to mix properly with the electrolyte.) Hydrometer readings should be corrected for any considerable change in temperature during the charge in accordance with the scale shown in Fig. 4. Should the gravity rise above 1.300 in any cell, draw off its electrolyte down to the top of the plates and put in as much distilled water as possible without overflowing. Continue the charge, and if the gravity again goes above 1.300, it shows that acid has been added during the previous operation of the battery. The electrolyte should then be emptied out, replaced with pure water, and the charge continued. The treatment can only be considered complete when there has been no rise in the gravity of any cell during a period of at least twelve hours of continuous charging.

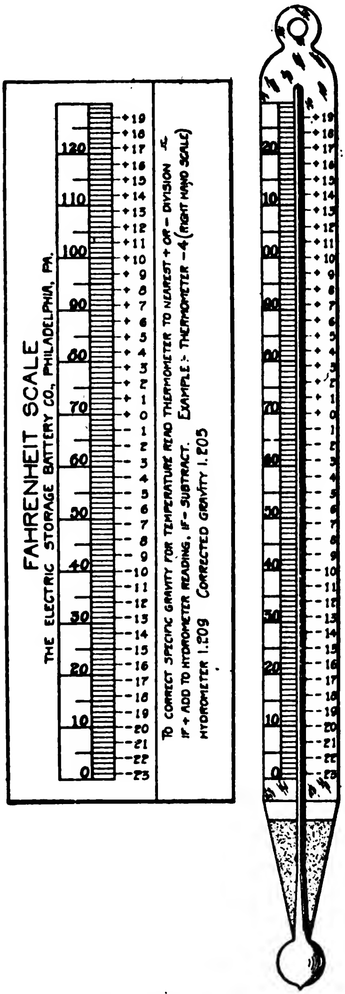


Fig. 4. Fahrenheit Thermometer with Special Temperature Scale for Correcting Density of Electrolyte

Upon completion of the treatment, the specific gravity of the electrolyte should be adjusted to its proper value of 1.270 to 1.280, using distilled water or 1.300 acid as may be necessary. In cases where one or more individual cells have become sulphated, while the balance of the battery is in good condition, it is better to remove such cells and treat them individually. The active material of sulphated negative plates is generally of light color and either hard and dense or granular and gritty, being easily disintegrated. It is the negative plates which require the prolonged charge necessary to restore a sulphated battery. Sulphated positives, unless physically disintegrated or badly buckled, are but little changed in appearance and can be restored to operative condition, although their life will not be as great as if they had not been subjected to this abuse. Sulphated plates of either type should be handled as little as possible. By strictly following the simple rules of operation given in connection with charging and discharging the battery, the expense and trouble inseparable from restoring a sulphated battery may be avoided.

Capacity of Cell. *Depends upon Plate Area.* The ampere-hour capacity of a cell, or the amount of current which it is capable of absorbing and reproducing through the medium of the chemical processes described, is determined by the area of its plates. This area

Fig. 5. Complete Battery of Cells for Pleasure Car

depends upon the area of the single plate as well as upon the number of plates the cell contains. It is customary to make both outside plates in a cell negatives, so that the cell contains an odd number of plates and its capacity is fixed by the number of positives. The ampere-hour capacity of a battery, the cells of which are all connected in one series, is the same as that of a single cell in the series; just as, in connecting up dry cells or other primary batteries in series, the current output is always that of a single cell, while the voltage of the battery increases over the voltage of one cell in proportion to the number of cells thus connected. The capacity of the cell, in turn, limits the safe rate at which its output may be discharged.

A complete assemblage of cells for a pleasure car is shown in Fig. 5.

Measurement of Capacity. The standard unit for measuring capacity of a storage cell is the ampere hour, which means a current of one ampere flowing for a period of one hour. When the capacity of a cell is stated as a certain number of ampere hours, this indicates that the cell will deliver 1 ampere of current for the period given, 2 amperes for one-half that period, etc. This does not mean, however, that this progression may be carried to the other limit, as the efficiency of the cell falls away as the discharge rate becomes greater. In other words, while a 100-ampere-hour cell will produce 1 ampere for 100 hours, 2 amperes for 50 hours, 4 amperes for 25 hours, and so on in the same proportion, it will be found, as the rate of discharge increases, that the capacity will fall off, the same cell not being able to deliver 25 amperes for four hours, or 50 amperes for two hours.

In former years, the capacities of all lead-plate cells for vehicle use were based on a four-hour rate of discharge. Thus a 140-ampere-hour cell was guaranteed to discharge 35 amperes for four hours. Since the introduction and more or less general use of thinner plates, many makes are sold on a basis of a 5-, 5½-, and even a 6-hour rate, so that 35 and even 37 or 38 amperes are guaranteed for five hours or more from a battery occupying no greater space.

Rate of Discharge. Since the current is produced by the action of sulphuric acid combining with lead in the plates, the rate at which the acid can penetrate the active material determines the maximum rate at which current can be produced. For instance, if the same amount of material used in making a nine-plate cell were employed in but two plates, one positive and one negative, the ampere-hour capacity at a sufficiently low discharge rate would be just the same as if this material were divided into four positives and five negatives. At ordinary rates of discharge, however, the acid could not penetrate the active material of such a thick plate fast enough to maintain the discharge rate for the required time. If these same plates were split into thinner plates, the acid could much more readily get to that portion of the material which in the thick plates was farther removed from the surface, and current could therefore be produced more rapidly.

Safe Discharge Point for Plates. The point to which the cell can be safely discharged is not limited by the period during which it is used so much as by the voltage of the cell itself. The discharge should never be carried so far that the voltage falls below 1.8 volts per cell, while the voltage when charged should be 2.2 volts per cell, or slightly in excess of this, especially just after the completion of the charge. The majority of vehicle batteries are designed to have a normal eight-hour rate of discharge, and their capacity, for pleasure cars, seldom exceeds 180 ampere hours. Such cells will discharge 10 amperes for a period of 10 hours without falling below 1.8 volts, provided conditions of charging and discharging have been favorable, and the battery is otherwise in good condition. During the discharge the sulphuric acid, as indicated by the chemical equation already given, is partially converted into water and lead sulphate, and when carried to extremes, the electrolyte would be practically all water, and the voltage would fall to about 1.46, virtually ruining the cells. However, the sulphion, or SO_3, is only abstracted from the electrolyte where it is in con-

Fig. 6. Part Section of Exide Storage Cell Showing Complete Assembly
Courtesy of Electric Storage Battery Company, Philadelphia

tact with the plates. As it is removed, the density of the fluid decreases, and a circulation is set up, thus permitting fresh acid to take the place of that exhausted. The chemical action is naturally most rapid in the minute pores of the plates where circulation is most difficult, so that when the cell is allowed to stand idle, the fresh electrolyte penetrates the plates and there is a correspondingly marked rise in the voltage of the cell. This explains what is known as the *recuperative power* of the storage cell.

Use of Separators between Plates. In a storage cell for stationary service the plates are separated merely by allowing a certain space between them, but this would obviously be out of the question in a vehicle battery. An insulating separator is accordingly quite as important a component of the cells as the electrodes. Very thin sheets of corrugated wood are generally employed, with thin sheets of perforated hard rubber placed on each side of them, Fig. 6. These insulating unit groups exactly fill the space between adjacent plates so as to permit of no relative movement whatever. No matter how well the cell is made, or of what type, where lead grids are employed, disintegration of the active material is constantly going on in service; hence, the plates are placed on strips of wood or hard rubber ribs, Fig. 6, to prevent short circuits.

TYPES OF CELLS

General Characteristics. It will be noted that there is considerable difference in the appearance of the various plates illustrated here, and it may be added that there is a corresponding difference in their construction. Despite the almost innumerable attempts that have been made to discover materials that would not have the disadvantages of bulk and weight for storage-battery work, the lead-sulphuric-acid type is still commercially supreme. Although there are many minor variations of design and construction, there are two general classes of lead plates employed. These are the Planté and the Faure. In both, lead peroxide is the active material at the positive electrode and finely divided spongy metallic lead at the negative, one of the means of distinguishing the plates apart being their color, the negative showing a dull gray, while the positive is red. The plates of the Planté type consist of pure lead of relatively small sectional area, with all exposed surfaces scored, fluted, or corrugated in similar manner to increase the area that can be reached by the electrolyte.

Pure lead is very soft and yielding, and it is often necessary to supply a supporting framework of hard cast lead to lend additional stiffness to the plates, particularly for vehicle work. These plates and the electrolyte complete the Planté type of cell, as the active material is directly formed electrochemically from the material of the plates themselves by being subjected to a series of charges and discharges. In the Faure type, a cast grid of comparatively hard lead is employed as the foundation, and the active material is placed in the interstices in the form of a stiff paste, the whole plate being subsequently subjected to considerable pressure. On this account it is usually referred to as a pasted type of plate. The Exide cell, plates of which have been illustrated in part section, Fig. 6, is representative of this class.

Only the Faure type is used for vehicle batteries as the Planté is a "formed" plate from which the active material would be shaken by the vibration.

Improved Forms

Nature of Improvements. The foregoing are what are known as *flat-plate* types of elements, and the life of this form of battery is usually measured in terms of the life of the positive plate, as it is the latter which suffers most from the charging and discharging process. It is nothing unusual for the other elements in the cell combination to outlast the positive plate two or three times over, new separators being installed with each renewal. Accordingly, the problem has been to devise a type of positive plate that would equal the negative in durability. Many forms of protective coverings designed to prevent the active material from washing out of the plate have been tried with varying degrees of success. Among these have been plates built up of parallel cylindrical pencils of the active material. While the latter did not prove a solution of the problem in its simple form, this idea, in combination with a basic principle originated by a French maker, served as the foundation for what is known as the "Ironclad" Exide type. For this form, the makers claim that the positive plate not only lasts practically as long as the negative, but that the battery is capable of withstanding the abuse of overcharging to a degree never before attained. The importance of the latter in the commercial use of electric vehicles can hardly be overestimated and is brought out in the paragraphs on "Boosting", Part II.

Ironclad Exide Type. *Positive Plate.* The Ironclad Exide positive plate consists of a grid composed of a number of parallel vertical metal rods united integrally to horizontal top and bottom frames, the former being provided with the usual conducting lug for carrying the current. Each vertical rod forms a core, which is surrounded by a cylindrical pencil of peroxide of lead, which is the active material. These pencils are enclosed in hard-rubber tubes having a large number of horizontal slits, which serve to provide access for the electrolyte, or solution, to the active material, but are of such small dimensions as to practically eliminate the washing out of the material. Fig. 7, which shows a vertical section of one of these composite pencils, makes this construction clear. The outside tubes are reinforced by leaving the exposed edge solid, i.e., without slits. Each tube is provided with two parallel vertical ribs projecting on opposite sides at right angles to the face of the plate. These ribs not only serve to stiffen the tubes, but, being of hard rubber as are the tubes them-

Fig. 7. Vertical Section of Positive Plate Pencil

Fig. 8. Positive Pencil Showing Rib

Fig. 9. Assembled Exide Positive Plate

selves, also act as insulating spacers, allowing the use of a flat piece of wood veneer in place of the ribs on the wood separators in other types.

The reinforcing rib is shown by Fig. 8, which is a side view of the tube. These rubber tubes have a certain amount of elasticity allowing them to compensate for changes in volume of the active material, owing to the expansion and contraction during charge and discharge. A complete positive plate of this type is illustrated by Fig. 9. This cylindrical form of tube is peculiarly well adapted to perform its function, since no amount of expansion or contraction will tend to alter its shape, and the internal stresses are thus kept uniform. Another advantage is that most of the electrolyte necessary is carried within the confines of the plate itself. This is illustrated by a comparison of horizontal sections of portions of the Ironclad Exide plate and the standard Exide plate, as shown in Fig. 10.

Negative Plate. To conform to the construction of the new positive, the negative is also modified somewhat, the upper and

Fig. 10. Comparative Sections of "Ironclad" and Standard Exide Plates

lower edges of the plates being encased in rubber vulcanized in the plate. This eliminates the possibility of short-circuits from material bridging across from the positive frames. The negative frames are undercut, so that the rubber sheathing is flush and does not project beyond the face of the plate. The thickness of this negative plate is calculated to provide approximately the same life as the positive, thus avoiding partial renewals, which cut down the efficiency of the cell.

Separators. The special form of the positive plates renders unnecessary the flat perforated rubber sheet used in the standard types of cells, the only separator employed being the wood veneer mentioned. The greatly increased life of the new cell made it necessary to employ a separator of greater durability than those in current use and, after investigation, a special kind of wood possessing great toughness, as well as ability to resist the action of the electrolyte to a remarkable degree, was adopted. These separators are made with the grain of the wood running horizontally in order not to register with the vertical ribs on the positive plates, which would tend to split the wood. The positive and negative plates are

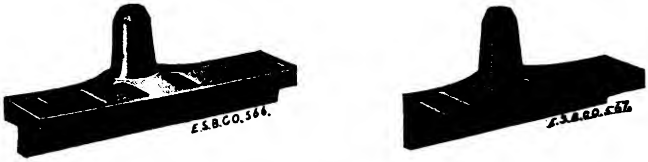


Fig. 11. Pillar Type of Strap Connectors
Courtesy of Electric Storage Battery Company, Philadelphia

grouped in the customary manner, the lugs being burned directly to the usual lead straps, except that the straps are of the pillar type, illustrated by Fig. 11.

Improved Connectors. Mention has been previously made of the necessity of providing the maximum conductivity in the elements of the cell as well as in the units of the battery in order to keep its internal resistance down, as upon the latter depends its ability to discharge its energy at a high rate, this being a valuable characteristic for hill climbing or bad road conditions. The usual practice has been to employ the same alloy of lead and antimony for connecting the cells, the latter having strips of the metal burned to the pillars or other projections designed for receiving the inter-cell connections. For this purpose, the makers of the Ironclad Exide cells have brought out an improved form of connector, shown in Fig. 12. This is known as a built-up type, consisting of thin strips of copper, lead-covered to prevent corrosion. A number of these strips, depending upon the current to be carried, are laid face to face, and their ends cast into lead-alloy terminals, a special welding process insuring effective and permanent contact between the flexible strips and the cast terminal. By this means, good conductivity is obtained under all conditions of vibration and temperature changes. The lead-alloy terminals are ring shaped to fit over the pillar of the strap and are burned in place. The use of copper gives a higher conductivity than lead alloy, while the laminated structure provides a flexible, instead of a rigid, connection.

Fig. 12. Lead-Covered Copper Connecting Strip
Courtesy of Electric Storage Battery Company

Starting Batteries. The advent of electric starting motors on the automobile has been responsible for adding to the problems of the storage-battery maker. As outlined in the chapters devoted to starting and lighting, the requirements are such that the maximum output of which the battery is capable is called for instantaneously

Fig. 13. Sectional View of Titan Cell Showing Diagonal Ribs of Active Material to Lessen Resistance
Courtesy of Horseless Age

every time the gasoline motor is started. Any one who has cranked a car on a very cold morning after the motor has been idle over night will realize the greatly increased effort necessary to move the pistons, owing to the adhesion caused by gummed, or partly frozen, lubricating oil. Special provision is accordingly necessary to reduce the internal resistance of the cells of the battery in order that it may deliver its maximum output, the demand usually representing a considerable overload. One method of attaining this is shown in the "Titan" cell, in the positive plates of which the conductivity afforded by the grid is greatly increased by the provision of diagonal ribs running in the general direction of the points where connection is made to the strap, as illustrated by Fig. 13, which shows a section of the cell. This increased conductivity tends to reduce the tendency of the plate to buckle and force out its active material when subjected to such a heavy demand for current.

In addition to the service being of such a severe nature, the conditions under which a starting battery must operate are equally strenuous in other respects. Touring cars are driven at very much higher speeds than electric cars and frequently over rough roads, which greatly adds to the amount of vibration that the plates must endure. Special provision must accordingly be made for the reception of a greater amount of sediment and in a manner which will prevent the latter from reaching the bottom of the plates. This takes the form of an increased depth of electrolyte below the elements, while the space thus allowed is provided with an increased number of baffle plates, or partitions, to prevent the sediment from being washed about and accumulating in one place. The Titan cell is an illustration of this, and it is also shown in the Gould cell, Fig. 14, which also incorporates the use of built-up connectors of copper and lead. Both of these cells likewise embody an improved form of cover. They are enclosed by two hard-rubber covers and an intermediate layer of sealing compound in adhesive contact with the sides of the jar. Sleeves of hard rubber permit of some flexibility at the pillars while still insuring an air-tight joint with the sealing compound.

Fig. 14. Gould Starting Battery Cell Showing High Mud Space

Integral with the lower cover is an expansion chamber communicating with the interior of the cell and provided with a threaded cap. In the case of the Gould cell, leakage is guarded against by the inverted conical form of this cap, and as the battery boxes are now made in accordance with the S. A. E. standard dimensions, they may be placed end to end, reducing the thickness to 4½ inches in the largest size, and permitting the battery to be suspended between the chassis frame and the running board, concealed by an apron.

Edison Battery. Inasmuch as the Edison battery represents the only successful attempt to make use of a reaction other than that of the lead-sulphuric-acid couple discovered by Planté, the inventor of the so-called storage battery, the Edison cell is of unusual interest. Placing this battery on the market in commercial form is said to have involved the expenditure of more than two million dollars, as special processes and costly machinery had to be originated for its manufacture, while more than fifty thousand separate experiments were made in a period of seven years before the solution of the problem itself reached the stage where manufacturing could be undertaken.

The elements of the Edison cell consist of nickel and iron in an alkaline solution, and, as the capacity of a storage cell depends upon the area of the active material in contact with the electrolyte and upon the conductivity of its members, the problem was to utilize these materials in the form best adapted to give efficiency and durability. Three years were devoted to this phase of the problem, after the reaction giving promise of success had been discovered, before the first crude cell was made.

Composition of Plates. The positive plate of the Edison cell consists of vertical rows of thin, perforated steel tubes filled with nickel hydrate, these tubes being supported in a steel frame somewhat similar in appearance to a pencil-form lead grid, as will be noted by reference to Fig. 15, which shows a positive and a negative plate complete. Rows of flat, perforated steel jackets filled with iron oxide, likewise held in a thin steel frame, compose the negative plate. The elements are, accordingly, nickel, iron, and steel in a 21 per cent solution of potash in distilled water, and these elements constitute a storage cell which differs radically in every respect from the lead-plate type. In fact, this is the only storage cell the elements of which are not attacked by the electrolyte when left standing in a charged, partly-charged, or wholly-discharged condition for any length of time. Apparently the potash acts as a preservative of all the elements entering into the combination.

Iron oxide will be recognized as one of man's most persistent and ubiquitous enemies, rust. Nickel hydrate is the product of a special electrolytic process originated by Mr. Edison. When on charge, this iron oxide, or rust, of the cell's negative plate is converted into metallic iron, while the oxygen generated passes over to the positive plate and converts the nickel-hydrate content into a new form of nickel oxide, previously unknown to science. The oxidizing of the nickel hydrate causes it to expand just as the peroxide

Fig. 15. Assembled Positive and Negative Edison Plates

Fig. 16. Completely Assembled Edison Cell

of lead of the lead positive plate does, but there is no danger of loosening or loss of the active material in this case, as it is held in a rigid steel tube. The latter has numerous fine perforations to permit access of the electrolyte, but these are so numerous that the steel approximates wire netting or gauze.

The container is of steel welded in a special machine making it an integral unit which cannot be opened without destroying it.

Protruding through the top and surrounded by hard-rubber washers are the two tapering terminals, and between them is the filler cap through which the solution of potash and distilled water is introduced. This cap acts as an automatic relief valve which allows the gas generated to escape but prevents the entrance of air. The cells are connected by nickel-plated solid copper strips fastened to the threaded terminals with nuts so that the units of a battery may be taken apart readily, Fig. 16. The cells are fitted in wooden trays and tightly clamped in place, Fig. 17.

Advantages and Disadvantages. Chief among the advantages of the Edison battery for commercial-vehicle use are its long life and

Fig. 17. Tray of Four A-4 Edison Cells

its ability to withstand what would be considered flagrant abuse, if applied to a lead battery. It may be charged or discharged at any rate within the current-carrying capacity of its connections, allowed to stand either charged or wholly discharged for any length of time, without injury, and in other ways subjected to electrical abuse which would ruin a lead-plate battery in a comparatively short time. As evidence of its durability and continued electrical efficiency even under such treatment, it is guaranteed for four years' use.

While the voltage of each cell is but 1.25 volts as compared with 2 volts for the lead cell, its construction is so much lighter that there is a saving in weight in battery of Edison cells when compared with a

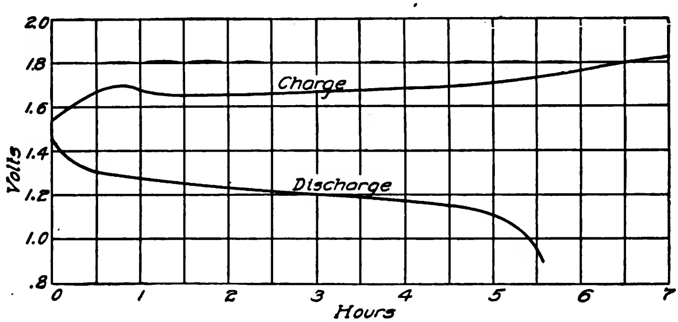


Fig. 18. Charge and Discharge Curves for Edison Cell

lead battery of the same voltage and capacity, despite the added number of the former necessary to give the same potential. Fig. 18 illustrates the charge and discharge curve.

Size of Battery. The voltage of the vehicle circuit has a twofold bearing upon the latter's efficiency. On one hand, there is the factor of efficient utilization of the energy and, on the other, of the charging efficiency of the battery. Thus there is a constant loss at both ends which accounts for the abandonment of 24- and 30-volt batteries which were common in electric cars of the pleasure type about 1905. The most common voltage of direct-current lighting and power circuits is 110. To charge less than 42 or 44 lead cells or 60 alkaline cells means a loss of current in the rheostat, this loss increasing as the number of cells decreases. This makes the vehicle owner pay for many more kilowatt hours than he receives in the form of energy in the battery. With a 30-cell lead battery, for example, charging on 110 volts, one-third of the current paid for by the user is wasted, so that it is now customary to employ 42- or 44-cell batteries on most of the heavy-type commercial vehicles, though practice in this respect varies on pleasure cars according to their weight, the range usually being from 30 to 42 cells, the former number being used for light three-passenger vehicles and the 40- and 42-cell batteries in broughams and limousines. With alternating currents this objection does not hold good.

THE MOTOR

Quite in contrast with that of the gasoline car, the motor of an electric vehicle is probably responsible for less of the troubles encountered than any other one of the essential components. While the relative amount of attention it requires at the hands of the owner of the vehicle is small, a knowledge of its construction and working will be found of value in the operation and maintenance of the car. It is here that the energy held in reserve in the storage battery is converted into the mechanical power necessary to move the vehicle. The reason for the small amount of attention required is apparent in the small number of parts as well as their great simplicity, though the great amount of attention that has been devoted to the development of the electric motor over a long period of years is largely responsible for the elimination of the numerous shortcomings of the earlier types.

Essentials of Motor. The motor consists of a *field*, an *armature* suitably mounted on bearings so that it may be revolved in that field, a *frame*, a *commutator*, and *brushes*. The term *field* is the generally accepted abbreviation for magnetic field, which is the zone of influence exerted by a magnet, and is referred to in terms of its "lines of force". A common horseshoe magnet, technically known as a *permanent magnet*, will attract to its ends or poles particles of iron and steel placed within a certain distance of it. The space bounded by the poles of the magnet and the limits to which its attraction reaches, is known as its *field*. With reference to electric motors and generators, the word is employed to designate the magnets and pole pieces which serve to create this field, rather than the scope of magnetic attraction itself, and it is used to embrace all of them, regardless of their number.

Principle of Rotation. The fundamental principle upon which the functioning of all apparatus of this type is based is to be found in the fact that when a current of electricity is passed through a coil of wire surrounding a bar or other form of iron or steel, the metal becomes magnetic in proportion to the number of turns in the coil of wire and the strength of the current employed. Every magnet consists of a north and a south pole, and *like poles repel while unlike poles attract one another*. In other words, if two small common magnets are placed on a table with their like poles, i.e., north to north and south to south, facing one another, the magnets as a whole will tend to repel one another, and were they sufficiently powerful, would actually recede from the common center until the limits of their field were reached. By reversing the polarity of the opposing ends of the magnets, they would then tend to be drawn to one another until the poles butted. This, in brief, sums up the philosophy of the electric motor.

In order to amplify the power, a large number of magnets are employed; and in order that the energy thus developed may be utilized, one group of magnets is made stationary while the other group is free to revolve. In these two groups will be recognized respectively the field and the armature of the motor, and each magnet of the groups is of the type known as *electromagnets*, so termed because they are magnetic only while a current is passing through their exciting coils. Those of the field may be distinguished as they take the form of short thick spokes radiating from the rim or frame toward the center. They thus surround the space in which the armature revolves, and are further provided with what are known as *pole pieces* in order to fill as much of the space with iron as is possible. As already mentioned, the field of a magnet is most powerful in close proximity to it and the armature will be seen to run as closely to the faces of the pole pieces as good design and construction will permit.

Now it will be remembered that the direction in which the current of electricity is sent through the exciting coil determines the polarity of the resulting magnet. If, with the current traveling round the coil in one direction, the right-hand end of a bar becomes of north polarity and the left-hand end of south polarity, it will be evident that, by reversing the direction of current flow, there will be a corresponding change in the location of the poles. Coming back to practice, in which one set of magnets—the field—is held stationary, while the other may revolve, it will be apparent that as each of the armature magnets approaches a field magnet by virtue of the attraction between them, the motion will tend to accelerate up to the point where they are opposite, but when the moving magnet passes by, the attraction which still exists will tend to stop the rotation. It is clear, therefore, that, to bring about the desired rotation of the armature some device must be used to reverse the direction of the current in each electromagnet when it has reached a point opposite the field magnet which is attracting it so that the resulting *opposite polarity* may develop a repulsion which will carry the armature in the same direction. This is just where the function of the commutator and the brushes comes in. The brushes serve to lead the current to the circular group of copper bars which forms the commutator, without retarding the rotation of the armature. Each section of the commutator is insulated from its neighbors and as the brushes touch opposite sections simultaneously the rotation makes the current enter the armature coils first in one and then in the opposite direction, through successive sections of the commutator, the current being reversed and the polarity of the field magnets being changed for each new position.

The Armature. The foundation of the armature consists of a cylinder built up of laminations of iron, or punchings, with recesses cut into their circumferences to receive the coils of wire, or windings, each one of which converts the particular section of the core that it surrounds into a powerful electromagnet when the current is passing. All the wire employed is strongly insulated, not only to protect neighboring turns from one another, but each winding is also well insulated from its foundation, whether this be the armature or a field core. If this precaution were not taken, *short circuits* or *grounds* would occur. The former term is really self-defining as it shows that the current instead of passing round the entire coil or circuit intended, would choose the shorter path thus accidentally provided. A ground, on the other hand, is caused where non-insulated portions of two different wires carrying a current come in contact with the same or a connecting piece of metal, or other conducting medium. This opens up a path of practically zero resistance for the current, thus diverting it entirely from the path it should follow if its energy were to be utilized.

Both short circuits and grounds are things with which the owner of the electric vehicle will have to become familiar to a greater or less extent in caring for the battery of his car, as well as the remainder of its electrical equipment, so that their nature has been explained in detail. While both cause similar results, they are not interchangeable terms and are employed to convey the distinction mentioned. In other words, a ground may be a short circuit, but a short circuit is not always a ground, as the latter implies the diversion of the current through some normally unused conducting medium, while the short-circuit signifies a breakdown of the insulation of the wiring or allied appurtenances that permits of the return of the current after having traversed but a fraction of the path intended for it. Either trouble naturally places the piece of apparatus in which the break occurs out of running order until the defect is remedied. In view of their nature, grounds are usually much more difficult to locate than short-circuits. Some of their further causes and results are mentioned in the chapter devoted to the care of the batteries, also that on the wiring.

Capacity for Overloads. It is this capacity of the motor to stand excessive overloads that fits in with the requirements of the road, for it must be borne in mind that the amount of power required to keep a vehicle rolling after it is once started is very small as compared with the pull necessary to start it, or to accelerate its speed. The total amount of energy required is in direct proportion to the total weight, and to the square of the velocity.

Motor Stands 500 Per Cent Overload. The pull, or *torque* of the motor as it is called, must be very heavy at starting, particularly when on an upgrade, and also for mounting inclines. For this reason, the motor employed is of a type capable of standing for short periods as much as 500 per cent in excess of its normal rated capacity. It will be apparent that this converts the 2½-horsepower motor into one of 12½ horsepower in cases of emergency, without increasing its current consumption under the ordinary conditions of load at which the greater part of its service is rendered, such as in running on the level or ascending ordinary inclines. The available amount of power being so closely restricted by the capacity of the battery, it will be manifest that this is a most important provision, and as the average layman talks in terms of horsepower without adequately comprehending the meaning of the latter, electric vehicle makers have found it expedient to omit any mention of this factor. The electric not only is not intended to be capable of the speeds of the gasoline car, but it does not require such an excessive amount of reserve power as it has become customary for the manufacturer to provide on the latter type.

Under usual conditions of running, the average gasoline machine does not employ more than a small fraction of the available power of its motor and, in consequence, is seldom being operated at what is technically termed its *critical speed*, that is, the speed at which it is most efficient, and therefore most economical. In the case of the majority of gasoline cars, this critical speed is from 25 to 30 miles an hour, or even higher, while for the average electric car it is from 10 to 15 miles an hour, a speed which corresponds so nearly with the usual speed on the road that the economy of the electric is very great.

Parts of Motor. The foregoing description of the electric motor for automobile use will be clear upon reference to Fig. 19,

Fig. 19. Parts of Typical Electric Vehicle Motor

which represents a largely used standard type. In the foreground is shown the armature, at the left hand of which is shown the commutator. The coils of wire on the armature run parallel to its length, but in order to save them from injury they are protected by a covering and this is in turn held on by the circular bands shown, which prevent any tendency of the heavy coils to fly out of their slots owing to the effect of centrifugal force. At the commutator end of the armature will be seen one of the annular ball bearings upon which it runs. This is the most advanced type of anti-friction bearing extant, and while its first cost is correspondingly high, its use is justified by the great power saving accomplishment as well as the extremely small need for attention that it involves. These bearings consist of two parallel races and a number of very accurately dimensioned balls distributed at equal distances around the circle by means of a bronze spacer. Only the very finest materials and the most accurate workmanship are permissible in successful bearings of this type. They are generally employed in electric vehicles, and a further reference is made to them in connection with transmission design.

Directly back of the armature is seen the frame, and from the description, the field coils and the pole pieces will be readily recognizable. The great amount of attention that has been devoted to making the motor as compact as possible will be evident from the mounting of its accessories. It will be seen that the housings are designed to carry both the bearings and the brushes, the latter being attached to the inner face of the cover plate shown at the right. The parts shown in the illustration comprise the motor complete, even including the cap screws necessary to assemble it.

Motor Speeds. *Types of Motor Windings.* The speed of electric vehicles is a most elusive quantity to the uninitiated, principally because the characteristics of the series-wound motor employed are not commonly understood by the layman. The series type of motor is one in which the windings of the armature and field are connected in series, i. e., so that the entire current fed to the motor passes through both of its elements consecutively, so to speak. In a shunt-wound motor the field is in multiple with the armature, so that, while the entire current passes through the latter, the amount taken by the field is always proportioned to that required by the armature for the load it happens to be carrying. As this type of motor is designed for a constant speed, it is not an economical motor to use on the electric vehicle owing to the wide fluctuation of both speed and load imposed, so that its employment is comparatively rare in this field. A compound-wound motor is one having both series and shunt-coil windings on the fields. Since most commercial motors for driving machinery, elevators, and the like are of the constant-speed, compound-wound type, there is a general impression that the electric car should have a certain nearly constant speed for all road conditions.

Advantages of Series-Wound Motor. But in the series-wound motor, the speed varies inversely as the power produced. In other words, its torque, or pulling power, is highest at low speeds, which is just the requirement demanded in starting or pulling through heavy roads. This type cannot be employed for ordinary commercial use, since it will instantly "run away" or race upon the load being released, but it can be employed to advantage on vehicles and in railway service because it is never disconnected from the load. "Load" in this case refers to the effort required to move the vehicles rather than the live load. Series motors are employed on the electric car because of their higher efficiency, which is of prime importance, since the object is to produce the greatest amount of useful energy from a given and limited amount of potential energy stored in the battery. Just the opposite of the gasoline engine, the chief characteristic of the series-type electric motor is the development of increased power with a decrease in the speed. Therefore, as the vehicle requires greater power for bad roads or grades, it slows down automatically and in a fixed relation to the power demanded.

High-Speed Single Motor Present Practice. Opinion and practice are divided on the subject of motor speeds. The higher-speed motors are more efficient, are better for grades and starting, but mechanical limitations frequently make them undesirable. Where formerly motor speeds ranged from 650 to 1100 r.p.m., modern practice favors higher r.p.m. rates, ranging from 1000 to 2000. Normal speeds under 1000 are not satisfactory for most conditions, the use of a low-speed type of motor being one of the causes of the low efficiency of the earlier electric cars. Another reason was the employment of two motors on comparatively light cars. This had a certain advantage in eliminating the differential, but its electrical efficiency was very low. Modern practice does not sanction the employment of more than one motor on even the heaviest of pleasure cars and on commercial vehicles up to 3- or 5-ton capacity. Beyond that point practice varies somewhat, some makers employing two driving units on the ground that no differential is needed, that starting torque is bettered by connecting the armature in series, and that damage to one motor will still permit the vehicle to travel. These advantages are more than offset by the higher efficiency possible in a single and larger electric motor, beside the benefits derived from the saving in weight of the motor and from the ability of the manufacturer to combine the two speed reductions necessary with two motors into one. This avoids some power loss in transmission from the motor to the driving wheels.

THE TRANSMISSION

Similarity to Gasoline Practice. The types of power transmission on the electric vehicle have been the same as on the gasoline car except that the order of their application has been chronologically reversed. The latter started in generally as a chain-driven machine, and quite a number of years elapsed before any other method of transmitting the power to the rear wheels was attempted. The electric, on the other hand, began as a gear-driven car, as the practice of direct-connecting electrical generators and power units, which first assumed a strong vogue shortly prior to the advent of the electric automobile, was taken as a precedent. From the point of view of operating conditions, there is considerable similarity between the gasoline and the electric machine as far as its power transmitting system is concerned.

Usual Gear Reduction. Owing to weight and space limitations, the size of the motor is correspondingly limited, and it is accordingly necessary to employ high initial rotative speeds, i.e., a very high-speed motor is essential in both cases, while the starting torque or pull must likewise be very strong in order to enable the vehicle to get under way quickly and to start readily on grades. This necessitated gearing down to a very great extent, the usual ratio on the majority of the electric vehicles being 10 to 1, i.e., for every ten revolutions of the motor, the road wheels make but one turn. In order to accomplish such a reduction without employing gear wheels of a prohibitive diameter, it was necessary to bring about this lowering of the motor speed by means of two steps, or a double train of gears. Spur, or plain straight-tooth, gears were employed at first, and proved to be not only noisy, but very wasteful of power.

They were accordingly replaced by chains in many instances, and by gears of special types, such as the *herringbone reducing gears* of the Waverley. In some instances, such as the light Baker runabout placed on the market several years ago, it was found possible to drive directly from the motor to the rear axle through the medium of a single chain, but with this exception the custom of employing two distinct reductions of speed was generally followed up to a year or two ago. While there were several variations in the manner of accomplishing this, the general principle was practically the same in every instance, a single chain being taken from the end of the armature shaft of the motor to a countershaft extending clear across the car and having sprockets at each end. The reduction in speed from the motor to the countershaft was usually about five to one, and a similar second reduction was carried out by means of small sprockets on the ends of the countershaft, and large ones on the driving wheels. A third class of transmission consists of a combination of gearing and chain drive, such as were used on the earlier models of the Woods, and the Waverley electrics, the first reduction of which is a silent chain.

Chain Drive. During the past few years, practice in the electric field has closely followed that of gasoline car transmission design,

Fig. 20. Gear Type of Transmission

where the final drive is concerned, and in some cases anticipated it. But for the advent of several low-priced electric cars, some of which have perpetuated the single-chain drive—using a roller-type chain and sprockets as the second step in the reduction—this form would have practically disappeared. It is efficient and reliable, but not as clean and sightly as the shaft type, though this objection may be readily overcome by enclosing the chain. Economy in initial cost is one of its chief advantages and, in the case of cars which are sold at a very low figure, this is naturally of paramount importance.

Gear Drive. The self-contained unit shown in Fig. 20 is an illustration of what might be termed an instance of reducing the power plant and final drive to the last degree of compactness. Referring to the figure it will be noticed that the usual type of motor is mounted on a forward extension of the rear axle, the first step in the speed reduction being a pair of herringbone gears. Apart from this, it is practically a replica of gasoline car practice, as the axle is of the full floating type commonly employed on the latter, the second

Fig. 21. Well-Designed Unit of the Shaft-Driven Type with Bevel-Gear Rear Axle

speed consisting of the usual bevel drive, except that the propeller shaft is only a few inches long and consequently does not require any universal joints. A somewhat similar type of transmission is employed on the Broc electrics. A *full floating* type of axle with shaft drive is also a feature of the Borland, this form taking its name from the fact that the two driving shafts are not rigidly fastened at either end—either the differential or the driving-wheel end—the power being transmitted through a square-ended section of the shaft *floating* in the differential and a jaw or similar type of clutch at the wheel, the entire weight of the car being carried by the tubes or axle housing. An example of a single reduction-shaft drive is to be found in the Century, using a Timken bevel-gear rear axle.

An equally compact form which gives a better weight distribution is the drive illustrated in Fig. 21. This bears a very strong resemblance to the driving unit of a well-known light gasoline car. It is a type which affords great rigidity with a very simple construction. The propeller shaft is practically a continuation of the armature shaft, no universal joint being necessary. At its after end this shaft meshes with a bevel gear giving a reduction of 2 to 1, while a spur-pinion reduction lowers the ratio again 4 to 1, or a total of 8 to 1 between the high-speed motor and the driving wheels.

Fig. 22. Combined Bevel and Spur Gear. Double Speed Reduction of the Axle Shown in Fig. 28.

The arrangement of the two speed reductions in the axle is shown by Fig. 22. These bevels have an adjustment by means of a collar which can be loosened or tightened until a perfect adjustment is obtained. The larger bevel is mounted on a short jackshaft carried on ball bearings on both ends, and upon this shaft is mounted the small spur pinion. On each side of the jackshaft is a threaded collar which allows for the movement of this shaft either in or out, which, in conjunction with the adjustment of the bevel gears, permits of a perfect setting of both sets of gears. The housings consist of tapering swaged steel tubes which extend from each side of the differential housing through the brake housings and the wheels, while the driving effort is taken on the combined torsion and radius rods pivoted on saddles on the axle just inside the brake drums and on the rear end of the motor housing.

In this, as in all representative types of final drive on electric pleasure cars, annular ball bearings are used throughout. One of these bearings is shown just forward of the small bevel pinion in the two-speed reduction axle. This is an advanced type of bearing which the automobile has been largely responsible for developing. It is far more costly than even the very best of plain bearings, but it cuts friction down to a practically negligible factor, while it will also run with a very small supply of lubricant and requires a minimum of attention. Such bearings are now universally employed, not alone in the electric motors of these vehicles, but also for the countershafts and wheels, and in similar locations. If the ball bearing is not employed, the taper roller type is substituted, the latter being very much favored for wheel bearings on both gasoline and electric cars, owing to their ability to withstand heavy thrust as well as radial loads.

Worm Drive. *Development.* What would appear to be the ultimate development in electric car transmission, however, has been the adoption of the worm drive; and, in taking it up so generally, the electric vehicle manufacturers have anticipated what is bound to come on the gasoline pleasure car in the near future, as it already has in England to a great extent. In this adoption, the history of the electric self-starter on the gasoline car has been repeated, in that experiments were carried on for a number of years with little progress apparent to the world at large, and then, within a comparatively short time, the worm drive came into more or less general use. In this case, however, most of the research work was carried out in England, and a considerable proportion of the worm drives used on American electric cars are imported from that country. In itself, this form of drive is not a novelty, the Hindley worm drive, made in Philadelphia, having been employed on electric elevators for quite a number of years. Its successful application to the automobile represented far more of a problem than the bevel-gear type as, unless correctly designed and machined to the highest degree of accuracy, the friction and thrust are excessive and the resulting efficiency is low.

Advantages of Worm-Gear Transmission. Consideration of the fundamentals of electric vehicle design, i.e., a light high-speed motor and a comparatively slow axle speed, will make apparent the great desirability of the worm drive in this connection. It represents the most practical means of power transmission from a high-speed motor direct to the rear axle by means of a *single reduction.* This means saving in weight and the avoidance of the power loss entailed through the use of the second reduction in the gear ratio otherwise necessary. A further advantage is its silence in operation, the worm and worm wheel representing the closest approach to this much-to-be-desired feature that is attainable in the transmission of power by direct metal contact. While its initial cost is as high, if not higher, than even the best forms of double reduction, it eliminates several parts, and accordingly affords a simpler form of construction with a more direct transmission of the power.

Fig. 23. Rauch and Lang Worm and Gear

Details of Worm Drive, Rear Axle, and Brake. The worm is of alloy steel while the worm wheel is bronze, a multiple thread of long pitch being cut on the former while the latter is made with a special form of tooth, as will be noted by the Rauch and Lang worm shown in Fig. 23. This is an American type developed by the makers of the Rauch and Lang electrics especially for this purpose. In both this make and the Woods electric the worm meshes with the worm wheel on its upper side, the relation being shown by Fig. 24, which illustrates the Rauch and Lang motor and propeller shaft in addition. Two universal joints, one of them of the slip type to allow for relative longitudinal movement between the motor and rear axle, are employed. A brake is placed on the forward end of the armature shaft, this showing in the same illustration. Fig. 25 shows the complete Rauch and Lang motor and driving unit. A torsion rod, parallel with and below the propeller shaft, also serves as a distance rod between the motor and rear axle and takes all torsional or twisting stresses to which the axle is subjected when under power. The forward end of this torsion rod is connected by means of a

Fig. 24. Rauch and Lang Motor, Shaft, Universal Joints, and Worm and Gear

flexible joint of the ball-and-socket type, with the top of the torsion rod link, which in turn swivels on the rear motor yoke. The rear end of the torsion rod is taper fitted into a nickel-steel forging, which

Fig. 25. Rauch and Lang Motor and Rear Axle Unit

sets into a vertical taper bearing in the front end of the axle housing. The method of hanging the torsion rod leaves the rear axle housing perfectly free to adjust itself to the relative movement of the axle and frame due to the compression of the springs. The latter are of the seven-eighths elliptic type, the upper and lower members of

Fig. 26. Rear View of Rauch and Lang Worm Drive Chassis

which are shackled at the rear ends so that they are flatter than usual, thus giving better riding qualities. They are held at three points, which decreases the tendency toward lateral movement or side sway, the driving strains being taken on the front ends of the lower leaves. The worm and worm wheels are adjusted in perfect alignment in assembling the unit, and the latter is housed in, so that no adjustments can be made from the outside. Contrary to the bevel-gear drive, which in course of time wears out of alignment, a worm gear continues in alignment regardless of wear, within prac-

Fig. 27. Forward End Torsion Rod, Spring Suspension and Brake Details on Rauch and Lang Car

Fig. 28. Details of Rear Wheel Brake Construction as Employed on Several Makes

tical limits, and once properly adjusted can only be deranged by subsequent adjustments. A better idea of the various essentials of the drive will be obtained by reference to the rear view of the Rauch and Lang worm-driven chassis, Fig. 26. As mentioned previously, a brake is carried on the armature shaft on this car, the second set being of the internal expanding type operating against the drums shown attached to the driving wheels, Fig. 27. On the

Fig. 29. Detroit Worm Drive, Rear Axle and Motor
Courtesy of Anderson Electric Car Company, Detroit

Argo and several other cars both sets of brakes are of the internal expanding type, the details of this type of brake construction being shown in Fig. 28.

This is likewise the case on the Detroit electric, the rear axle unit of which is shown in Fig. 29, the details of the brake construction appearing plainly. The Lanchester (British) type of worm is employed on this car. As will be noted from the part sectional illustration, Fig. 30, the worm drives through the lower part of the

Fig. 30. **Lanchester Worm Gear Used on the Detroit Electric Car**

worm wheel and runs in a bath of oil, the oil level being shown in the figure. In the types previously described, the worm-wheel housing itself is partly filled with heavy oil.

This sectional illustration also shows a marked difference in pitch of the worm thread as compared with the Rauch and Lang, and makes clear the detail of the mounting. The latter consists of a combination radial and thrust annular ball bearing at each end of the worm and on each side of the worm wheel. Upon the correct alignment of its mounting and proper provision for taking the thrust, quite as much as upon correct design and accurate machining, depends the success or failure of any worm drive.

THE CONTROL

Unlike the gasoline car, in which the control of its speed and climbing abilities is divided between a provision for changing the gear ratio existing between the motor and the driving wheels, and a means of increasing the speed and power output of the motor itself through the admission of more fuel and advancing the point of ignition, that of the electric vehicle is entirely electric. This is largely responsible for its great simplicity, all changes in either direction being effected through a single small lever, the manipulation of which calls for no more skill than the shifting of a trolley-car controller. But there is quite as much latitude of design to be found in the methods of control of electrical vehicles as there is in the method of transmitting the power to the rear wheels, though, as in the case of the power transmission, there is more or less similarity in the principles involved

Counter-E.M.F. Neither a steam engine nor a gasoline motor can be given "full throttle" to start it without danger of damaging it. This is due to the inertia of the moving parts, which must be set in motion gradually and allowed to attain a certain speed before full power is developed. As the electric motor has no reciprocating parts, and its revolving armature is carried on the finest type of anti-friction bearings, the factor of inertia is practically negligible in so far as it affects starting. It has already been mentioned that the passage of too great an amount of current through a wire, i.e., too great for its carrying capacity, has a heating effect. The heating increases in proportion to the excess of current flow over the safe capacity of the wire until it is sufficient not only to burn off the insulation on the wire, but even to fuse the wire itself.

Now the resistance of the motor armature windings is very low, but when the armature is revolving, the electrical resistance is increased by two factors—first, a counter-e.m.f., which is developed by virtue of the rotation of the armature, and second, the fact that the wire in the windings becomes warmer, it being a peculiar and inexplicable phenomenon that the resistance of a wire increases in proportion to its temperature.

Controller. The inability of the motor to carry more than a fraction of its normal operating current when starting makes necessary the use of something equivalent to the throttle of the steam engine for accomplishing this necessary control. As not alone the character of the external source of power—in this case the battery—is capable of manipulation, but also the internal relations of the power-producing elements of the motor itself—the armature and the field—are susceptible of various changes, it will be evident that the speed range possible under the circumstances may be made as

Fig. 31. General Electric Controller

wide as the designer desires. Ordinarily, most electric vehicles are provided with a controller giving five speeds forward and two or three reverse.

Drum Type. In the majority of cases, the controller employed on the electric automobile is of the drum type, and is practically a duplicate on a reduced scale of that employed on street railways, except that the automobile controller is what is known as a *continuous torque* type. That is, there are no dead spots or idle gaps between different speeds, the current always being on except when the controller handle is at the neutral position. This insures a continuous and gradual increase in the speeds without any jerking between the various steps, and prevents a sudden heavy load being placed on the motor, as would be the case where a pause was made in shifting the handle of the controller over a dead gap. The motor continues to run at the lower current value until the next set of contacts on the controller is actually delivering a greater voltage or more current. The drum, or cylinder, is of insulating material and has mounted on it a number of copper segments of substantial thickness. These are so spaced that they make contact with corresponding fingers, also of heavy spring copper, that are held stationary alongside the drum. The copper bars on the drum are "grounded" to provide the continuous torque, that is, they have a common return permitting

Fig. 32. Controller of the Detroit Electric
Courtesy of Anderson Electric Car Company, Detroit

the current to reach the motor constantly, i.e., while changing speeds. A controller of this pattern is shown in Fig. 31, which is of General Electric make.

The drum in this instance is seen to be but a section of a cylinder, on the curved surface of which the spacing of the bars will be apparent. It will also be seen that there is a corresponding finger making contact with each bar, or in a position to do so when the drum is turned to bring it around to that particular point. These fingers are held against the drum very firmly by springs. The open socket visible at the lower end of each finger is intended to receive the bared copper wire of which it represents the terminal connection. A variation of this type of controller is shown in the illustration, Fig. 32, and it will at once be evident that it is provided with a greater number of contacts than is the first controller shown. It should be mentioned here that the drum is spring controlled as well as the contact fingers, and is also provided with notched stops in order to hold the contacts on it directly under the ends of the fingers. In the present instance, which represents the type of controller employed on the Detroit car, the contact fingers themselves are directly attached to leaf springs, which are plainly in evidence. The terminals mentioned are also to be seen along the bottom, while at the left there is an extension of the shaft on which the drum is mounted. This carries a

Fig. 33. Chassis of Detroit Electric Car

lever by means of which the drum may be revolved in order to give the different speeds, forward and reverse. The latter is generally accomplished by means of a pole reversing switch, most frequently incorporated directly in the controller itself, and which always remains locked under normal running conditions. In order to bring the reverse into play, it is usually necessary to depress a small pedal or similar release, in order that the driver may not inadvertently start the car backward. A view of the Detroit chassis is shown in Fig. 33.

Flat Radial Types. A good illustration of a totally different form of controller is found in the Rauch and Lang cars, and is known as the *flat radial* type. In the construction of the earlier models of the Rauch and Lang car, it was combined with the motor and countershaft unit, but is now mounted independently and in the accompanying illustration, Fig. 34, it is shown separately. Instead of being mounted on a drum, the contacts are placed on a stationary segment representing about one-fourth of the arc of a circle. A pivoted arm, held at what would be the center of the circle, is so mounted that it may be turned in order to make contact with the different blocks, these in turn being electrically connected to the terminals shown attached to the upright piece at the left of the controller. As a matter of fact, there are two separate series of contacts around the arc, and two movable levers arranged to be moved over them. In this case, the moving contacts are made of thin copper leaves assembled together and are held against the contacts by a spring.

Fig. 34. Flat Radial Controller

Fig. 35. Flush Type of Controller

Flush Types. Fig. 35 illustrates a type of controller which is designed to be countersunk in the seat of its surface so as to be flush with the latter. This is a plan view, showing the controller as seen from above, the pattern being one in which the drum is a complete cylinder. The left-hand panel of the controller holds the fingers and contacts for the forward speeds, while those at the right are the reverse speeds, there being four in each direction in this case. Further to the right is to be seen the operating lever, the pinion visible on the end of the drum shaft constituting part of the mechanism for advancing or returning the drum. This consists of a rack in the shape of a quadrant which meshes with the pinion in question. At the extreme left is shown the spring-controlled stop which prevents the drum from being rotated more than one space at a time in either direction, and holds it with the fingers pressing directly on the contacts at each point of its revolution. The type of controller employed on the Baker cars is shown in Fig. 36.

Fig. 36. Baker Controller and Operating Lever

Magnetic Type. To facilitate the handling of the comparatively heavy current that is necessary in starting, changing speed in going up hill, and the like, without having to employ wiring of large size to a point near the hand-control lever, a modification of the multiple-unit system of control as used in electric railway service, and particularly on elevated trains, has been applied to the electric automobile. In this system only a current of small value is actually passed through the hand-controlling mechanism, which takes the form of a small "controller box", as shown in Fig. 37, which represents part of the control of the Ohio. The controller of the Century is shown in Fig. 38. By setting this to the speed desired, current is passed through a magnet in the controller proper. The armature of the magnet is attracted, and in so doing it closes a switch or contact for the corresponding speed. There is a magnet or solenoid for each speed ahead and reverse, which are so connected that, in changing to a higher speed, the contact of the speed below is not broken until either the switch giving the higher current value is closed, or the current is shut off, thus releasing all the magnets and

Fig. 37. Control Disk of the Ohio Magnetic Controller
Courtesy of Ohio Electric Car Company, Toledo, Ohio

obtaining the advantages of the continuous-torque type of hand controller. The arrangement effected by the opened and closed positions of the various magnets determines the direction and

Fig. 38. Magnetic Controller of the Century Electric Car

magnitude of the current in the motor circuit in a similar manner to that provided by the segments and fingers of the drum controller. The essential difference between the magnetic controller and the ordinary type is that the former is electrically operated, while the latter is mechanically operated. Hence its location is not governed by the necessity of mechanically connecting it with the hand lever through rods, gears, or chains, and it may be placed in any convenient location. In the Ohio it is placed under the seat. The various speeds are obtained by turning the disk on the end of the contactor box near the driver's hand. Turning to the right gives

Fig. 39. Wiring Diagram for Primary Circuit of the Ohio Magnetic Controller

the various forward speeds in consecutive order. The neutral position is as far to the left as the disk will go; by pushing the button on top the controller may be turned still further to the left to give the reverse speeds. When in the neutral position it may be locked there by pushing in the button at the back, and the controller cannot then be operated until unlocked with a key. Buttons are also provided for ringing the bell and operating the magnetic brake. The contacts are made by spring-held carbon brushes pressing against the inner face of the disk. In this system of control there are two independent circuits—the primary circuit passing through the magnetically-operated switches of the controller from the battery to the motor, and the secondary circuit, which handles the current of lesser value employed to operate the magnets, and which is controlled by the movement of the disk mentioned. The primary wiring diagram of the Ohio is shown in Fig. 39, and the secondary wiring diagram in Fig. 40.

Duplex Control. To facilitate the handling of closed cars of the brougham and other large types of enclosed cars seating five or more passengers, duplicate-control wiring and duplicate-brake pedals

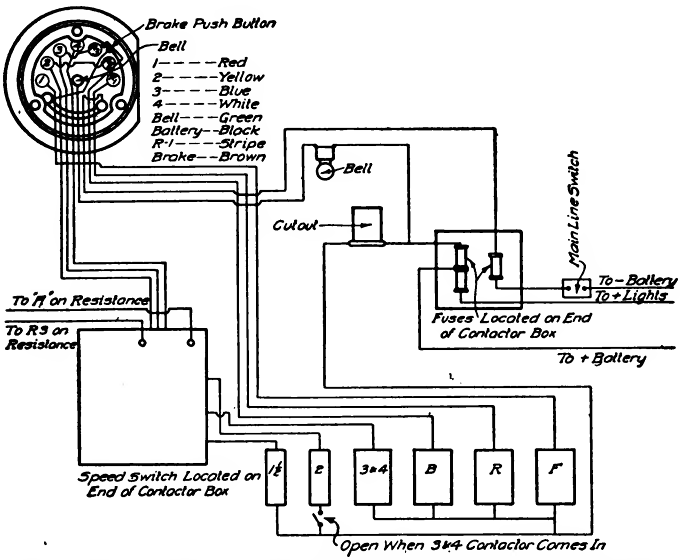


Fig. 40. Wiring Diagram for Secondary Circuit of the Ohio Magnetic Controller

are provided at two positions; one forward, designed to be operated from a front seat, and the other similarly located with relation to the rear seat on the same side. Brake pedals and steering connections are also duplicated, so that to shift the control of the car from one location to the other, it is only necessary to release the steering column at one place and insert and lock it in the socket provided for this purpose at the other. This enables the driver to keep the way clear ahead no matter how many passengers are carried and also drive from the rear seat when the load is light.

Care of Controller. The contacts of the hand-operated type of controller should be inspected at intervals to note whether they are making proper contact or not. In case the spring of one of the fingers loses its tension, an arc is apt to form between it and the segment on the drum and burn the metal. The presence of such an arc will be noted by a peculiar hissing sound which will be plainly audible if the cover of the controller box is removed and the car run in a comparatively quiet place. This action will also take place to a certain extent if the controller is held between the notches in changing speed. The blistered surface of the metal thus resulting will make poor contact, and will continue to burn more and more unless this condition is remedied by sandpapering the finger and correcting the tension of the spring so that contact is made all over the surfaces that touch. If a finger has become badly burned, it should be replaced and the new one adjusted to an even, moderate tension. When necessary to face the fingers to the drum, the sandpapering should be done on the fingers themselves rather than on the segments of the drum, as the latter are not so easy to replace. The drum segments should be kept bright and clean, and should be lubricated occasionally by wiping with a linen rag and some vaseline.

Methods of Control. As it is equally important for the owner of an electric vehicle to familiarize himself with the manner in which the amount of current sent through the motor is controlled, quite as much as with the apparatus for effecting this, it has been thought advisable to devote a short section to this subject. Before taking up this matter, it will be well to return momentarily to a previously discussed subject of series and parallel connections.

Series and Multiple Connections. Each cell of a storage battery is a complete self-contained unit capable of delivering current of a certain amount according to its size and capacity, at an electrical pressure of slightly more than two volts when fully charged. For purposes of illustration, each individual cell may be likened to a pump, capable of exerting a pressure of two pounds. It will be quite apparent that if 24 such pumps, corresponding to the 24 cells of a 48-volt storage battery, were connected together—the outlet of the first to the inlet of the second and so on throughout the entire 24—the series of units would be capable of producing a pressure of 48 pounds. The water delivered could accordingly be forced 24 times as far, or as high, as one pump could send it, but the quantity raised would only be that of which one unit was capable. This analogue affords a very clear idea of what is meant by a series connection, as the statement just made regarding the ability of pumps so connected applies literally to the storage cells under the same conditions. Again taking the 24-cell battery as an illustration, this being the former standard for light pleasure vehicle use, it will be seen that the output of the battery connected in series, i. e., the positive of one to the negative of the next and so on throughout the set, would be the ampere-hour capacity of one cell at 48 volts. The voltage is seldom constant, but ranges from 2.2 to 1.7 volts per cell, according to the state of charge that the cell is in at the time; but when a number of cells are connected in series, the voltage of the battery thus formed will always be that of the voltage of one cell multiplied by the number in the battery. For purposes of reference, it is customary to consider the potential of the storage cell as 2 volts.

To return to the analogue of the pumps, where the conditions are such that a greater quantity of water is required, but it is not necessary to raise it to more than half the height to which the 24 pumps in series are capable of sending it, they may be arranged in two series of 12 each. Double the volume of liquid may then be raised to a height represented by the ability of the 24-pound pressure developed. The two groups of pumps are still in series, so far as they alone are concerned, and each group would have but the capacity of a single pump at twelve times its pressure. But when the inlets and the outlets of the two groups are brought together in the case of either pumps or storage cells, the volumetric capacity is increased to two units at a pressure of 24 pounds or volts. If, on the other hand, all the inlets were brought together into one connection and all the outlets into another, there would result a capacity of 12 pumps, at the pressure of but one. This last-named arrangement is termed a *multiple* connection, while that described above is a combination of the series and multiple connections, and is accordingly designated by the term *series-multiple.*

Given 24 cells or more, the number of series-multiple combinations possible is quite extended, but it will be evident that those at either extreme of the range would be useless for all practical purposes in the running of an electrical vehicle. It is accordingly customary to assemble the cells in sets of six or eight connected in series, which cells are securely packed in oak cases, the number of the units employed depending upon the voltage of the motor of the vehicle.

Resistance in Circuit. Another source of control is to be found in the motor itself. It will be recalled that the latter generates power by means of the alternating magnetic attraction and repulsion of the sections of the armature by the field magnets. The strength of the latter, as well as that of the electromagnets composing the armature, is naturally dependent upon both the amount of current sent through them and its voltage. One of the simplest forms of control is naturally that in which the entire battery is in series with the motor, and in which the relation of the two undergoes no change. In such a case, resistances of the type shown in Fig. 41 are employed

Fig. 41. Controlling Rheostat

to cut down the current sufficiently to give what are usually termed the *starting speeds*. In every case, the full energy of the battery is being drawn upon, but only a part is being utilized on these first speeds, the remainder being dissipated by the resistance in the form of heat. In view of the very short period during which they are employed, the use of resistances in these starting speeds is not a detriment. This system of control is to be found on the Rauch and Lang cars, among others, and has the great advantage of discharging all the cells of the battery uniformly. All the speeds are obtained at the same voltage and the motor is working at every position of the controller handle, so that there are accordingly no dead spots and the circuit is never open, even momentarily. A similar system of control is employed on the Baker vehicles. This will be evident upon a little study of the accompanying diagram, Fig. 42, illustrating the wiring and all the connections. The large squares, marked plus and minus, represent the groups of cells into which the battery is divided. The individual cells in each group are connected in series and it will be seen by tracing the connections that the groups are likewise in series, a positive being connected to a negative and so on throughout.

Wiring Diagram. Wiring diagrams appear extremely intricate to the uninitiated at first sight, but in each instance the course taken by the current may easily be followed after a little study, and as familiarizing himself with all the wiring and connections of his car is a

Fig. 42. Control Wiring Diagram

part of the education that no electric vehicle owner should overlook, it should not be slighted. The diagram received from the manufacturer of his car will be a blue print similar to the one from which the accompanying illustration was taken, so that it may be studied here as well as at first hand. Familiarity with one of these diagrams will prove an "open sesame" to all others, for, while they all differ to a greater or less extent, it will be easy to trace the different circuits, once the rudiments are known.

The fact that all of the cells in the battery are in series has already been mentioned. It will be seen that there are 24 cells in the battery, giving a working potential of 42 to 60 volts according to the state of charge. The different points of the controller are represented by the group of parallel bars in the lower center of the drawing, marked *R*-4, *R*-2, etc. In this case it will be noted that there are four connections of this nature, *R*-1 to *R*-4, these representing resistances to cut down the current for starting. They are accordingly known as *starting speeds*, and are only designed for getting the vehicle under way, an operation that calls for a heavy torque or pull on the part of the motor. This requires a large amount of current and, as already mentioned, it would be apt to burn out the motor windings if sent through the latter before it had attained sufficient speed to build up its counter-e.m.f. to a point where the full current may be safely handled. The external resistances themselves are represented by the bars marked in the same manner, seen diagonally to the left and above the controller on the diagram, the connections between the two being easily traceable.

Further points on the controller are designated as *F*-1 and *F*-2, and *FF*-1 and *FF*-2, and refer to the connections for altering the relation of the field and armature. Electric motors employed on automobiles are generally of what is known as the *series type* in which the armature and fields are normally in series with one another. In other words, the entire current passes through the complete winding of the motor. By varying this relation in several ways, several steps in the speed control are possible without the intervention of any resistance. For instance, in the control, as illustrated, the first speed is obtained by placing the field in series with a resistance, giving a car speed of 8 miles an hour. By cutting out part of the resistance and still maintaining the same relation, the car speed is increased to 10 miles an hour, corresponding to the second point on the controller. At the third point, the resistance is eliminated altogether, resulting in an increase to 12 miles an hour. A further increase to 14 miles an hour is obtained by shunting the fields, while the fifth speed of 16 miles an hour results from placing the field in series-multiple. The last point on the controller shunts the series-multiple field and gives 19 miles an hour.

Office of the Shunt. The term *shunt* may be explained by turning again to the water analogy. Electricity, water, or anything else under pressure will naturally follow the path of least resistance. Take, for instance, a two-foot water main, with a one-inch outlet tapped into it. The amount of water that will flow through the one-inch pipe is not alone dependent upon the pressure in the main, but likewise upon the resistance offered by the one-inch pipe. This, by analogy, is practically an application of Ohm's law. Substitute for the water main an electric circuit. At a certain point, connect to it a by-path in the shape of another circuit of smaller wire, and in consequence, representing a greater resistance. The current can pass through these two circuits simultaneously and the amount of current in the second, or shunt circuit, will be smaller than that flowing in the main circuit. In fact, the current will divide itself inversely as the resistance; that is, if a shunt has ten times the resistance of the wire in the main circuit between the terminals of the shunt, this shunt circuit will carry only one-tenth of the total current.

The best example of a shunt connection is to be found in the case of the volt-ammeter, as shown in Fig. 42. For convenience, the voltmeter and ammeter (ampere-meter) are combined in a single case as if they were one instrument, but it will be noted that the connections are the same as if both were independent. As the voltmeter is always in circuit, whether the car is running or not, it is wound to a very high resistance so as to consume the minimum amount of current for its operation. The shunt marked on the lower part of the diagram, just under the position of the instrument, is really a part of the ammeter itself. Where only small quantities of current are to be measured, the full strength is usually passed directly through the ammeter, but on an electric automobile, this would not be practicable in view of the wide range and the sudden variation of the storage-battery current, which in starting frequently takes the form of a heavy surge. The instrument is accordingly designed to employ but a fraction of the total current, this fraction bearing a direct relation to the total current passing, the scale reading of the ammeter being the same as if the full strength of the current passed through it.

It will be evident that any circuit, such as the field winding of the motor, when placed in shunt with its supply circuit, will only take an amount of current depending upon the ratio between its resistance and that of the main circuit, and that economy in current consumption results. This explains its employment for two of the higher speeds of the car, the wiring diagram of which is illustrated in Fig. 42. It will be noted that this connection is only employed for the higher speeds; in one case, the field windings being in series themselves, and the whole in shunt with the main circuit, to give 14 miles an hour; and in the second, the field windings themselves being in series-multiple and in shunt with the main circuit to give a speed of 19 miles an hour. This is due to the fact that at the higher speeds, only a relatively small amount of power is required to keep the machine moving. Electric vehicles as a rule do not run at speeds high enough to make wind resistance a factor of great importance, and as a result operate under ideal power conditions when once under way. In other words, the *draw-bar pull*, by which is meant the effort necessary to keep the vehicle moving, is very light. At starting, however, in common with other cars, it is heavy, so that it will be evident that the shunt connection is not applicable to the starting speeds. Its rôle is that of economy, rather than power, and to obtain the latter the series connection is necessary.

Fuses. The fuses are a part of the electrical equipment of the car, mention of which may be appropriately made in this connection, as their function is that of acting as a safety valve in the control. The varying resistances of different kinds of metals have been explained, as well as the heating effect incident to sending a current through a wire, particularly where the latter is of a size too small to carry the current. It is well known that lead and similar materials have a very low melting point, and advantage has been taken of this in connection with the phenomenon just referred to, to make what are known as *electric fuses*. These are strips of lead alloy of accurately determined sizes, each size being designed to carry a certain amount of current at a certain voltage. This is known as the *capacity* of the fuse, and between it and the amount of current that the motor or other apparatus which the fuse is designed to protect can safely stand there is an ample margin of safety. In consequence, whenever there is a rush of current through the circuit, as when the controller lever is pushed sharply forward toward the *full on* point, and the brakes happen to be holding the car, the fuses will "blow out" or melt, and save the motor from destruction.

Electric Brake. In addition to the usual mechanical brakes, the construction of which is along lines practically identical with those employed on gasoline cars, some manufacturers equip their cars with an electric brake. Just how this acts will be clear from a perusal of the chapter devoted to a description of the motor and its method of operation. It will be evident that upon reversing the function of the motor and driving it from an external source of power, which in this case will be the motion of the car itself, it will act as a generator of electric current, and in doing so, it will absorb power in proportion to the speed at which it is driven. Connections are accordingly provided on the controller to permit of this, but the motor provides such an extremely powerful brake, that this has been regarded as a disadvantage in some cases, so that certain makes of electrics are only equipped with mechanical brakes.

This disadvantage is doubtless due to the fact that the series type of motor ordinarily employed on the electric car does not lend itself readily to this service. Its *braking power* increases as the square of the speed of the car, i.e., at sixteen miles an hour, the effect is four times as great as at eight miles, and when suddenly applied this is apt to stop the car very suddenly, much to the detriment of its tires and mechanism, if not to the occupants themselves. Should a small particle of dust or burnt metal lodge on a contact and momentarily prevent the brake from "taking hold", the motor will suddenly "build up", with disagreeable results.

DETROIT ELECTRIC AUTOMOBILE

Courtesy of Detroit Electric Car Company, Detroit, Michigan

ELECTRIC AUTOMOBILES

PART II

CARE AND OPERATION OF THE ELECTRIC

CHARGING THE BATTERY

SOURCES OF CHARGING CURRENT

Sources of Direct Current. *Small Generators.* There are few towns, or even villages, in this country at the present day that cannot boast of electric-lighting facilities, so that the owner of an electric vehicle will find it possible to obtain charging current for the maintenance of this type of automobile regardless of where he lives. In case he should reside too far outside the corporate limits of a village to find such service at his command, or in case he is of a sufficiently mechanical turn of mind to undertake it, he will find apparatus for generating the current on his own premises available for a comparatively moderate outlay. Though not the simplest, a small direct-current dynamo driven by a gasoline engine requires but little attendance, and will prove by far the most economical method of charging. This is particularly the case where the generating set's chief employment is that of lighting the house, although where an isolated plant may be installed, the owner of an electric vehicle will find it a great advantage for charging purposes alone.

This may be seen from the fact that in small towns and villages rates for electric current are usually high. The power unit, the *watt*, has already been explained. A kilowatt is 1000 watts, and electric current is sold by the kilowatt hour, which means the employment of one kilowatt of current for one hour. Where current is purchased in comparatively small quantities, the rate is seldom less than 10 cents per kilowatt hour, and sometimes 15 cents, or more. With an ordinarily efficient generator and gasoline engine, current may be produced in a small isolated plant for less than 5 cents per kilowatt hour.

The average runabout battery requires 75 to 80 ampere hours for a charge, while a surrey, phaeton, victoria, brougham, or similar type will need 100 ampere hours.

Service Mains. If the current be taken from the service mains at 115 volts, the charge for the runabout battery would be 75×115 =8625 watt hours, or more than 8½ kilowatt hours. The cost of this would be 86 cents at a 10-cent rate. Even where current is to be had at more favorable rates, such as 7 or 8 cents a kilowatt hour, a small engine and dynamo are very much more economical where no extra attendance has to be figured on.

Sources of Alternating Current. Turning now to the usual source of electricity, the *alternating current,* one is confronted with

Fig. 43. Motor-Generator Set, 115 A.C. to 125 D.C.

the fact that the *charging current must in all cases be "direct," never "alternating."*

Alternating current has been found much more practical for long-distance transmission and distribution, and its use is now very general throughout the country, so that where the owner of an electric vehicle decides to fit up his own garage for storing and charging the car, the first thing to be considered will usually be some means of rectifying the alternating current, that is, making it direct. This may take several different forms, such as the motor-generator set and the mercury arc rectifier, but for reasons which will be made plain the mercury arc rectifier will be found the most practical and economical apparatus for the purpose.

Motor Generator. Where there is a considerable amount of charging to be done, the motor-generator set is frequently employed.

Fig. 44. Motor-Generator and Charging Panel for Charging Twelve Electric Trucks
Courtesy of Curtis Publishing Company, Philadelphia

This consists of an alternating-current motor and a direct-current generator combined in a single unit, both armatures being on the same shaft, the supply current simply being utilized to run the motor. A set of this kind is shown in the accompanying illustration, Fig. 43. The apparatus is designed to take alternating current at 115 volts and generate a direct current at 125 volts. In Fig. 44 is shown a very well-arranged and complete motor-generator charging plant.

Mercury Arc Rectifier. Owing to its simplicity, as well as to the fact that it is entirely automatic in action, the mercury arc rectifier has come into very general favor for storage-battery charging on a small scale. The apparatus itself is shown in Figs. 45 and 46, giving, respectively, a front and rear view; the connections are shown diagrammatically in Fig. 47. It will be seen that the panel board of the instrument incorporates everything necessary for regulating the charge, including a voltmeter, an ammeter, resistance, main switch, starting switch, circuit breaker, and fuses. The *circuit breaker* is a device designed to protect the apparatus with which it is connected by opening the circuit when there is an excess of current, or when the current supply is accidentally cut off. By opening the circuit as soon as this occurs a rush of current through the apparatus is prevented when the service is resumed. Should it fail to act, the fuses represent the second step in the protective link, but naturally their only func-

Fig. 45. Switchboard, Front View

Fig. 46. Switchboard, Rear View

tion is to rupture the circuit by melting under the heating effect of an excessive flow of current.

The mercury arc rectifier consists of a glass vessel, Fig. 48, from which the air has been exhausted and a certain quantity of metallic mercury inserted. The tube also has fused into the glass the several connections necessary. The one negative terminal, called the *cathode*, is sealed into the bottom of the tube while two positive terminals, called *anodes*, are on opposite sides and a short distance above the cathode. The anodes are graphite and the cathode mercury. When at rest, there is no electrical connection between them. A starting anodes is accordingly provided. If the tube be rocked gently after the switch has been closed, an arc is established between these two points. This liberates sufficient mecury vapor to start the main arc; the starting switch is then opened. An automatic starting device for use when charging at night, takes the form of a shunt coil and a solenoid, in which a plunger operates. When the arc is broken, the current is shunted through this solenoid and the plunger shakes the tube gently, thus re-establishing the arc and continuing the charge.

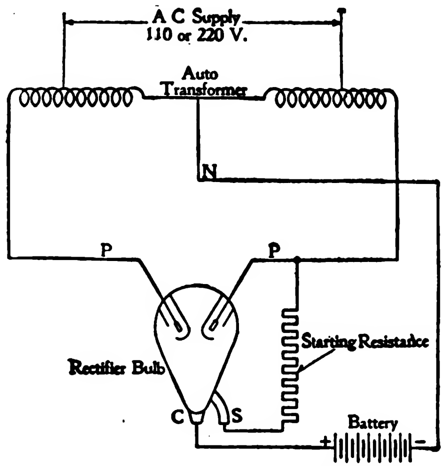


Fig. 47. Wiring Diagram for Mercury Arc Rectifier Circuit

METHOD OF CHARGING

Making Proper Connections. Batteries are not usually shipped with the vehicle itself, but are packed separately in a charged condition; as a freshening charge is required before the battery is used, it will prove an advantage to carry this out before placing the battery in the car. The groups of cells must be connected in series—the plus terminal of one group to the minus terminal of the next, and so on, *the final positive and negative terminals of the entire set being connected respectively to the positive and negative terminals of the source of the charging current.* The charging current must flow into the battery at the positive pole; a wrong connection will not

Fig. 48. Mercury Arc Rectifier Tube

only fail to charge it, but will do a great deal of damage and seriously impair the life of the battery.

Determining Polarity. Where the polarity of the charging terminals is unknown, the simplest method of determining it is to take a glass of water into which a few drops of acid or a little salt has been put. Place the wires in it, *taking care to keep them well separated.* Bubbles of gas will form on both of the wires, but one will give off gas much more freely than the other. This is the negative pole and should be attached to the negative charging terminal of the battery. The other wire will give off comparatively little gas and will rapidly blacken. This is the positive pole. There are numerous other tests equally simple, but as this calls for apparatus easily obtained anywhere, it will be an advantage to memorize it, particularly as occasions will arise when the vehicle will have to be charged away from home in the absence of the usual facilities. The wire or connections to the battery from the charging side must be of ample size to carry the heaviest current used in charging without undue heating. The sizes used in the car itself form the best guide for this.

Voltage After Charging. The operation of charging will be the same whether the battery is in or out of the vehicle, but as the battery was fully charged when shipped, this initial charge will be a short one. But the greatest care must be taken to charge the battery fully. The voltage per cell should reach 2.55 volts, with the current still on, when the cell is fully charged. This would mean 60 to 62 volts for a 24-cell battery.

These voltages, Table II, are approximate and are intended for guidance only. A battery when cold will show a higher voltage than one at a higher temperature, and the same thing is true of a new battery as compared with an old one. It is not safe to regard a fixed voltage as the end of the charge, but a maximum voltage for the battery in question.

The rubber plugs should be removed from the cells during the operation, as the cells will be gassing very freely toward the end of the charge. This gas is hydrogen and, as it is not only highly inflammable, but likewise very explosive when mixed in certain proportions with oxygen, care must be taken not to bring a naked flame anywhere near the battery while in this condition. The plugs may be left out for a short time after the charge is finished to permit the

TABLE II

Charging Voltage for Lead Batteries*

Number of Cells	Volts At	
	Start	Finish
12	26	31
14	30	36
16	34	41
18	39	46
20	43	51
22	47	56
24	52	61
26	56	66
28	60	71
30	64	76
32	69	81
34	73	87
36	77	92
38	82	97
40	86	102
42	90	107
44	95	112
46	100	117
48	105	123
50	110	128

*Cushing and Smith, *Electrical Vehicle Handbook.*

escape of the gas. The latter carries more or less of the acid electrolyte with it in the shape of a fine spray, and care should be taken to keep this spray from falling on the clothes or similar objects, as it causes ruinous stains, and only a comparatively small quantity is required to burn holes in cloth.

Temperature of Battery. When the battery is out of the vehicle, as in the case under consideration, the matter of temperature is not so important, but when it is in the vehicle, precautions must be taken to provide all possible ventilation. The charging causes a rise in the temperature of the cells and this should never be allowed to exceed 110° F. under any circumstances. The lower it can be kept the better, and a battery which is never allowed to exceed 90° F. while under charge will last much longer and give better service. The reason for this is to be found in the fact that the heating causes the active material in the grids to expand. If this expansion be excessive, as where the temperature is allowed to get too high, the material is apt to bulge completely out of the retaining pockets, so that it does not return when cooled off again. This destroys its connection with the lead grid, cutting down its conductivity and greatly lowering the efficiency of the cell. Furthermore, after this bulging of the paste has occurred, there is the possibility at any time that flakes of active material will drop down below the plates and cause a short-circuit. Even if it does not cause this trouble, the accumulation of the material in the bottom may soon be enough to short-circuit the whole cell unless it is of the type provided with an especially deep space below the plates. The temperature should accordingly be noted from time to time during the charge and, if it passes safe limits, the charging rate must either be reduced or

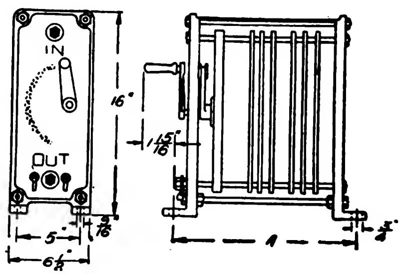


Fig. 49. Typical Battery-Charging Rheostat
Courtesy of General Electric Company, Schenectady, New York

discontinued altogether in order to give the cells an opportunity to cool off.

Experience has shown that the best results are obtainable from a storage battery when its temperature is maintained between 70° and 90° F. during both the charge and discharge. A considerably lower temperature will materially reduce the available charge of the battery, but this does not tend to injure it in any way, as a return to normal temperature restores its capacity. This is not true of a higher temperature, however, for if it is kept above normal for any length of time the wear on the plates is excessive.

Charging Rate. Every battery has a certain charging rate, and this should be taken from the chart sent with it by the manufacturer. It will be found that there are two rates—a starting rate and a finishing rate—and, as it is during the final part of a charge that the greatest wear falls on the battery plates, instructions regarding the strength of the current to be employed for starting and finishing the charge should be closely followed. The more slowly a battery can be charged within reasonable limits, the better will be its condition at all times, and the longer its life. It is not always convenient, however, to give a battery as slow a charge as desirable in electric vehicle work. On the contrary, the car is often wanted at short notice not long after the battery has been discharged, and consequently it is abused by being charged at an injurious rate for a short period. Theoretically, 10 amperes for ten hours and 50 amperes for two hours are the same and should give a battery capacity of 100 ampere hours. Instructions furnished by the manufacturer as to rates of charge should be noted and carefully complied with by the owner.

Fig. 50. Typical Charging Rheostat

The manufacturer specifies that each type of cell shall be started at a certain charging rate, say, 10 amperes. The charging rheostat is manipulated until the ammeter shows that the amount of current in question is going into the batteries. Figs. 49 and 50 show two forms of charging rheostats. This rate is maintained until the voltmeter indicates that a certain potential has been reached, which is usually a voltage of about 2.55 volts per cell, measured with current flowing. The charging rate should then be reduced to 4 amperes, which causes a considerable drop in the battery voltage. This reduced charging rate is then maintained until the voltage again rises to the point at which the voltmeter stood when the current was reduced, i. e., until the voltage ceases to rise, which will generally be the same as the voltage at which the high rate of charge must be reduced. The total voltage of the battery is usually taken as an indication, and when this fails to reach the desired figure, it is usually a symptom that some of the individual cells have defaulted. The remedy for this is given later.

Precautions. At the end of both the *starting* and *finishing* periods, the cells will be gassing freely, i.e., giving off large quantities of hydrogen, and for this reason the battery space of the vehicle should be open and the room in which the charging is done should be well ventilated. In addition to being highly inflammable and explosive, this gas is also very irritant to the throat and lungs and when present in any quantity causes constant coughing. Nothing but electric light should ever be employed in a private garage used for the charging of an electric car.

There are a number of other precautions to be observed when placing the battery on charge in the vehicle besides that of providing ample ventilation, as already mentioned. The controller handle should be locked in the off position, the lamps switched off, and the bell should not be rung during the progress of the charge. The reason for the first of these precautions is self-evident and for the latter two is found in the increased voltage during the charge, and particularly as it approaches completion. This would be sufficient to cause the lamps to burn out and to injure the bell. It is important that the manufacturer's directions with regard to the charging rate be closely observed. In order to be certain that this is done, the current should be measured by an accurate ammeter mounted on a panel board in the garage. The ammeter on the vehicle should never be employed for this purpose, as the vibration and road shocks to which it is subjected make the accuracy of such a delicate instrument a very uncertain quantity.

Starting the Charge. To start charging, the rheostat handle should be turned so as to throw all the resistance in. The switch on the panel board should be open, and the charging plug should then be inserted in its receptacle on the car. These plugs are usually made so that they can be inserted only in the proper way, and there is no danger of reversing the polarity of the current in this manner. Where not thus designated, the terminals are properly marked and care must be taken to see that the plug is correctly inserted. When the plug is in, the switch may be thrown on. Battery manufacturers supply tables showing what the starting and finishing voltages of the battery should be, as well as its final voltage; but as this will be influenced by varying conditions, such as the temperature of the battery and the age of the plates, the figures given are only approximate. Furthermore, a new battery will have a higher final voltage than an old one under the same temperature conditions, and both old and new cells will read higher with the temperature low than when it is comparatively high. In view of the foregoing, a fixed voltage cannot be considered as an accurate test in determining the completion of the charge. Instead, a maximum voltage will be found the only certain indication. This may be determined by noting when the voltage ceases to rise as the end of the charge approaches.

When charging during the day, the progress of the charge should be noted at half-hour intervals, the current being cut off as soon as the voltage has stopped rising. *One of the commonest ways of abusing a battery is to overcharge it.* This is most often done under the impression that an increased mileage will result, doubtless on the theory that if a certain distance can be covered by the vehicle on a full battery, "cramming" it a bit should give as many more miles proportionately as the excess charge bears to the normal capacity. Needless to add, this is a fallacy. No additional mileage will result from excessive overcharging, and where this occurs it causes the plates to deteriorate and thus reduces instead of increases the distance that may be covered. A direct indication of excessive overcharge takes the form of a noticeable increase in the temperature of the cells.

The question of temperature during the charge has already been touched upon. This should not exceed 110° F., and when charging with the battery in the vehicle, as is usually done, the middle cells should be taken as a guide. Unless it cannot be avoided, it is preferable not to allow the cells to rise above 100° F., reducing the charging rate or stopping the charge altogether for a time if the temperature does reach this point.

Automatic Charge-Stopping Device. Where constant attendance during charging is neither practicable nor desirable—as in the case of the owner who takes care of his own car—an automatic charge-stopping device is a great convenience. This is an attachment to the Sangamo ampere-hour meter, and is much used on such installations. It consists of a solenoid-actuated trip-circuit breaker, Fig. 51, which is set in operation by the pointer of the meter when closing a circuit on arriving at the point of full charge, a point which has been fixed by the operator in advance. However, as it is necessary to put more current into a storage battery than can be obtained from it, a certain amount of overcharge must be allowed for in every case. The amount necessary will naturally depend upon the condition of the battery as influenced by its age and the treatment it has received, but it can be determined readily after a little experience. In the Sangamo differential shunt ampere-hour meter referred to, a sliding adjustment is provided for this purpose and, once set, it need not be disturbed for a considerable period unless made necessary by a change in the condition of the battery. With this adjustment made, the charging can be done by any unskilled laborer, as it is only necessary to make the charging connection and leave it. Since the circuit cannot

Fig. 51. Solenoid-Actuated Trip Circuit Breaker
Courtesy of Sangamo Electric Company, Springfield, Illinois

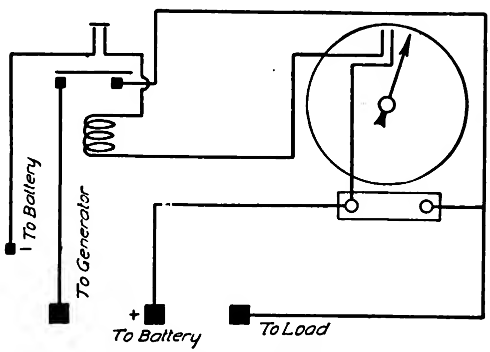


Fig. 52. Circuit Diagram of Charge-Stopping Device, Sangamo Ampere-Hour Meter

TABLE III

Temperature Correction for Specific Gravity of Electrolyte*

30° F.	40° F.	50° F	60° F.	70° F.	80° F.	90° F.	100° F.
1.317	1.313	1.310	1.307	1.303	1.300	1.297	1.293
.12	.08	.05	.02	1.298	1.295	.92	.88
.07	.03	.00	1.297	.93	.90	.87	.83
.02	1.298	1.295	.92	.88	.85	.82	.78
1.297	.93	.90	.87	.83	.80	.77	.73
.92	.88	.85	.82	.78	.75	.72	.68
.87	.83	.80	.77	.73	.70	.67	.63
.82	.78	.75	.72	.68	.65	.62	.58
.77	.73	.70	.67	.63	.60	.57	.53
.72	.68	.65	.62	.58	.55	.52	.48
.67	.63	.60	.57	.53	.50	.47	.43
.62	.58	.55	.52	.48	.45	.42	.38
.57	.53	.50	.47	.43	.40	.37	.33
.52	.48	.45	.42	.38	.35	.32	.28
.47	.43	.40	.37	.33	.30	.27	.23
.42	.38	.35	.32	.28	.25	.22	.18
.37	.33	.30	.27	.23	.20	.17	.13
.32	.28	.25	.22	.18	.15	.12	.08
.27	.23	.20	.17	.13	.10	.07	1.203
.22	.18	.15	.12	.08	.05	1.202	.98
.17	.13	.10	.07	1.203	1.200	.97	.93
.12	.08	.05	1.202	.98	.95	.92	.88
.07	1.203	1.200	.97	.93	.90	.87	.83
1.202	.98	.95	.92	.88	.85	.82	.78
.97	.93	.90	.87	.83	.80	.77	.73
.92	.88	.85	.82	.78	.75	.72	.68
.87	.83	.80	.77	.73	.70	.67	.63
.82	.78	.75	.72	.68	.65	.62	.58
.77	.73	.70	.67	.63	.60	.57	.53
.72	.68	.65	.62	.58	.55	.52	.48
1.167	1.163	1.160	1.157	1.153	1.150	1.147	1.143

*Cushing and Smith, *Electric Vehicle Handbook.*

be broken until the predetermined number of ampere hours have been absorbed by the battery, the latter will remain connected to the mains until fully charged, so that there is no danger of either undercharging or overcharging, as may occur where the charge is simply limited by the time considered necessary. The circuit of this charge-stopping device is shown by the diagram, Fig. 52. The circuit breaker also opens the exciting circuit, so that it carries the current only for an instant.

Rated specific gravity for various stages of charge is based on a temperature of 80° F. Corrections for temperatures above and below this point may be made from Table III.

Testing Progress of Charge. Upon the completion of the charge, the rheostat handle should always be turned back before opening the battery switch. It is essential that any voltage readings taken as a guide of the battery's condition should be noted only while the charging current is on. This applies likewise to readings during the discharge of the battery, which should be taken while the vehicle is running, as the voltage with the battery standing idle is of no value as an indication of its condition.

But the voltage alone must not be depended upon. The specific gravity of the electrolyte as well as the voltage will rise and reach a maximum as the end of the charge approaches. Specific gravity readings should therefore be taken with the hydrometer syringe provided for this purpose. This instrument consists of a glass syringe in which there is a hydrometer, Fig. 53. By inserting the point of the syringe in the venthole of a battery, it may be filled with the electrolyte, thus causing the hydrometer to float. The specific gravity of the solution may be noted and the latter replaced in the cell without any necessity for handling. Several cells in various parts of the battery should thus be tested as

Fig. 54. Syringe Hydrometer Set

Fig. 53. Acid Testing Set in Separate Parts

TABLE IV

Baumé Scale of Specific Gravities

Baume	Specific Gravity	Baume	Specific Gravity
0	1.000	18	1.141
1	1.006	19	1.150
2	1.014	20	1.160
3	1.021	21	1.169
4	1.028	22	1.178
5	1.035	23	1.188
6	1.043	24	1.198
7	1.050	25	1.208
8	1.058	26	1.218
9	1.066	27	1.228
10	1.074	28	1.239
11	1.082	29	1.250
12	1.090	30	1.260
13	1.098	31	1.271
14	1.106	32	1.283
15	1.115	33	1.294
16	1.124	34	1.306
17	1.132	35	1.318

a check of the voltage. An older form of testing set is shown in Fig. 54. When fully charged, the specific gravity of the electrolyte should be between 1.270 and 1.280. Because of the spraying through the ventholes when the cells are gassing freely, and the loss by sloppage and evaporation, there is a gradual lowering of the specific gravity. It may be permitted to run as low as 1.250 when fully charged. It is not necessary to make both the voltage and specific gravity tests every time the battery is charged, but they should be carried out at least once a fortnight, when all the cells should be tested to determine if they are in uniform condition.

Baumé Scale. Hydrometers are often graduated according to the Baumé scale. The Baumé scale for liquids heavier than water is based upon the following equation:

$$\text{Sp. Gr.} = \frac{145}{145 - \text{Baumé degrees}} \text{ at } 60° \text{ F.}$$

Table IV gives the corresponding specific gravities and Baumé degrees.

Should the specific gravity of some of the cells be lower than the remainder of the battery, the low cells should first be charged separately at a low rate. If the specific gravity increases, it is an indication that the cell had been discharged to a lower point than the others and simply needed additional charging. Should this not be the case, and if neither the specific gravity increases nor the temperature rises rapidly during the charge, it indicates that the gravity of the electrolyte has been lowered by the addition of water to compensate for loss due to leakage or similar cause. The cell should accordingly be examined for the cause of the loss by sawing through the connections or straps and removing the cell from the battery. If the jar is found to be broken or cracked, a new one should be substituted, new electrolyte of the same specific gravity as that of the remaining cells put in, and the cell fully charged. The specific gravity of the electrolyte should then correspond with that in the other cells. If the loss of electrolyte has been due merely to slopping over, electrolyte should be added and the whole tested for the right specific gravity. The outside of the jar and the tray beneath it should be thoroughly cleaned, and the cell put back and its connections burned into place, care of course being taken to have positive and negative plates connected as they were before removal.

As the electrolyte of the Edison cell does not vary with its state of charge, the specific gravity test cannot be employed, the voltmeter affording an accurate indication of the condition of the cells. Electrolyte cannot be lost from the Edison cell as it is sealed in, but there is a certain amount of loss by evaporation which must be replaced with distilled water.

Electrolyte. Manufacturers of storage batteries usually recommend that small users purchase their supplies of electrolyte from them in order to be certain of its purity and specific gravity. Where this is not convenient, the owner of the electric vehicle may mix his own solution. This should consist of *distilled water* and *pure sulphuric acid* in the proportion by volume of one part acid to four and three-quarter parts of water for electrolyte of 1.200 specific gravity, or one part acid to three of water for 1.275. A glass, porcelain, or earthenware vessel must be employed for mixing the solution, and the acid must be poured very slowly into the water. Never pour water into acid, for while the effect of slowly adding acid to water is negligible, the adding of water to concentrated acid is accompanied by violent chemical action and an evolution of heat will usually break the containing vessel and always cause a dangerous spattering of the acid.

The sulphuric acid should be chemically pure, and, wherever possible, distilled water should be used. If this is not obtainable, the use of clean rain water is recommended as being likely to contain less impurities than any other. The keeping of the electrolyte free from impurities is a matter of the utmost importance and one that must ever be borne in mind. All dirt and foreign substances, both liquid and solid, must be rigidly excluded. A piece of iron in the shape of a stray tack, small nut, or wire may fall into a cell and ruin it before its presence is discovered. The presence of iron will be indicated by the electrolyte and the positive plate becoming a dirty yellow color. Some other impurities also make their presence readily known, for instance, chlorine will give off fumes that are easily recognizable by their disagreeable odor.

Whenever such a condition is discovered, the only remedy is to dismantle the cell immediately, regardless of the state of charge or discharge it may be in. Discard the electrolyte and the wood separators, and thoroughly rinse in running water all parts of the cell, such as the jar, rubber separators, and both of the elements; the latter should be washed separately. Reassemble with new electrolyte of the same specific gravity as that discarded, and new wood separators. Charge the cell and discharge fully several times. After the last of these discharges and before recharging, take the cell apart a second time, again discarding the electrolyte, rinsing the parts of the cell in running water and soaking the wood separators in several changes of water. The cell may now be reassembled permanently with electrolyte of 1.200 specific gravity. It should be given a long charge before being put into service again. Care must be taken not to allow the negative elements to become dry at any time during this operation, in fact, it is better to keep both sets of plates under water until reassembled.

Dangers of Overcharging. To revert to the subject of charging in general, too much cannot be said regarding the evils of giving an excessive overcharge, an abuse which may occur in two ways: charging the battery for too long a time, and charging too frequently. The commoner of these—that of charging too long a time—is easy to avoid. The other is not so apparent, and is the result of a practice which is apt to be indulged in by the uninitiated owner of an electric car, being due to a desire to have it always ready to run its available mileage. This is the custom of charging too frequently. For instance, if the capacity of the battery will run the car 40 miles on a charge, and but 5 miles are covered and a short charge given, then 10 miles are covered, and a second charge, followed by a second and third installment of 10 miles with a charge between each and after the last, it is obvious that but 35 miles have been covered altogether, but the battery has been charged four times. This is three times more than was necessary under the circumstances, besides which the available radius was not covered, so that the battery would really not have been discharged had the entire distance in question been covered without recharging. The greatest wear on the plates of a battery occurs during the final part of a charge, so that the oftener the battery is charged the shorter its life will be. As stated at the outset, the life of the very best cell made is measured by a certain number of discharges, but this is on the assumption that it is not recharged until actually discharged each time. Where a vehicle is employed for short runs, such as those mentioned, the capacity of the battery will not give as great a mileage as if the entire distance were covered in one run. When covering but a few miles in daily service, it is not advisable to recharge until between 50 and 75 per cent of its capacity has been exhausted.

Where it is desired to use the car within a comparatively short time after the battery has been exhausted, it is permissible to hurry the charge within certain limits by using a higher rate than normal. This should be employed only at the start of the charge and should be reduced immediately the cells begin to "gas." When the "finishing" voltage has been reached, the charge should be reduced to the normal starting charge, the remainder of the charge being carried out as if the battery had been started on the latter. Great injury may be done to the plates by "pounding" a nearly full battery at a high rate of charge. The foregoing precautions do not apply to the Edison cell.

Time Required to Charge. The time required for charging will naturally depend upon the extent of the preceding discharge. If the latter has been two-thirds of the rated capacity of the battery, the usual pleasure car will require about three hours at the starting rate and one and a half to two hours at the finishing rate. In other words, about 10 to 15 per cent in excess of the amount discharged is usual. At least once a fortnight, a prolonged charge should be given by continuing the charge for one hour after the specific gravity of the electrolyte has ceased to rise. Where a vehicle is maintained by its owner in a small private garage, and is used more or less during the day, it will be found a great convenience to do most of the charging during the night, and for this purpose the mercury arc rectifier, described in the chapter on "Methods of Charging", will be found a great help. Where direct-current service is available at 110, 220, or 500 volts, such an adjunct will naturally not be necessary. In over-night charging, precautions must be observed to prevent an excessive overcharge. To do this, a careful estimate of the current required to fully charge the battery must be made before putting it on charge, and the rate adjusted accordingly. If 12 hours be available for charging and 84 ampere hours are necessary, the average rate of charge must be 7 amperes. Should the time be only 9 hours, as where a vehicle has been used in the evening and is wanted again early in the morning, the average rate would be slightly more than 9 amperes. Where 72 ampere hours are required in 9 hours, the rate would be 8 amperes, and so on. The rate, however, will also depend to some extent on the voltage of the charging circuit, in charging from a source with constant voltage, the rate into the battery will fall as the charge progresses. This is also the case where the charging is done with the aid of a mercury arc rectifier. After the charge is ended, the voltage will drop immediately when the battery is disconnected.

Charging an Edison Battery. The charging rates of Edison cells are based on a voltage of 1.85 volts per cell, so that the potential required to charge a battery of this type is as follows:

Number of Cells	Volts Across Cells
10	18.5
20	37.0
30	55.5
40	74.0
50	92.5
60	111.0
70	130.0
80	148.0
90	167.0
100	185.0

These voltages are just sufficient to charge the number of cells in question at the normal rate during the end of the charge, as the alkaline cell increases its voltage during charge in the same manner as the lead cell, there being also a similar drop in voltage when the charging current is shut off. While a slight reduction in voltage from the potentials given will not materially affect the charge, allowance should be made for what is required in every case, if necessary, by charging the battery in series multiple.

Owing to their construction the Edison cells are capable of being *boosted* at high rates when it is necessary to charge quickly, but the temperature must not be allowed to exceed 115° F. The following are the boosting rates recommended by the makers as the result of experience:

5 minutes at 5 times the normal rate
15 minutes at 4 times the normal rate
30 minutes at 3 times the normal rate
60 minutes at 2 times the normal rate

The sizes, capacities, charge and discharge rates of the Edison cells are as follows:

Type A-4	A-5	A-6	A-8	A-10	A-12
Capacity 150 ampere hours	187.5	225	300	375	450
Normal charge / Normal discharge } 30	37.5	45	60	75	90

They are capable of discharge rates in excess of these figures in the same proportion as the boosting rates.

BOOSTING

Advantages of Boosting. The term "boosting" as applied to electric-vehicle batteries may be defined as "auxiliary charging", and must not be confused with its use in connection with the charging of large stationary batteries. As the lead-plate cell becomes completely charged, its voltage rises to 2.5 volts per cell, which for the 55 cells required to deliver current at 110 volts, would mean a potential of 137.5 volts, or an increase of more than 20 per cent over that of the generator. The latter, not only being a constant potential dynamo, but also being called upon to deliver current for other service while charging the battery, it is necessary to raise the voltage of the charging current in order that it may exceed that of the battery without, at the same time, altering the output of the generator. For this purpose, what is known as a "booster" is employed, i.e., a motor-generator which imposes a higher voltage on the charging current than that at which it is produced by the main generator.

In the case of a vehicle battery, it usually implies a partial charge given in a comparatively short time and at current rates considerably higher than normal, and it represents a practice which has had an important influence on the use of the electric vehicle for commercial purposes. For example, many of New York's several thousand electric trucks of three to five tons' capacity are now sent on trips that were considered beyond the range of the electric only a few years ago, as it is not unusual for five-ton brewery trucks to make a fifty-to-sixty-mile day's run in one round trip from the plant. How this is accomplished with batteries whose normal output only suffices to run the car forty miles on a charge will be apparent from a consideration of the practice of "boosting" the battery, which is usually carried out during the noon hour.

Regulation of Boosting Charge. Stress has already been laid on the fact that overcharging at high rates is injurious to the lead battery, and is the one thing to be most carefully avoided. However, the improved forms of vehicle batteries now in use have considerable ability to absorb current at high rates under proper conditions. The only factors which act injuriously in high-rate charging are *gassing* and *heating*, and these appear only when the battery is receiving more current than the plates can utilize. Therefore, any current rate which the cells will absorb without gassing is not injurious, and it is upon this principle that boosting is applied.

Possible Safe Charging Rates. The more nearly discharged a battery is the higher charging rate it can take, and by starting the charge at a high rate and tapering to a low rate at the end, a large proportion of the discharge can be replaced in a very short time. Table V gives the additional battery capacity which can be obtained by constant potential boosts with the battery in different states of discharge.

TABLE V

Potential Boosts at Different States of Discharge

Battery Charge	20-Minute Boost Increase	40-Minute Boost Increase	60-Minute Boost Increase
Battery fully discharged.................	22%	38%	50%
Battery three-quarters discharged.........	19%	33%	42%
Battery one-half discharged..............	15%	26%	32%
Battery one-quarter discharged...........	10%	16%	20%

Expressed in terms of mileage, this would mean that a car, after having given forty miles on a complete discharge, could have its battery boosted as follows:

In 20 minutes so as to give 9 miles additional
In 40 minutes so as to give 15 miles additional
In 60 minutes so as to give 20 miles additional

Thus, by charging during the noon hour, 140 per cent of the battery capacity is obtained in one day, bad weather conditions particularly representing conditions under which it is advantageous to be able to boost the battery.

Methods of Boosting. There are several methods by which boosting can be practically carried out, and the method chosen depends upon the available charging facilities.

Constant-Potential Method. The ordinary incandescent lighting circuit is supplied by a constant-potential generator, i.e., the voltage does not vary regardless of the current utilized within the limits of the capacity of the generator. Where conditions permit, this is the best method because it is entirely automatic and requires little attention. It is applicable wherever there is available a voltage of about 2.3 volts per cell of battery—say 110 volts for 48 cells—and the charging equipment and wiring have sufficient capacity to carry current up to four or five times the usual charging rate. A voltage higher than 2.3 volts per cell can be reduced by having a set of counter-e.m.f. cells figured at 3 volts per cell, which are always put in series with the battery when it is boosted. This is a special type of cell designed for this purpose. Thus if the line voltage is 110 and the battery consists of 40 cells, a reduction of 18 volts will be necessary, and six of the counter-e.m.f. cells will be required.

With the charging voltage thus fixed at 2.3 volts per cell, a battery in any state of discharge can be put on charge and will receive in a short time a large proportion of the discharge which has been utilized. The current input will taper automatically from a high rate at the start to a low rate at the finish, and no attention or adjustment is required. The cells will not reach the *free gassing* point or, under normal conditions, a high temperature and, therefore, no harm will result from their being inadvertently left on charge.

Approximate Constant-Potential Method. This is employed with a fixed resistance in series with the battery; and when the time available for boosting is one hour or less, the following method is often the simplest. Connect a rheostat in series with the battery and adjust the resistance so that the voltage across the *battery terminals* corresponds to that given as follows for the approximate number of cells.

Number of Cells	Voltage at Battery Terminals
48	110
44	98
42	92
40	86
38	80

The circuit can then be left without attention for an hour or so, and the current will taper off as the voltage of the battery rises. The table is figured for a line voltage of $\frac{110}{120}$, and the voltages given are too high for a boost of more than one hour's duration.

Constant-Current Method. In some cases it is more convenient to boost at a constant rate of current, and, as there is usually a limited time available, it is desirable to know under any given conditions what rate is safe. This may easily be determined as follows:

$$\text{Charging current (amperes)} = \frac{\text{ampere hours already discharged}}{1 + (\text{hours available for boosting})}$$

This gives the maximum current which can be employed for the time specified without the cells reaching the gassing point. The method is most conveniently employed where the car is equipped with an ampere-hour meter. For example, 100 ampere hours have

TABLE VI

Boosting Rates*

Ampere Hours Discharged	Time Available for Boosting							
	¼ hour	½ hour	¾ hour	1 hour	1¼ hours	1½ hours	1¾ hours	2 hours
	Amperes	Amperes	Amperes	Amperes	Amperes	Amperes	Amperes	Amperes
10	8	6	5	5	4	4	3	3
20	16	13	11	10	9	8	7	6
30	24	20	17	15	13	12	11	10
40	32	26	23	20	18	16	14	13
50	40	33	28	25	22	20	18	16
60	48	40	34	30	26	24	22	20
70	56	46	40	35	31	28	25	23
80	64	53	45	40	35	32	29	27
90	72	60	51	45	40	36	33	30
100	80	66	57	50	44	40	36	33
110	88	73	63	55	49	44	40	37
120	96	80	68	60	53	48	43	40
130	104	87	74	65	58	52	47	43
140	112	93	80	70	62	53	51	47
150	120	100	86	75	67	60	54	50
160	128	106	91	80	71	64	58	53
170	136	113	97	85	75	63	62	57
180	144	120	103	90	80	72	65	60
190	152	127	108	95	84	76	69	63
200	160	133	114	100	89	80	73	67
210	168	140	120	105	93	84	76	70
220	176	147	126	110	98	88	80	73
230	184	153	131	115	102	92	84	77
240	192	160	137	120	106	96	87	80
250	200	167	143	125	111	100	91	83

*Courtesy of Electric Storage Battery Company.

Explanation. In the left-hand column find the figure nearest to the ampere hours discharged from the battery; follow across to the column headed by the available time. The figure at this intersection is the current to be used.

Example. Ampere-hour meter reading, 103 ampere hours discharged; time available for boosting, one hour. Start at 100 in the left-hand column; follow across to the column headed 1 hour and find 50, which is the current to be used.

been discharged and there is one hour available for boosting. Then

$$\text{Charging current} = \frac{100}{1+1} = 50 \text{ amperes}$$

In general, this method will not put in as much charge in a given time as the constant-potential method, and the current must not be continued *beyond the time for which the rate is figured,* as injurious gassing and heating will result. When a considerable period is available for boosting, and it is convenient to regulate the current at intervals, a greater amount of charge is possible by dividing the time into several periods and regulating the amount of current for each period separately. It will usually be found that one of the methods outlined will be available, but to obtain the advantages of boosting without injury to the battery, gassing must be avoided and the temperature of the cells kept below 110° F.

Table VI is based upon the above formula and saves the necessity of making calculations.

CARE OF BATTERY

Importance of Careful Attention to Battery. The battery is naturally the chief factor in any electric automobile and, as its initial cost is no small fraction of the total cost of the vehicle, its proper maintenance is a matter of economy no less than of good service. More so than any other piece of electrical apparatus, a storage battery has a definitely determined life. Regardless of the care given it, the active period of service of which it is capable may be expressed as a certain number of discharges. By properly looking after it, this number may be realized, and a greater percentage of the energy put into it taken advantage of. In other words, its life will not only be longer, but its efficiency much higher during that period as the result of proper care.

Limits of Discharge. To obtain the best possible service from a battery, it should never be discharged below 1.70 volts per cell, this being measured when the vehicle is running at full speed on the level, all of the cells then being connected in series. If the average discharge rate is for any reason considerably more than the normal rate of the battery, the working voltage will be correspondingly lowered, so that a slightly lower limiting voltage is permissible. In general, however, it is safer not to go below 1.70 volts per cell, except momentarily, as when starting or on a grade. The battery should never be allowed to stand fully discharged, as local action and sulphating rapidly take place.

Sulphating. It has been pointed out in the introductory section of Part I that during each discharge both the positive and negative plates become covered with lead sulphate, but in the normal use of the battery the sulphate is converted during the following charge to lead peroxide on the positive plate and spongy metallic lead on the negative. Should the battery be allowed to stand in a discharged state for any length of time, however, the lead sulphate on the plates will harden, causing what is usually termed "sulphating." When the battery is put into use again this will result in loss of capacity, buckling, shedding of the active material from the positives, and greater heating of the cells due to increased internal resistance. Sulphating can be remedied by continuous charging for a long period at a low rate, i.e., for 24 to 36 hours, or longer, at a rate not exceeding 10 to 15 per cent of normal. This loosens the sulphate and reconverts it, thus restoring the plates to their normal condition. The great loss of capacity, with the possible total ruin of the battery if sulphating is allowed to go on long enough, explains the emphasis laid on the instructions—*never let the lead-plate battery stand discharged.*

When it is not convenient to have the battery fully charged at once, a partial charge should be given and completed as soon thereafter as possible, and before the battery is again discharged. When the vehicle is out of service, the battery should be given a freshening charge at least every month, and every two weeks would be preferable.

As an additional indication of the relative condition of the cells in a battery, the voltage of each cell should be taken with a low-reading voltmeter—i.e., one calibrated to read to 3 volts by tenths—at least once every two weeks, and the specific gravity of the electrolyte of each cell should also be tested at about the same interval. The voltage readings in question should be taken just before the end of the prolonged charge mentioned, or just before the end of a complete discharge, and always with the current flowing. Should any of the cells read lower than the average, it is an indication of trouble and they should be treated as explained later.

Condition of the Cells. *Electrolyte.* One of the cardinal points to be observed in the care of the battery is to keep the plates covered with electrolyte to the depth of at least half an inch, but no more. Except where the level has been lowered by slopping or leaking, any loss should be replaced by the addition of distilled water, and should always be added at the beginning of a charge.

Connections. Attention should be paid to keeping the connections and terminals, the outside of the jars, the straps, battery trays, and the battery space in the vehicle dry and free from dirt and acid. This is a far more important precaution than may appear at first sight, for if not attended to, corrosion and loss of capacity will result. In storage batteries for starting and lighting gasoline cars, this difficulty has been obviated to a considerable extent by the use of a special form of cover incorporating an expansion chamber.

CLEANING OR WASHING A BATTERY

Methods of Avoiding Injurious Effect of Sediment in Cells. During the normal use of a battery, the gradual wear of the plates results in a deposit of sediment which collects in the bottom of the jar where a space is provided to hold a considerable quantity before it accumulates sufficiently to touch the bottom of the plates, Fig. 55. The rate at which sediment accumulates depends very largely upon whether the battery is charged properly or not. If the battery is charged in such a way as to cause excessive gassing, the gas coming out of the pores of the positive plates tends to soften and dislodge the active material. This is the reason the charging current must be reduced as soon as the cells begin to gas freely. If a battery is constantly undercharged, the sulphate which is thus allowed to accumulate in the negative plates will eventually lose its cohesion and the surface will gradually wash

Fig. 55. Elba Cell with Low Mud Space and Bolted Connections

away, falling to the bottom of the jar as a deposit of sediment. It is neither necessary nor desirable that every charge be carried to completion, but in order to make certain that the plates do not become sulphated, a weekly "equalizing" charge is given.

If a battery has been neglected so that cleaning is not undertaken until the deposit of sediment has actually reached the plates, the sediment is then deposited much more rapidly. Permanent injury and decreased life of the plates result. The Elba cell, Fig. 56, is designed with a mud space sufficiently high to accommodate the entire deposit of sediment occurring during the life of the elements, so that washing is not necessary in this type of cell, the jars only being cleaned out when the elements are renewed.

Fig. 56. Elba Cell with High Mud Space

Since the conditions under which batteries are operated vary so widely, the best method of determining when it will be necessary to clean a battery is to remove the element from one of the cells after about 100 to 150 charges have been given it, to determine the rate at which the sediment is accumulating. From the amount of sediment compared with the depth of the space in the bottom of the jar, it is possible to estimate when cleaning will be required. *Always clean a battery before there is any possibility of the sediment reaching the bottoms of the plates.* To insure this, the entire depth of the space should not be taken as a fixed quantity in estimating the rate of sediment deposit, but a margin of safety of ½ to ¾ inch should be allowed, since the jolting of the vehicle is apt to bring the sediment in contact with the plates and short-circuit them momentarily, if allowed to rise any closer. At the expiration of the estimated time, cut out a different cell and examine it to determine definitely if the time for cleaning has arrived.

Various Conditions to be Found. The method of procedure in cleaning will depend upon the condition of the battery, as follows:

1. If the battery has not been allowed to become sulphated and the sediment has not reached the bottoms of the plates, its cleaning is a comparatively simple operation and the only preliminary treatment is to first bring the battery to a state of full charge.

2. If the battery is in a sulphated condition due to improper charging, but the sediment has not reached the bottoms of the plates, it should be given the treatment detailed under "Restoring a Sulphated Battery", before cleaning.

3. If the sediment has been allowed to reach the bottoms of the plates because cleaning was not carried out soon enough, the battery will, as a matter of course, be in a sulphated condition by reason of the short-circuits through the sediment. Such a battery must first be cleaned as described below and afterward given the treatment referred to under "Restoring a Sulphated Battery". This treatment cannot be given successfully in its short-circuited condition.

Materials to Have on Hand. Before starting the work of cleaning the battery, have on hand a set of new wood separators and sufficient new acid of 1.300 specific gravity with which to mix new electrolyte. Many of the old rubber separators can be used again, but, as is the case when renewing the entire element of the cell, about twenty-five per cent of new rubber separators should be at hand for replacements. Three or four extra jars and covers should also be at hand, and the trays should be examined to note if their condition is such that they may be depended upon to last the remaining life of the cells. If new trays are necessary, see instructions under "Renewal".

In fact, as the process of cleaning is, to a large extent, the same as that of renewing the elements, the instructions for dismantling the battery are the same. All the connectors should be removed by pulling or drilling. The jar covers should be lifted by running a hot putty knife around their edges, and the covers should be washed in hot water and then stacked one on top of the other with a heavy weight on them to press them flat.

Treating the Plates. Lift all the jars out of the trays, leaving their elements in the electrolyte. The trays can then be examined, and, if usable, given the treatment described in connection with renewals to neutralize any acid in the wood. Proceeding further, one cell should be treated at a time. The element is pulled out with the aid of pliers, meanwhile holding the jar with the feet; it is laid on the bench and the plates spread slightly to permit of removing the separators, taking care not to injure the rubber sheets, Fig. 57. Separate the positive group from the negative. If the active material of the negative be swollen beyond the surface of the grid, press it back into position before it has a chance to dry by placing boards of suitable thickness between the plates and carefully squeezing the group between heavy boards in a vise or press, as shown in Fig. 58. Boards of sufficient size and thickness must be used between the plates or

Fig. 57. Removing Old Separators from Elements

Fig. 58. Pressing Negative Group

Courtesy of Electric Storage Battery Company, Philadelphia, Pennsylvania

breakage will result. Charged negative plates, when exposed to the air, will become hot in a short time and in this event should be allowed to cool before reassembling. Remove any loose particles adhering to the positive plates by passing a smooth wooden paddle over the surface, *but do not wash the positive plates.*

Washing or Renewing Separators and Assembling Cells. Wash all the sediment out of the jar to have it ready for the element when reassembled. Wash and save the rubber sheets, but throw away the old wood separators. "Wash" in this connection means to place under running water that is known not to contain any injurious impurities, for fifteen minutes or more. Reassemble the positive and negative groups with the plates on edge in order to insert the separators. Place a rubber separator against the grooved side of a wood separator, Fig. 59, and insert a positive plate near the center of the element. The rubber sheet must be against the positive plate and the wood separator against the negative plate. In this manner, insert separators in all the spaces, working in both directions from the center, exactly the same as in renewing the element. An omitted separator means a short-circuited cell.

The separators should be practically flush with the bottoms of the plates to bring their tops against the hold-down below the strap, and must extend to, or beyond, the side edges of the plates. Grip the element near the bottom to prevent the plates from flaring out while placing in the jar. Fill the cell to within ½ inch of the top of the jar, using electrolyte of a specific gravity of 1.250, unless the battery is in a sulphated condition, in which case, use water. After all of the cells have been given the same treatment and reassembled, place them in the trays in the proper position, so that the *positive of each will be connected to the negative of the adjoining cell*, and connect temporarily by pressing the old connectors into position.

Fig. 59. Wood and Rubber Separator

Charging Process after Washing Battery. Put the battery on charge at the regular finishing rate and, after charging about fifteen minutes, note the voltage of each cell, recording these readings as mentioned in connection with renewals. This is to insure the cells having been correctly connected with regard to their polarity. If this is the case, each cell should read above 2 volts; any cell with a lower reading is likely to have been connected backward. When the cells begin to gas freely and uniformly, take and record a hydrometer reading of each cell and the temperature of one cell. Reduce the current to one-half the normal finishing rate. Should the temperature reach 100° F., reduce the charge or interrupt it temporarily so as to prevent the cells getting any hotter. Both hydrometer and temperature readings must be taken at regular intervals, say four to six hours apart, to determine if the specific gravity is still rising or if it has reached its maximum. Continue the charge and the readings until there has been no further rise in any cell during a period of at least twelve hours. Maintain the height of the electrolyte constant by adding water after each reading. (If water were added just before taking the reading, it would not have time to mix with the electrolyte, and the reading would be misleading.)

Should the specific gravity rise above 1.300 in any cell, draw off its electrolyte down to the level of the top of the plates and refill with as much water as possible without overflowing. Continue the charge, and if the specific gravity again exceeds 1.300 all the electrolyte in that cell should be dumped out and replaced with water, then continue the charge. The charge can be considered complete only when there has been no rise in the gravity of any cell during a period of at least twelve hours of continuous charging.

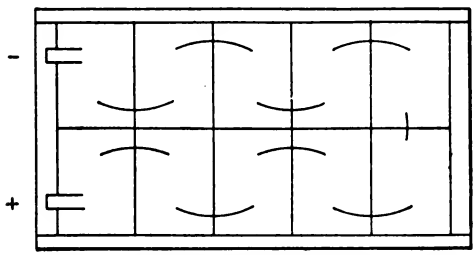


Fig. 60. Diagram of Battery Connections Drawn before Dismounting

Upon completion of the charge, the specific gravity should be adjusted to its proper value (1.270 to 1.280), using water or 1.300 acid as may be necessary, and the electrolyte level adjusted to a uniform height of ½ inch above the plates.

Discharge the battery at its normal discharge rate (see "Renewal") to determine if there are any low cells caused by defective assembly, which should immediately be corrected. Recharge and then remove the temporary connectors. When the cells are arranged in their trays, as shown in the sketch made before the battery was taken apart, Fig. 60, put the rubber covers in place, wipe the inside edges of the jars dry, and seal with the compound supplied for this purpose. Heat the sealing compound, taking care that it is not allowed to burn, and apply around the edges of the cover, smoothing down with a hot putty knife.

It is preferable to use new connectors, but if these have not been provided, the old ones may be replaced if sufficient care has been taken in removing them. Before putting the connectors in place, scrape the posts clean and smooth. In using old connectors, clean out the eyes with a knife blade. When the connectors have been put in place, tap them down firmly to insure good contact. Before reburning the connectors in place, test each cell with a low-reading voltmeter to make certain that the cells have all been reconnected in the proper direction, i.e., that their polarity has not been reversed. It is not sufficient to note that the voltage of the cell is correct, i.e., 2 volts or over; but care must be taken also to note that it is in the right direction. With a voltmeter having a needle that can move in both directions from zero, one polarity will be evidenced by the needle moving over the scale to the right of the neutral line, while if the polarity be reversed, the needle will move to the left, so that a cell having the proper polarity should be tested, and then, to be correct, all the remaining cells should cause the needle to move in the same direction and read to approximately the same voltage when the instrument leads are held to the cell terminals in the same way for each. Where the voltmeter needle can move only in one direction, i.e., to the right, a change of polarity will be indicated by the needle of the instrument attempting to move to the left and, in so doing, butting up against the stop provided to prevent this.

Complete the reassembly of the battery by burning the connectors of all the cells together, detailed instructions for this being given under "Lead Burning". The cleaning of a battery which has been properly charged and in which the sediment has not been allowed to reach the bottoms of the plates is a simple operation compared with treatment necessary to clean and restore a battery which has been neglected. The process of cleaning is also frequently referred to as "washing the battery", which refers to the internal treatment already outlined, and not to washing it outside.

It is of the utmost importance that the battery be cleaned before the sediment is allowed to accumulate to a point where it reaches the plates.

Replacing a Defective Jar. When a cell requires the addition of distilled water more frequently than the other cells in the same battery, or does not test to the same specific gravity as the others, it is usually an indication that there is a leak in the jar. Failure to give

Fig. 61. Drilling off Connectors
Courtesy of Electric Storage Battery Company, Philadelphia, Pennsylvania

Fig. 62. Lifting Cell out of Tray
Courtesy of Electric Storage Battery Company, Philadelphia, Pennsylvania

the same gravity reading is not always proof of this condition, as the cell may be low from other causes, but the loss of electrolyte is certain evidence of it. The only remedy is to replace the jar at fault. While the following directions for doing this apply to the Exide battery in particular, they will be found equally applicable to all other makes.

After locating the jar at fault, first mark its connectors so that there will be no mistake in replacing them the same way. With a $\frac{5}{8}$-inch bit or twist drill of the same size, drill the connectors centrally in the top of the enlarged ends joined to the two cells adjacent to the jar that is to be replaced, Fig. 61. Lift the complete cell out of the tray, Fig. 62, and with an ordinary gasoline blow torch warm the sides of the jar around the top to soften the sealing compound that holds the cover, Fig. 63. Grip the jar between the feet, take hold of the two connectors, and pull the element almost out of the jar, Fig. 64; then grip the element near the bottom in order to keep the plates from flaring out, Fig. 65, while transferring to the new jar, taking care not to let the outside plates start down over the outside of the jar, Fig. 66. After the element is in the new jar, reseal the cell by pressing the sealing compound into place with a hot knife. Fill the cell with 1.250 electrolyte to the proper point, the old electrolyte being discarded.

Fig. 63. Softening Sealing Compound on Cell

Before replacing the connector, clean both the post and the inside of the eye of the connector by scraping smooth with a knife. When the connector has been placed in position, tap it down firmly over the post to insure good contact. To complete the connection, melt the lead of the connector and the post at the top so that they will run together, and, while the lead is still molten, melt in more lead until the eye of the connector is filled, Fig. 67. This is termed *lead burning* and is described at greater length in a succeeding section. Where no special facilities are at hand for carrying it out, it may be done with an ordinary soldering copper. The latter is brought to a red heat so that all the "tinning" is burned off and no flux of any kind is used.

Fig. 64. Lifting Element out of Jar by Hand

Fig. 65. Gripping Element near Bottom to Keep Plates from Flaring out

Fig. 66. Installing Element in Jars

Courtesy of Electric Storage Battery Company, Philadelphia, Pennsylvania

The method of handling the iron and the lead-burning strip to supply the extra metal required to fill the eye is shown in Fig. 68.

Put the battery on charge, and when the cells begin to gas freely, reduce the current to half the "finishing" rate given on the battery name plate, and

Fig. 67. Reburning Cell with Carbon Arc
Courtesy of Electric Storage Battery Company, Philadelphia, Pennsylvania

charge at this rate as long as there is any rise in gravity in the electrolyte in this or in any of the other cells. The maximum gravity has been reached when there has been no rise for a period of three hours. If the gravity of the cell having the new jar is then over 1.280, draw off some of the electrolyte and replace with

Fig. 68. Reburning Cell with Soldering Iron After Replacements Previously Described Have Been Made
Courtesy of Electric Storage Battery Company, Philadelphia, Pennsylvania

distilled water. If the gravity is below 1.270, draw off some of the electrolyte and replace with 1.300 electrolyte. If necessary to put in 1.300 electrolyte, allow the battery to continue charging for about one-half hour longer at a rate sufficient to cause gassing, which will cause the stronger acid to become thoroughly mixed with the rest of the electrolyte in the cell.

COMPLETE RENEWAL OF BATTERY

Materials Needed. In garages caring for a number of electric vehicles, it is customary to carry out all the repair work demanded by the batteries, including the complete renewal of the cells. The material is ordered from the maker of the battery, and the form in which it is sent for will depend upon the facilities at hand. The following material is required for a complete renewal: positive groups, i.e., plates already burned to straps, or positive plates and positive straps, negative groups or negative plates and negative straps, connectors, burning strip, wood separators, rubber separators, rubber jars, rubber covers, rubber plugs, sealing compound, electrolyte, trays, handles, and terminals.

Note the number of plates and their size and type, this information usually being given on the plate on the tray. Unless facilities are at hand for burning the plates into groups, it is better to order groups. If the plates are ordered loose, positive and negative straps must also be ordered, and, in any case, the following information must be given: size and type of plate, number of plates per cell, length of jar outside, width of jar outside, height of jar outside, height from top of rib of jar. In ordering connectors, give the distance between the center of the eyes, noting if more information than the size is required. Two pounds of burning strip is sufficient for burning the connectors of an ordinary battery; when loose plates are ordered, provide one pound additional for each fifty plates. The clippings from the plate lugs can be melted down and cast into strips for this purpose, if desired.

Where the separator type cannot be identified by name or number, send samples of the old ones to the manufacturer. All new wood separators will be necessary, and in ordering these it is advisable to provide at least 10 per cent more than are actually required. Most of the old rubber separators can be used again, but it is well to provide about 25 per cent of new ones. Order three or four extra jars and covers, giving the dimensions as already noted. A new set of rubber plugs will usually be found advisable. The average pleasure-car battery or that of a light truck requires about $\frac{1}{8}$ pound of sealing compound per cell; this compound is supplied in 5-, 10-, and 30-pound tins. In dismantling the old battery, measure the amount of electrolyte necessary in one cell to bring its level $\frac{1}{2}$ inch over the plates, and order sufficient 1.300 electrolyte to fill all the cells. Electrolyte is usually longer in transit than any other material, so this must be allowed for. In ordering new trays, make a sketch showing the inside and outside length, width, and depth, and whether the sides are solid or slatted, also specify the size and type of handles and their position. When obtained locally, trays should be well painted with an acid-resisting paint. Upon receipt of the material, immediate attention must be given the wood separators to prevent their drying out. *Wood separators must always be kept wet.*

Dismantling the Battery. To dismantle the old battery that is to be renewed, first remove all the connectors by drilling centrally in the top of the enlarged ends, as already explained in connection with the replacement of a jar. Where much of this work is done, a device termed a "connector puller" may be obtained from the battery maker. After removing the connectors, lift all the covers by running a hot putty knife around the sealed edges and, after they have been taken out, clean all the compound off them and place them in hot water. This will clean the acid from the covers and also soften them. In this condition, stack the covers and place a weight on them to keep them flat.

Lift all of the cells out of the trays. When making a complete renewal, the old trays are seldom worth saving, but if they are to be used again, immerse them in a barrel of water in which about 10 pounds of bicarbonate of soda (common baking soda) has been dissolved, to neutralize the acid in the wood. After drying, they will be ready for use. Grip one jar firmly between the feet and lift out the element with the aid of two pairs of pliers, Fig. 69. Spread the plates slightly and remove the wood and rubber separators, taking care not to injure the rubber sheets. Throw away the old wood separators and scrap the old plates. Wash all sediment out of the jars to have them ready for assembling the new elements.

Fig. 69. Lifting Element out of Jar with Pliers

Burning Groups. When new plates and straps have been ordered separately and are to be burned into groups, first provide a "burning box", as shown in Fig. 70. Scrape the plate lugs clean and bright and arrange the plates as shown in the burning box. The height of this box should be $\frac{7}{8}$ inch less than the distance from the top of the ribs of the rubber jar to the top of the jar. The burning iron, which acts as a space between the plates and as a support for the strap, should be made of iron $\frac{1}{8}$ inch thick and slotted to fit the plate lugs. This $\frac{1}{8}$ inch in addition to the height of the burning box will give the right height for the strap, the bottom of which should be $\frac{3}{4}$ inch below the top of the jar.

Fig. 70. Assembling Group in Burning Box

Place the strap over the plate lugs to rest on the burning iron. The plate lugs should be trimmed about flush with the top of the strap. After burning, cut off the projecting ends of the negative straps so that the elements may enter the jars, Fig. 71. It is not necessary to clip off the ends of the positive straps.

Before dismantling the old battery, a sketch of the position and polarity of the cells in each tray should be made, indicating the position of the tray terminals and their polarity, that is, whether the positive is to the right or left side of the tray when facing the terminal end, Fig. 60.

Fig. 71. Clipping off End of Negative Strap

Reassembling the Cells. Assemble the new positive and negative groups with the plates on edge in order to insert the separators.

Place a rubber separator against the grooved side of a wood separator, Fig. 59, and insert between a positive and a negative plate near the center of the element. The rubber sheet must be against the positive and the smooth side of the wood separator against the negative, Fig. 72. In like manner, insert separators *in all the spaces*, working in both directions from the center. *Leaving out a separator means a short-circuited cell.* The separators should be practically flush with the bottom of the plates to bring their tops against the hold-down below the strap and must extend to or beyond the side edges of the plates. Grip the element near the bottom in order to prevent the plates from flaring out when placing the element in the jar.

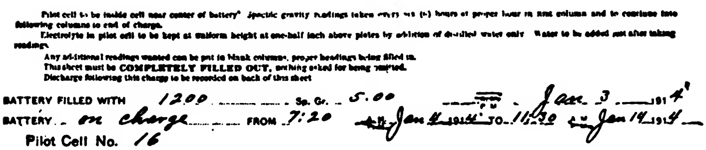
Fill the cells to within ½ inch of the top of the jars, using electrolyte of a specific gravity of 1.300 and allow the cells to stand from

Fig. 72. Installing Separators
Courtesy of Electric Storage Battery Company, Philadelphia, Pennsylvania

twelve to twenty-four hours before starting to charge. After all the cells have been assembled, place them in trays in the proper position, so that the positive of each will be connected to the negative of the adjoining cell and connect temporarily by pressing the connectors into position by hand, using the old ones if available.

Initial Charge. Give the initial charge by putting the battery on the regular finishing charge rate. After charging about thirty minutes, note the voltage of each cell, recording these readings as shown in the first column of the form, Fig. 73.

This is to insure that all the cells have been properly connected up, i.e., in the direction as to polarity. If they have been properly connected, each cell will show in excess of 2 volts. Any cell showing less than 2 volts is probably connected backward and should be inspected. Then reduce the charging current to as near one-half of the regular finishing rate as the charging apparatus will permit. Select one cell near the center of the battery, which will be the


Pilot cell to be inside cell near center of battery. Specific gravity readings taken every [illegible] hours at proper hour in first column and to continue into following columns to end of charge.

Electrolyte in pilot cell to be kept at uniform height at one-half inch above plates by addition of distilled water only. Water to be added just after taking readings.

Any additional readings wanted can be put in blank columns, proper headings being filled in.

This sheet must be COMPLETELY FILLED OUT, nothing asked for being omitted.

Discharge following this charge to be recorded on back of this sheet

BATTERY FILLED WITH 1200 Sp. Gr. 5.00 P.M. Jan 3 1914

BATTERY on charge FROM 7:20 A.M. Jan 4 1914 TO 11:30 A.M. Jan 14 1914

Pilot Cell No. 16

Fig. 73. Specimen Battery Charging Record
Courtesy of Electric Storage Battery Company, Philadelphia, Pennsylvania

"pilot cell" throughout the charge. Record readings of time and current and the specific gravity and temperature of this pilot cell, as indicated in the lower form, Fig. 73, at intervals of from six to twelve hours. Should the temperature at any time reach 100° F., reduce the current or temporarily interrupt the charge so as not to exceed this temperature.

Maintain the level of the electrolyte by adding water as necessary. Never add water just before taking hydrometer readings because it would not have time to mix with the electrolyte and would give a misleading reading. Hydrometer readings should be corrected for any substantial change in the temperature, as detailed in the section on the Use of the Hydrometer, Part I. When the gravity of the pilot cell has shown no further rise for a period of twenty-four hours, record hydrometer readings of each cell in the column marked "specific gravity", Fig. 73. In recording readings, start at the positive terminal of cell No. 1, and follow the direction of the electric circuit. Individual cell readings should be recorded at intervals of about twelve hours *to insure that each reaches a maximum.* Bear in mind that the object of the initial charge is to remove all acid combined in the plates.

Do not stop the initial charge just because a specific gravity of 1.270 or 1.280 may have been reached, because this may not be the maximum. Continue to charge as long as the gravity continues to rise. The charge can be considered complete only when there has been *no rise in the gravity of any cell during a period of twenty-four hours of continuous charging.* In case the gravity rises about 1.290 in any cell, draw off its electrolyte down to the top of the plates and replace with water, saving this electrolyte for adjusting the specific gravity of the cells as follows: Upon completion of the charge adjust the specific gravity to its proper value (1.270 to 1.280), using water or electrolyte as may be required, and bring the level of the electrolyte to a uniform height of ½ inch above the tops of the plates. Some variation on the specific gravity among different cells is to be expected, since the amount of water in the separators and difference in level when filled affect this.

Importance of Initial Charge. The foregoing outline of procedure is based on the assumption that the initial charge is continuous, since this will require the shortest time. It is especially desirable that the first twenty-four hours of the charge be given without interruption, even if the entire charge cannot be made continuous. Where there are interruptions, the twenty-four hours of maximum gravity must be actual charging time and must not include any idle time. The accuracy of the ammeter should be checked for the current readings used.

A battery which has not received sufficient initial charge cannot be expected to give satisfactory service and life. Therefore, in case of any doubt, prolong the charge rather than run the chance of stopping it too soon. As a further precaution, it is advisable to see that the first few charges after the battery goes into service are somewhat prolonged.

Test Discharge. After giving the battery its initial charge, it is customary to make a test discharge and, if necessary, recharge and make a second test discharge, to avoid the possibility of the battery being put into service with any low cells in it caused by defective

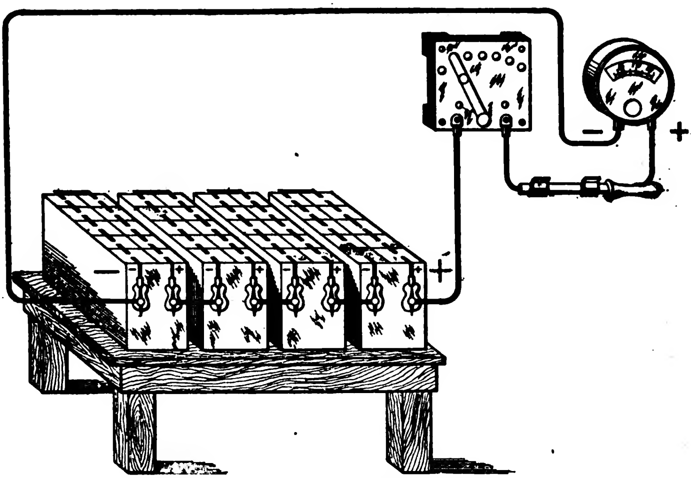


Fig. 74. Wiring Diagram for Battery Test Discharge, Using Rheostat

assembly. The test is also made to determine its capacity. Capacity, however, does not necessarily indicate the completeness or incompleteness of the initial charge. The only sure indication is the maximum specific gravity reached in each cell. This test discharge should preferably be made at the normal discharge rate of the battery and may be carried out with the aid of a rheostat, as shown in Fig. 74, or, where one of this or similar type is not available, by constructing an emergency water rheostat, as shown in Fig. 75. The container should preferably be a wooden tub or an earthenware jar, as a metal container naturally would not be suitable, since the current could then follow a shorter path from the electrodes to the container instead of being compelled to pass through the solution between the electrodes. The solution employed is weak electrolyte, while the electrodes may be either strips of metal or pieces of carbon. They should be mounted on a piece of board so that the distance between them may be adjusted, as the amount of current that flows will depend upon this distance. Separating them further will decrease the amount of current passing, while bringing them closer together will increase it, the rate of discharge being shown by the ammeter. In case the rate is too high at the maximum distance to which the electrodes can be separated, weaken the electrolyte solution of the rheostat by adding more water or, if necessary, make it plain water. If the rate of dis-

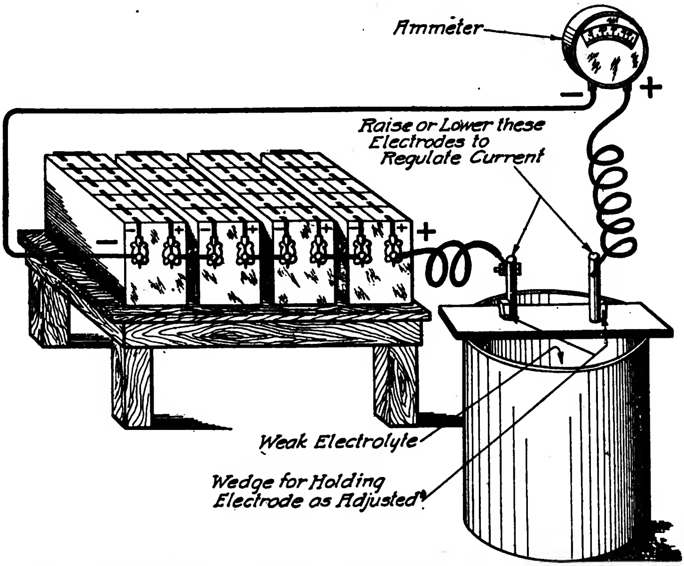


Fig. 75. Wiring Diagram for Battery Test Discharge, Using Water Rheostat

charge is insufficient even when the electrodes are brought close together, strengthen the electrolyte slightly. A convenient form for keeping the discharge record is shown by Fig. 76. Should a second test discharge be made, the capacity will be less than the first, but, after several discharges, the battery will not only recover but will exceed its first capacity.

Recharging. The battery should then be fully charged, and the specific gravity of the electrolyte adjusted to the proper point. On this occasion, all the precautions mentioned in connection with the initial charge and the polarity of the charging connections must be observed. The battery should then be fully discharged. (Fig. 74 shows the method of connecting the battery to discharge through a rheostat, while the water resistance described is illustrated by Fig. 75.)

First discharge voltage reading to be taken for "Exide" cells at end of three and one-half (3½) hours for "Hycap-Exide" cells at four and one-half (4½) hours; for "Thin-Exide" at five and one-half (5½) hours, and second reading twenty (20) minutes after first reading, third reading twenty (20) minutes after second reading. Final reading when several cells reach 1.7 volts, noting total elapsed time.

Additional readings may be recorded in blank columns, proper headings being filled in.

If this is final discharge before shipment, make a note to this effect in the space provided for remarks.

REMARKS:

Fig. 76. Specimen Battery Discharge Record
Courtesy of Electric Storage Battery Company, Philadelphia, Pennsylvania

If a suitable resistance is not at hand for this purpose, a water resistance may easily be made as follows:

Take a vessel of wood, or any other material except metal, and fill it almost full of a diluted solution of sulphuric acid and water. Connect the ammeter to one plate of metal and the battery to a second plate of metal, both of which should be suspended in the solution, care being taken to prevent the current from passing from one plate to the other except through the solution. The remaining terminal of the battery and of the ammeter should be connected together. There is then a complete circuit through the improvised resistance, and the strength of the current may be varied by placing the plates nearer together or farther apart, or by adding acid to the solution, either of which operations will decrease the resistance. This should be adjusted until the ammeter shows that the battery is discharging through the resistance at its normal rate. After cleaning, the capacity of a battery may not be as great as it was previous to the operation until it has had several charges and discharges. While dismantled, the wood trays of the battery should be well rinsed with a strong solution of bicarbonate of soda and water in order to neutralize any acid on them. After that, they should be well rinsed with water and, when dry, painted with acid-resisting paint.

PUTTING BATTERY OUT OF COMMISSION

Methods of Storage. When a battery is not to be used for some time, it must be specially prepared before being stored. There are two general methods of preparing a battery for storage, one known as "wet storage" and the other as "dry storage", the method adopted depending upon the condition of the battery and the length of time it is to be out of commission. The wet-storage method is usually applied to any battery that is to be out of commission for less than a year, provided its condition is such that it will not soon require repairs necessitating dismantling it. The dry-storage method is used for any battery that is to be out of commission for more than a year, regardless of its condition, and it is also applied to any battery that will shortly require repairs necessitating its dismantling.

Wet Storage. Examine the condition of the plates and separators and also the amount of sediment in the bottom of the jars. If it is found that there is very little sediment and the plates and separators are in sufficiently good condition to give considerable additional service, the battery may be put into wet storage by giving it an equalizing charge and covering it to exclude dust. Replace evaporation periodically by adding distilled water to maintain the level of the electrolyte ½ inch above the top of the plates. At least once every four months, charge the battery at one-half the normal finishing rate until all the cells have gassed continuously for at least three hours. Any cells not gassing should be examined and the trouble remedied.

Dry Storage. When the examination shows that the battery will soon require repairs that necessitate dismantling, it should be put into dry storage. Dismantle the battery in accordance with the instructions given in a preceding section under this head, first making the sketch of the layout and connections as there illustrated. If the positive plates show much wear, they should be scrapped; if not, remove any loose particles adhering to them by passing a smooth paddle over the surface but *do not wash the positive plates.* Charged negative plates will become hot in a short time when exposed to the air; they should be allowed to stand in the air until cooled.

Empty the electrolyte out of all the jars into a glazed earthenware jar or lead-lined tank and save it for giving the negative plates their final treatment before storage. Wash all the sediment out of the jars; wash the rubber separators carefully, dry them, and tie them in bundles. Place the positive groups in pairs, put them into jars, and store them away. Place the negative groups together in pairs, put into the remaining half of the jars, cover them with the electrolyte saved for the purpose, and allow them to stand in it for five hours at least. Then pour off the electrolyte, which may now be discarded, and store away the jars containing the negatives. If the negative plates showed any bulging of the active material, they should be subjected to the pressing treatment first, using boards and a vise as described in connection with dismantling the battery. The jars containing the positives, as well as those containing the negatives, should be well covered to exclude all dust.

Make a memorandum of the amount of material required to reassemble the battery and, when ordering this, provide for extra jars and covers, extra rubber separators, and an entire lot of wood separators, with a sufficient excess to take care of possible breakage in handling. Unless the old connectors were very carefully removed, order a new set. Include a supply of new electrolyte of 1.300 specific gravity to fill all the jars. It is always well to advise the customer when the battery is put in storage of the material that will be necessary to reassemble it and request that at least a month's notice be given in which to procure it. To reassemble the battery, proceed as in making a complete renewal of the elements.

MISCELLANEOUS OPERATIONS

Lead Burning. *Type of Outfit.* In the manufacture of storage batteries and in garages where a large number of batteries are maintained, a hydrogen-gas apparatus is employed for this purpose. For the electric-car owner or the garage doing a comparatively small amount of battery repair work, the Electric Storage Battery Company has placed an arc lead-burning outfit on the market. This is low in first cost and, with a little practice, good results can be obtained with it. As the battery itself supplies the power neces-

Fig. 77. Arc-Welding Outfit for Burning Connections

sary, the only material required is the lead in the form of a flexible strip or heavy wire. The complete outfit is illustrated in Fig. 77. At one end is the clamp for making electrical connection, while at the other is a clamp of different form having an insulated handle and holding a quarter-inch carbon rod. The two are electrically connected by a flexible cable. This simple outfit can be employed in two ways, the second being preferable for the beginner, at least until a sufficient amount of skill has been acquired to use the arc without danger of melting the straps.

First Method of Burning. In the first method, a potential of from 28 to 30 volts (12 to 15 cells) is required. The clamp should, therefore, be fastened to the positive pole of the twelfth to the fifteenth cell away from the joint to be burned, counting toward the negative terminal of the battery. The carbon then forms the negative terminal of the circuit. Otherwise particles of carbon will be carried into the joint, as the carbon rod quickly disintegrates when it forms the positive pole. The carbon should project 3 or 4 inches from the holder. The surfaces of the parts to be burned should be scraped clean and bright and small pieces of clean lead about $\frac{1}{4}$ to $\frac{1}{2}$ inch square provided for filling the joint. The carbon is then touched to the strap to be burned and immediately withdrawn, forming an electric arc which melts the lead very rapidly. By moving the carbon back and forth the arc is made to travel over the joint as desired, the small pieces of lead being dropped in to fill the gap as required. Owing to the high temperature generated, the work must be carried out very quickly, otherwise the whole strap is liable to melt and run.

As this method is difficult and requires practice to secure good results, the beginner should try his hand on some scrap pieces of lead before attempting to operate on a cell. Its advantages are that, when properly carried out, it takes but a short time to do the work, and the result is a neat and workmanlike joint. It is extremely hard on the eyes, however, and should never be attempted without wearing smoked or colored glasses, and even with this protection the eyes should be directed away from the work as much as possible.

Second Method of Burning. The second method, utilizing the hot point of the carbon rod instead of the arc, is recommended for general practice. Scrape the parts to be joined and connect the clamp between the third and fourth cells from the joint. With this method it is not necessary to determine the polarity of the carbon. The latter is simply touched to the joint and held there; on account of the heavy flow of current it rapidly becomes red- and then white-hot. By moving it around and always keeping it in contact with the metal, the joint can be puddled. To supply lead to fill the joint, an ordinary lead-burning strip can be used, simply introducing the end into the puddle of molten lead, touching the hot carbon. The carbon projecting out of the holder should be only an inch, or even less, in length. After the joint has been made, it can be smoothed off by running the carbon over it a second time.

Use of Forms to Cover Joint. In joining a strap which has been cut in the center, it is best to make a form around the strap by means of a piece of asbestos sheeting soaked in water and fastened around the strap in the shape of a cup, which will prevent the lead from running down. It will be found that sheet asbestos paper is thick enough, but it should be fairly wet when applied. By this means a neat joint can be easily made. The asbestos will adhere very tightly to the metal, due to the heat, but can be removed by wetting it again. When burning a pillar post to a strap, a form may be made around the end of the strap in the same manner, though this is not necessary if reasonable care is used. Two or three pieces of $\frac{1}{16}$-inch strap iron about one inch wide and some iron nuts about one inch square are also of service in making the joint, the strap iron to be used under the joints and the nuts at the side or ends to confine the molten lead. Clay can also be used in place of asbestos, wetting it to a stiff paste. As the holder is liable to become so hot from constant use as to damage the insulation, besides making it uncomfortable to hold, a pail of water should be handy and the carbon dipped into it from time to time. This will not affect its operation in any way, as the carbon becomes hot again immediately the current passes through it.

Oxy-Acetylene Blowpipe. In most garages an oxy-acetylene outfit is available which may be advantageously used for lead-burning work. The blowpipe should be handled so that the flame will strike the work perpendicularly; this will prevent the flame from heating the surrounding metal too high. To make a successful job the operator must do the work quickly, bringing the flame down to the work, fusing the metal, adding the necessary burning bar or filling wire, smoothing off the work, and removing the flame —all as rapidly as possible. When burning plates to terminal bars, a small flame should be used and the work should be held in a fixture. The small ends on the plates should extend up into the terminal bar slots about two-thirds of the way. The burning should be carried on by first fusing the end of the plates to the bottom of the slots, then filling up the rest of the slot by adding lead from a coil of wire or a burning bar.

When working on links and poles it is advisable to do only part of one pole, move to another for a few minutes, and then come back to the first for a few minutes. This will allow the work to cool off slightly and will prevent breaking down or melting away. When burning this class of work, especially if the lead is old and pitted with dirt and cut by acid, it is advisable to use an oxidizing flame when working down in the pocket.

Freezing. In addition to taking care that the temperature of the cells does not exceed 100° F. on charge, precautions are also necessary to prevent the temperature of the battery falling too low, as a drop in temperature causes a falling off in the efficiency. This is particularly true of the alkaline battery, the output curve of which drops off rapidly below 60° F., so that this type of battery is usually installed in a manner which keeps it at an even temperature, making it possible to operate it successfully in zero weather. Furthermore, in the case of the lead cell, freezing must be guarded against. To avoid this, the battery should always be kept fully charged in cold weather, as a charged cell will not freeze in the temperatures ordinarily experienced. Electrolyte will freeze at various temperatures, according to the state of charge as follows:

Sp. Gr. 1.120 battery fully discharged	20° F. above zero
Sp. Gr. 1.160 battery three-quarters discharged	Zero F.
Sp. Gr. 1.210 battery half-discharged	20° F. below zero
Sp. Gr. 1.260 battery one-quarter discharged	60° F. below zero

When a battery is stored away for the winter, care should be taken not to let the temperature of the place in which it is kept fall below 20° F., or else the battery should be kept fully charged.

Putting New Battery in Commission. One of the things that the garage man caring for electric vehicles will be called upon to do at intervals will be the ordering and installation of a new battery in a car. As received from the manufacturer, the battery is in a charged condition, but it must be inspected and tested before being placed in the car.

Inspection of Battery. To avoid spilling the electrolyte from the cells, care must be taken in unpacking the trays. After cleaning off the excelsior and other packing from the tops of the cells, the soft rubber plugs should be removed from all the latter to note if they all contain the proper amount of electrolyte. This should be ½ inch over the tops of the plates. If the electrolyte is uniformly below the proper level in all the cells, this is evidently due to evaporation; add enough distilled or rain water to bring the level to the proper height. But if the level of the electrolyte is found to be low in some cells only this is due to loss of electrolyte. If this has resulted from the tray having been turned over in shipment, the excelsior around the top of the tray will be wet (the acid does not evaporate), and some acid would be spilled from *all* the cells in that tray. In this case, replace the amount lost by filling the low cells to the proper height with chemically pure electrolyte of 1.250 specific gravity (seven parts of water to two pure sulphuric acid, by volume).

Replacements. If the electrolyte in a cell is low, due to a broken jar, the bottom of the tray will be wet, though the excelsior around the the top may be dry. Replace the broken jar as detailed in the instructions given under that heading and add sufficient electrolyte of 1.250 specific gravity to make up for that lost. Should it be found, after replacing the broken jar and giving the battery an equalizing charge, that the gravity does not reach approximately 1.275, it is due to not having replaced the same amount of acid as was spilled. To adjust this, draw off with a syringe some of the electrolyte from the top of the cell and add water or 1.300 acid to bring the specific gravity to between 1.270 and 1.280.

Charging. Put the battery on charge at the low rate given on the name plate on each tray. Charge at about this rate until all the cells gas uniformly. Reduce the current to one-half that rate and continue the charge for three hours longer, when the battery will be ready to put into service. It is advisable, however, before putting the battery into service, to take and record the specific gravity of the electrolyte of each cell and the temperature of one or more of the cells.

Packing a Battery. It is sometimes necessary to ship a battery back to the manufacturer for repairs, and the amount of damage occasioned in transit by improper packing has led the makers to issue special instructions for doing this. A box at least 2 inches larger in each direction than the overall size of the battery tray should be made of strong 1-inch or 1¼-inch planks. It should be made with an A-shaped top to prevent placing it any other way than upright. Where more than one tray is shipped in a box, 2 inches must be allowed between the trays. The maximum permissible weight, however, is 200 pounds. Cover the bottom of the box with a layer of sawdust, excelsior, or coarse shavings to a depth of 2 inches, and on this place the tray of cells. Over the top of the cells place paraffined paper and then cover the whole tray with stout wrapping paper, folding it down over the sides of the tray to keep packing material and dust out of the cells. Fill the space around the sides with sawdust or excelsior, or even with waste paper twisted into balls and wads, ramming the whole down tightly so that the tray cannot move. Nail slats on the box for a cover (never make a solid cover), and nail a stout strip on each side extending beyond the ends, for handles. The slatted cover enables the freight handlers to see the contents and makes for more careful handling. Label the box "handle with care" and "do not drop". Put your own name and address on the package as well as that of the battery manufacturer, and notify the latter of the shipment. Complete batteries should be shipped as "electric storage batteries assembled". No railroad caution labels are required as the electrolyte in the cells is so dilute that acid in this form is exempted from the rules applying to its shipment in other forms. Boxes of good elements, or plates, should be shipped as "Lead Battery Plates", while worn-out plates may be shipped as "Scrap Lead", boxes of jars as "Rubber Battery Jars", covers and separators as "Rubber Goods", and empty trays as "Empty Wood Crates". By properly designating the material as above in the bill of lading, the most favorable freight rate may be obtained.

Causes of Low Battery Power. A decrease in the speed or mileage of a car does not necessarily mean a lack of capacity in the battery. If the current consumption is greater than normal, it may be due to trouble with the transmission, motor, or running gear—the car "runs hard"—or it may be due to poor connections. When other causes fail, then it is probably the battery, and its lack of capacity may always be traced to some definite cause. There may be a dry cell, due to a leaky jar; some or all of the cells may be in a state of incomplete charge, due to the battery having been run too low and not sufficiently charged. The plates may be short-circuited by excessive deposit of sediment, or by something falling into the jar.

If the trouble cannot be located upon examination, connect the battery in series and discharge it at the normal rate through a suitable resistance, as already explained. As the discharge progresses the voltage will gradually decrease, and it should be frequently read at the battery terminals. As soon as it shows a sudden drop, the voltage of each cell should be taken with a low-reading voltmeter. While the readings are being taken, the discharge rate should be maintained constant, and the discharge continued until the majority of the cells read 1.70 volts. Those reading less than this should be noted. The discharge should then be followed by a charge until the cells which show 1.70 volts are up. Then the low cells should be cut out and examined and the trouble remedied. Assuming that there are no short-circuits, low specific gravity of the electrolyte in such a cell will indicate sloppage or a leak, the loss from which has been replenished with water alone. Or it will be a sign of insufficient charge, over-discharge, standing in a discharged condition, or a combination of these abuses. Any one of these indicates that there is acid in combination with the active material of the plates, and it should be brought out by a long charge at one-quarter the normal discharge rate. Continue charging until the specific gravity of the electrolyte stops rising; then adjust to normal (1.270 to 1.280) by drawing off some of the electrolyte and adding water if it be above normal, and by adding acid if it be below normal. The low cells should be grouped by themselves and charged as a separate battery.

STANDARD INSTRUCTIONS FOR STORAGE BATTERIES

As Issued by the Society of Automobile Engineers

1. Batteries must be properly installed.

Keep battery securely fastened in place.

Battery must be accessible to facilitate regular adding of water to, and occasional testing of, solution. Battery compartment must be ventilated and drained, must keep out water, oil, and dirt and must not afford opportunity for anything to be laid on top of battery. Battery should have free air space on all sides, should rest on cleats rather than on a solid bottom and holding devices should grip case or case handles. A cover, cleat, or bar pressing down on the cells or terminals must not be used.

2. Keep battery and interior of battery compartment wiped clean and dry.

Do not permit an open flame near the battery.

Keep all small articles, especially of metal, out of, and away from, the battery. Keep terminals and connections coated with vaseline or grease. If solution has slopped or spilled, wipe off with waste wet with ammonia water.

3. Pure water must be added to all cells regularly and at sufficiently frequent intervals to keep the solution at the proper height.

The proper height for the solution is usually given on the instruction- or name-plate on the battery. In all cases the solution must cover the battery plates.

The frequency with which water must be added depends largely upon the battery, the system with which it is used, and the condition of operation. Once every two weeks is recommended as good practice in cool weather; once every week in hot weather.

Plugs must be removed to add water; then replaced and screwed home after filling.

Do not use acid or electrolyte, only pure water.

Do not use any water known to contain even small quantities of salts of any kind. Distilled water, melted artificial ice, or fresh rain water are recommended.

Use only a clean non-metallic vessel.

Add water regularly, although the battery may seem to work all right without it.

4. The best way to ascertain the condition of the battery is to test the specific gravity (density) of the solution in each cell with a hydrometer.

This should be done regularly.

A convenient time is when adding water, but the reading should be taken before, rather than after, adding the water.

A reliable specific gravity test cannot be made after adding water and before it has been mixed by charging the battery or by running the car.

To take a reading, insert the end of the rubber tube in the cell. Squeeze and then slowly release the rubber bulb, drawing up electrolyte from the cell until the hydrometer floats. The reading on the graduated stem of the hydrometer at the point where it emerges from the solution is the specific gravity of the electrolyte. After testing, *the electrolyte must always be returned to the cell from which it was drawn.*

The gravity reading is expressed in "points", thus the difference between 1250 and 1275 is 25 points.

5. When all cells are in good order the gravity will test about the same (within 25 points) in all.

Gravity above 1200 indicates battery more than half charged.

Gravity below 1200 but above 1150 indicates battery less than half charged.

When battery is found to be half discharged, use lamps sparingly until, by charging the battery, the gravity is restored to at least 1200. See Section 8.

Gravity below 1150 indicates battery completely discharged or "run down".

A run-down battery should be given a full charge at once. See Sections 7 and 8.

A run-down battery is always the result of lack of charge or waste of current. If, after having been fully charged, the battery soon runs down again, there is trouble somewhere else in the system, which should be located and corrected.

Putting acid or electrolyte into the cells to bring up specific gravity can do no good and may do great harm. Acid or electrolyte should never be put into the battery except by an experienced battery man.

6. Gravity in one cell markedly lower than in the others, especially if successive readings show the difference to be increasing, indicates that the cell is not in good order.

If the cell also regularly requires more water than the others, a leaky jar is indicated.

Even a slow leak will rob a cell of all its electrolyte in time, and a leaky jar should be immediately replaced with a good one.

If there is no leak and if the gravity is, or becomes, 50 to 75 points below that in the other cells, a partial short-circuit or other trouble within the cell is indicated.

A partial short-circuit may, if neglected, seriously injure the battery and should receive the prompt attention of a good battery repair man.

7. A battery charge is complete when, with charging current flowing at the rate given on the instruction-plate on the battery, all cells are gassing (bubbling) freely and evenly and the gravity of all cells has shown no further rise during one hour.

The gravity of the solution in cells fully charged as above is 1,275 to 1,300.

8. The best results in both starting and in lighting service will be obtained when the system is so designed and adjusted that the battery is normally kept well charged, but without excessive overcharging.

If, for any reason, an extra charge to maximum specific gravity is needed, it may be accomplished by running the engine idle, or by using direct current from an outside source.

In charging from an outside source use *direct* current only. Limit the current to the proper rate in amperes by connecting a suitable resistance in series with the battery. Incandescent lamps are convenient for this purpose.

Connect the positive battery terminal (painted red, or marked POS or P or +) to the positive charging wire and negative to negative. If reversed, serious injury may result. Test charging wires for positive and negative with a voltmeter or by dipping the ends in a glass of water containing a few drops of electrolyte, when bubbles will form on the negative wire.

9. A battery which is to stand idle should first be fully charged. See Sections 7 and 8.

A battery not in active service may be kept in condition for use by giving it a freshening charge at least once every two months, but should preferably also be given a thorough charge, after an idle period, before it is replaced in service.

A battery which has stood idle for more than two months should be charged at one-half normal rate to maximum gravity before being replaced in service.

It is not wise to permit a battery to stand for more than six months without charging.

Disconnect the leads from a battery that is not in service so that it may not lose through any slight leak in car wiring.

SOME SOURCES OF POWER LOSS

As the power of the electric vehicle is closely limited by the capacity of the battery it carries, it is absolutely essential that every part of the mechanism be kept in good running order so that none of the power may be wasted. Whether the machine is considered as a whole, or each component is treated separately, the electric vehicle is about as simple as it possibly could be. But the number of places at which power losses may occur will greatly surprise the uninitiated owner when he comes to look into the subject. It is nothing unusual for the purchaser of an electric vehicle to write the maker a year or so after he has bought it that while the car ran perfectly satisfactorily at first, its mileage has now been very much reduced. He has followed instructions implicitly, the battery has been well looked after, and, according to all indications, it is in as good condition as ever it was, but it is impossible to obtain anything like the rated mileage from a full charge of the battery. A little investigation will show that, in the majority of cases, the owner, who has not had the advantage of a mechanical training, has become so impressed with the great importance of properly maintaining the electrical end of the car that he has disregarded its mechanical efficiency entirely.

Non-Alignment of Steering Wheels. One of the most prolific sources of power losses, and one of the last to be suspected, is non-alignment of the wheels. A chance blow in drawing up alongside a curb is sometimes sufficient to make one of the front wheels "toe in" slightly. The fault is not noticed and may be aggravated by subsequent blows at the same spot, or on the other wheel. This may cause the bearings to bind to a certain degree and also to impose a heavy load on the motor by the new angle which the tires make with the road surface. It is difficult for the average layman to appreciate how great an increase in the load such a seemingly trivial fault as this may create, and it can only be realized to a certainty by keeping a record of the ammeter readings at all of the speeds under normal conditions. Just how much current is required to start and to mount various grades should be noted. As the service of an electric vehicle is chiefly confined to urban travel and covers practically the same routes day after day, it is possible to keep a close check on current consumption by noting how far the ammeter needle travels over the dial in running on the level and in mounting grades that have to be climbed frequently. Small increases in the current required to do the same work at different times would then be readily apparent, and as the malady is imposing an extra drain on the battery, which is simply a waste of energy, its cause should be looked for and remedied.

The electric vehicle is a power-measuring machine without an equal, and the driver who has familiarized himself with the performance of his car under favorable conditions should be able readily to detect the presence of trouble by the increased current consumption and the correspondingly decreased mileage per charge. The causes may be electrical as well as mechanical, and where a car has not been properly looked after, it is more than likely that the falling off in the available radius on a single charge will be traceable to an accumulation of causes small in themselves, but of considerable importance in the aggregate. Disalignment of the front wheels may sometimes be due to the steering gear—that is, the connecting rod which serves to keep these wheels parallel—working out of adjustment. Unless they are perfectly aligned, they not only make more current necessary to propel the vehicle, but they also serve to wear out the front tires more rapidly than would otherwise be the case. Sagging of the rear axle, which was not an uncommon fault in earlier years, but which is now rare, will produce similar conditions at the rear wheels and, as the entire power of the car is utilized at this point, the result is just that much worse.

Worn Chains and Sprockets. Next in the order of importance to badly aligned driving or steering wheels from a mechanical point of view, comes a worn driving chain. This naturally applies to the chains employed for either of the reductions in motor speed. It is likewise equally true of the sprockets, but a worn sprocket is practically always the result of the continued use of an old chain. The latter is allowed to wear to a point where its pitch is greater than that of the teeth of the sprocket, and, in consequence, the chain shows a constant tendency to ride the teeth of the sprocket instead of fitting snugly between them, as should be the case. This tightens the chain and imposes a greatly added load upon it and the sprocket, with the result that the teeth of the latter are also soon worn out of pitch. When this occurs, the only remedy lies in the replacement of both chains and sprockets, as the fitting of a new chain on a worn sprocket aggravates the evil and causes the new chain to wear to a point of uselessness in a very short time. The best preventive is to watch the driving chains for such conditions and to replace a chain as soon as it gives any indication of mounting the teeth instead of running smoothly.

These instructions apply only to pleasure models antedating 1913-14, as practically all models are now made with the shaft drive using a bevel gear or worm; but there are thousands of the older chain-driven cars in service, the electric having a much longer effective life than the gasoline car.

Non-Alignment of Axles. On all electric cars, whether they be of the chain- or shaft-driven variety, it will be found that some means are provided for aligning the rear axle. These take the form of *distance* or *radius rods*, attached through the medium of a hinge joint to the axle and some form of pivot joint at the countershaft, this construction having been referred to in connection with the description of the transmission of a double chain-driven car. Although effective means of locking these rods are provided, they are subjected to constant vibration and jolting and sooner or later will require attention. It will be apparent that if one is adjusted so as to be somewhat shorter than the other, an excessive fraction of the load will be imposed on the driving chain on the short side. This will also place a very heavy strain on the differential or balance gear, and a greatly added amount of power will be required to drive the car. The importance of accurately adjusting the distance rods so that the rear axle will be at right angles with the frame and of maintaining it in that condition may accordingly be appreciated.

Dry Bearings. It would appear almost superfluous to mention lack of oil as a mechanical source of power loss, but many electric vehicle owners seldom attach sufficient importance to the necessity for oiling the moving parts. It is a popular fallacy, quite generally indulged in, that the anti-friction bearing is a mechanical device that requires no lubrication. Ball bearings do call for less attention in this direction than any other. They need very little oil, and at much longer intervals than a plain bearing, but they cannot render efficient service without some lubricant. In fact, it is this very ability to stand an uncommon amount of abuse that seems to have earned for the ball bearing its popular reputation for ability to run quite as well whether it is dry or oiled. The lubricant not only serves the same end that it does in any bearing—that of reducing friction, but it also acts as a preventive of rust—the greatest enemy of the ball bearing; and as these bearings are rather expensive replacements, it pays to avoid this by regular oiling at least once a month. Only the best grade of light machine oil should be employed, or a thin-bodied and highly-refined vaseline with which the bearing may be packed. It is quite essential that the lubricant should be entirely free from acid, which would attack the highly polished surfaces of the balls and races and destroy the efficiency of the bearing. The electric-vehicle user's chief safeguard against this is to confine his purchases to brands recommended by the manufacturer of the car. Where the presence of acid is suspected, a simple test may be made by dipping a small piece of cotton waste in the lubricant and then wrapping it around a piece of polished steel. This should be placed in the sun and examined at the end of a week or more. If the lubricant contains acid, there will be traces of its etching effect on the polished surfaces and it is useless. Oil that is entirely free from acid will not affect the most highly polished surface.

Wheels and axles out of alignment, worn chains and sprockets, improperly adjusted brakes, which may be dragging, and neglected bearings sum up the chief mechanical sources of power loss.

It is quite as important, however, that losses of electric power be guarded against, as they interfere with the efficient utilization of the energy stored in the batteries and decrease the available mileage on a charge, regardless of the condition of the mechanism. Vibration will prove the undoing of almost anything in the course of time, and, while every precaution is taken by the manufacturer to provide durable and permanent connections, it seems practically impossible to provide a form of terminal that will be absolutely proof against this influence and still permit of being disconnected conveniently when required. Air interposes a very high resistance in a circuit, and but a slight amount of looseness in a connection creates an air gap that must be bridged by the current in order to complete the circuit. This causes *arcing*, or a flashing of the current across the gap, which is destructive of the terminals and is not infrequently responsible for the ignition of adjacent material. As will be apparent from the wiring diagram given, there are quite a number of such connections, and going over them systematically at regular intervals is the only way to guard against current losses from this source.

Brushes and Commutator. The brushes and commutator are the only parts of the electric motor that are subject to wear, and the life of the commutator is naturally equivalent to that of several sets of brushes, so that the latter constitute practically the sole item to be looked after in connection with the motor. They are either plain blocks of carbon, or carbon with fine copper wire embedded in it, and are held against the commutator by springs. To examine their condition closely, the housing should be removed, the rear axle jacked up, and the motor run on the first speed. No attempt should be made to run it on any of the other speeds when in this condition, nor should it be run any longer than necessary. This does not exactly simulate actual driving conditions as, with the wheels off the ground, practically no load is imposed on the motor and, while the latter may spark badly under load, it will frequently give little indication of this form of trouble when running light.

If the brushes have been sparking badly in actual service there will be certain signs of this in the shape of the blackened commutator bars. They should be wiped clean and, if any oil has leaked on to them from the bearing, all traces of it should be removed. If this does not suffice to remove the blackened appearance, the sparking has been such as to burn the copper, and this blackened surface should be removed with the aid of a piece of very fine sandpaper held against the commutator while it is turning slowly. Never use emery cloth for this purpose, as the abrasive material employed in its manufacture is of a metallic nature, and not only tends to embed itself in the insulation between the bars, but, once there, serves as a conductor and may short-circuit some of the armature coils, resulting in serious damage to the motor. If the brushes merely appear to be glazed but still make good contact all over the bearing surface, the latter may be rubbed with the sandpaper as well. If they have worn to a point where the contact is not good, new brushes should be substituted, and it would be well for the owner of the electric vehicle who is not familiar with the motor, to have an experienced person put them in for him the first time—every time, in fact, unless he is perfectly sure of his own ability in this line. A set of brushes will seldom, if ever, need replacement more than once during an entire season.

For instructions covering seating of brushes, testing springs, and the like, refer to sections on these faults in the article on Starting Motors and Lighting Generators.

Armature Troubles. When the housing is off, the brush connections and other motor connections should be inspected for looseness or other faults. Instructions for locating grounds, short-circuits, or open circuits in the armature and field windings are given in connection with the articles on Starting and Lighting Systems.

The armature is supported on annular ball bearings in the majority of cases, and while these bearings require little attention, they should be packed with vaseline as already directed, when needing lubrication. Oil should not be used as it will flow out on to the commutator at one end or the armature windings at the other.

Miscellaneous. In speaking of connections, those at the battery are included and they should be inspected as well. The connections between the different cells are usually made by burning the lead-strap terminals together, though some have bolted connections, and these may jar loose; but the various groups are connected to one another and to the remaining apparatus, and these terminals are probably more apt to give trouble than some of the others, as it is nothing unusual to remove the battery at times and sufficient care is not always exercised to have the connections solidly fast.

The loss of electrical energy, due to undercharged and short-circuited cells in the battery, has been treated in detail in connection with the care of the battery.

Tires are, without doubt, one of the greatest sources of power loss on the electric vehicle, and it is one that mystifies the uninitiated exceedingly. This matter is gone into at length in connection with tire equipment.

TIRES AND MILEAGE

Relation of Tires to Mileage. It will appear odd and somewhat inexplicable at first sight that these two headings should be included in the same chapter, for the average man thinks that the only thing which has any direct influence on the mileage of the car is the amount of energy the battery is capable of giving forth. As is pointed out under "Sources of Power Loss", there are many other factors that affect the available radius of the car more or less indirectly. Tires are not included among these indirect sources, as the tire equipment has a *most direct* and, therefore, a most important bearing on the distance the electric car is capable of traveling on a single charge of the battery. The gasoline machine is endowed with such a liberal surplus of driving power that the loss occasioned by tires represents but an insignificant fraction of the whole; in other words, is a totally negligible factor. Had it not been for extensive experiments carried out in connection with the electric automobile, the importance of these losses would not have been definitely known.

When all the points which contribute to both the electrical and mechanical efficiency of the car have been carefully maintained in proper working order, and still both the speed and total capacity of the battery fail to respond, the cause of the trouble may be summed up in a single word—"tires." For tires constitute the most important element in the determination of mileage and, though that fact is seldom, if ever, mentioned in connection with accounts of phenomenal mileages made on a single charge, they are the chief controlling factor. The tires usually employed for such "stunts" are specially made for the purpose and are not adapted to ordinary service. They have extremely thin walls, with the thread of the fabric reinforcement running continuously round the tread of the tire in the same direction, and are not only very likely to puncture on slight provocation, but are far from durable. The expense of employing such tires regularly would be prohibitive, particularly as they are very difficult to repair when punctured.

Kinds of Tires. *Pneumatic.* On the gasoline car, in view of the great weights and high speeds, it is solely a question of being able to make the pneumatic tire sufficiently strong to stand the unusually severe stresses to which it is subjected. To accomplish this end, the fabric structure forming the foundation of the shoe, or outer envelope of the tire, is made of various layers of heavy canvas placed at angles to one another and solidly vulcanized together. This construction makes an extremely stiff wall, as is evidenced by the difficulty in forcing a clincher type of tire on to the rim. Such a tire will yield to the minimum degree under the weight of the car or road obstacles when inflated to the proper pressure. In consequence, it absorbs considerable power. This loss is still further increased by the use of chains, studs, or similar anti-skid devices. Tests made on the recording dynamometer of the Automobile Club of America in New York City have shown that some forms of non-skid treads, particularly those employing heavy steel studs embedded in thick leather, absorbed as much as 5 horsepower per wheel to drive them. Tests showing 2 to 2½ horsepower per wheel were not uncommon, and in but few instances did the loss drop below 1 horsepower per driving wheel, regardless of the type of tire employed.

It would be manifestly out of the question to expect much in the way of mileage from an electric vehicle if handicapped in this manner. Non-skid devices of any kind are rarely seen on electric automobiles for this reason, about the only occasion when they are in evidence being in winter, when they are actually required on ice or slushy pavements to afford sufficient traction. For electric service a structure is required in which the fabric foundation is so constituted as to be able to adapt itself most readily to the distortion caused by being pressed out flat on its contact area with the road.

Solid. Viewed from one aspect, the electric has an advantage over the gasoline car. Owing to its greatly reduced speed, the owner of an electric finds the solid-rubber tire a practical option. Naturally, there can be no comparison between the riding qualities of a solid and a pneumatic tire, but as most electric-vehicle work is over smoothly paved streets, and the reasonable driver should never take obstructions except at a greatly reduced speed, the solid tire provides an amount of comfort out of proportion to its greatly reduced cost as compared with the pneumatic. The mileage radius possible with a good solid tire is about the same as that possible with the standard fabric type of pneumatic usually referred to by the electric-vehicle manufacturer as a "gasoline" type of tire, with the advantage in favor of the former in that it is free from puncture.

Test Curves. An extensive investigation has been made of the subject of tires in the past few years and considerable data compiled. Herewith is given a series of curves prepared by the builders of the Rauch and Lang electrics which will suffice to reveal the great differences in tires where the question of mileage is concerned, Fig. 78. The curves show that of the solid types experimented with the Motz tire rendered the best performance. On referring to the chart, it will be apparent that the showing of the tire in question is somewhat more uniform than the Diamond pneumatic type. At the high limit of the range is to be found the Palmer cord tire, which is a single-tube type of pneumatic with thread fabric. Bearing in mind the fact that increasing speed means a corresponding reduction in the mileage, the application of the chart is simple. Taking the Palmer tire just referred to as an example, select in the vertical column at the left marked "miles per hour," the rate at which the car is to travel. Trace this along the horizontal line representing the speed, to the right until it intersects the characteristic curve of the tire in question. At that point, rise perpendicularly to the point where the vertical line meets the top of the chart, which is divided into sections giving total mileage, by increments of 10 miles. For instance, suppose it be desired to run a car at 15 miles an hour on Palmer cord tires. Tracing the 15-mile line to the right, it will be found to intersect the Palmer-tire curve at the vertical line corresponding to 100 miles. A striking example of the manner in which mileage increases with reduced speed may be seen by tracing the 12½-mile

Fig. 78. Curves Showing Tests of Various Tires Made by Rauch and Lang Carriage Company

line to the right until it intersects the Palmer curve. It gives a total mileage of 123, or an increase of 23 per cent in the distance covered for a decrease of but 2½ miles per hour in the speed. By making a further reduction to 10 miles an hour, 130 miles could be covered on a charge. This, of course, is not due to any characteristic of the tire, but to the fact that the lower the discharge rate the greater the capacity of the battery, the phenomenal mileages given being the result of employing a tire that presents the minimum of resistance to bending.

New Tire Equipment. A little study of the foregoing will serve to reveal one of the most prolific causes of complaint on the part of uninitiated owners of electric vehicles. After wearing out one or two tires in service, they instruct the garagemen to put "new ones" in their place, or they renew the old ones by purchasing in the open market themselves. Unless informed as to the purpose for which the tires are needed, both the garagemen and the tire salesman are more than apt to supply a gasoline type of tire. A distinct falling off in the mileage radius of the car is at once noticeable, particularly if the owner has been in the habit of making use of the higher speeds. The cause is apparently inexplicable, and the result is a complaint to the manufacturer that something has gone wrong or that the car is not fulfilling the promises made for it, when, as a matter of fact, greater care should have been taken to maintain the tire equipment the same throughout.

Improper Inflation. Tires have been previously mentioned as one of the sources of power loss, and the foregoing serves to explain to a great degree why this is so. An item of considerable importance in the treatment of tires, which has not been referred to, is improper inflation. A soft tire naturally consumes more power to drive it because of the increased friction due to the greater area of the tire in contact with the ground. Such a condition is detrimental to the tire itself as it increases the amount of wear and the danger of rim cuts.

If the tire be too soft, the weight of the car will cause it to spread unduly at the point of contact with the road and this condition will be immediately noticeable. On the other hand, when the tire is pumped up too hard, the tire will stand just as if it were bearing no load. Such a condition obviously places too great a strain on both the fabric and the rubber, and is frequently the cause of tire failures that are usually assigned to a totally different reason. With its ordinary load of passengers, the electric should only cause a slight flattening of the tires at the tread, experiment showing that the best results are obtained when the increase in the width of the tire is about 20 to 25 per cent, that is, a 3-inch tire when properly inflated should measure approximately $3\frac{5}{8}$ inches across its horizontal diameter at the part in contact with the road. Of course, the surest method of avoiding improper inflation is a tire pressure gage.

ELECTRIC INDICATING INSTRUMENTS AND THEIR USES

Volt-Ammeter. With an electric, it is important to watch the volt-ammeter. An example of this type of combined instrument is shown by the accompanying illustration, Fig. 79. It will be noted that the indicating needle of the ammeter does not go to the end of its scale, but reads both ways, the scale to the left hand being for the charging current, and that to the right for the discharging current. These instruments are manufactured in various forms, one type very much in use having the voltmeter and ammeter

Fig. 79. General Electric Volt-Ammeter

scales parallel in a vertical plane. Some also have the voltmeter scale so divided that the reading of the individual cells may be taken.

By becoming familiar with the readings of the instrument and by realizing their significance, the driver of an electric automobile is in a position not only to judge whether the battery is giving the proper service, but he also has an accurate gage on the condition of the running gear and transmission of the vehicle itself. The instrument is capable, therefore, of giving ample warning by its deflections of any weakness, electrical or mechanical.

Ampere-Hour Meter. While the volt-ammeter affords a constant indication of the working of the battery, as well as the efficiency of the transmission, and is accordingly indispensable, it does not permit of the direct reading of the state of charge nor indicate off-hand how much of the energy has been utilized and how much remains available at any given time. For this purpose the Sangamo ampere-hour meter has been developed and generally adopted by the builders of both pleasure and commercial electric cars.

Method of Use. To keep the battery plates in good working condition, it is necessary to give the battery a certain amount of charge, so that under normal conditions more ampere hours must be put into the battery than can be taken out of it. This difference is the overcharge, and it must be taken into account in figuring the number of ampere hours in a battery available for useful work. Since the only information desired by the driver is how much energy can be taken from the battery, the Sangamo ampere-hour meter is designed to compensate for the overcharge, and indicates at all times the current available without the necessity of resetting the pointer every time the battery is charged.

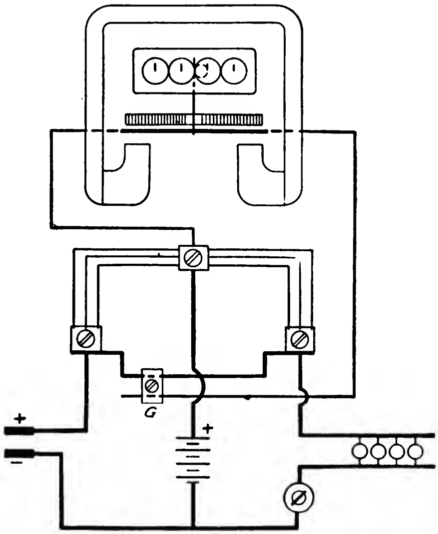


Fig. 80. Circuit Diagram of Differential Shunt Type Sangamo Ampere-Hour Meter

This is accomplished by means of a differential shunt, as shown by the diagram, Fig. 80. Two shunts are employed, and the relative value of their resistance is adjustable by means of the sliding connection *G*, so that the meter can be made to run slow on charge or fast on discharge, as desired. The usual method is to allow the meter to register less than the true amount on charge and the exact amount on discharge, the difference representing the loss in the battery, or overcharge.

Readjusting the Meter. However, over long periods of use under varying conditions, the battery losses will vary and in time the meter and battery will get out of step. Therefore, it is good practice to give the battery an extra overcharge at stated intervals and reset the meter, a simple device being provided for this purpose. Moreover, in vehicle work the batteries are frequently subjected to excessively high discharge rates and, under such conditions, the battery suffers an actual loss of capacity, which requires further compensation, as otherwise the meter will give a false indication of the number of ampere hours available. The variation in the capacity of the battery with its discharge rate is shown by the curves, Fig. 81.

In the Edison battery, the transfer of active material does not take place between the electrolyte and the plates, but from one

Fig. 81. Variation of Useful Ampere-Hour Capacity of Lead Battery with Discharge Rate

plate to the other, as in the ordinary electrolytic cell, commonly known as a primary battery. Therefore, the specific gravity of the electrolyte does not change with the state of charge and, consequently, the only direct way to measure the state of charge is with an ampere-hour meter, the hydrometer being of no use. But the loss of capacity due to high discharge rates is not a characteristic of the alkaline cell as it is with the lead type, so that an Edison battery does not require a compensated meter as just described. However, the drop in voltage of the Edison cell under high discharge rates is such that, from the user's viewpoint, the result is practically the same as with the lead-plate cell.

GLOSSARY

GLOSSARY

THE following glossary of automobile terms is not intended in any sense as a dictionary and only words used in the articles themselves have been defined. The definitions have been made as simple as possible, but if other terms unfamiliar to the reader are used, these should be looked up in order to obtain the complete definition.

A

A. A. A.: Abbreviation for American Automobile Association.

Abrasive: Any hard substance used for grinding or wearing away other substances.

Absorber, Shock: See "Shock Absorber".

Accelerate: To increase the speed.

Acceleration: The rate of change of velocity of a moving body. In automobiles, the ability of the car to increase in speed. Pickup.

Accelerator: Device for rapid control of the speed for quick opening and closing of the throttle. Usually in the form of a pedal, spring returned, the minimum throttle opening being controlled by the setting of the hand throttle.

Accessory: A subordinate machine that accompanies or aids a more important machine; as, a horn is an accessory of an automobile.

Accumulator: A secondary battery or storage battery. It usually consists of chemically prepared lead plates combined with an acid solution. Upon being charged with an electric current from a primary source, a chemical change takes place which enables the plates in their turn to give a current of electricity when used as a source of power, the plates at the same time returning to their original chemical state.

Acetone: A liquid obtained as a by-product in the distillation of wood alcohol, and used in connection with reservoirs for storing acetylene for automobile lights, as it dissolves many times its own volume of acetylene gas.

Acetylated Alcohol: Alcohol which has been denatured by the addition of acetylene, which also increases its fuel value. See "Alcohol, Denatured".

Acetylene: A gaseous hydrocarbide used as an illuminant; is usually generated for that purpose by the action of water on calcium carbide.

Acetylene Generator. A closed vessel in which acetylene gas may be produced by the action of water on calcium carbide and which supplies the gas under uniform pressure.

Acetylene Lamp: A lamp which burns acetylene gas.

Acetylite: Calcium carbide which has been treated with glucose. It is used to obtain a more uniform and slower production of acetylene gas than can be obtained with the untreated calcium carbide.

Acid: In connection with automobiles the term usually means the liquid or electrolyte used in the storage battery. See "Electrolyte".

Acid Cure. Method of rapid vulcanization of rubber without heat. Used in tire repairs. The agent is sulphur chloride.

Acidimeter. An instrument for determining the purity of an acid.

Active Material: Composition in grids that forms plates of a storage battery. It is this material in which the chemical changes occur in charging and discharging.

Adapter: Device by which one type of lamp burner may be used instead of the one for which the lamp was designed. Usually a fitting by which a gas or oil lamp may be converted into an electric lamp.

Adhesion: That property of surfaces in contact by virtue of which one of them tends to stick to the other. It is used as synonymous with friction. The adhesion of wheels acts to prevent slipping.

Adjustment: The slackening or tightening up of parts to compensate for wear, reduce friction, or secure better contact.

Admission: In a steam engine, the letting in of the steam to the cylinder; in gas engine, the letting in of mixture of gas and air to the cylinder.

Advanced Ignition: Usually called *advancing the spark.* Setting the spark of an internal-combustion motor so that it will ignite the charge at an earlier part of the stroke.

Advance Sparking: A method by which the time of occurrence of the ignition spark may be regulated, by completing the electric circuit at the earlier period.

Advancing the Spark: See "Advanced Ignition".

Aerodynamics: The science of atmospheric laws, i.e., the effects produced by air in motion.

After-Burning: Continued burning of the charge in an internal-combustion engine after the explosion.

After-Firing: An explosion in the muffler or exhaust passages.

A-h: Abbreviation for *ampere hour.*

Air Bottle: A portable container holding compressed air or carbon dioxide for tire inflation.

Air-Bound: See "Air Lock".

Air Compressor: A machine for supplying air under pressure for inflating tires, starting the motor, etc.

Air Cooled: Cooled by air direct. Usually referring to the cylinder of an engine, whose heat caused by the combustion within it is carried away by air convection and radiation.

Air Cooling: A system of dispersing by air convection the heat generated in the cylinder of an internal-combustion motor.

Air Intake: An opening in a carbureter to admit air.

Air Leak: Entrance of air into the mixture between carbureter and cylinder.

Air Lock: Stoppage of circulation in the water or gasoline system caused by a bubble of air lodging in the top of a bend in the pipe.

Air Pump: A pump operated by the engine or by hand to supply air pressure to the oil tank or gasoline tank; sometimes called *pressure pump*.

Air-Pump Governor: A device to regulate the speed of the air pump so as to give a uniform air pressure.

Air Resistance: The resistance encountered by a surface in motion. This resistance increases as the square of the speed, which makes it necessary to employ four times as much power in order to double a given speed.

Air Tube: See "Pneumatic Tire".

Airless Tire: Name of special make of non-puncturable resilient tire.

A. L. A. M.: Abbreviation for Association of Licensed Automobile Manufacturers, now out of existence.

A. L. A. M. Horsepower Rating: The horsepower rating of an automobile found by the standard horsepower formula approved by the Association of Licensed Automobile Manufacturers. Since the dismemberment of this organization, the formula is usually called the S.A.E. rating. This formula is h.p. = bore of cylinder (in inches) squared × No. of cylinders ÷ 2.5, at a piston speed of 1000 r.p.m.

Alarm, Low-Water: See "Low-Water Alarm".

Alcohol: A colorless, volatile, inflammable liquid which may be used as fuel for internal-combustion engines.

Alcohol, Denatured: Alcohol rendered unfit for drinking purposes by the addition of wood alcohol, acetylene, and other substances.

Alignment: The state of being exactly in line. Applied to crankshafts and transmission shafts and to the parallel conditions of the front and rear wheels on either side.

Alternating Current: Electric current which alternates in direction periodically.

Ammeter: An instrument to measure the values of current in an electric circuit directly in amperes. Also called *ampere meter*.

Amperage: The number of amperes, or current strength, in an electric circuit.

Ampere: The practical unit of rate of flow of electric current, measuring the current intensity.

Ampere Hour: A term used to denote the capacity of a storage battery or closed-circuit primary battery. A battery that will deliver three amperes for six hours is said to have an eighteen-ampere-hour capacity.

Ampere Meter: See "Ammeter".

Angle-Iron Underframe: An underframe constructed of steel bars whose cross section is a right angle.

Anneal: To make a metal soft by heating and cooling. To draw the temper of a metal.

Annular Gear: A toothed wheel upon which the teeth are formed on the inner circumference.

Annular Valve: A circular valve having a hole in the center.

Annunciator: An installation of electric signals or a speaking tube to allow the passengers in an enclosed car to communicate with the driver.

Anti-Freezing Solution: A solution to be used in the cooling system to prevent freezing in cold weather; any harmless solution whose freezing point is somewhat below that of water may be used.

Anti-Friction Metal: Various alloys of tin and lead used to line bearings, such as Babbitt metal, white metal, etc.

Anti-Skid Device: Any device which may be applied to the wheels of a motorcar to prevent their skidding, such as tire coverings with metal rivets in them, chains, etc.

Apron: Extensions of the fenders to prevent splashing by mud or road dirt.

Armature: In dynamo-electric machines, the portion of a generator in which the current is developed, or in a motor, the portion in which the current produces rotation. In most generators in automobile work, the armature is the rotating portion. In magnetic or electromagnetic machines the armature is the movable portion which is attached to the magnetic poles.

Armature Core: The iron portion of the armature which carries the windings and serves as part of the path for the magnetic flux.

Armature Shaft: The shaft upon and with which the armature rotates.

Armature Winding: Electrical conductors, usually copper, in an armature, and in which the current is generated, in case of a generator, or in which they produce rotation in a motor.

Artillery Wheel: A wheel having heavy wood spokes.

Aspirating Nozzle: An atomizing nozzle to make the liquid passing through it pass from it in the form of a spray.

Assembled Car: A car whose chief parts, such as engine, gearset axles, body, etc., are manufactured by different parts makers, only the final process of putting them together being carried out in the car-making plant.

Atmospheric Line: A line drawn on an indicator diagram at a point corresponding with the pressure of the atmosphere.

Atmospheric Valve: See "Suction Valve".

Atomizer: A device by which a liquid fuel, such as gasoline, is reduced to small particles or to a spray; usually incorporated in the carbureter.

Auto: (1) Popular abbreviation for automobile. (2) A Greek prefix meaning self.

Auto-Bus: An enclosed motor-driven public conveyance, seating six or more people; usually has a regular route of travel.

Autocar: A motorcar or automobile; a trade name for a particular make of automobile.

Auto-Cycle: See "Motorcycle".

Autodrome: A track especially prepared for automobile driving, particularly for races.

Autogenous Welding: See "Welding, Autogenous".

Auto-Igniter: A small magneto generator or dynamo for igniting gasoline engines, the armature of which is connected with the flywheel by gears or by friction wheels, so that electric current is supplied as long as the engine revolves.

Autoist: One who uses an automobile.

Automatic Carbureter: A vaporizer or carbureter for gasoline engines whose action is entirely automatic.

Automatic Cut-Out: See "Cut-Out, Automatic".

Automatic Spark Advance: Automatic variation of the instant of spark occurrence in the cylinder. Mechanical advancing and retarding of the spark to correspond with and controlled by variations in crankshaft speed.

Auto-Meter: Trade name for special make of combined speedometer and odometer.

Automobile: A motor-driven vehicle having four or more wheels. Some three-wheeled vehicles are properly automobiles, but are usually called *tricars.*

Automobilist: The driver or user of an automobile.

Auto Truck: A motor-driven vehicle for transporting heavy loads; a heavy commercial car.

Auxiliary Air Valve: Valve controlling the admission of air through the auxiliary air intake of a carbureter.

Auxiliary Air Intake: Opening through which additional air is admitted to the carbureter at high speeds.

Auxiliary Exhaust: Ports cut through cylinder walls to permit exhaust gases to be released from the cylinder when uncovered by the piston. These are sometimes used as an additional scavenging means for the regular exhaust valves.

Auxiliary Fuel Tank: See "Fuel Tank, Auxiliary".

Auxiliary Spark Gap: See "Spark Gap, Outside".

Axle: The spindle with which a wheel revolves or upon which it revolves.

Axle, Cambered: An axle whose ends are slanted downwards to camber the wheels.

Axle, Channel: An axle which is U-shaped in cross section.

Axle, Dead: Solid, fixed, stationary axle. An axle upon which the wheels revolve but which itself does not revolve.

Axle, Dropped: An axle in which the central portion is on a lower level than the ends.

Axle, Floating: A full-floating axle. A live axle in which the shafts support none of the car weight, but serve only to turn the wheels.

Axle, I-Beam: An axle whose cross section is in the shape of the letter I.

Axle, Live: An axle in which are comprised the driving shafts that carry the power of the motor to the driving wheels.

Axle, Semi-Floating: A live axle in which the driving shafts carry a part of the car weight as well as transmitting the driving torque.

Axle, Three-Quarters Floating: A live axle in which the shafts carry a part of the weight of the car, but less than that carried by the semi-floating axle. It is intermediated by a floating axle and the semi-floating axle.

Axle, Trussed: An axle in which downward bending is prevented by a truss.

Axle, Tubular: An axle formed of steel tubing. Usually applied to the front axles, but sometimes used in referring to tubular shafts of rear axles.

Axle Casing: That part of a live axle that encloses the driving shafts and differential and driving gears. Axle housing.

Axle Housing: See "Axle Casing".

Axle Shaft: The member transmitting the driving torque from the differential to the rear wheels.

B

Babbitt: A soft metal alloy used for lining the bearings of shafts.

Back-Firing: An explosion of the mixture in the intake manifold or carbureter caused by the communication of the flame of explosion in the cylinders. Usually due to too weak a mixture. Popping.

Back Kick: The reversal of direction of the starting, caused by back-firing.

Backlash: The play between a screw and nut or between the teeth of a pair of gear wheels.

Back Pressure: Pressure of the exhaust gases due to improper design or operation of the exhaust system.

Baffle Plate: A plate used to prevent too free movement of a liquid in the container. In a gas engine cylinder, a plate covering the lower end of the cylinder to prevent too much oil being splashed into it. The plate has a slot through which the connecting rod may work.

Balance Gear: See "Differential Gear".

Balancing of Gasoline Engines: Insuring the equilibrium of moving parts to reduce the vibration and shocks.

Ball-and-Socket Joint: A joint in which a ball is placed within a socket recessed to fit it, permitting free motion in any direction within limits.

Ball Bearing: A bearing in which the rotating shaft or axle is carried upon a number of small steel balls which are free to turn in annular paths, called *races.*

Balladeur Train: A French name for a sliding change-speed gear.

Barking: The sound made by the explosions caused by after-firing.

Base Bearing: See "Main Bearing".

Base Explosion: See "Crankcase Explosion".

Battery: A combination of primary or secondary cells, as dry cells or storage cells.

Battery, Dry: See "Dry Battery".

Battery, Storage: See "Accumulator".

Battery Acid: The electrolyte in a storage battery.

Battery-Charging Plug: Power terminals to which the leads of a storage battery may be connected for charging the battery.

Battery Gage: (1) Voltmeter or ammeter or voltammeter for testing the specific gravity of the electrolyte in a secondary battery.

Battery Syringe: A syringe used to draw out a part of the electrolyte or solution from a storage battery cell to test its density and specific gravity.

Baumè: A scale indicating the specific gravity or density of liquids and having degrees as units. Gasoline of a specific gravity of .735 has a gravity of 61 degrees Baumé.

Bearing: A support of a shaft upon which it may rotate.

Bearing, Annular Ball: A ball bearing consisting of two concentric rings, between which are steel balls.

Bearing, Ball: A bearing in which the rotating shaft and the stationary portion of the bearings are separated from sliding contact by steel balls. A steel collar fitted to the shaft rolls upon the balls, which in turn roll upon steel collar attached to the stationary portion of the bearing.

Bearing, Cup and Cone: A ball bearing in which the balls roll in a race, which is formed between a cone-shaped fixed collar and a cup-shaped shaft collar.

Bearing, Main: The bearing in which rotates the crankshaft of an engine.

Bearing, Plain: A bearing in which the rotating shaft is in sliding contact with the bearing supporting it.

Bearing, Radial: A bearing designed to resist loads from a direction at right angles to the axis of the shaft.

Bearing, Roller: A bearing in which the journal rests upon, and is surrounded by, hardened steel rollers which revolve in a channel or race surrounding the shaft.

Bearing, Thrust: A bearing designed to resist loads or pressures parallel with the axis of the shaft.

Bearing Cap: That portion of a plain bearing detachable from the stationary portion, and which holds the bearing bushing and shaft.

Bearing Surface: The projected area of a bearing in a perpendicular plane to the direction of pressure.

Beau de Rochas Cycle: The four-stroke cycle used in most internal-combustion engines. This cycle was proposed by M. Beau de Rochas and put into practical form by Dr. Otto. See "Four-Cycle".

Belt and Clutch Dressing: A composition to be applied to belts and clutches to prevent them from slipping.

Belt Drive: A method of transmitting power from the engine to the countershaft or jack shaft by means of belts.

Benzine: A petroleum product having a specific gravity between that of kerosene and gasoline. Its specific gravity is between 60 degrees and 65 degrees Baumé.

Benzol: A product of the distillation of coal tar. Coal tar benzine. Used as a rubber solvent and in Europe as a motor fuel.

Berline Body: A limousine automobile body having more than two seats in the back part.

Bevel-Gear: Gears the faces of whose teeth are not parallel with the shaft, but are on a beveled edge of the gear wheel.

Bevel-Gear Drive: Method of driving one shaft from another at an angle to the first. The chief method of transmitting the drive from the propeller shaft to the rear axle shafts.

B. H. P.: An abbreviation for brake horsepower.

Bicycle: A two-wheeled vehicle propelled by the pedaling of the rider.

Binding Posts: See "Terminals".

Bleeder: A by-pass in the' sight-feed of a mechanical oiling system by which the oil delivered through that feed is allowed to pass out instead of going to the bearings.

Blister: A defect in tires caused by the separation of the tread from the fabric.

Block Chain: A chain used in automobiles, bicycles, etc., of which each alternate link is a steel block.

Blow-Back: The backward rushing of the fuel gas through the inlet valve into the carbureter.

Blower Cooled: A gas engine cooled by positive circulation of air maintained by a blower.

Blow-Off: A blow-out caused by the edge of the bead of tire becoming free from the rim and allowing the tube to protrude through the space thus formed.

Blow-Out: The rupture of both the inner tube and outer casing of a pneumatic tire.

Blow-Out Patch: See "Patch, Tire Repair".

Body: (1) The superstructure of an automobile; the part that resembles and represents the body of a horse-drawn vehicle. (2) In oils, the degree of viscosity. The tendency of drops of oils to hang together.

Body Hangers: Attachments to or extensions of the frame for holding the body of the vehicle. They should be properly called frame hangers.

Boiler: A vessel in which water is evaporated into steam for the generation of power.

Boiler, Fire-Tube: A tubular steam boiler in which the end plates are connected by a number of open ended thin tubes, the spaces around which are filled with water, the hot gases passing through the tubes.

Boiler, Flash: A steam boiler in which steam is generated practically instantaneously. There is practically no water or steam stored in the boiler. A flash generator.

Boiler, Water-Tube: A steam boiler in which the water is carried in metal tubes, around which the hot gases circulate.

Boiler Alarm: See "Low-Water Alarm".

Boiler Covering: A non-conducting substance used as a covering for boilers to prevent loss of heat by radiation.

Boiler-Feed Pump: An automatic and self-regulating pump for supplying a boiler with feed water.

Boiler-Feed Regulator: A device to make the feed-water supply of the boiler automatic.

Bonnet: (1) The hood or metallic cover over the front end of an automobile. See "Hood". (2) The cover over a pump-valve box, or a slide-valve casing. (3) A cover to enclose and guide the tail end of a steam-engine-valve spindle or the cover of a piston-valve casing. (4) The pan underneath the engine in an automobile.

Boot: A covering to protect joints from dirt and water or to prevent the leakage of grease. (2) Space provided for baggage at the rear of a car.

Bore: The inside diameter of the cylinder.

Boss: An enlarged portion of a part to give a point for attachment of another part.

Bottom: The meshing of gears without clearance.

Bow Separator: A part to prevent chafing of the bows of a top when folded.

Boyle's Law of Gases: A law defining the volume and pressure of gases at constantly maintained temperatures. It states that the volume of a gas varies inversely as the pressure so long as the temperature remains the same; or, the pressure of a gas is proportional to its density.

Brake: An apparatus for the absorption of power by friction, and by clamping some portion of the driving mechanism to retard or stop the forward motion of the car.

Brake, Air-Cooled: A brake whose parts are ridged to present a large surface for transferring to the air the frictional heat generated in them.

Brake, Band: A brake which contracts upon the outside of a drum attached to some part of the driving mechanism.

Brake, Constricting Band: A form of brake applied by tightening a band around a pulley or drum.

Brake, Differential: A brake acting upon the differential gear.

Brake, Double-Acting: A brake which will hold when the drum is rotating in either direction.

Brake, Drum, and Band: See "Brake, Band".

Brake, Emergency: A brake intended to be used in case the service brake does not act to a sufficient extent.

Brake, Expanding-Band: A drum brake in which the braking force is exerted by a band forced outward against the inner rim of a pulley.

Brake, External-Contracting: A brake consisting of a drum affixed to a rotating part, the outer surface of which is encircled by a contracting band.

Brake, Foot: A brake designed to be operated by the driver's foot. A pedal brake. Usually the service brake.

Brake, Front-Wheel: A brake designed to operate on the front wheels of the car.

Brake, Gearset: A brake designed to act on the transmission shaft and attached to the gearbox.

Brake, Hand: A brake designed to be operated by means of a hand lever. Usually the emergency brake.

Brake, Hub: A brake consisting of a drum secured to one of the wheels. This is the usual type.

Brake, Internal: A brake in which an expanding mechanism is contained within a rotating drum, the expansion bringing pressure to bear on the drum.

Brake, Internal-Expanding: A brake consisting of a drum, against the inside of which may be expanded a band or a shoe.

Brake, Motor: A brake in an electric vehicle which acts upon the armature shaft of the motor.

Brake, Service: A brake designed to be used in ordinary driving. It is usually operated by the driver's foot.

Brake, Shoe: A brake in which a metal shoe is clamped against a revolving wheel.

Brake, Transmission: A brake designed to act upon the transmission shaft.

Brake, Water-Cooled: A brake through which water may be circulated to carry off the frictional heat.

Brake Equalizer: A mechanism applied to a system of brakes operated in pairs to assure that each brake shall be applied with equal force.

Brake Horsepower: The horsepower supplied by an engine as shown by the application of a brake or absorption dynamometer.

Brake Housing: A casing enclosing the brake mechanism.

Brake Lever: The lever by which the brake is applied tc the wheel.

Brake Lining: The wearing surface of a brake; usually arranged to be easily replaced when worn.

Brake Pedal: Pedal by which the brake is applied.

Brake Pull Rod: A rod transmitting the tension from the lever or pedal to the movable portion of the brake proper.

Brake Ratchet: A device by which the brake lever or brake pedal can be set in position and retained there; usually consists of a notched quadrant with which a movable tongue on the lever head or pedal engages.

Brake Rod: The rod connecting the brake lever with the brake.

Brake Test: A test of a motor by means of a dynamometer to determine its power output at different speeds.

Braking Surface: The surface of contact between the rotating and stationary parts of a brake.

Braze: To join by brazing.

Brazing: The process of permanently joining metal parts by intense heat.

Breaker Strip: A strip of canvas placed between the tread and body of an outer tire casing to increase the wearing qualities.

Breather: An opening in the crankcase of a gas engine to permit pressure therein to remain equal during the movement of the pistons.

British Thermal Unit. The ordinary unit of heat. It is that quantity of heat required to raise the temperature of one pound of pure water one degree Fahrenheit at the temperature of greatest density of water.

Brougham Body: A closed-in automobile body having windows at the side doors, and in front, but with no extension of the roof over the front seat.

Brush Holder: In electrical machinery, an arrangement to hold one end of a connection flexible in contact with a moving part of the circuit.

B. T. U.: Abbreviation for *British Thermal Unit.*

Buckboard: A four-wheeled vehicle in which the body and springs are replaced by an elastic board or frame

Buckling: Irregularities in the shape of the plates of storage cells following a too rapid discharge.

Bumper: (1) A contrivance at the front of the car to minimize shock of collision; it consists of plungers working in tubes and gaining elasticity from springs. (2) A bar placed across the end of a car, usually the front end, to take the shock of collision and thus prevent damage to the car itself. A rubber or leather pad interposed between the axle and frame of a car.

Burner, "Torch" Igniter: A movable auxiliary vaporizer for starting the fire in steam automobile burners.

Bushing: A bearing lining. Usually made of anti-friction metal and capable of adjustment or renewal.

Bus-Pipe: A manifold pipe.

Butterfly Valve: A valve inserted in a pipe, usually circular and of nearly the same diameter as the pipe, designed to turn upon a spindle through its diameter and thus shut off or permit flow through the pipe. Usually employed for throttle valves and carbureter air valve .

Buzzer: (1) A name sometimes applied to the vibrator or trembler of a jump-spark ignition coil. (2) A device used in place of a horn, and consisting of a diaphragm which is made to vibrate rapidly by an electromagnet.

By-Pass: A small valve to provide a secondary passage for fluids passing through a system of piping.

C

C: Abbreviation for a centigrade degree of temperature.

Calcium Carbide: A compound of calcium and carbon used for the generation of acetylene by the application of water.

Calcium Chloride: A salt which dissolved in water is used as an anti-freezing solution.

Cam: A revolving disk, irregular in shape, fixed on a revolving shaft so as to impart to a rod or lever in contact with it an intermittent or variable motion.

Cam, Exhaust: A cam designed to operate the exhaust of an engine.

Cam, Ignition: A cam designed to operate the ignition mechanism. In magnetos it operates the make-and-break device.

Cam, Inlet: A cam designed to operate the inlet valve of an engine.

Camber: (1) The greatest depth of curvature of a surface. (2) The amount of bend in an axle designed to incline the wheels.

Camber of Spring: The maximum distance between the upper and lower parts of a spring under a given load.

Cambered Frame: A narrowing of the front of a motor car to permit of easier turning.

Cam Gear: The gear driving the camshaft of a gas engine. In a four-cycle engine this is the same as the two-speed gear.

Camshaft: A shaft by which the valve cams are rotated; also known as the *secondary shaft.*

Camshaft, Overhead: The camshaft carried along or above the cylinder heads, to operate overhead valves.

Camshaft Gears: The gears or train of gears by which the camshaft is driven from the crankshaft. Half-time gears, timing gears, distribution gears.

Canopy: An automobile top that can not be folded up.

Capacity of a Condenser: The quality of electricity or electrostatic charge. Of a storage battery, the amount of electricity which may be obtained by the discharge of a fully charged battery. Usually expressed in ampere hours.

Cape Hood: An automobile top which is capable of either being folded up or extended.

Car: A wheeled vehicle.

Carbide: See "Calcium Carbide".

Carbide Feed: A type of acetylene generator in which the calcium carbide is fed into the water.

Carbon Bridge: Formation of soot between points of spark plug.

Carbon Deposit: A deposit upon the interior of the combustion chamber of a gasoline engine composed of carbonaceous particles from the lubricating oil, too rich fuel mixture, or road dust.

Carbon Remover: A tool or solution for removing carbon deposits from the cylinder, piston, or spark plug of a gasoline engine.

Carbonization: The deposit of carbon.

Carbureter: An appliance for mixing an inflammable vapor with air. It allows air to be passed through or over a liquid fuel and to carry off a portion of its vapor mixed with the air, forming an explosive mixture.

Carbureter, Automatic: A carbureter so designed that either the air supply alone or both the air and gasoline supplies are regulated automatically.

Carbureter, Constant-Level: A carbureter the level of the gasoline in which is maintained automatically at a constant height. A float-feed carbureter.

Carbureter, Exhaust-Jacketed: A carbureter whose mixing chamber is heated by the circulation of exhaust gas.

Carbureter, Multiple-Jet: A carbureter having more that one spray nozzle or jet.

Carbureter, Water-Jacketed: A carbureter whose mixing chamber is heated by the circulation of water from the cooling system.

Carbureter Float: A buoyant part of the carbureter designed to float in the gasoline and connected to a valve controlling the flow from the fuel tank, designed to maintain automatically a constant level of the gasoline in the flow chamber.

Carbureter Float Chamber: A reservoir containing the float and in which a constant level of fuel is maintained.

Carbureter Jet: The opening through which liquid fuel is ejected in a spray from the standpipe of a carbureter nozzle.

Carbureter Needle Valve: A valve controlling the flow of fuel from the flow chamber to the standpipe.

Carbureter Nozzle: See "Carbureter Jet".

Carbureter Standpipe: A vertical pipe carrying the nozzle.

Carburetion: The process of mixing hydrocarbon particles with the air. The action in a carbureter.

Cardan Joint: A universal joint or Hooke's coupling.

Cardan Shaft: A shaft provided with a Cardan joint at each end.

Casing: The shoe or outer covering of a double-tube automobile tire.

Catalytic Ignition: See "Ignition,Catalytic".

Cell: One of the units of a voltaic battery.

Cell, Dry: See "Dry Cell".

Cell, Storage: See "Accumulator".

Cellular Radiator: A radiator in which the openings between the tubes are in the form of small cells. The same as a *honeycomb radiator*.

Cellular Tire: A cushion tire which is divided into compartments or cells.

Center of Gravity: That point in a body, which, if the body were suspended freely in equilibrium, would be the point of application of the resultant forces of gravity acting upon the body.

Center Control: The location of the gear-shift and emergency brake levers of a car in the center of a line parallel to the front of the front seat.

Centigrade Scale: The thermometer scale invented by Celsius. Used universally in scientific work.

Century. In automobiling, a hundred-mile run.

C. G. S. System: Abbreviation for centimeter-gram-second system of measurement; the standard system in scientific work.

Chain, Drive: A heavy chain by which the power from the motor may be transmitted to the rear wheels of an automobile.

Chain, Roller: A sprocket chain, the cross bars of whose links are rollers.

Chain, Silent: See "Silent Chain".

Chain, Tire: A small chain fastened about the tire to increase traction and prevent skidding.

Chain Wheel: A sprocket wheel for the transmission chains of a motor-driven vehicle.

Change-Speed Gear: See "Gear, Change-Speed".

Change-Speed Lever: See "Lever, Change-Speed".

Charge: The fuel mixture introduced into the cylinder of a gas engine. The act of storing up electric energy in an accumulator.

Charging: The passing of a current of electricity through a storage cell.

Charles' Law of Gases: See "Gases, Gay Lussac's Law of".

Chassis. The mechanical features of a motor car assembled, but without body, fenders, or other superstructure not essential to the operation of the car.

Chauffeur: In America this term means the paid driver or operator of a motor car. The literal translation from the French means stoker or fireman of a boiler.

Check. Steering: See "Steering Check".

Check Valve: An automatic or non-return valve used to control the admission of feed water in the boiler, etc.

Choke: The missing of explosions or poor explosions due to too rich mixture.

Circuit, Primary: See "Primary Circuit".

Circuit, Secondary: See "Secondary Circuit".

Circuit Breaker: A device installed in an electric circuit and intended to open the circuit automatically under predetermined conditions of current flow.

Circulating Pump: A pump which keeps a liquid flowing through a series of pipes which provides a return circuit. In a motor car, water and oil circulation is maintained by circulating pump.

Circulation Pump: A mechanically operated pump by which the circulation of water in the cooling system is maintained.

Circulating System: The method or series of pipes through which a continuous flow of water or oil is maintained and in which the liquid is sent through the system over and over.

Clash Gear: A sliding change-speed gear.

Clearance: (1) The distance between the road surface and the lowest part of the under-body of an automobile. (2) The space between the piston of an engine when at the extremity of its stroke, and the head of the cylinder.

Clearance, Valve: See "Valve Clearance".

Clearance Space: The space left between the end of the cylinder and the piston plus the volume of the ports between the valves and the cylinder.

Clevis: The fork on the end of a rod.

Clevis Pin: The pin passing through the ends of a clevis and through the rod to which the clevis is joined.

Clincher Rim: A wheel rim having a turned-in edge on each side, forming channels. Into this the edge or flange of the tire fits, the air pressure within locking the tire and rim together.

Clincher Tire: A pneumatic tire design to fit on a clincher rim.

Clutch: A device for engaging or disconnecting two pieces of shafting so that they revolve together or run free as desired.

Clutch Cone: A clutch whose engaging surfaces consist of the outer surface of the frustrum of one cone and the inner surface of the frustrum of another.

Clutch, Contracting-Band: A clutch consisting of a drum and band, the latter contracting upon the former.

Clutch, Dry-Plate: A clutch whose friction surfaces are metal plates, not lubricated.

Clutch, Expanding-Band: A clutch consisting of a drum and band, the latter expanding within the former.

Clutch, Jaw: A clutch whose members lock end to end by projections or jaws in one entering corresponding depressions in the other.

Clutch, Multiple-Disk: A clutch whose friction surfaces are metal plates or disks, alternate disks being attached to one member and the rest to the other member of the drive.

Clutch Brake: A device designed to stop automatically the rotation of the driven member of a clutch after disengagement from the driving member.

Clutch Lining: The wearing surface of a clutch. This may be easily removed and replaced when worn.

Clutch Pedal: The pedal by which the clutch may be disengaged, engagement being obtained automatically by means of a spring.

Clutch Spring: A spring arranged to either hold a clutch out of gear or throw it into gear.

Coasting: The movement of the car without constant applications of the motive power, as in running downhill with the aid of gravity or on the level, through the momentum obtained by previous power applications.

Cock, Priming: A small cock, usually operated by a lever, for admitting gasoline to the carbureter to start its action.

Coil, Induction: See "Spark Coil".

Coil, Non-Vibrator: A coil so designed that it will supply a sufficient spark for the ignition with one make and break of the primary circuit.

Coil, Primary: See "Primary Coil".

Coil, Secondary: See "Secondary Spark Coil".

Coil, Spark: See "Spark Coil".

Coil, Vibrator: A spark coil with which is incorporated an electromagnetic vibrator to make and break the primary circuit.

Coil Vaporizer: An auxiliary vaporizer to assist in starting a steam boiler. It is a coil of tubing into which liquid gasoline is admitted and burned to start the generation of gas in the main burner.

Cold Test: The temperature in degrees Fahrenheit at which a lubricant passes from the fluid to the solid state.

Combustion Chamber: That part of an explosive motor in which the gases are compressed and then fired, usually by an electric spark.

Combustion Space: See "Clearance" and "Clearance Space".

Commercial Car: A motor-driven vehicle for commercial use, such as transporting passengers or freight.

Commutator: In the ignition system of an explosive motor, the commutator is a device to automatically complete the circuit of each of a number of cylinders in succession.

Commutator of Dynamo or Motor: That part of a dynamo which is designed to cause the alternating current produced in the armature to flow in one direction in the external circuit; in a motor, to change the direct current in the external circuit into alternating current.

Compensating Carbureter: An automatic attachment to a carbureter controlling either air or fuel admission, or both, so that the proportion of one to the other is always maintained under any vibration of power required.

Compensating Gear: See "Differential Gear".

Compensating Joint: See "Universal Joint".

Compound Engine: A multiple-expansion steam engine in which the steam is expanded in two stages, first in the high-pressure cylinder and then in the low-pressure cylinder.

Compression: (1) That part of the cycle of a gas engine in which the charge is compressed before ignition; in a steam engine it is the phase of the cycle in which the pressure is increased, due to compression of the exhaust steam behind the piston. (2) The greatest pressure exerted on the gas in the compression chamber.

Compression Chamber: The clearance volume above the piston in a gas engine; also called "Compression Space".

Compression Cock: See "Compression-Relief Cock".

Compression Line: The line on an indicator diagram corresponding to the phase of the cycle in which the gas is compressed.

Compression-Relief Cock: A small cock by which the compression chamber of an internal-combustion motor may be opened to the air and thus allow the compression in the cylinder to be relieved to facilitate turning by hand, or *cranking*.

Compression Space: See "Compression Chamber".

Compression Tester: A small pressure gage by which the degree of compression of the mixture in a gas-engine cylinder may be tested.

Compressor, Air: See "Air Compressor".

Condenser: (1) In a steam motor, an apparatus in which the exhaust steam is converted back into water. (2) A device for increasing the electric capacity of a circuit. Used in an ignition circuit to increase the strength of the spark.

Cone Bearing: A shaft bearing in which the shaft is turned to a taper and the journal turned to a conical or taper form.

Cone Clutch: A friction clutch in which there are two cones, one fitting within the other.

Connecting Rods: The part of an engine connecting the piston to the crank, and by means of which a reciprocating motion of the piston is converted into the rotary motion of the crank.

Constricting Band Brake: See "Brake, Constricting Band".

Constricting Clutch: A friction clutch in which a band is tightened around a drum to engage it.

Contact Breaker: A device on some forms of gasoline motors having an induction coil of the single jump-spark type, to open and close the electric circuit of the battery and coil at the proper time for the passage of the arc or spark at the points of the spark plug.

Contact Maker: See "Contact Breaker".

Continental Drive: Double-chain drive.

Control: The levers, pedals, etc., in general with the speed and direction of a car is regulated by the driver. In speaking of right, left, or center control, the gearshift and emergency brake levers only are meant.

Control, Spark: Method of controlling the power of an engine by varying the point in the stroke at which ignition takes place.

Control, Throttle: Method of governing the power of the engine by altering the area of the passage leading to the admission valve so that the amount of the fuel introduced into the cylinder is varied.

Controller, Electric: Apparatus for securing various combinations of storage cells and of motors so as to vary the speed of the car at will.

Converter: A device for changing alternating current into direct current for charging storage batteries, etc. Converters may be any of three kinds: rotary, electrolytic, or mercury-vapor. The mercury-vapor converter is most widely used.

Convertible Body: An automobile body which may be used in two or more ways, usually as an open or closed carriage, or in which several seats may be concealed, and raised to increase the seating capacity.

Cooling Fan: Fan used in automobiles to increase the current of air circulating around the cylinders, or through the radiator.

Cooling System: The parts of a gas engine or motor car by which the heat is generated in the cylinder by the combustion of the fuel mixture. See "Water Cooling" and "Air Cooling".

Cork Inserts: Pieces of cork inserted in friction surfaces of clutches or brakes to give softer action.

Cotter Pin: A split metal pin designed to pass through holes in a bolt and nut to hold the former in place.

Coulomb: The unit of measure of electrical quantity. Sometimes called "Ampere Second". It is equivalent to the product of the current in amperes by the number of seconds current has been flowing.

Counterbalance: Weights attached to a moving part to balance that part.

Countershaft: An intermediate or secondary shaft in the power-transmission system.

Coupé: An enclosed body seating one or two passengers and the driver, all within.

Coupling, Flexible: See "Universal Joint".

Cowl: That portion of the body of the car which forms a hood over the instrument board or dash.

Cowl Tank: A fuel tank carried under the cowl and immediately in front of the dash.

Crank: A lever designed to convert reciprocating motion into rotating motion or *vice versa;* usually in the form of a lever formed at an angle with the shaft, and connected with piston by means of connecting rod.

Crank, Starting: A handle made to fit the projecting end of the crankshaft of a gas engine, so that the engine may be started revolving by hand.

Crankcase: The casing surrounding the crank end of the engine.

Crankcase Explosion: Explosion of unburned gases in the crankcase.

Crank Chamber: The enclosed space of small engines in which the crank works.

Cranking: The act of rotating the motor by means of a handle in order to start it. Turning the flywheel over a few times causes the engine to take up its cycle, and after an explosion it continues to operate.

Crankpin: The pin by which the connecting rod is attached to the crank.

Crankshaft: The main shaft of an engine.

Crankshaft, Offset: A crankshaft whose center line is not in the same plane as the axis of its cylinders.

Creeping of Pneumatic Tires: The tendency of pneumatic tires to push forward from the ground, and thus around the rim, in the effort to relieve and distribute the pressure.

Cross Member: A structural member of the frame uniting the side members.

Crypto Gear: See "Planetary Gear".

Crystallization. The rearrangement of the molecules of metal into a crystalline form under continued shocks. This is often the cause of the breaking of the axles and springs of a motor car.

Cup, Priming: A small cup-shaped device provided with a cock, by which a small quantity of gasoline can be introduced into the cylinder of a gasoline engine.

Current: The rate of flow of electricity; the quantity of electricity which passes per second through a conductor or circuit.

Current Breaker: See "Contact Breaker".

Current Indicator: A device to indicate the direction of current flow in a circuit; a polarity indicator.

Current Rectifier: A device for converting alternating current into direct current. See "Converter".

Cushion Tire: See "Tire, Cushion".

Cut-Off, Gas Engine: That point in the cycle of an internal-combustion engine at which the admission of the mixture is discontinued by the closing of the admission valve.

Cut-Off, Steam Engine: That point in the cyle of a steam engine, or that point on an indicator diagram, at which the admission of steam is discontinued by the closing of the admission valve.

Cut-Out, Automatic: A device in a battery charging circuit designed to disconnect the battery from the circuit when the current is not of the proper voltage.

Cut-Out, Muffler: A device by which the engine is made to exhaust into the air instead of into the muffler.

Cut-Out Pedal: Pedal by means of which the engine is made to exhaust into the air instead of into the muffler.

Cycle: A complete series of operations beginning with the drawing in of the working gas, and ending after the discharge of the spent gas.

Cycle, Beau de Rochas: See "Beau de Rochas Cycle".

Cylinder: A part of a reciprocating engine consisting of a cylindrical chamber in which a gas is allowed to expand and move a piston connected to a crank.

Cylinder Bore: See "Bore".

Cylinder Cock: A small cock used to allow the condensed water to be drained away from the cylinder of a steam engine, usually called a *drain cock.*

Cylinder Head: That portion of a cylinder which closes one end.

Cylinder Jacket: See "Jacket, Water".

Cylinder Oil: Lubricant particularly adapted to the lubrication of cylinder walls and pistons of engines.

D

Dash: The upright partition of a car in front of the front seat and just behind the bonnet.

Dash Adjustment: Connections by which a motor auxiliary may be adjusted by a handle on the dash. Usually applied to carbureter adjustments.

Dash Coil: An induction coil for jump-spark ignition, having an element for each cylinder, with dash connections to the commutator on the engine or camshaft.

Dash Gage: A steam, water, oil, or electric gage placed upon the dash of the car.

Day Type of Engine: The two-cycle internal-combustion engine with an air-tight crankcase.

Dead Axle: See "Axle, Dead".

Dead Center: The position of the crank and connecting rod in which they are in the same straight line. There are two positions, and in these positions no rotation of the crankshaft is caused by pressure on the piston.

Decarbonizer: See "Carbon Remover".

Deflate: Reduction of pressure of air in a pneumatic tire.

Deflector: In a two-cycle engine, the curved plate on the piston head designed to cause the incoming charge to force out the exhaust gases and thus assist in scavenging.

Deflocculated Graphite: Graphite so finely divided that it remains in suspension in a liquid.

Demountable Rim: A rim upon which a spare tire may be mounted and carried, and so arranged that it may be easily and quickly taken off or put on the wheel.

Denatured Alcohol: See "Alcohol, Denatured".

Densimeter: See "Hydrometer".

Depolarizer: Material surrounding the negative element of a primary cell to absorb the gas which would otherwise cause polarizing.

Detachable Body: A body which may be detached from and placed upon the chassis.

Detachable Rim: See "Demountable Rim".

Diagram Indicator: See "Indicator Card".

Diagram, Jeantaud: A diagrammatic representation of the running gear of an automobile, showing it turning corners of various radii for the purpose of determining the front-axle and steering connections.

Diesel Gas Engine: Four-cycle internal-combustion engine in which the explosion of the charge is accomplished entirely by the temperature produced by the high compression of the mixture.

Differential, Bevel-Gear: A balance gear in which the equalizing action is obtained by means of bevel gears.

Differential, Spur-Gear: A differential gear in which the equalizing action is obtained by spur gears.

Differential Brake: See "Brake, Differential".

Differential Case: See "Differential Housing".

Differential Gear: A mechanism to permit driving the wheels and yet allow them to turn a corner without slipping. An arrangement such that the driving wheels may turn independently of each other on a divided axle, both wheels being under the control of the driving mechanism. Sometimes called *balance, compensating,* or *equalizing gear*.

Differential Housing: The case that encloses the differential gear.

Differential Lock: A device which prevents the operation of the differential gear, so that the wheels turn as if they were on a solid shaft.

Dimmer: An arrangement for lowering the intensity of, or reducing the glare from headlights.

Direct Current: A current which does not change its direction of flow, as the current from a battery or a direct-current generator. Distinguished from an alternating current, which reverses its direction many times a minute.

Direct Drive: Transmission of power from engine to the final driving mechanism at crankshaft speed.

Discharge: In a storage battery, the passage of a current of electricity stored therein. In the ignition circuit, the flow of high-tension current at the spark gap.

Disk Clutch: A clutch in which the power is transmitted by a number of thin plates pressed face to face.

Distance Rod: See "Radius Rod".

Distribution Shaft: See "Camshaft".

Distributor: That part of the ignition system which directs the high-tension current, to the respective spark plugs in the proper firing order.

Double Ignition: A method of ignition which comprises two separate systems, either of which may be used independently of the other, or both together as desired. Usually distinguished by two current sources and two sets of plugs.

Drag: That action of a clutch or brake which does not completely release.

Drag Link: That rod in a steering gear which forms the connection between the mechanism mounted on the frame and the axle stub, and transmits the movements of steering from steering post to wheels.

Drive Shaft: The shaft transmitting the motion from the change gears to the driving axle; the torsion rod.

Driving Axle: The axle of a motor car through which the power is transmitted to the wheels.

Driving Wheel: The wheel to which or by which the motion is transmitted.

Dry Battery: A battery of one or more dry cells.

Dry Cell: A primary voltaic cell in which a moist material is used in place of the ordinary fluid electrolyte.

Dual Ignition: An ignition system comprising two sources of current and one set of spark plugs.

Dust Cap: A metal cap to be screwed over a tire valve to protect the latter from dust and water.

Dynamo: The name frequently applied to a dynamo-electric machine used as a generator. Strictly, the term *dynamo* should be applied to both motor and generator.

Dynamometer: The form of equalizing gear attached to a source of power or a piece of machinery to ascertain the power necessary to operate the machinery at a given rate of speed and under a given load.

E

Earth: See "Ground".

Economizer, Gas: An appliance to be attached to a float-feed carbureter to improve the mixture by automatically governing the amount of air in the float chamber.

Eccentric: A disk mounted off-center on a shaft to convert rotary into reciprocating motion.

Economy, Fuel: The fuel economy of a motor is the relation between the heat units in the fuel used in the motor and the work or energy given out by the motor.

Efficiency: The proportion of power obtained from a mechanism as compared with that put into it.

Efficiency of a Motor: The efficiency of a gasoline motor is the relation between the heat units consumed by the motor and the work of energy in foot-pounds given out by it. Electrical efficiency of a motor is the relation between the electrical energy put into the motor and the mechanical energy given out by it.

Ejector: An apparatus by which a jet of steam propels a stream of water in almost the same way as an injector, except that the ejector delivers it into a vessel having but little pressure in it.

Electric Generator: A dynamo-electric machine in which mechanical energy is transformed into electrical energy; usually called *dynamo*.

Electric Horn: An automobile horn electrically operated.

Electric Motor: A dynamo-electric machine in which electrical energy is transformed into mechanical energy.

Electric Vehicle: An automobile propelled by an electric motor, for which current is supplied by a storage battery carried in the vehicle.

Electrolyte: A compound which can be decomposed by electric current. In referring to storage batteries, the term electrolyte means the solution of sulphuric acid in water in which the positive and negative plates are immersed.

Electromagnet: A temporary magnet which obtains its magnetic properties by the action of an electric current around it and which is a magnet only as long as such current is flowing.

Electromotive Force: A tendency to cause a current of electricity to flow; usually synonymous with *potential, difference of potential, voltage*, etc.

Element: The dissimilar substances in a battery between which an electromotive force is set up, as the plates of a storage battery.

Emergency Brake: A brake to be applied when a quick stop is necessary; usually operated by a pedal or lever.

En Bloc: That method of casting the cylinders of a gasoline engine in which all the cylinders are made as a single casting. Block casting; monoblock casting.

End Play: Motion of a shaft along its axis.

Engine, Alcohol: An internal-combustion engine in which a mixture of alcohol and air is used as fuel.

Engine, Gasoline: An internal-combustion motor in which a mixture of gasoline and air is used as fuel.

Engine, Kerosene: An internal-combustion engine in which a mixture of kerosene and air is used as fuel.

Engine, Steam: An engine in which the energy in steam is used to do work by moving the piston in a cylinder.

Engine Primer: A small pump to force fuel into the carbureter.

Engine Starter: An apparatus by which a gasoline engine may be started in its cycle of operations without use of the starting crank. It belongs usually to one of four classes: (1) Mechanical or spring actuated, such as a coil spring wound up by the running of the engine or a strap around the flywheel; (2) fluid pressure, such as compressed air or exhaust gases induced into the cylinder to drive the piston through one cycle; (3) the electric system, in which a small motor is used to turn the engine over; (4) combinations of these.

Epicyclic Gear: See "Planetary Gear".

Equalizing Gear: See "Differential Gear".

Exhaust: The gases emitted from a cylinder after they have expanded and given up their energy to the piston; the emission of the exhaust gases.

Exhaust, Auxiliary: See "Auxiliary Exhaust".

Exhaust Horn: An automobile horn in which the sound is produced by the exhaust gases.

Exhaust Lap: The extension of the inside edges of a slide valve to give earlier closing of the exhaust. Also called *inside lap*.

Exhaust Manifold: A large pipe into which the exhaust passages from all the cylinders open.

Exhaust Port: The opening through which the exhaust gases are permitted to escape from the cylinder.

Exhaust Steam: Steam which has given up its energy in the cylinder and is allowed to escape.

Exhaust Stroke: The stroke of an internal-combustion motor during which the burned gases are expelled from the cylinder.

Exhaust Valve: A valve in the cylinder of an engine through which the exhaust gases are expelled.

Expanding Clutch: A clutch in which a split pulley is expanded to press on the inner circumference of a ring which surrounds it, and thus transmits motion to the ring.

Expansion, Gas Engine: That part of the cycle of a gas engine immediately after ignition, in which the gas expands and drives the piston forward.

Expansion, Steam Engine: That portion of the stroke of the steam engine in which the steam is cut off by the valves and continues to perform work on the piston, increasing in volume and decreasing in pressure.

Explosive Motor: See "Internal-Combustion Motor".

F

Fan, Cooling: A mechanically operated fan for producing a current of air for cooling the radiator or cylinder of a gas engine.

Fan, Radiator: A mechanically operated rotary fan used to induce the flow of air through the radiator to facilitate the cooling of the water.

Fan Belt: The belt which drives the cooling fan.

Fan Pulley: A pulley permanently attached to the fan and over which the fan belt runs to drive it.

Fat Spark: A short, thick, ignition spark.

Feed Pump: A pump by which water is delivered from the tank to the boiler of a steam car.

Feed Regulator: A device to maintain a uniform water level in a steam boiler by controlling the speed of the feed pump.

Feed-Water Heater: An apparatus for heating the boiler-feed water, either by means of a jet of steam or steam-heated coils.

Fender: A mud guard or shield over the wheels of a car.

Field, Magnetic: Space in the neighborhood of the poles of a magnet in which the magnetism exerts influence. Field also refers to the coils which produce the magnetism in an electromagnet.

Fierce Clutch: A clutch which cannot be engaged easily. A grabbing clutch.

Filler Board: Woodwork shaped to fill the space between the lower edge of the windshield and the dash.

Fin: Projections cast on the cylinders of a gas engine to assist in cooling.

Final Drive: That part of a car by which the driving effort is transmitted from the parts of the transmission carried on the frame to the transmission parts on the rear axle. The propeller shaft in a shaft-drive car.

Fire Test: A test of a lubricant to determine the temperature at which it will burn.

Firing: (1) Ignition of the charge in a gas engine. (2) The act of furnishing fuel under the boiler of a steam engine.

First Speed: That combination of transmission gears which gives the lowest gear ration forward. Slow speed; low speed.

Flash Boiler: A boiler arranged to generate highly superheated steam almost instantaneously, by allowing water to come in contact with very hot metal surfaces.

Flash Generator: See "Flash Boiler".

Flash Point: The temperature at which an oil will give off a vapor that will ignite when a flame comes in contact with it.

Flash Test: A test to determine the flash point of oils.

Flexibility: In an engine the ability to do useful work through a range of speeds.

Flexible Coupling: See "Universal Joint".

Flexible Shaft: A pliant shaft which will transmit considerable power when revolving.

Flexible Tubing: A tube for the conduction of liquids or gases, which may be bent at a small radius without leaking.

Float Carbureter: A carbureter for gasoline engines in which a float of cork or hollow metal controls the height of the liquid in the atomizing nozzle. Sometimes called *float-feed carbureter*.

Float Valve: An automatic valve by which the admission of a liquid into a tank is controlled through a lever attached to a hollow sphere which floats on the surface of the liquid and opens or closes the valve according as it is high or low.

Floating Axle: See "Axle, Floating".

Floating the Battery on the Line: Charging the battery while it is giving out current.

Flooding: Excessive escape of fuel in a carbureter from the spraying nozzle.

Flushing Pin: In a float-feed carbureter, a pin arranged to depress the float in priming. Also called *primer* and *tickler*.

Flywheel: A wheel upon the shaft of an engine which, by virtue of its moving mass, stores up the energy of the gas transmitted to the flywheel during the impulse stroke and delivers it during the rest of the cycle, thus producing a fairly constant torque.

Flywheel Marking: Marks on the face of a flywheel to indicate the time of valve opening and closing and thus assist in valve setting.

Foaming: See "Priming".

Fore Carriage: A self-propelled vehicle in which the motor is carried on the forward trucks, and propelling and steering is done with the forward trucks.

Fore-Door Body: An automobile body having doors in the forward compartment.

Four-Cycle or Four-Stroke Cycle: The cycle of operations in gas engines occupying two complete revolutions or four strokes.

Four-Wheel Drive: Transmission of driving effort to all four wheels.

Fourth Speed: That combination of transmission gears which gives the fourth from the lowest gear ratio forward. Usually the highest speed.

Frame: The main structural part of a chassis. It is carried upon the axles by the springs and carries the different elements of the car.

Frame Hangers: See "Body Hangers".

Free Wheel: A wheel so arranged that it can rotate more rapidly than the mechanism which drives it.

Friction: The resistance existing between two bodies in contact which tends to prevent their motion on each other.

Friction Clutch: A device for coupling and disengaging two pieces of shafting while in motion, by the friction of cones or plates on one another.

Friction Disk: The thin plate used in a disk or friction clutch. See "Disk Clutch".

Friction Drive: A method of transmitting power or motion by frictional contact.

Fuel: A combustible substance by whose combustion power is produced. Gasoline and kerosene are the chief automobile fuels.

Fuel Economy. See "Economy, Fuel".

Fuel Feed, Gravity: See "Gravity Fuel Feed".

Fuel Feed, Pressure: See "Lubrication, Force-Feed."

Fuel Feed, Vacuum. See "Vacuum Fuel Feed".

Fuel-Feed Regulator: A device in the fuel system of steam motor by which the rate of flow of fuel to the burner is automatically regulated.

Fuel Level: The height of the top of the fuel in the float chamber of a carbureter.

Fuel-Level Indicator: An instrument either permanently connected to the fuel tank or which may be inserted thereon to indicate the quantity of fuel in the tank.

Fuel Tank, Auxiliary: A tank designed to hold a supply of fuel in addition to that carried in the main shaft.

Fuse: A length of wire in an electric circuit designed to melt and open the circuit when excess current flows through it and thus prevent damage to other portions of the circuit.

Fusible Plug: A hollow plug filled with an alloy which melts at a point slightly above the temperature of the steam in a boiler, as when the water runs low, thus putting out the fire and preventing the burning out of the boiler.

G

Gage: (1) Strictly speaking, a measure of, or instrument for determining dimensions or capacity. Practically, the term refers to an instrument for indicating the pressure or level of liquids, etc. (2) The distance between the forward or rear wheels measured at the points of contact of the tires on the road. Tread; track.

Gage Cock: A small cock by which a pipe leading to a gage may be opened or closed.

Gage Lamp: Lamp, usually electric, placed above or near the gages to enable them to be read at night.

Gage, Oil: See "Oil Gage".

Gage, Tire: See "Tire-Pressure Gage".

Gap: In automobiles, the spark gap.

Garage: A building for storing and caring for automobiles.

Garage, Portable: A garage which may be moved from one place to another either as a whole or in sections.

Gas: Matter in a fluid form which is elastic and has a tendency to expand indefinitely with reduction in pressure.

Gas Economizer: See "Economizer".

Gas Engine: An internal-combustion motor in which a mixture of gas and air is used as fuel. The term is also applied to the gasoline engine.

Gas Engine, Otto: A four-stroke cycle engine developed by Otto and using the hot-tube method of ignition.

Gas Generator: An apparatus in which a gas is generated for any use.

Gas Lamp: See "Acetylene Lamp".

Gases, Boyle's Law of: See "Boyle's Law of Gases".

Gases, Gay Lussac's Law of: Called *Charles's Law* and the *Second Law of Gases.* Law defining the physical properties of gases at constantly maintained pressure. It states that at constant pressure the volume of gas varies with the temperature, the increase being in proportion to the change of temperature and volume of the gas.

Gasket: A thin sheet of packing material or metal used in making joints, piping, etc.

Gasoline: A highly volatile fluid petroleum distillate; a mixture of fluid hydrocarbons.

Gasoline-Electric Transmission: A system of propulsion in which a gasoline engine drives an electric generator, and the power is transmitted electrically to motors which drive the wheels.

Gasoline Engine: An internal-combustion motor in which a mixture of gasoline and air is used as a fuel.

Gasoline Primer: The valve on the carbureter of a gasoline engine by which the action of the engine can be started.

Gasoline-Tank Gage: A fuel-lever indicator for gasoline.

Gasoline Tester: A hydrometer graduated to indicate the specific gravity of gasoline, usually in degrees Baumé.

Gate: A plate which guides the gearshift lever in making speed changes.

Gather: Convergence of the forward portions of the front wheels. Toeing in.

Gay Lussac's Law of Gases: See "Gases, Gay Lussac's Law of".

Gear, Balance: See "Differential Gear".

Gear, Bevel: See "Bevel Gear".

Gear, Change-Speed: An arrangement of gear wheels which transmits the power of the motor to the differential gear at variable speeds independently of the motor speed.

Gear, Differential: See "Differential".

Gear, Fiber: A gear cut from a vulcanized fiber blank.

Gear, Helical: A gear whose teeth are not parallel to the axis of the cylinders.

Gear, Internal: A gear whose teeth project inward toward the center from the circumference of gear wheel.

Gear, Planetary: See "Planetary Gears".

Gear, Progressive: See "Progressive Change-Speed Gears".

Gear, Rawhide: A gear cut from a blank made up of compressed rawhide.

Gear, Selective: See "Selective Change-Speed Gears".

Gear, Timing: See "Timing Gears".

Gear, Worm: A helical gear designed for transmitting motion at angles, usually at right angles and with a comparatively great speed reduction.

Gearbox: The case covering the change-speed gears.

Gear Shifting: Varying the speed ration between motor and rear wheels by operating the change-speed gears.

Gear-Shift Lever: A lever by which the change-speed gears are shifted.

Geared-Up Speed: A speed obtained by an arrangement of gears in the gearset such that the propeller shaft rotates more rapidly than the crankshaft.

Gearset: See "Gear, Change-Speed".

Generator, Acetylene: See "Acetylene Generator".

Generator, Electric: See "Electric Generator".

Generator, Steam: A steam boiler.

Generator Tubing: Tubing by which acetylene is conducted from the generator to the lamp.

Gimbal Joint: A form of universal joint.

Gong: A loud, clear sounding bell, usually operated either electrically or by foot power.

Governor: A device for automatically regulating the speed of an engine.

Governor, Dynamo: A method of automatic control of the generator (usually an ignition generator, in automobile work) by which its speed is maintained approximately constant.

Governor, Hydraulic: A governor applied to engines cooled by a pump circulation of water in such a way that the throttle opening is controlled by the pressure of the water.

Governor, Spark: A method of automatically controlling the speed of the engine by varying the time of ignition. See "Governor".

Grabbing Clutch: See "Fierce Clutch".

Gradometer: An instrument for indicating the degree of the gradient or the per cent of the grade. It consists of a level with a graduated scale.

Graphite: One of the forms in which carbon occurs in matter. Also known as *black lead* and *plumbago*. Used as a lubricant in powdered or flake form in the cylinders of explosive engines.

Gravity-Feed Oiling System: See "Lubrication, Gravity".

Gravity Fuel Feed: Supply of fuel to the carbureter from the tank by force of gravity.

Grease and Oil Gun: A syringe by means of which grease or oil may be introduced into the bearings of the machinery.

Grease Cup: A device designed to feed grease to a bearing by the compression of a hand screw.

Grid: A lead plate formed in the shape of a gridiron to sustain and act as a conductor of electricity for the active material in a storage battery.

Grinding Valves: See "Valve Grinding".

Gripping Clutch: See "Fierce Clutch".

Ground: An electric connection with the earth, or to the framework of a machine.

H

Half-Motion Shaft: See "Half-Time Shaft".

Half-Time Gear: See "Timing Gears".

Half-Time Shaft: The cam shaft of a four-cycle gas engine. It revolves at one-half the speed of the crankshaft.

Hammer Break: A make-and-break ignition system in which the spark is produced when the moving terminal strikes the stationary terminal like a hammer.

Header: A pipe from which two or more pipes branch. Manifold.

Heater, Automobile: A device for warming the interior of an automobile, usually electric, or by means of exhaust gases or jacket water.

High Gear: That combination of change-speed gears which gives the highest speed.

High-Tension Current: A current of high voltage, as the current induced in the secondary circuit of a spark coil.

High-Tension Ignition: Ignition by means of high-tension current.

High-Tension Magneto: A magneto which delivers high-tension current.

Honeycomb Radiator: A radiator consisting of many very thin tubes, giving it a cellular appearance.

Hood: (1) That part of the automobile body which covers the frame in front of the dash. The engine is usually under the hood. (2) The removable covering for the motor.

Hooke's Coupler: See "Universal Joint".

Horizontal Motor: A motor the center line of whose cylinder lies in a horizontal plane.

Horn, Automobile: A whistle or horn for giving warning of the approach of the automobile.

Horsepower: The rate of work or energy expended in a given time by a motor. One horsepower is the rate or energy expended in raising a weight of 550 pounds one foot in one second, or raising 33,000 pounds one foot in one minute.

Horsepower Brake: The power delivered at the flywheel of an internal combustion engine as ascertained by a brake test.

Horsepower, Rated: The calculated power which may be expected to be delivered by a motor. In America the term usually refers to the horsepower as calculated by the S.A.E. formula.

Hot-Air Intake: The pipe or opening conveying heated air to the carbureter.

Hot-Head Ignition: The method of igniting the charge in a gas-engine cylinder by maintaining the head of the combustion chamber at a high temperature from the internal heat of combustion, as in the Diesel engine.

Hot-Tube Ignition. An ignition device formerly used for gas engines in which a closed metal tube is heated red-hot by a Bunsen flame. When the compressed gases in the cylinder are allowed to come in contact with this, ignition takes place.

Housing: A metallic covering for moving parts.

H.P.: (1) Abbreviation for *horsepower*. (2) Abbreviation for *high pressure*.

Hub Cap: A metal cap placed over the outer end of a wheel hub.

Hydrocarbons: Chemical combinations of carbon and hydrogen in varied proportions, usually distillates of petroleum, such as gasoline, kerosene, etc.

Hydrometer: An instrument by which the specific gravity or density of liquids may be ascertained.

Hydrometer Scale, Baumé's: An arbitrary measure of specific gravity.

I

I-Beam: Sometimes called *I-Section*. A structural piece having a cross section resembling the letter I. I-Beam front axle.

Igniter: An insulated contact plug without sparking points, used in make-and-break ignition with low-tension magneto.

Igniter, High-Speed: An igniter having a short spark coil for high-speed engines.

Igniter, Jump-Spark: A system of ignition in which is used a current of high pressure, which will jump across a gap in the high-pressure circuit, causing a spark at the gap.

Igniter, Lead of: Amount by which the ignition is advanced. See "Advanced Ignition".

Igniter, Primary: The apparatus in a primary circuit for making and breaking the circuit.

Igniter Spring: A spring to quickly break the circuit of a primary igniter.

Ignition, Advancing: See "Advanced Ignition".

Ignition, Battery: A system which gets its supply of current from a storage battery or dry cells. This system usually consists of a battery, a step-up coil, and a distributor for sending the current to the different spark plugs.

Ignition, Catalytic: Method of ignition for explosive motors based on the property of some metals, particularly spongy platinum, of becoming incandescent when in contact with coal gas or carbonized air.

Ignition, Double: See "Double Ignition".

Ignition, Dual: See "Dual Ignition".

Ignition, Fixed: Ignition in which the spark occurs at a given point in the cycle and cannot be changed from that point at the will of the operator except by retiming the ignition system. Fixed spark.

Ignition, Generator: Ignition current which is furnished by a combination lighting generator and magneto. The generator is fitted with an interrupter and distributor. Sometimes refers to system in which a generator charges a battery and the latter furnishes the ignition current in connection with a coil and distributor.

Ignition, High-Tension: Sometimes called jump-spark. Ignition which is effected by means of a high-tension or high-voltage current which is necessary to jump a gap in the spark plug.

Ignition, Hot-Head: See "Hot-Head Ignition".

Ignition, Jump-Spark: See "Ignition, High-Tension".

Ignition, Low-Tension: See "Ignition, Make-and-Break".

Ignition, Make-and-Break: A system in which the spark is produced by the breaking or interruption of a circuit, the break occurring in the combustion space of the cylinder. The current used is of low-voltage, hence the synonym, low-tension ignition.

Ignition, Magneto: Ignition produced by an electric generator, called a magneto, which is operated by the gas engine for which it furnishes current. Dynamo ignition. Generator ignition.

Ignition, Master Vibrator: A system which uses as many non-vibrator coils as there are cylinders, and one additional coil, called the master vibrator, for interrupting the primary circuit for all coils. The master vibrator also is used with vibrator coils in which the vibrators are short-circuited.

Ignition, Premature: Ignition occurring so far before the top dead center mark that the explosion occurs before the piston has reached upper dead center.

Ignition, Primary: An ignition system in which a low-tension current flows through a primary coil, the circuit being mechanically opened, allowing a high-tension spark to jump across the gap. See "Primary Coil".

Ignition, Retarding: Setting the spark of an internal-combustion motor so that the ignition will occur at a later part of the stroke.

Ignition, Self: Explosion of the combustible charge by heat other than that produced by the spark. Incandescent carbon will cause this. Motor overheating because of lack of water is another cause.

Ignition, Single: A system using but one source of current.

Ignition, Synchronized: Ignition by means of which the timing in each cylinder of a multicylinder engine is the same. In synchronized ignition the spark occurs at the same point in the cycle in each cylinder. This type of ignition is obtained with a magneto and is lacking in a multi-coil system using vibrator coils.

Ignition, Timing of: The adjustment of the ignition system so that ignition will take place at the desired part of the cycle.

Ignition, Two-Independent: See "Ignition, Double".

Ignition, Two-Point: A system comprising two ignition sources, or a double-distributor magneto, and two sets of spark plugs, both of which spark at the same time.

Ignition Distributor: See "Distributor."

Ignition Switch: A control or switch for turning the ignition current on and off voluntarily.

I. H. P.: Abbreviation for *indicated horsepower*.

Indicated Horsepower: (1) The horsepower developed by the fuel on the pistons, in contradistinction to brake horsepower. See "Horsepower, Brake". (2) The horsepower of an engine as ascertained from an indicator diagram.

Indicator: An instrument by which the working gas in an engine records its working pressure.

Indicator Card: A figure drawn by means of an indicator by the working gas in an engine. Also called *indicator diagram*.

Induction Stroke: The downstroke of a piston which causes a charge of mixture to be drawn into the cylinder.

Inflammation: The act or period of combustion of the mixture in the cylinder.

Inflate: To increase the pressure within a tire by forcing air into it.

Inflator, Mechanical Tire: A small power-driven air-pump for inflating the tire; either driven by gearing, chain, or belt from the engine shaft, or by friction from the flywheel.

Inherent Regulation: Expression applied to electric generators which use no outside means of regulating the output, the regulation being affected by various windings of the armature and fields.

Initial Air Inlet: See "Primary Air Inlet".

Initial Pressure: Pressure in a cylinder after the charge has been drawn in but not compressed.

Injector: A boiler-feeding device in which the momentum of a steam jet, directed by a series of conical nozzles, carries a stream of water into the boiler, the steam condensing within and heating the water which it forces along.

Inlet, Valve: The valve which controls the inlet port and so allows or prevents mixture from passing to the cylinder.

Inlet Port: Passage or entrance in the cylinder wall through which the fuel mixture is taken. Sometimes called intake port.

Inlet Manifold: Sometimes called intake manifold or header. A branched pipe connected to the mixing chamber at one end and at the branch ends to the cylinders so as to communicate with the inlet ports.

Inlet Manifold, Integral: A manifold or header cast integral with the cylinder.

Inner-Tire Shoe: A piece of leather or rubber placed within the tire to protect the inner tube.

Inner Tube: A soft air-tight tube of nearly pure rubber, which fits within a felloe upon the casing.

Inside Lap: See "Exhaust Lap".

Intake Manifold: The large pipe which supplies the smaller intake pipes from each cylinder of a gas engine.

Intake Pipe: Sometimes made synonymous with inlet manifold. Correctly, the pipe from the carbureter to the inlet manifold.

Intake Stroke: See "Induction Stroke".

Intensifier: See "Outside Spark Gap".

Intermediate Gear: A gear in a change-speed set between high and low. In a three-speed set it would be second speed. In a four, either second or third.

Intermediate Shaft: See "Shaft, Intermediate".

Internal-Combustion Motor: Any prime mover in which the energy is obtained by the combustion of the fuel within the cylinder.

Internal Gear: See "Gear, Internal".

Interrupter: See "Vibrator".

J

Jack: A mechanism by which a small force exerted over a comparatively large distance is enabled to raise a heavy body. Used for raising the automobile axle to remove the weight from the wheels.

Jacket, Water: A portion of the cylinder casting through which water flows to cool the cylinder.

Jacket Water: The cooling water circulating in a water-cooling system.

Jackshaft: Shaft used in double-chain drive vehicles. Shaft placed transversally in the frame and driving from its ends chains which turn the rear wheels mounted on a dead axle.

Jeantaud Diagram: See "Diagram, Jeantaud".

Joint Knuckle: See "Swivel Joint."

Joule's Law of Gases: See "Gases, Joule's Law of".

Jump Spark: A spark produced by a secondary jump-spark coil.

Jump Spark, Circuit Maker: A mechanically operated switch by which the circuit in a jump-spark ignition system is opened and closed.

Jump-Spark Coil: An electrical transformer and interrupter, consisting of a primary winding of a few turns of coarse wire surrounding an iron core, and a secondary winding consisting of a great number of turns of very fine wire. The condenser is usually combined with this. Also known as *secondary spark coil.*

Jump-Spark Igniter: See "Igniter, Jump-Spark".

Jump-Spark Plug: See "Spark Plug".

Junction Box: A portion of an electric-lighting system to which all wires are carried for the making of proper connections.

Junk Ring: A packing ring used in sleeve-valve motors. It has the same functions as a piston ring. See "Piston Ring".

K

Kerosene: A petroleum product having a specific gravity between 58° and 40° Baumé. It is used as a fuel in internal-combustion engines and can often be used in gasoline engines by starting the engine on gasoline, then switching to kerosene.

Kerosene Burner: A burner especially adapted to use kerosene as a fuel.

Kerosene Engine: An engine using kerosene as fuel.

Key: A semicircular or oblong piece of metal used to hold a member firmly on a revolving shaft so as to prevent the member from rotating.

Key, Baldwin: A key with an oblong section.

Key, Woodruff: A key with a semicircular section.

Keyway: Slot in a rotating member used to hold the key

Kick Switch: Ignition switch mounted so that the driver can operate it with the foot.

Kilowatt: An electrical unit equal to 1000 watts.

Knuckle Joint: See "Swivel Joint".

L

Labor: The jerky operation of an engine. The engine is said to labor when it cannot pull its load without misfiring or jerking.

Lag, Combustion: The time between the instant of the spark occurrence and the explosion.

Lag, Ignition: The time between the instant of spark occurrence and the time at which the spark mechanism producing it begins to act.

Lamp, Trouble: Sometimes called inspection lamp. A small electric bulb carried in a suitable housing, and attached to a long piece of lamp cord. Used for inspecting parts of the car.

Lamp Bulb: The incandescent bulb used in a lamp.

Lamp Bracket: A support for a lamp.

Lamp Lighter: An apparatus for lighting gas lamps by electricity. The lamps are usually so arranged that by pushing the button the gas is turned on and the spark made at the same time.

Landaulet: A type of car which may be used as an open or closed car. The rear portion of the body may be folded down like a top.

Landaulet Body: An automobile body resembling a limousine body, but having a cover fitted to the back, which may be let down, leaving the back open. The top generally extends over the driver.

Lap: To make parts fit perfectly by operating them with an abrasive, such as ground glass, between the rubbing surfaces. To finish.

Lap of Steam Valves: In the slide valve of a steam engine, the amount by which the admission edges overlap the steam port when the valve is central with the cylinder case.

Layshaft: A countershaft or secondary shaft of a gearset operated by the main or shifter shaft.

Lead, or Lead Wire: Any wire carrying electricity.

Lead: In a steam engine the amount by which the steam port is opened when the piston is at the start of its stroke.

Lead Battery: See "Accumulator".

Lead of Igniter: See "Igniter, Lead of".

Lead of Valve: In an engine the amount by which the admission port is opened when the piston is at the beginning of the stroke; according as this is greater or less, the admission of working fluid is varied through several fractions of the stroke.

Lean Mixture: Fuel after leaving the carbureter, which contains too much air in proportion to the gasoline. Sometimes called thin mixture, rare mixture, or weak mixture.

Lever, Brake: See "Brake Lever."

Lever, Change-Speed: Lever by which the different combinations of change gears are made so as to vary the speed of the driving wheels in relation to the speed of the engine; also called gearshift lever.

Lever, Spark: Lever by which the speed and power of the engine are controlled by adjusting the time of ignition.

Lever, Steering: See "Steering Lever".

Lever, Throttle: A lever by which the speed and power of the engine are controlled by adjusting the amount of mixture admitted to the cylinder.

Lever Lock: An arrangement for locking the gearshift lever in free position so that with the engine running the driving axle will not be driven.

Lift: The distance through which a poppet valve is moved in opening from fully-closed to fully-open position.

Lifting Jack: See "Jack".

Lighting Outfit, Electric: An outfit for electrically lighting an automobile. This usually consists of a dynamo, storage battery, and lamps and switchboard, with the necessary wiring and cut-outs.

Limousine Body: An enclosed automobile body having the front and sides with side doors. The top extends over the seat of the driver.

Liner: One or more pieces of metal placed between two parts so they may be adjusted by varying the thickness of the liner. Sometimes called a shim. Also refers to a tool used for lining up parts.

Liner, Laminated: A liner or shim made in a number of parts, the thickness being varied by removing or adding parts.

Lines of Force: See "Field, Magnetic".

Link Motion: In a steam engine, the name for the arrangement of eccentric rods, links, hangers, and rocking shafts by which the relative motion and position of the slide valves are changed at will, providing for varying rates of expansion of the steam and thus varying the speed for either forward or backward motion.

Live Axle: See "Axle, Live".

Lock, Auto Safety: A device arranged so that it is impossible to start the motor car except by the proper combination or key.

Lock Nut: A nut placed on a bolt immediately behind the main nut to keep the main nut from turning.

Lock Switch: A switch in the ignition circuit so arranged that it can not be thrown on except by the use of a key.

Lock Valve: A valve capable of being secured with lock and key.

Long-Stroke: A gas engine whose stroke is considerably greater than its bore.

Lost Motion: Sometimes called play or backlash. Looseness of space between two moving parts.

Louver: A slit or opening in the side of a hood or bonnet of a motor car. Used to allow air from the draft to escape. A ventilator.

Low Gear: The lowest speed gear. First speed in a change-speed set.

Low-Speed Adjustment: A carbureter adjustment which regulates the mixture when the motor is operating slowly, with little throttling opening.

Low-Speed Band: The brake or friction band which controls the low speed of a planetary change-speed set.

Low-Tension Current: A current of low voltage or pressure, such as is generated by dry cells, storage battery, or low-tension magneto.

Low-Tension Ignition: See "Ignition, Make-and-Break".

Low-Tension Magneto: A magneto which initially generates a current of low voltage.

Low-Tension Winding: The winding of a transformer or induction coil through which the primary or low-tension current flows.

Low Test: Gasoline which has a high density, thus giving a low reading on the Baumé scale. Low-grade gasoline.

Low-Water Alarm: An automatic arrangement by which notice is given that the water in the boiler is becoming too low for safety.

Lubricant: An oil or grease used to diminish friction in the working parts of machinery.

Lubrication: To supply to moving parts and their bearings grease, oil, or other lubricant for the purpose of lessening friction.

Lubrication, Circulating: A system in which the same oil is used over and over.

Lubrication, Constant-Level: A system in which the level in the crankcase is kept to a predetermined level by means of a pump.

Lubrication, Force-Feed: Method of lubricating the moving parts of an engine by forcing the oil to the points of application by means of a pump.

Lubrication, Gravity: Method of supplying oil to moving parts of an engine by having a reservoir at a certain height above the highest point to be lubricated and allowing the oil to flow to the points of application by gravity.

Lubrication, Non-Circulating: A system in which the same oil is used but once.

Lubrication, Pressure-Feed: See "Lubrication, Force-Feed".

Lubrication, Sight-Feed: System of lubrication in which the oil pipe to different points of application is led through a glass tube in plain sight; usually at a point on the dashboard.

Lubrication, Splash: Method of lubricating an engine by feeding oil to the crankcase and allowing the lower edge of the connecting rod to splash into it.

Lubricator: A device containing and supplying oil or grease in regular amounts to the working parts of the machine.

Lubricator, Force-Feed: A pump-like device which automatically forces oil to the moving parts.

M

Magnet: A piece of iron or steel which has the characteristic properties of being able to attract other pieces of iron and steel.

Magnet, Horseshoe: A magnet shaped like the letter U.

Magnet, Permanent: A magnet which when once charged retains its magnetism.

Magnetic Field: See "Field, Magnetic".

Magnetic Spark Plug: A spark plug used in a make-and-break system of ignition in which contact is obtained by means of a magnet.

Magneto: See "Ignition, Magneto".

Magneto: See "Magneto-Electric Generator".

Magneto, Double-Distributor: A magneto with two distributors feeding two sets of spark plugs, two in each cylinder and both sparking at once. See "Ignition, Two-Point."

Magneto, High-Tension: A magneto has two armature windings and requires no outside coil for the generation of high-tension current.

Magneto, Induction: A type of magneto in which the armature and fields are stationary and a rotator or spool-shaped piece of metal is used to break the lines of force.

Magneto, Low-Tension: See "Low-Tension Magneto".

Magneto, Rotating Armature: A magneto in which the armature winding revolves.

Magneto Bracket: A shelf or portion of the crankcase web used to support the magneto.

Magneto Coupling: A flexible joint which connects the magneto with a revolving motor shaft.

Magneto Distributor: See "Distributor".

Magneto-Electric Generator: A machine in which there are no field magnet coils, the magnetic field of the machine being due to the action of permanent steel magnets. Usually contracted to *magneto*.

Main Bearing: A bearing used for supporting the crankshaft.

Manifold: A main pipe or chamber into which or from which a number of smaller pipes lead to other chambers. See "Intake Manifold", "Exhaust Manifold", and "Inlet Manifold".

Manometer: A device for indicating either the velocity or the pressure of the water in the coiling system of a gasoline motor.

Master Vibrator: A single vibrator which interrupts the current to each of a set of several spark coils in order.

Mean Effective Pressure: The average pressure exerted upon a piston throughout its stroke.

M. E. P.: Abbreviation for *mean effective pressure.*

Mercury Arc Rectifier: A mercury vapor converter. See "Mercury Vapor Converter".

Mercury Vapor Converter: An apparatus for converting alternating current into direct current by means of a bubble of mercury in a vacuum. The vapor of mercury possesses the property of allowing the flow of current in one direction only. Its principal use is for charging storage batteries.

Mesh: Two gears whose teeth are so positioned that one gear will drive the other are said to be in mesh.

Misfire: Failure of the mixture to ignite in the cylinder; usually due to poor ignition or poor mixtures.

Miss: The failure of a gas engine to explode in one or more cylinders. Sometimes called misfiring.

Mixing Chamber: A pipe or chamber placed between the carbureter and inlet manifold. Sometimes integral with the carbureter or manifold.

Mixing Tube: A tubular carbureter for a gas or gasoline engine.

Mixing Valve: A device through which air and gas are admitted to form an explosive mixture. The carbureter of a gasoline engine combines the mixing valve and vaporizer.

Mixture: The fuel of a gas engine, consisting of sprayed gasoline mixed with air.

Monobloc: Cast *en bloc* or in one piece. Refers usually to cylinders, which are cast two or more at once.

Motocycle: A trade name for a special make of motorcycle.

Motor, Electric: See "Electric Motor".

Motor, Gasoline: See "Gasoline Motor".

Motor, High-Speed: A gas engine whose rotative speed is very high and whose power output goes up with the speed to an unusual degree.

Motor, Horizontal: A gas engine whose cylinder axis lies in a horizontal plane.

Motor, I-head: A gas engine which has cylinders, a section of which resembles the letter I. This type has the valves in the head.

Motor, L-Head: A gas engine in which a section of cylinders resembles the letter L. The valves in this type are all on one side.

Motor, Long-Stroke: See "Long-Stroke Motor".

Motor, Non-Poppet: A gas engine whose valves are not of the poppet type. In this class is the Knight sleeve valve, the rotary valve, and the piston valve.

Motor, Overhead Valve: A motor with cylinders whose valves are in the head.

Motor, Piston Valve: A gas engine using valves which are in the form of pistons.

Motor, Poppet: A gas engine using poppet-type valves. See "Poppet Valve".

Motor, Revolving Cylinder: A motor whose cylinders revolve as a unit.

Motor, Rotary Valve: One in which the valves consist of slots cut out along cylindrical rods which rotate in the cylinder casting.

Motor, Sliding Sleeve: The Knight type motor in which thin sleeves slide up and down in the cylinder, the sleeves having ports which register with the inlet and exhaust manifolds.

Motor, T-Head: A gas engine with the valves on opposite sides of the cylinders, a section of which resembles the letter T.

Motor, V-Type: A motor whose cylinders are set on the crankcase so as to form an angle of 45 to 90 degrees between them.

Motor, Vertical: A motor with the cylinder axis in a vertical plane.

Motorcycle: A bicycle propelled by a gasoline engine.

Mud Guard: Metal or leather strips placed over the wheels to catch the flying mud and to prevent the clothing from coming in contact with the wheels when entering and leaving the car.

Muffler Cut-Out: See "Cut-Out, Muffler".

Muffler Cut-Out Pedal: See "Cut-Out Pedal".

Muffler Exhaust: A vessel containing partitions, usually perforated with small holes and designed to reduce the noise occasioned by the exhaust gases of an engine, by forcing the gases to expand gradually.

Muffler Explosion: Explosion of unburned gases in exhaust passages of the muffler, usually due to poor ignition or poor mixture.

Multiple Circuit: A compound circuit in which a number of separate sources or electrically operated devices, or both, have all their positive poles connected to a single positive conductor and all their negative poles to a single negative conductor.

N

N.A.A.M.: Abbreviation for National Association of Automobile Manufacturers.

Naphtha: A product of the distillation of petroleum used to some extent for marine engines.

Needle Valve: A valve in a carbureter used for regulating the amount of gasoline to flow in with the mixture.

Negative Plate: Plate of a storage battery to which current returns from the outside circuit.

Negative Pole: That pole of an electric source through which the current is assumed to enter or flow back into the source after having passed through the circuit external to the source.

Neutral Position: The position of the change-speed lever which so places the gears that the motor may run idle, the car remaining still.

Non-Deflatable Tire: See "Tire, Non-Puncturable".

Non-Freezing Solution: A solution placed into the radiator of a motor car to prevent the water therein from freezing. Alcohol and glycerine are the usual anti-freezing agents. See "Anti-Freezing Solution".

Non-Puncturable Tire: See "Tire, Non-Puncturable".

Non-Skid Device: See "Anti-Skid Device".

O

Odometer: (1) The mileage-recording mechanism of a speedometer. (2) An instrument to be attached to an automobile wheel to automatically indicate the distance traveled.

Odometer, Hub: A speed-recording device which is placed on the hub cap of a wheel.

Offset: Off center, as a crankshaft in which a line vertically through the crankpins does not coincide with a line vertically through the center of the cylinder.

Ohm: (1) Unit of electrical resistance. (2) Amount of electrical resistance. Such resistance as would limit the flow of electricity under an electromotive force of one volt to a current of one ampere.

Ohm's Law: The law which gives the relation between voltage, resistance, and current flow in any circuit. Expressed algebraically, $C=\frac{I}{R}$ where C is the current flowing in amperes, I the voltage and R the ohmic resistance.

Oil Burner: A burner equipped with an atomizer for breaking up liquid fuel into a spray.

Oil Engine: An internal-combustion motor using kerosene or other oil as fuel.

Oil Gage: (1) A gage to indicate the flow of oil in the lubricating system. (2) Used to show the level of oil in a compartment in the base of a gas engine.

Oil Gun: A cylinder with a long point and a spring plunger for squirting oil or grease into inaccessible parts of a machine.

Oil Pump: A small force pump providing a constant positive supply of oil under pressure; usually considered to be more reliable than a lubricator.

Oiler: An automobile device for oiling machinery.

Opposed Motor: A gasoline engine whose cylinders are arranged in pairs on opposite sides of the crankshaft, both connecting rods of each pair being connected to the same crank, so that the shock of the explosion in one will be balanced by the cushioning effect of the compression in the other. In general these motors are two-cylinder, horizontal.

Otto Cycle: See "Four-Stroke Cycle".

Outside Spark Gap: See "Spark Gap, Outside".

Overcharged: The state of the storage battery when it has been charged at too high a rate or for too great a length of time.

Overhead Camshaft: A camshaft which is placed above the cylinder of a gas engine.

Overhead Valves: See "Motor, Overhead Valve".

Overheating: The act of allowing the motor to reach an excessively high temperature due to the heat of combustion being not carried away rapidly enough by the cooling devices, or to insufficient lubrication. Overheating of a bearing is due to insufficient lubrication.

P

Packing: The material introduced between the parts of couplings, joints, or valves, to prevent the leakage of gas or liquids to or from them.

Panel, Charging: A small switchboard for charging a storage battery.

Parallel Circuit: See "Multiple Circuit".

Patch, Tire-Repair: Rubber strips for making repairs in punctured or ruptured tires.

Petcock: A control cock which when open allows gas or liquid to escape from the chamber to which it is attached.

Petrol: Word used in England for gasoline.

Picric Acid: Acid which may be added to gasoline to increase the motor efficiency. Gasoline will absorb about five per cent of its weight of picric acid.

Pin, Taper: A conically shaped pin.

Pinch: A cut in an inner tube caused by the tube being caught or pinched between the outer casing and the rim.

Pinion: (1) The smaller of any pair of gears. (2) A small gear made to run with a larger gear.

Piston: The hollow, cylindrical portion attached to the connecting rod of a motor. The reciprocating part which takes the strain caused by the explosion.

Piston Air Valve: A secondary air valve in the piston of earlier types of gas engines to compensate the imperfect operation of surface carbureters used with those engines and to secure the injection of a sufficient quantity of air to insure the combustion of the charge.

Piston Head: The top of the piston.

Piston Pin: A pin which holds the connecting rod to the piston.

Piston Ring: (1) A metal ring inserted in a groove cut into a piston assisting in making the latter tight in the cylinder. There are usually three rings on each piston. (2) Rings about the circumference of a piston, whose diameter is slightly greater than that of the piston. These are to insure closer fit and prevent wearing of the piston, as the wear is taken up by the rings which may be easily removed.

Piston Rod: Usually called connecting rod. The rod which connects the piston with the crankshaft.

Piston Skirt: The portion of a piston below the piston pin.

Piston Speed: The rate at which the piston travels in its cylinder.

Piston Stroke: The complete distance a piston travels in its cylinder.

Pitted: Condition of a working surface which has become covered with carbon particles which have been imbedded in the metal.

Planetary Gear: An arrangement of spur and annular gears in which the smaller gears revolve around the main shaft as planets revolve around the sun.

Planetary Transmission: A transmission system in which the speed changes are obtained by a set of planetary gears.

Plate: Part of a storage battery which holds active material. See "Negative Plate".

Pneumatic Tire: A tire fitted to the wheels of automobiles, consisting usually of two tubes, the outer of India rubber, canvas, and other resilient wear-resisting material, and the inner composed of nearly pure rubber which is inflated with compressed air to maintain the outer tube in its proper form under load.

Polarizing: Formation of gas at the negative element of a cell so as to prevent the action of the battery. This formation of gas is caused by the violent reaction taking place in a circuit of low resistance.

Pole Piece: A piece of iron attached to the pole of a magneto used in an electric generator.

Poppet Valve: A disk or drop valve usually seating itself through gravitation or by means of springs, and frequently opening by suction or cams.

Port: An opening for the passage of the working fluid in an engine.

Portable Garage: See "Garage, Portable".

Positive Connection: A connection by which positive motion is transmitted by means of a crank, bolt, or key, or other method by which shipping is eliminated.

Positive Motion: Motion transmitted by cranks or other methods in which slipping is eliminated.

Positive Plate: Plate in a storage battery, from which the current flows to the outside circuit.

Positive Pole: The source from which electricity is assumed to flow; the opposite of negative pole. In a magnet the positive pole is the end of the magnet from which the magnetic flux is assumed to emanate.

Pounding in Engine: Pounding noise at each revolution, usually caused by either carbon deposit, loose or tight piston, loose bearing or other part, or pre-ignition.

Power Stroke: The piston stroke in a gas engine in which the exploded gases are expanding, thus pushing the piston downward.

Power Tire Pump: A pump which is operated by a gas engine and is used to inflate the tires of a motor car.

Power Unit: The engine with fuel, cooling, lubrication, and ignition systems, without the transmission or running gears. Sometimes the gearset and driving shaft are included by the term.

Pre-Ignition: See "Premature Ignition".

Premature Ignition: Ignition of fuel before the proper point in the cycle.

Pressure-Feed: See "Lubrication, Force-Feed".

Pressure Gage: A gage for indicating the pressure of a fluid confined in a chamber, such as steam in a boiler, etc.

Pressure Lubricator: A lubricating device in which the oil is forced to the bearings by means of a pump or other device for maintaining pressure.

Pressure Regulator: A device for maintaining the pressure of the steam in the principal pipe at a constant point irrespective of the fluctuations of pressure in the boiler.

Primary Air Inlet: The main or fixed air intake of a carbureter.

Primary Circuit: The circuit which carries low-tension current.

Primary Coil: A self-induction coil consisting of several turns of wire about an iron core.

Primary Spark Coil: An induction coil which has only a single winding composed of a few layers of insulated copper wire wound on a bundle of soft iron wires, known as the *core*, also as a *wipe*, or *touch, spark coil*.

Primer: A pin in a float-feed valve so arranged that it may depress the float in priming a gasoline engine. Also called *tickler* and *flushing pin*.

Priming: (1) The carrying of water over with the steam from the boiler to the engine, due to dirty water, irregular evaporation, or forced steaming. (2) Injecting a small amount of gasoline into the cylinder of a gasoline engine to assist in starting.

Priming Cock: A control cock screwed into the cylinder and which when open communicates with the combustion chamber allowing gasoline to be poured into the cylinder.

Progressive Change-Speed Gears: Change-speed gears so arranged that higher speeds are obtained by passing through all the intermediate steps and *vice versa*.

Prony Brake: A dynamometer to indicate the horsepower of an engine. A band encircles the flywheel of the engine and is secured to a lever, at the other end of which is a scale to measure the pull.

Propeller Shaft: The shaft which turns the rear axle of a motor car. The drive shaft.

Pump, Centrifugal: A pump with a hollow hub and curved blades which by centrifugal force throw water or oil into the system requiring it.

Pump, Circulation: See "Circulation Pump".

Pump, Fuel-Feed: A mechanically operated pump for insuring positive feed of fuel to the burner of a steam engine or carbureter of a gas engine.

Pump, Oil: See "Oil Pump".

Pump, Plunger: Sometimes called piston pump. One containing a piston which forces a liquid to a system.

Pump, Power Tire: See "Tire Pump".

Pump, Steam Boiler-Feed: See "Boiler-Feed Pump".

Pump, Water Circulating: See "Circulation Pump".

Pump Gear: A pump composed of two gears in mesh placed in a housing. When the gears revolve they carry oil or water, as the case may be, on their teeth, which deliver it to an outlet.

Puncture: The perforation of an inflated rubber automobile tire by some sharp substance on the roadbed.

Puncture-Closing Compound: A viscous compound placed within the inner tire tube to close the hole caused by a puncture.

Push Rod: A rod which operates the valves of a poppet-valve motor. A rod which imparts a pushing motion.

R

Race: (1) The parts upon which the balls of a ball bearing roll. (2) When referring to a gas engine, to operate at high speed without a load.

Racing Body: A low, light automobile body, having two seats with backs as low as possible; designed for large fuel capacity and very high speed.

Radiator: A device consisting of a large number of small tubes, through which the heated water from the jacket of the engine passes to be cooled, the heat being carried away from the metal of the radiator by air.

Radiator, Cellular: See "Honeycomb Radiator".

Radiator, Tubular: A radiator consisting of many tubes, through which water passes to be cooled.

Radiator Protector: See "Bumper".

Radius Rod: A bar in the frame of an automobile to assist in maintaining the proper distance between centers. Also called *distance rod.*

Rawhide Gear: Tooth gears, built up of compressed rawhide, used for high-speed drive. Sometimes a metal gear is merely faced with rawhide for the purpose of reducing noise.

Reach Rod: See "Radius Rod".

Reciprocating Parts: The parts such as pistons and connecting rods which have a reciprocating motion.

Rectifier, Alternating-Current: See "Current Rectifier".

Relief Cock: See "Compression-Relief Cock".

Removable Rim: See "Demountable Rim".

Resiliency: That property of a materia by virtue of which it springs back or recoils on removal of pressure, as a spring.

Resistance, Electrical: (1) A part of an electric circuit for the purpose of opposing the flow of the current in the circuit. (2) The electrical resistance of a conductor is that quality of a conductor by virtue of which the conductor opposes the passage of electricity through its mass. Its unit is the *ohm.*

Retard: With reference to the ignition system, causing the spark to occur while the piston is retarding or moving downward on the working stroke.

Retarding Ignition: See "Ignition, Retarding".

Retarding the Spark: See "Ignition, Retarding".

Retread: To replace the tread of a pneumatic tire with a new one.

Reverse Cam: On a gasoline engine a cam so arranged that by reversing its motion or shifting it along its shaft it will operate the valves and cause the engine to reverse.

Reverse Gear: In a steam engine, a device by which the valves may be set to effect motion of the car in either direction. In a gasoline automobile, the reversing gear is usually incorporated with the change-speed gears.

Reverse Lever: A lever by which the direction of movement of the driving wheels may be reversed without reversing the engine. This is usually combined with the change-speed levers.

Rheostat: A device for regulating the flow of current in a closed electrical circuit by introducing a series of graduated resistances into the circuit.

Rim: The portion of a wheel to which a solid or pneumatic tire is fitted. A circular, channel-shaped portion attached to the wheel felloe.

Rim, Demountable: A rim which may be removed from the wheel easily in order that another with an inflated tire may take its place.

Rim, Quick-Detachable: A rim made of two or more parts so that the tire may be detached and attached quickly.

Rim, Removable: See "Demountable Rim".

Road Map: A map of a section or locality showing the best roads for motor-car travel, and usually the best stopping places and repair stations.

Roadster: A small motor car designed to be fairly speedy; usually has carrying capacity for an extra large quantity of fuel and supplies; generally seats two persons, with provision for one or two more, by the attachment of a rumble seat in the rear.

Rocker Arm: A pivoted lever used to operate overhead valves in a T-head motor

Rod, Radius: See "Radius Rod".

Rod, Steering: See "Steering Rod".

Roller Bearings: See "Bearing, Roller".

Roller Chain: A chain whose links are provided with small rollers to decrease the friction and the noise.

Rotary Valve: A type of valve somewhat similar to the Corliss engine valve used on automobile motors.

Rumble: A small single seat to provide for an extra passenger on a two-seated vehicle. Usually detachable.

Runabout: A small two-seated vehicle, usually of a lower power and lower speed, as well as lower operating radius, than a roadster.

Running Board: A horizontal step placed below the frame and used to assist passengers in leaving and entering a motor car.

Running Gear: The frame, springs, motor, wheels, speed-change gears, axles, and machinery of an automobile, without the body; used synonymously with *chassis*.

S

Safety Plug: See "Fusible Plug".

Safety Valve: A valve seated on the top of a steam boiler, and loaded so that when the pressure of the steam exceeds a certain point the valve is lifted from the seat and allows the steam to escape.

Saturated Steam: The quality of the steam when no more steam can be made in the closed vessel without raising the temperature or lowering the pressure.

Scavenging: The action of clearing the cylinder of an internal-combustion motor of the burned-out gases.

Score: To burn, or abrade a moving part with another moving part.

Screw: An inclined plane wrapped around a cylinder; a cylinder having a helical groove cut in its surface.

Searchlight: A headlight designed to throw a very bright light on the road. Electricity or acetylene is usually used as an illuminant, and the lamp has a parabolic reflector and may be turned to throw the light in any direction.

Secondary Battery: See "Accumulator".

Secondary Circuit: A circuit in which the electromotive force is generated by induction from a primary circuit in which a variable current is flowing. The high-tension circuit of a jump-spark ignition system.

Secondary Circuit: The circuit which carries high-tension current.

Secondary Spark Coil: An induction coil having a double winding upon its core. The inner winding is composed of a few layers of insulated wire of large size, and the outer winding consists of a great many layers of very small insulated copper wire. Also known as a *jump-spark coil*.

Seize: Refers to moving parts which adhere because of operation without a film of oil between the working surfaces.

Selective Change-Speed Gears: Change-speed gears so arranged that any desired speed combination can be obtained without going through the intermediate steps.

Self-Firing: Ignition of the mixture in a gas engine due to the walls of the cylinder or particles attached to them becoming overheated and incandescent.

Self-Starter: See "Engine Starter".

Separator, Steam: A device attached to steam pipes to separate entrained water from live steam before it enters the engine, or to separate the oily particles from exhaust steam on its way to the condenser.

Series Circuit: A compound circuit in which the separate sources or the separate electrical receiving devices, or both, are so placed that the current supplied by each, or passed through each, passes successively through the other circuits from the first to the last.

Set Screw: A small screw with a pointed end used for locking a part in a fixed position to prevent it from turning.

Setting Valves: See "Valve Setting".

Shaft, Intermediate: The shaft placed between the first and third motion gearing and acting as a carrier of motion between the two.

Shaft Drive: System of power transmission by means of a shaft.

Shim: See "Liner".

Shock Absorber: A device attached to the springs or hangers of motor cars to decrease the jars due to rough roads, instead of allowing them to be transmitted to the frame of the carriage.

Short Circuit: A shunt or by-path of comparatively small resistance around a portion of an electric circuit, by which enough current passes through the new path to virtually cut out the part of the circuit around which it is passed, and prevent it from receiving any appreciable current.

Sight Feed: An indicator covered with glass which shows that oil is flowing in a system. A telltale sight. A check on the oiling system.

Side-Bar Steering: See "Steering, Side-Bar".

Side-Slipping: See "Skidding".

Silencer: See "Muffler, Exhaust".

Silent Chain: A form of driving chain in which the links are comprised of sections which so move over the sprocket that practically all noise is eliminated. Silent chains are used specially for driving timing gears, gearsets, etc.

Skidding: The tendency of the rear wheels to slide sideways to the direction of travel, owing to the slight adhesion between tires and the surface of the roadbed, also called *side-slipping*.

Skip: See "Miss".

Sleeve Valve: A form of valve consisting of cylindrical shells moving up and down in the cylinders of such a motor as the Silent Knight.

Sliding Gears: A change-speed set in which various gears are placed into mesh by the sliding on a shaft of one or more gears.

Sliding Sleeve: See "Motor, Sleeve-Valve".

Slip Cover: A fabric covering for the top when down or for the upholstery of a motor vehicle.

Smoke in Exhaust: Smoky appearance in the exhaust due to too much oil, too rich mixture, low grade of fuel, or faulty ignition.

Solid Tire: See "Tire, Solid".

Sooting of Spark Plug: Fouling of the spark plug with soot, due to poor mixture, impure fuel, or improper lubrication.

Spare Wheel: An extra wheel complete with inflated tire, carried on the car for quick replacement of wheel with damaged tire.

Spark, Advancing: See "Advanced Ignition".

Spark Coil: A coil or coils of wire for producing a spark at the spark plug. It may be either a secondary or primary spark coil.

Spark Gap: A break in the circuit of a jump-spark ignition system for producing a spark within the cylinder to ignite the charge. The spark gap is at the end of a small plug called the *spark plug*.

Spark Gap, Extra: See "Spark Gap, Outside".

Spark Gap, Outside: A device to overcome the short circuiting in the spark gap due to fouling and carbon deposits between the points of the high-tension spark plug. It is a form of condenser, or capacity in which the air acts as the dielectric between two surfaces at the terminals of a gap in a high-tension circuit.

Spark Intensifier: See "Spark Gap, Outside".

Spark Lever: See "Timing Lever".

Spark Plug: The terminals of the secondary circuit of a jump-spark ignition system mounted to leave a spark gap between the terminals projecting inside the cylinder for the purpose of igniting the fuel in the cylinder by means of a spark crossing the gap between them.

Spark Plug, Pocketing: Mounting the spark plug in a recess of the cylinder head to reduce the sooting of the sparking points.

Spark Plug, Sooting of: See "Sooting of Spark Plug".

Spark Regulator: A mechanism by which the time of ignition of the charge is varied by a small handle on or near the steering wheel.

Spark, Retarding: See "Ignition, Retarding".

Spark Timer: See "Timer, Ignition".

Speaking Tube: See "Annunciator".

Specific Gravity: The weight of a given substance relative to that of an equal bulk of some other substance which is taken as a standard of comparison. Air or hydrogen is the standard for gases, and water is the standard for liquids and solids.

Specific Heat: The capacity of a substance for removing heat as compared with that of another which is taken as a standard. The standard is generally water.

Speed-Change Gear: A device whereby the speed ratio of the engine and driving wheels of the car is varied.

Speed Indicator: An instrument for showing the velocity of the car.

Speedometer: A device used on motor cars for recording the miles traveled and for indicating the speed at all times.

Speedometer Gears: Gears used to drive a shaft which operates the speedometer.

Speedometer Shaft: A flexible shaft which operates a speedometer.

Spiral Gear: A gear with helically-cut teeth.

Splash Lubrication: See "Lubrication, Splash".

Spline: A key.

Spontaneous Ignition: See "Self-Firing".

Sprag: A device to be let down (usually at the rear of the car) to prevent its slipping back when climbing a hill.

Spray Nozzle: That portion of a carbureter which sprays the gasoline.

Spring: An elastic body, as a steel rod, plate, or coil, used to receive and impart power, regulate motion, or diminish concussion.

Spring, Cantilever: A type of spring which appears like a semi-elliptic reversed; and which is flexibly attached in the center, rigidly at one end, and by a shackle at the other.

Spring, Elliptic: A spring, elliptic in shape, and consisting of two half-elliptic members attached together.

Spring Semi-Elliptic: A spring made up of a number of leaves, the whole resembling a portion of an ellipse.

Spring, Supplementary: See "Shock Absorber".

Spring, Underslung: A spring which is fastened under the axle instead of over it.

Spring Hangers: See "Body Hangers".

Spring Shackle: A link attached to one end of a spring which allows for flattening of the spring.

Sprocket: A wheel with teeth around the circumference, so shaped that the teeth will fit into the links of a chain which drives or is driven by the sprocket.

Starboard: The right-hand side of a ship or vessel.

Starter, Engine: See "Engine Starter".

Starting, Gas Engine: The operation necessary to make the engine automatically continue its cycle of events. It usually consists of opening the throttle, retarding the spark, closing the ignition circuit, and cranking the engine.

Starting Crank: A crank by which the engine may be given several revolutions by hand in order to start it.

Starting Device: See "Engine Starter".

Starting on Spark: In engines having four or more cylinders with well-fitting pistons, it is often possible to start the motor after it has stood idle for some time by simply closing the ignition circuit, provided that the previous stopping of the engine was done by opening the ignition circuit before the throttle was closed, leaving an unexploded charge under compression in one of the cylinders.

Steam: The vapor of water; the hot invisible vapor given off by water at its boiling point.

Steam Boiler: See "Boiler".

Steam Condenser: See "Condenser".

Steam, Cycle of: A series of operations of steam forming a closed circuit, a fresh series beginning where another ends; that is, steam is generated in the boilers, passes through the pipes of the engine, doing work successively in its various cylinders, escaping at exhaust pressure to the condenser, where it is converted into water and returned to the boiler, to go through the same operations once more.

Steam Engine: A motor depending for its operation on the latent energy in steam.

Steam Gage: See "Pressure Gage".

Steam Port: See "Admission".

Steering, Side-Bar: Method of guiding the car by means of an upright bar at the side of the seat.

Steering Angle for Front Wheels: Maximum angle of front wheels to the axle when making a turn; should be about 35°.

Steering Check: A device for locking the steering gear so that the direction will not be changed unless desired.

Steering Column: See "Steering Post".

Steering Gear: The mechanism by which motion is communicated to the front axle of the vehicle, by which the wheels may be turned to guide the car as desired.

Steering Knuckle: A knuckle connecting the steering rods with the front axle of the motor.

Steering Lever: A lever or handle by which the car is guided.

Steering Neck: The vertical spindle carried by the steering yoke. It is the pivot of the bell crank by which the wheel is turned.

Steering Pillar: See "Steering Post".

Steering Post: The member through which the twist of the steering wheel is transmitted to the steering knuckle. The steering post often carries the spark and throttle levers also.

Steering Rod: The rod which connects the steering gear with the bell cranks or pivot arms, by means of which the motor car is guided.

Steering Wheel: The wheel by which the driver of a motor car guides it.

Steering Yoke: The Y-shaped piece in which the front axle terminates. The yoke carries the vertical steering spindle or steering neck.

Stephenson Link Motion: A reversing gear in which the ends of the two eccentric rods are connected by a link or quadrant sliding over a block at the end of the valve spindle.

Step-Up Coil: A coil used to transform low- into high-tension current.

Storage Battery: See "Accumulator".

Stroke: See "Piston Stroke".

Strainer, Gasoline: A wire netting for preventing impurities entering the gasoline feed system.

Strangle Tube: The narrowing of the throat of the carbureter just above the air inlets in order to increase the speed of the air, and thus increase the proportion of gas which will be picked up.

Stroke: The distance of travel of a piston from its point of farthest travel at one end of the cylinder to its point of farthest travel at the other end. Two strokes of the piston take place to every revolution of the crankshaft.

Stud Plate: The plate or frame in a planetary transmission system carrying studs upon which the central pinions revolve.

Suction Valve: The type of admission valve on an internal combustion engine which is opened by the suction of the piston within the cylinder and admits the mixture. The valve is normally held to its seat by a spring.

Sulphating of Battery: The formation of an inactive coating of lead sulphate on the surface of the plates of a storage battery. It is a source of loss in the battery.

Superheated Steam: Steam which has been still further heated after reaching the point of saturation.

Supplementary Air Valve: See "Auxiliary Air Valve".

Swivel Joint: The joint for connecting the steering arm of the wheel or lever-steering mechanism to the arms on the steering wheel. Also called *knuckle joint.*

T

Tachometer: An instrument for indicating the number of revolutions made by a machine in a unit of time.

Tandem Engine: A compound engine having two or more cylinders in a line, one behind the other, and with pistons attached to the same piston rod.

Tank Gage: See "Fuel-Level Indicator".

Tappet Rod: See "Push Rod".

Taxicab: A public motor-driven vehicle in which the fare is automatically registered by the taximeter.

Taximeter: An instrument in a public vehicle for mechanically indicating the fare charged.

Terminals: The connecting posts of electrical devices, as batteries or coils.

Thermal Unit: Usually called the *British Thermal Unit*, or *B. t. u.* A measure of mechanical work equal to the energy required to raise one pound of water one degree Fahrenheit.

Thermostat: An instrument to automatically regulate the temperature.

Thermosiphon Cooling: A method of cooling the cylinder of a gas engine. The water rises from the jackets and siphons into a radiator from whence it returns to the supply tank, doing away with the necessity for a circulating pump.

Three-Point Suspension: A method used for suspending motor car units, such as the motor, on three points.

Throttle: A valve placed in the admission pipe between the carbureter and the admission valve of the motor to control the speed and power of the motor by varying the supply of the mixture.

Throttle, Foot: See "Accelerator".

Throttle, Lever: A lever on the steering wheel which operates the carbureter throttle. See "Throttle".

Throttling: The act of closing the admission pipe of the engine so that the gas or steam is admitted to the cylinder less rapidly, thus cutting down the speed and power of the engine.

Thrust Bearing: A bearing which takes loads parallel with the axis of rotation of the shaft upon which it is fitted.

Tickler: A pin in a carbureter arranged to hold down the float in priming, also called *flushing pin* and *primer.*

Timer, Ignition: An ignition commutator.

Timing Gears: The gears which operate the camshaft and magneto shaft. The camshaft gear is twice as large as the crankshaft gear.

Timing Lever: A lever fitted to gas engines by means of which the time of ignition is changed. Also called *spark lever.*

Timing Valve: In a gas engine using float-tube ignition, a valve controlling the opening between the combustion space and the igniter.

Tip, Burner: A small earthen, aluminum, or platinum cover for the end of the burner tube of an acetylene lamp. It is usually provided with two holes, so placed that the jets from them meet and spread out in a fan shape.

Tire, Airless: See "Airless Tire".

Tire, Clincher: A type of pneumatic tire which is held to a clincher.

Tire, Cushion: Vehicle tire having a very thick rubber casing and very small air space. It is non-puncturable and does not have to be inflated, but is not as resilient as a pneumatic tire.

Tire, Non-Deflatable: See "Tire, Non-Puncturable".

Tire, Non Puncturable: A tire so constructed that it cannot be easily punctured or will not become deflated when punctured.

Tire, Punctures in: Holes or leaks in pneumatic tires caused by foreign substances penetrating the inner tube and allowing the air to escape.

Tire, Single-Tube: A pneumatic tire in which the inner and outer tubes are combined.

Tire, Solid: A tire made of solid, or nearly solid rubber.

Tire Band: A band to protect or repair a damaged pneumatic tire. See "Tire Protector".

Tire Bead: Lower edges of a pneumatic tire which grip the curved portion of a rim.

Tire Case: (1) A leather or metal case for carrying spare tire; same as *tire holder.* (2) The outer tube.

Tire Chain: See "Anti-Skid Device".

Tire Filling: Material to be introduced into the tire to take the place of air and do away with puncture troubles

Tire Gage: Gage used for measuring the air pressure in a pneumatic tire.

Tire Holder: A metal or leather case for carrying spare tires.

Tire-Inflating Tank: A tank containing compressed air or gas for inflating the tires.

Tire Inflater, Mechanical: A small mechanical pump for inflating pneumatic tires.

Tire Patch: See "Patch, Tire Repair".

Tire-Pressure Gage: A pressure gage to indicate the pressure of air in the tire.

Tire Protector: The sleeve or band placed over a tire to protect it from road wear.

Tire Pump: A pump for furnishing air under pressure to the tire, may be either hand- or power-operated.

Tire Sleeve: A sleeve to protect the injured part of a pneumatic tire. It is a tire protector which covers more of the circumference of the wheel than a tire band. See "Tire Protector".

Tire Tape: Adhesive tape used to bind the outer tube to the rim in repairing tires.

Tire Tool: Tool used to apply and remove a tire.

Tire Valve: A small valve in the inner tube to allow air to be pumped into the tube without permitting it to escape.

Tires, Creeping of: See "Creeping of Tires".

Tonneau: The rear seats of a motor car. Literally, the word means a round tank or water barrel.

Torque: Turning effort, or twisting effort of a rotating part.

Torque Rod: A rod attached at one end to the rear axle and at the other to the frame; used to prevent twisting of the rear-axle housing.

Torsion Rod: The shaft that transmits the turning impulse from the change gears to the rear axle. Usually spoken of as the *shaft.*

Touch Spark: See "Wipe Spark".

Tourabout: A light type of touring car.

Touring Car: A car with no removable rear seats, and a carrying capacity of four to seven persons.

Town Car: A car having the rear seats enclosed but the driver exposed.

Traction: The act of drawing or state of being drawn. The pull (or push) of wheels

Tractor: A self propelled vehicle for hauling other vehicles or implements; a traction engine.

Transmission, Individual Clutch: A transmission consisting of a set of spur gears on parallel shafts which are always in mesh, different trains being picked up with a separate clutch for each set.

Transmission, Planetary: A transmission system in which a number of pinions revolve about a central pinion in a manner similar to the revolution of the planets about the sun; usual type consists of a central pinion surrounded by three or more pinions and an internal gear.

Transmission, Sliding Gear: A transmission system in which sliding change-speed gears are used.

Transmission Brake: Brake operating on the gearset shaft or end of the propeller shaft.

Transmission Gears: A set of gears by which power is transmitted. In automobiles, usually called *change-speed gears.*

Transmission Ratio: The ratio of the speed of the crankshaft to the speed of the transmission shaft or driving shaft.

Tread: That part of a wheel which comes in contact with the road.

Tread, Detachable: A tire covering to protect the outer tube, which may be taken off or replaced.

Trembler: The vibrating spring actuated by the induction coil magnet which rapidly connects and disconnects the primary circuit in connection with jump-spark ignition.

Truck: (1) A strong, comparatively slow-speed vehicle, designed for transporting heavy loads. (2) A swiveling carriage having small wheels, which may be placed under the wheels of a car.

Try Cock: A faucet or valve which may be opened by hand to ascertain the height of water in the boiler.

Tube Case: See "Tire Case".

Tube Ignition: See "Hot-Tube Ignition".

Tubing, Flexible: See "Flexible Tubing".

Tubular Radiator: An automobile radiator in which the jacket water circulates in a series of tubes.

Tungsten Lamp: Incandescent bulb with the filament made of tungsten wire.

Turning Moment: See "Torque".

Turning Radius: The radius of a circle which the wheels of a car describe in making its shortest turn.

Turntable: Device installed in the floor of a garage and used for turning motor cars around.

Two-Cycle or Two-Stroke Cycle Engine: An internal-combustion engine in which an impulse occurs at the beginning of every revolution, that is, at the beginning of every downward stroke of the piston.

Two-to-One Gear: The system of gearing in a four-cycle gas engine for driving the camshaft, which must revolve once to every two revolutions of the crankshaft.

U

Under Frame: The main frame of the chassis or running gear of a motor vehicle.

Unit-Power Plant: A power system consisting of a motor, gearset, and clutch which may be removed from the motor car as a unit.

Universal Joint: A mechanism for endwise connection of two shafts so that rotary motion may be transmitted when one shaft is at an angle with the other. Also called *universal coupling, flexible coupling, Cardan joint* and *Hooke's joint.*

Upkeep: The expenditure for maintenance or expenditure required to keep a vehicle in good condition and repair.

V

Vacuum Fuel Feed: A system of feeding the gasoline from a tank at the rear of an automobile by maintaining a partial vacuum at some point in the system, usually at the dash, the fuel flowing from this point by gravity to the carbureter.

Vacuum Line: In an indicator diagram, the line of absolute vacuum. It is at a distance corresponding to 14.7 pounds below the atmospheric line.

Valve: A device in a passage by which the flow of liquids or gases may be permitted or stopped.

Valve, Admission: The valve in the admission pipe of the engine leading from the carbureter to the cylinder by which the supply of fuel may be cut off.

Valve, Automatic: See "Automatic Valve".

Valve, Inlet: See "Inlet Valve".

Valve, Mixing: See "Mixing Valve".

Valve, Muffler Cut-Out: See "Cut-Out, Muffler".

Valve, Overhead: See "Overhead Valve".

Valve, Poppet: See "Poppet Valve".

Valve, Rotary: See "Motor, Rotary Valve".

Valve, Suction: An admission valve which is opened by the difference between the pressures in the atmosphere and in the cylinder.

Valve Cage: A valve-retaining pocket which is attached to the cylinder.

Valve Clearance: The clearance of play between the valve stem and the tappet.

Valve Gear: The mechanism by which the motion of the admission or exhaust valve is controlled.

Valve Grinding: The act of removing marks of corrosion, pitting, etc., from the seats and faces of poppet or disk valves. The surfaces to be ground are rotated in contact with each other, an abrasive having been supplied.

Valve Lift: See "Lift".

Valve Lifter: A device for raising a poppet valve from its seat.

Valve Seat: (1) That portion of the engine upon which the valve rests when it is closed. (2) The portion upon which the face of a valve is in contact when closed.

Valve Setting: The operation of adjusting the valves of an engine so that the events of the cycle occur at the proper time. Also called *valve timing.*

Valve Spring: The spring which is around the valve stem and is used to return the valve to closed position after it has been opened by the cam:

Valve Stem: The rod-like portion of a poppet valve.

Valve Timing: See "Valve Setting".

Vaporizer: A device to vaporize the fuel for an oil engine. In starting it is necessary to heat the vaporizer, but the exhaust gases afterwards keep it at the proper temperature. The carbureter of the gas engine properly belongs under the general head of *vaporizer*, but the term has become restricted to the vaporizer for oil engines.

Variable-Speed Device: See "Gear, Change-Speed".

Vertical Motor: An upright engine whose piston travel is in a vertical plane.

Vibrator: The part of the primary circuit of a jump-spark ignition system by which the circuit is rapidly interrupted to give a transformer effect in the coil.

Vibrator, Master: See "Master Vibrator".

Volatile: Passing easily from a liquid to a gaseous state, in opposition to *fixed*.

Volatilization: Evaporation of liquids upon exposure to the air at ordinary temperatures.

Volt: Practical unit of electromotive force; such an electromotive force as would cause a current of one ampere to flow through a resistance of one ohm.

Voltammeter: A voltmeter and an ammeter combined; sometimes refers to wattmeter.

Voltmeter: An instrument for measuring the difference of electric potential between the terminals of an electric circuit. It registers the electric pressure in volts.

Vulcanization: The operation of combining sulphur with rubber at a high temperature, either to make it soft, pliable, and elastic, or to harden it.

Vulcanizer: A furnace for the vulcanization of rubber.

W

Walking Beam: See "Rocker Arm".

Water Cooling: Method of removing the heat of an internal-combustion motor from the cylinders by means of a circulation of water between the cylinders and the outer casing.

Water Gage: An instrument used to indicate the height of water within a boiler or other water system. It consists of a glass tube connected at its upper and lower ends with the water system.

Water Jacket: A casing placed about the cylinder of an internal-combustion engine to permit a current of water to flow around it for cooling purposes.

Watt: The unit of electric power. It is the product of the current in amperes flowing in a circuit by the pressure in volts. It is $\frac{1}{746}$ of a horsepower.

Watt Hour: The unit of electrical energy. The given watt-hour capacity of a battery, for instance, means the ability of a battery to furnish one watt for the given number of hours or the given number of watts for one hour, or a number of watts for a number of hours such that their product will be the given watt hours.

Welding, Autogeneous: A method of joining two pieces of metal by melting by means of a blow torch burning acetylene in an atmosphere of oxygen. This melts the ends of the parts and these are then run together.

Wheel, Artillery: A wood-spoked wheel whose spokes are in line with a line drawn vertically through the hub.

Wheel, Dished: A wheel made concave or convex so that the hub is inside or outside as compared with the rim. This is to counteract the outward inclination of the wheel due to the fact that the spindle is tapered and that its outward center is lower than its inner center.

Wheel, Double-Interacting: The mechanism by which two wheels are hung on one hub or axle, the outer being shod with an ordinary solid tire and the inner with a pneumatic tire, so that the weight of the vehicle bears against the lowest point of the pneumatic tire of the inner wheel to give the durability and tractive properties of a solid tire with the resiliency of a pneumatic.

Wheel, Spare: See "Spare Wheel".

Wheel Steering: See "Steering Wheel".

Wheel, Wire: A wheel with spokes made of wire.

Wheel Puller: A device used for pulling automobile wheels from their axles.

Wheel Steer: A method of guiding a car by means of a hand wheel.

Wheel, Steering Angle for: The angle which the steering column makes with the horizontal. It varies from 90° to 30° or less.

Wheelbase: The distance between the road contact of one rear wheel with the point of road contact of the front wheel on the same side.

Wheels, Driving on All Four: The method of using all four wheels of an automobile as the driving wheels.

Wheels, Driving on Front: The method of using the two front wheels as the drivers.

Wheels, Steering on Rear: Method of guiding the vehicle by turning the rear wheels.

Whistle: An automobile accessory consisting of a signalling apparatus giving a loud or harsh sound. Also called a *horn*.

Wind Guard: See "Wind Shield".

Wind Shield: A glass front placed upright on the dash to protect the occupants of the car from the wind.

Wipe Spark: Form of primary sparking device in which a spark is produced by a moving terminal sliding over another terminal, the break thus made causing a spark. Also called *touch spark.*

Wipe-Spark Coil: A primary spark coil with which the spark is made by wiping contact.

Wire Drawing: The effect of steam passing through a partially closed valve or other constricted opening; so called from the thinness of the indicator diagram.

Working Pressure: The safe working pressure of a boiler, usually estimated as ⅛ of the pressure at which a boiler will burst.

Worm: A helical screw thread.

Worm and Sector: A worm gear in which the worm wheel is not complete but is only a sector. Used especially in steering devices.

Worm Drive: A form of drive using worm gears. See "Gears, Worm".

Worm Gear: The spiral gear in which a worm or screw is used to rotate a wheel

Worm Wheel: A wheel rotated by a worm.

Wrist Pin: See "Piston Pin".

X

X Spring: A vehicle spring composed of two laminated springs so placed one upon the other that they form the letter X.

Y

Yorke, Steering: See "Steering Yoke".

INDEX OF WIRING DIAGRAMS

Diagrams with Plate Numbers Are Blueprints Placed in Numerical Order throughout Volumes III and IV; Numbers Opposite Remaining Diagrams Refer to Bottom Folio in the Volumes Noted.

D

E

F

N

O

P

GENERAL INDEX

In this Index the *Volume number* appears in Roman numerals —thus, I, II, III, IV, etc., and the *Page number* in Arabic numerals—thus, 1, 2, 3, 4, etc. For example, Volume IV, Page 327, is written, IV, 327.

The page numbers of this volume will be found at the bottom of the pages; the numbers at the top refer only to the section.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

D

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

E

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

S

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

T

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

U

V

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.

Note.—For page numbers see foot of pages.