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NO. 2 ENGINE. [FIG. 18, *Frontispiece.*

Turning a corner over an obstacle.

A NEW SYSTEM OF
HEAVY GOODS TRANSPORT ON COMMON ROADS

BY

BRAMAH JOSEPH DIPLOCK

WITH ILLUSTRATIONS

LONGMANS, GREEN, AND CO.
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1902

TO

LIEUT.-COLONEL R. E. B. CROMPTON, R.E., C.B.,

M.INST.C.E., M.I.M.E., M.I.E.E., ETC., ETC.

WHOSE EARLY SUPPORT, VALUABLE ADVICE, AND GENEROUS ASSISTANCE

HAVE CONTRIBUTED SO MATERIALLY TO THE SUCCESS ACHIEVED

THAT HE MAY BE RIGHTLY NAMED

THE FATHER OF THE ENTERPRISE

CONTENTS

A NEW SYSTEM OF
HEAVY GOODS TRANSPORT ON COMMON ROADS

CHAPTER I.

INTRODUCTION AND AXIOMS.

BETWEEN the years 1885 and 1892 the author had the superintendence of a large amount of traction-engine haulage under somewhat exceptional and difficult circumstances, and from watching the progress of the work from time to time he came to the conclusion that an improved system of goods transport on common roads could be designed on a very economical working basis, and that it would be of great public benefit.

From the dates mentioned it will be seen that the author's study of the subject commenced long before the revival of public interest in heavy transport on common roads, which resulted from the passing of the Light Locomotives Act in 1896, and he thus had the benefit of several years' start over those engineers who have since been engaged on the solution of the same problem. The system hereafter described has been developed by a process of gradual evolution of ideas, and differs materially, so far as the author is aware, from all other systems at present advocated.

A careful study of the problem has made it clear to the writer that a system to give the best *commercial* results must be based on the following axioms :—

1. Minimum *cost* of transport is of greater importance than *speed*.

2. Mechanical means must be devised to give the maximum of road-adhesion to the propelling power, or engine, and the minimum of road-resistance to the engine and the wagons.

3. Damage to roads must be minimized, and, if possible, altogether obviated.

4. Goods must be capable of being transported in very large quantities for the longer distances, or trunk routes, and of being easily split into smaller units for collection and distribution through branch routes and terminals.

5. The system must include a cheap and efficient means of collecting and distributing empty wagons or units, and a separate and more powerful means of collecting and distributing them when loaded.

6. Re-handling of goods must, as far as possible, be abolished.

7. The motive power must be separate from the wagons, and must not be kept waiting whilst the wagons are loading or unloading.

In laying down these axioms as essential, the author has been much influenced by the experience of ordinary railways, which, having stood the test of practical working for very many years under world-wide conditions, may be assumed to have attained a high state of efficiency. This valuable experience does not hitherto appear to have been utilized in dealing with road traffic by ordinary traction-engines or motor-wagons.

In the system advocated it is not proposed to deal with distances beyond, say, thirty to fifty miles. Long-distance traffic (in which terminal charges do not add a high percentage to the mileage cost of transport) will probably always be best dealt with by railways, and this would also apply to light parcel traffic, where speed is generally of great importance. The want, however, of some efficient means of dealing with heavy goods transport for moderate distances, especially in isolated country districts, is a matter of public notoriety, as proved by the Light Railways Act, which was passed entirely to encourage a solution of the problem, and which even went to the length of offering *Government financial assistance!*

Although an efficient and economical system of road transport would no doubt affect the earnings of railways so far as short-distance traffic is concerned, the author is of opinion that it would not ultimately prejudice railway traffics as a whole, as the system advocated would "tap" so many new districts, now practically isolated, that the railway *long-distance traffic* must eventually be largely increased thereby. Moreover, the road system would tend in the direction of encouraging the collection and assortment of the traffic into larger units or consignments before it arrives at the railways, so that it could be placed on the same basis as foreign traffic. Having regard to the great outcry against the preferential rates quoted by our railways for foreign traffic, any system that would make it possible for the home traffic to obtain the same advantageous treatment would undoubtedly be of the highest value to the country at large.

Before passing on to the history and general description of the system, the following remarks will be of interest as showing the reasons for the axioms, and also the difficulties to be surmounted :—

AXIOM 1.—*Minimum* cost *of transport is of greater importance than* speed.

Independently of the fact that heavy goods trains travelling at high speeds on public roads would be objectionable and even dangerous, the corresponding advantages of arriving at a destination *an hour or two* earlier would not be of sufficiently material value to justify increased cost.

As regards cost, Mr. Alfred Holt, in his capable paper on " Plateways," suggests that " *cost increases as the cubes* " *of the speed* ;[1] that is, that twenty miles an hour costs " eight times as much as ten. Books have been written " to prove that it is even greater, but to take perfectly " sure ground, it is beyond dissent that slow speeds are " very economical as compared with high."

Mr. Alfred Holt's contention is intended to apply to his plateway system, but it also applies to all *heavy* locomotion on common roads, except that in the latter case the speed should be still further reduced, and in the author's opinion should not exceed three to four miles an hour.

Another reason for this is that the existing Locomotive Acts limit the speed to four miles an hour in the

---

[1] This is not put forward by Mr. Holt as a mathematically accurate statement.

country and two miles an hour in towns, and if these speeds are not exceeded the delay and expense of obtaining any amendment of the existing Acts would be avoided.

Axiom 2.—*Mechanical means must be devised to give the maximum of road-adhesion to the propelling power, or engine, and the minimum of road-resistance to the engine and the wagons.*

Axiom 3.—*Damage to roads must be minimized, and, if possible, altogether obviated.*

Road-adhesion, road-resistance, and damage to roads are so closely allied that these axioms may well be coupled together. In an ordinary wheel only a very small proportion of its circumference is *actually in contact* with the road at any given moment. In railways adhesion is obtained by bringing an enormous weight to bear on these small areas of contact, and it consequently requires metal rails to withstand the pressure, which in a locomotive often amounts to as much as 100 tons. If anything like these weights were attempted on an ordinary highway the wheels would obviously sink into the road, and road-resistance would be enormously increased.

Few people, even in engineering circles, realize the full importance of dealing with road-resistance as a primary factor in the problem, but its effect on transport is well illustrated by the fact that it is possible for a horse to pull a weight of even 40 tons on a railway, whereas a tenth of this would be beyond its powers even on a good high-road, which offers less resistance than the soft or badly laid road, with which, however, the mechanical power must reckon.

Herein lies one of the great difficulties from a mechanical point of view, in the fact that road-resistance *varies* so enormously according to the character of the road. There are not only hard and soft roads, but level and uneven roads. In any well-considered scheme it would be useless designing a mechanical arrangement that would travel well on first-class hard roads, and be brought to a standstill in a soft place. The inference is obvious, that the mechanical arrangement referred to should enable the locomotive and wagons to travel over the *worst* portion of the road on which transport is contemplated, and at the worst seasons.

At a very early stage of the author's investigations he arrived at the conclusion that the first objective to aim at was to increase the *area* of the surface contact between the driving-wheels and the road, and this led to his first invention, patented in 1893, of a road engine which distributed its weight over all four wheels, all of which are driven and steered. This was followed by his invention of the "Pedrail," which increased the surface contact so largely as to practically *float* the load. Both these inventions are more fully described hereafter. For the present it is sufficient to point out that increased *area* of surface contact necessarily includes increased road-*adhesion* of the driving-wheels on the road, and must also tend in the direction of reducing, if not abolishing, *damage* to the roads. In other words, adhesion, which is obtained on railways by placing a large weight on a small surface, should in road work be obtained by a reduction of weight spread over a large surface.

The author noticed, with much surprise, that even when public interest in the whole problem was revived by the passing of the Light Locomotives Act in 1896, the chief attention of engineers appeared to be directed to the *motive-power* as being of the first importance, little or no attention being paid to the question of road-resistance, until Professor H. S. Hele-Shaw read his valuable paper on "Road Locomotion" at the Institution of Mechanical Engineers, in April, 1900. In his paper the problem of the behaviour of the wheel upon the road surface was placed before everything else, as being, what it undoubtedly is, the crux of the whole problem.[1]

Axiom 4.—*Goods must be capable of being transported in very large quantities for the longer distances, or trunk-*

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[1] Extract from paper on "Road Locomotion" by Professor H. S. Hele-Shaw, LL.D., F.R.S., etc., April 26, 1900 :—

"The provision of a suitable track, upon which the train moves and by which its motion is guided, is the real secret of railway development. Hence it is that with a steel wheel rolling upon a hard smooth track, a continuous increase of weight and of tractive force, together with increase of speed, is enabled to be obtained. The conditions of the historical "Rocket" were a weight of 6 tons, a speed of from 20 to 30 miles an hour, and a load of 20 tons, while the modern locomotive and tender together weigh 100 tons, having a speed of over 60 miles an hour, and drawing a load of 300 tons. Now, this result has been obtained by increasing the number of wheels, until the locomotive and its tender may have the weight distributed over from sixteen to twenty wheels, each resting upon a hard smooth surface of contact, whereas the motor-vehicle, at any rate at present, is limited to four wheels, which have to run upon an uneven surface which, if it is hard, intensifies the action of shocks and vibrations, and if it is soft, causes an enormous amount of resistance. The load thus being on four wheels, both this sinking and shock are magnified as the load is increased, and therefore inventive effort has been naturally almost entirely directed to lightening the working parts for obtaining a given power, and this correspondingly diminishes the tractive adhesion which is a necessary feature for successful working. In short, the conditions of the problem are such as to involve improvement *exactly in the opposite direction* to that in which the railway locomotive has been successfully developed.

"No doubt the progress of invention will ever increasingly enable a greater amount of power from a given weight of motor to be obtained, but *the surface to be moved over, which is the real difficulty of the road locomotive, will remain the chief factor of the problem.*"

routes, and of being easily split into smaller units for collection and distribution through branch routes and terminals.

The evolution of railways has shown that it is more economical to take a long train with one engine than a number of short trains with several engines, a saving being thereby effected, not only in the number of engines required to do a given amount of work, but also in the number of men employed and the corresponding expenditure in wages.

Hitherto long trains in road transport have been impossible, owing partly to the want of sufficient adhesion or hauling power of the ordinary traction-engine, and partly to the road-resistance before referred to, which applies to the engine and wagons alike. It has also been found that excessive loads have caused increased damage to the roads, owing to the fact that the *area* of road surface actually in contact with the driving-wheels of the engine has been *insufficient* to stand the strain. This has led to legislative restrictions in the Locomotives Act of 1898, in which the number of loaded wagons to be hauled is limited to three, though this number can be increased with the consent of the local authorities.

In addition to the above there are also the difficulties of getting a long road train round a corner and up steep gradients, and of preventing it from zigzagging and overrunning when travelling downhill, from the fact that the couplings between the wagons must necessarily be hinged joints to enable the train to negotiate much sharper curves than are attempted or required on railways.

Another great difficulty in traction-engine practice has been the want of some quick and efficient means of coupling and uncoupling the wagons when shunting, thus preventing the train from being easily split up into smaller units for collection and delivery.

On railways the separate wagons are easily disconnected, sorted, and shunted, owing to the fact that the guiding rail makes the wagons come together easily for recoupling; but on roads shunting and recoupling is a very tedious and difficult operation, especially at stations and other confined spaces, as the wagons will not travel backwards in any required direction without some kind of steering apparatus to take the place of the guiding rails.

AXIOM 5.—*The system must include a cheap and efficient means of collecting and distributing empty wagons or units, and a separate and more powerful means of collecting and distributing them when loaded.*

AXIOM 6.—*Rehandling of goods must, as far as possible, be abolished.*

Assuming that suitable and powerful engines were designed for dealing with long road trains, the difficult question of collection and delivery would still remain. It is now generally agreed that for short-distance traffic cheapness of collection and delivery and avoidance of rehandling is of even greater importance than actual transport, and no system would be complete that did not provide for this on an efficient and workable basis.

AXIOM 7.—*The motive power must be separate from the wagons, and must not be kept waiting whilst the wagons are loading or unloading.*

One important reason why traction-engine haulage has not hitherto been more economical is that, whereas on our railways the wagons are loaded before the engine arrives to take them away, with traction-engine haulage the engine is often obliged first to take the wagons to the place of loading and then remain idle whilst the loading is proceeding, only doing actual haulage work for a short interval.

The existing system, or want of system, in traction-engine practice does not admit of the paying load being picked up in small units along a fixed line of route, otherwise it might be possible for the wagons to be distributed and loaded in advance, though even this would not get over the shunting difficulty before referred to.

CHAPTER II.

NO. 1 ENGINE.

WITH the object of increasing the surface area of road contact before referred to, the author took out a patent in 1893 for an engine to drive and steer all four wheels, which would at least have the effect of *doubling* the surface contact of the driving-wheels. In an ordinary traction-engine two large wheels are used for driving and two smaller ones for steering; and, in order to obtain adhesion, the engine is so designed that the bulk of its weight is concentrated on the two driving-wheels, and is not, as is often supposed, distributed evenly over the four. Also, when pulling a heavy load, the winding action of the gear-wheels round the road-axle, so well-known to traction-engine men, further reduces the weight on the steering-wheels and concentrates it on the driving-wheels, even to the extent of occasionally lifting the steering-wheels off the ground, when it is obvious that the *entire* weight of the engine must be on the two driving-wheels. This more frequently happens when ascending an incline to pass over a bridge, which is just the very time when the weight should be spread over as large an area as possible, especially on small country bridges.

It is not generally known that the cost of breakages and the consequent repairs of an ordinary traction-engine form a very high proportion of the working cost. In the author's experience, which is corroborated by that of others, it has been found that the life of an ordinary traction-engine, even after a large amount has been spent on annual repairs, is only about four or five years, and that after this it practically becomes cheaper to buy a new engine than to go on repairing the old one; this means a very serious item for depreciation alone. The excessive breakages referred to are mostly caused by the want of efficient springs to ease the heavy weight of the engine when jolting over inequalities in the road. Various designs have been tried with the object of introducing springs into traction-engines, but although some of these designs have been adopted by leading makers, and are working with a fair amount of success, they none of them really give a true mechanical movement,

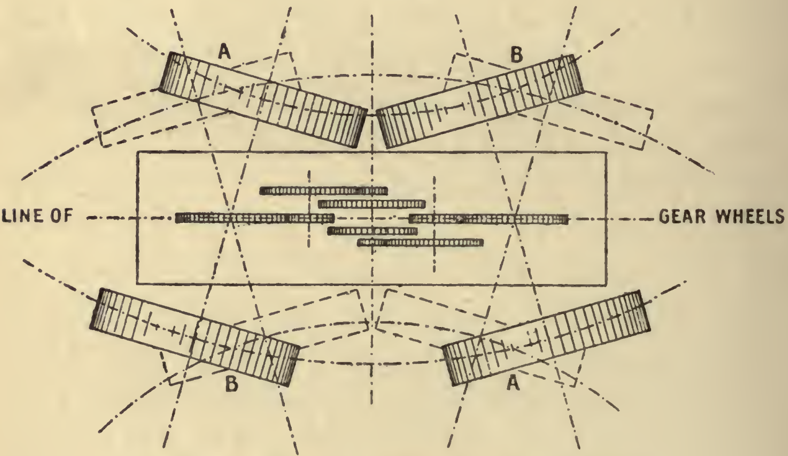

FIG. 1.—Plan of Frame of Engine with Boiler removed.
(*The dotted lines show the alternative positions of the four wheels.*)

and the spring action in all of them is confined to a *fraction of an inch.* These defects cause irregular wear in the working parts, and the small spring movement is wholly inadequate to the object for which it is designed.

In the author's invention the gear-wheels on the road-axles are mounted on the *centre* of the axles, with a special form of universal joint inside the gear-wheels which not only admits of *both* axles being steered for turning corners without disturbing the line of the gear-wheels with the rest of the engine[1] (see Fig. 1), but the same arrangement allows the axles to oscillate horizontally (as shown in Fig. 2) to an *almost unlimited extent.* In fact, it may be mentioned here that in an engine actually constructed the spring movement admits of the wheels **A, A** (Fig. 1) being simultaneously raised

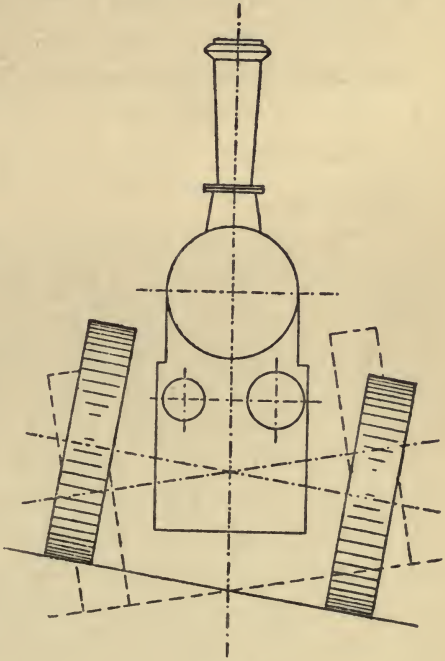

FIG. 2.

(*The dotted lines show the alternative positions of the four wheels.*)

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[1] In previous attempts to build "four-wheel drivers" only one axle was designed to steer, but this required a very large angular movement of this axle to negotiate a sharp corner, and thus caused an excessive twisting strain on the driving mechanism. It will be seen from Fig. 1 that by steering *both* axles this angular movement and twisting strain is divided evenly between the two axles, and is consequently *halved.*

6 inches higher than the wheels **B, B**, and consequently, by tilting the engine, any *one* wheel can rise *twelve inches* higher than the remaining three without disturbing the mechanism of the engine in any way.

With regard to this engine the following reports by Lieut.-Colonel R. E. Crompton, R.E., C.B., well known as a traction-engine expert, will be of interest :—

REPORT ON IMPROVEMENTS IN ROAD LOCOMOTIVES.

August 28, 1894.

B. J. DIPLOCK, ESQ.

DEAR SIR,

From the year 1869 to 1875 I was employed by the Indian Government to carry out a long series of experiments on road traction on the Grand Trunk road of India. I held the official title of Superintendent of the Government Steam Train 8th Circle Military Works, and during the above period had five large road locomotives continuously at work under every kind of condition likely to be met with when such engines are used for the transport of troops and war material. My experience in locomotive and traction-engine work is probably as full as that of any other engineer, and on account of the big facilities given to the steam-train by the Indian Government, I believe I have had more experience in working traction-engines at high speeds than any other living engineer. I consequently have paid much attention to all points of road locomotives that are affected by such high speeds. I refer more particularly to the arrangements of gear and of springs.

I have studied the drawings left by you, as well as the patent specification, No. 19,682, of 1893. I understand the main object of your invention to be the perfecting of the gearing for transmitting the power from the cylinders to two pairs of driving-wheels of a road locomotive, a feat which has hitherto been often attempted, but which has never been carried out satisfactorily in practice. I think it is unnecessary in this report to dwell on the obvious advantages of transmitting the power to four wheels instead of two as is now the case. Amongst these I need only mention the greatly reduced wear and tear of the road surface due to the weight of the engine being distributed over four wheels instead of being concentrated on two wheels, and that as the front wheels now become driving as well as steering wheels, side-skidding of these wheels is prevented, which obviates a serious difficulty well known to all users of traction-engines.

I have now to point out in what respects your invention successfully accomplishes these objects, by transmitting the power equally to all four wheels, and how far this great advantage is obtained without an introduction of corresponding disadvantages.

The arrangement of your gearing is very fairly shown and described in Figs. 1 and 2 of your patent with accompanying description.

The symmetry of the arrangement and the fact that you have been able to adopt a complete self-contained frame, supported on swivel-end carriages, at once commends the design to engineers who have had experience of road work.

I have carefully thought over the arrangement of the central ball-socket drive, by which the axle-boxes can rise and fall in horn-blocks without fear of jamming or causing strain on the axles themselves, and, as far as I am able to judge from the drawings, the action appears to be perfect, and there is no fear of such jamming action.

The movement appears also to be satisfactory in respect of the gearing; that is to say, that the action of the springs in combination with that of the ball-and-socket gear does not bring any twisting or irregular strain on the teeth of the gearing, so there will be no tendency for teeth to be broken from this cause.

Another point which I think will be found of great advantage is that the axles are not only free to swivel in the horizontal plane, but are also free to swivel round a horizontal axis when the engine is seen in end view, thus allowing all four driving-wheels to take a bearing when the engine is standing on irregular ground. This last advantage, I think, will have the effect of distributing the driving power over the four wheels very perfectly, and hence will largely increase the total tractive power. In regard to this swivelling movement of the two axles around a horizontal axis, I consider the compound distance-pieces, described on page 3, line 7, and following lines of your specification, are of great merit.

As far as I am aware, the invention of the compound distance-pieces is quite new, and it is probably the detail that was really wanting in previous attempts to make four-wheel geared traction-engines. It is difficult to estimate the amount of increased tractive power which will be obtained by this even bearing of all the four driving-wheels on the road surface, but I should be quite prepared to find that on trial it will be found one-third greater than that of a two-wheeled engine of ordinary make. Under your invention, a traction-engine weighing 8 tons, having 2 tons on each driving-wheel, will draw the same gross load as an engine of the old construction weighing $10\frac{3}{4}$ tons, and having $4\frac{1}{2}$ tons on each driving-wheel. If we take a case where the two-wheeled $10\frac{3}{4}$-ton engine hauls $19\frac{1}{4}$ tons of load and wagons, then your engine ought to haul 22 tons of load and wagons. If we further take it that the damage to the roads is in proportion to the weight on each driving-wheel, then in the above case the damage caused by the two-wheeled engine will be more than $2\frac{1}{2}$ times that caused by your engine, and this is independent of the reduced wear and tear obtained by the use of springs. All users of traction-engines know that the serious claims made against them for damages to the surface of the roads they use are the principal cause why the employment of traction-engines has hitherto not been more lucrative than it would have been if these claims had not in many cases been justified by the actual damage caused by the existing type of engines. The highway authorities assert with considerable truth that these damages are chiefly caused *after* the traction-engine has broken through the top crust of the road. If, as there is every reason to hope, your improved engine will be able to do its work without thus breaking through the top crust of the road, the wear and tear of the road caused by these engines will not be greater than that caused by other vehicles, and *there will then exist no special grounds for claim for such damages.*

Another advantage offered by your design is that the boiler is quite free from the stresses of the driving machinery, and that its expansion does not alter the distance between cylinders and crank-shaft. It is well known what an improvement Aveling's invention of prolonging the side plates of the fire-box to carry the bearings was considered at the time it was brought out, but although this invention did mitigate the strains, and hence the wear and tear of the boiler very considerably, yet it did not obviate them entirely. On the other hand, your arrangement, which so nearly resembles that adopted in the railway locomotive, does so completely do away with mechanical strains on the boiler that it must tend to greatly reduce boiler wear and tear.

The advantages of the use of springs have been obvious for many years, but I have as yet seen no arrangement of horn-blocks which was as satisfactory as your compound distance-pieces appear to be. Again, all the important gear-wheels are arranged inside the bearings, a point which is desired by traction-engine designers, and, as far as I am aware, has been here accomplished for the first time.

We have to weigh, on the other side, what disadvantages, if any, attend the introduction of your invention. At first sight the chief drawback appears to be that, as there are more parts, and as the engine is a much more perfect affair than the ordinary type, it will be considerably more costly to manufacture; but on careful examination I think it will be seen that this objection is more apparent than real. The design is so symmetrical and the parts are so much in duplicate that they lend themselves to easy and cheap manufacture; and it must be remembered that, as material forms a very large portion of the cost of these engines, and, as I have shown above, that to haul a certain load the weight of the material in the engine will in all probability be reduced by one-third, when this saving is considered it is probable that this perfected engine may be eventually put on the market at a price little, if at all, in excess of the present types of traction-engines.

Another difficulty is the number of gear-wheels employed. (A, see letter June 17, 1897.) I believe it will be found that the number of these can be reduced except in the cases where a great amount of gearing up is required; but even this disadvantage is a small one, and in no way to be reckoned against the preponderating advantages.

The last point to be raised by those objecting to the engine is that the adoption of four wheels of equal size and of a separate supporting frame, must necessarily lift the boiler higher, and consequently bring the centre of gravity higher than is usual in this type of engine. This, however, is not so, as will be seen if the engine is viewed from the front. It will be seen that although the boiler, as shown on the patent drawing, is lifted to a higher position than boilers of traction-engines of the same type, yet its stability or non-liability to turn over on to its side is far in excess of all possible requirements; moreover, it is quite possible to devise a type of boiler to suit these engines with a much shallower fire-box (B, see letter June 17, 1897), and by this means to keep the height down to the same as it is in present traction-engines.

In conclusion, I may say that your inventions constitute such a radical departure from existing traction-engine designs that the real and full value of the points can only be solved by actual trial of an engine constructed according to your design, *but the excellent features of the invention shown on the drawing to my mind amply warrant the expenditure on such an experiment.*

Yours faithfully,
(*Signed*) R. E. CROMPTON.

B. J. Diplock, Esq., *June* 17, 1897.
53, Ashley Gardens, S.W.

Dear Sir,

I have received from you the tracings showing the arrangement of your traction-engine, and I have examined the points in which the new design differs from the designs put before me at the time I wrote my report, dated August 28, 1894. I find that in all respects the alterations constitute an improvement on the first design, and I note that in two cases, namely, the reduction in the number of gear-wheels and in the reduction in the depth of the fire-box, you have satisfactorily succeeded in disposing of two difficulties which are referred to in my report. The first of these I have marked by a Note A on the original (see Report); in this case you have satisfactorily reduced the number of gear-wheels, and hence done away with a difficulty which, at the time of writing that report, I supposed would exist; and in the second case, B, you have altered the fire-box of the boiler so as to reduce the height. The engine as now arranged appears to me to be no higher than an ordinary traction-engine, and possesses ample stability for all practical purposes. I return my original report, which I have re-read, and to which I adhere in every particular.

Yours faithfully,
(*Signed*) R. E. Crompton.

Report on Traction-engine.

To the Chairman and Directors,
Diplock's Patent Traction Engine
Haulage Syndicate, Limited,
7, Victoria Street, London, S.W.

Thriplands,
Kensington Court,
London, W.,
December 28, 1899.

Dear Sirs,

In accordance with Mr. Diplock's request, I went down to Branbridge Mills, East Peckham, Kent, on December 5, and witnessed several tests of your patent traction-engine.

On that day the roads were in an exceptionally heavy condition in that part of Kent, so as to put a severe strain on the hauling capacity of the engine. They were not only very soft from continued wet weather, so that the road-resistance was very high, but from the same cause the surface was in such a state that the wheels were more than usually liable to slip, and hence damage the roads, than they would be under average conditions.

My first test consisted in setting the engine to work to haul behind it a train made up of two trucks containing 20 tons of stone, two trucks containing 14 tons of stone, and three trucks containing 18 tons of rock; the total weight of the train, including the trucks, was 71½ tons, and the gross weight of the train, including the engine itself, which weighed 15½ tons, amounted to *eighty-seven tons.*

Your engine started this heavy train and manœuvred it in the yard in a highly satisfactory manner. It gave a steady starting pull, hauling the whole train out of its standing position, where every wheel had to some extent sunk into the surface, without any of the jerking or uneven pulling which is usual under such circumstances.

My second test consisted in the engine hauling three of the heaviest trucks weighing 36½ tons, over a considerable length of the country roads and round some exceptionally *severe curves*, in one of which the *train was almost doubled on itself.*

A third test consisted in this train, which with the engine amounted to a gross load of 52 tons, being hauled up an incline of 1 in 15½, and during this last test I very carefully watched the behaviour of all four driving-wheels of the engine. I was informed by Mr. Diplock that the weight was not so equally distributed over all four wheels as ought to have been the case in order that his invention might show to the best possible advantage; but taking things as they were, and carefully watching the behaviour of the wheel that was lightest loaded, I observed no slipping or even displacement of the softened upper surface of the road metal by any tendency of this lightest-loaded wheel to slip on its surface.

I have been at some pains to ascertain the actual draw-bar pull exerted by the engine during this last test. There are two ways of doing this. The first is by calculations from the steam pressure, area of pistons, ratio of gearing and diameter of driving-wheels, with allowances for the frictional losses in the engine and gearing. The other method is by calculating the total pull of the train due to gravity and due to road-friction, the latter being taken at an assumed figure. From long experience in these matters, I should have said that the road-friction on that day was not less than 100 lbs. per ton, and, calculating in this manner, the draw-bar pull was 12,700 lbs. If we check this by calculating from the piston area, etc., we get a figure of 12,876 lbs., which coincides so closely with the first figure that we may safely assume the first figure to be as nearly correct as is possible under the circumstances. Assuming the draw-bar pull to be 12,700 lbs., we obtain the extremely satisfactory result that on this test the engine was able to exert a pull equal to 35 per cent. of the total weight of the engine, quite irrespective of the fact that the driving-wheels were unequally loaded, so that in the case of the lightest-loaded wheel the pull exerted without any slip on the road was certainly considerably in excess of 35 per cent. of the insistent weight.

I have had a wide experience in traction-engine haulage on roads, and I have never yet heard of any results approaching these figures as to satisfactory coefficient of adhesion, and I am pleased, therefore, to say that in this respect the results of the test are so satisfactory as to promise a great future for the engine.

I made a fourth set of trials in order to observe the effect of the special arrangement of the springs, and of Mr. Diplock's gearing for enabling the two axles to accommodate themselves to considerable inequalities in the road surface. The engine was at my request driven over obstacles so irregularly placed that they were encountered by the wheels on either side of the engine; they were so high that an engine of ordinary form would have been so jerked about as to have thrown the drivers off their seats, but in this case the engine was driven over them backwards and forwards several times without any difficulty, and with an *extraordinary absence from shock or vibration,* the compensating gear allowing each wheel to rise, lifting the engine through only half the height that it would ordinarily lift it in passing over the block, and this half height was again diminished to some extent by the action of the springs.

I consider that in this test Mr. Diplock's engine showed that his method of construction enables him to obtain all the advantages that I expected would be obtained when I made my first report on the invention at the time that I had only seen the drawings, but these tests have strongly confirmed me in my opinion that his invention is of great commercial value.

The experimental engine in its present condition is not satisfactory. It will be necessary to make several alterations in the design, owing to miscalculations, which are quite excusable, considering the difficulties which the designer had to contend with. There is no doubt that that portion of the framework which contains the compensating gear is too heavy, and that the boiler is too small for its work, so that the engine cannot make steam enough to utilize its magnificent hauling power.

The tests of December 5, following on others which have been made by Mr. Richard Muirhead on previous occasions, justify me in saying that I believe that the hauling power of Mr. Diplock's engine is *fifty per cent. in excess* of that of the ordinary form of hauling engines of the same total weight, and there is every possibility that the percentage of increase of hauling power *may be even greater than this* when the weight is more equally disposed over all four wheels than is the case in the experimental engine.

As regards future commercial prospects, I think that, in view of what has already been done to make it effective, other engines should be built embodying the improvements that have already suggested themselves as to the proper strength and weight of parts, and the size and capacity of the boilers.

Most of the advantages claimed in the original prospectus by Mr. Diplock have been proved by these experiments; some of them, such as the reduced wear and tear, can, however, only be ascertained by extended use of the engines on a commercial scale, but I see no reason why these claims should not also be substantiated, especially when the spring movement has shown itself to be so satisfactory, and hence so certain to reduce the wear and tear of the parts.

At the present time, when the attention of every one interested in haulage engines has been called to the necessity of developing means of *hauling artillery* of much greater weight than was before deemed necessary into positions where the hauling engines must necessarily pass over extremely rough ground, the advantages of Mr. Diplock's engine are so great that it is unnecessary for me to enlarge upon them.

Those who have used the ordinary form of engine, where the whole of the driving power is on one pair of wheels, will know how liable such engines are to lower their hind or driving wheels in the act of slipping, and hence, throwing out the loosened surface beneath the driving-wheels, the engine not only loses hauling power, but actually has to hoist itself out of an excavation that it has made for itself.

With Mr. Diplock's engine, even if the wheels do slip and excavate the surface, the engine would remain level, or, as it might be said, "on an even keel," and consequently the difficulty of extricating the engine will be very greatly lessened.

Finally, I may say that I am much impressed by what Mr. Diplock's invention has demonstrated by experiments, and I strongly recommend the construction of another engine on the same principle but of better design, as in this way the further advantages that the invention undoubtedly has, can be best shown to military authorities, intending users, or to licensees.

(*Signed*) R. E. CROMPTON.

Between Colonel Crompton's reports in 1894 and 1899 a syndicate was formed and an engine built which successfully demonstrated the importance of the *principle* involved, but the experience thereby gained suggested improvements in the design which were deemed essential to secure good commercial results, and led to Colonel Crompton's recommendation to build a second engine.

It is interesting to notice how accurately Colonel Crompton's forecast of 1894 was verified by the actual results, especially as regards the increase of total tractive power and the spring movement. At the time he made his forecast he had nothing before him but the somewhat crude patent-office drawings, as the working drawings of the engine were not prepared till afterwards.

One important discovery arose out of the first trial of the engine in 1898. The wheels being all of equal size, it was erroneously assumed that the front and rear axles would revolve at fairly equal speeds, and that any slight difference would not materially affect the hauling power. Provision had, of course, been made by differential gear on each axle for the difference in speed between the near and off wheels when turning corners; but the arrangement of the gearing did not admit of one *axle* and its wheels, as a whole, revolving faster than the other. The result was an extraordinary loss of power, which was at first erroneously ascribed to the friction of the somewhat numerous gear-wheels, but eventually the author arrived at what has since proved to be the correct solution of the problem, viz. that, owing to the inequalities in the road surface and the difference in the spring action on each axle, the two axles do *not* revolve at adaptable speeds, and that the battle going on between them absorbed nearly *the whole power of the engine!*

This led to the author's patent for the application of a third differential gear to take effect between the two axles, in addition to the differential gear on each axle already referred to. It may be mentioned incidentally that this patent is applicable to motor-cars and other vehicles when driving all four wheels by one motive power. The practical introduction of the third differential gear into an engine already constructed presented many difficulties, but these were eventually overcome, and produced the desired result.

The importance of driving all the wheels through differential gears from *one* motive power, instead of a separate motive power to each wheel or pair of wheels, lies in the fact that each *beat* of the engine is distributed *simultaneously* over all four driving-wheels, producing the same effect as in a boat when all the oarsmen pull together.

A series of trials, with the assistance of Mr. R. Muirhead and Mr. Watson Foggo, to ascertain the indicated horse-power of the engine under different conditions produced some interesting figures, of which the following is a summary :—

	M.E.P. High.	M.E.P. Low.	Revs. per. min.	Boiler-pressure.	I.H.P. High.	I.H.P. Low.	I.H.P. Total.	I.H.P. Average.
Tests with engine out of gear and a brake applied to the fly-wheel	90·2	32·2	190	160	20·39	15·29	35·68	38·37
	99·2	26·5	202	162	24·05	13·38	37·42	
	91·3	29·0	215	170	23·55	15·58	39·14	
	87·0	27·35	240	170	25·05	16·20	41·25	
With the engine driving the road wheels when blocked up clear of the ground, and having the axles in their normal position, *i.e.* parallel	13·7	2·4	198	140	3·25	1·18	4·44	4·22
	11·4	2·8	194	160	2·65	1·35	4·01	
As above, but with the axles locked to as great an angle as possible	15·3	3·85	204	160	3·74	1·96	5·70	
Engine running on level road without any load	35·3	7·75	180	160	7·62	3·48	11·11	10·6
	27·1	8·25	190	160	6·17	3·91	10·09	
Engine running round in a circle, 27 feet diameter, without any load	36·5	10·45	170	170	7·44	4·44	11·88	

The author believes that this is the first occasion on which the I.H.P. of a traction-engine has been tested when actually travelling on the road, and it is worthy of notice that the power absorbed in the friction of the engine and gearing is not excessive.

It is a well-known engineering theory that the total friction between two plane surfaces is not materially affected by the increase or reduction of the *area* of the surfaces in contact, provided that the *total weight* on these surfaces remains the same. Arguing on this theory, it would appear that spreading the total weight of the engine over four driving-wheels instead of over two should give the *same* hauling power in proportion to the same *total* weight. Notwithstanding this, several engineers predicted that the reduction of the weight on each individual driving-wheel, in road work, would have the effect of reducing the total hauling power, or, as one engineer put it, the wheels would go round like a cat scratching, and not pull anything.

As a matter of fact, the exact opposite took place, and, as will be seen in Colonel Crompton's report of 1899, the hauling power was increased certainly 50 per cent. in proportion to the *total* weight, and possibly more, but the boiler and cylinder power provided in the engine were not sufficient to test the full extent of the increased adhesion obtained. It should be borne in mind that this increase of hauling power is obtained with a *considerable reduction* of weight on *each* driving-wheel, the total weight being spread over four wheels instead of two.

This is only another example of the futility of basing a conclusion on a theory in which the conditions are not identical; in other words, a road is not a *plane surface.*

Frictional adhesion on roads is thus governed by two factors; one is area of surface *contact*, and the other is *weight.* The experiments described clearly show a result which is of *supreme importance* to road work, viz. that on roads *area of surface contact counts for more than weight* in obtaining adhesion. The demonstration of this fact led the author to the invention next described.

CHAPTER III.

THE "PEDRAIL."

Before describing the Pedrail it will perhaps be interesting to the reader to hear the further reasons which led to its evolution. It is well known that nature's great pulling instrument, the horse, possesses a hauling power altogether out of proportion to its weight, and it is therefore evident that the more nearly a mechanical tractive instrument assimilates in principle to the structure of the horse the better will be the result. A horse puts down a foot, to which is attached a leg, or lever, and the foot is mounted on an ankle-joint which enables it to twist to any reasonable angle to suit the surface of the road. To imitate this was all plain sailing so far as adhesion was concerned, but, as already described, another condition had to be considered, namely, *road-resistance*. It was quite clear that the minimum of road-resistance would be obtained by rolling metal on metal, as in *a railway*, and as a result the Pedrail is, as its name implies, a railway on feet, or, in other words, a combination of an endless railway with a trotting machine.

It only requires a little consideration to see that a wheel, though commonly used as a driving instrument on traction-engines, motor-cars, bicycles, etc., is not really a suitable *pulling* instrument at all; it is only a *rolling* instrument for reducing friction, and was never intended for anything else.

The sketch or drawing, Fig. 3, will best show how the required conditions have been carried out.

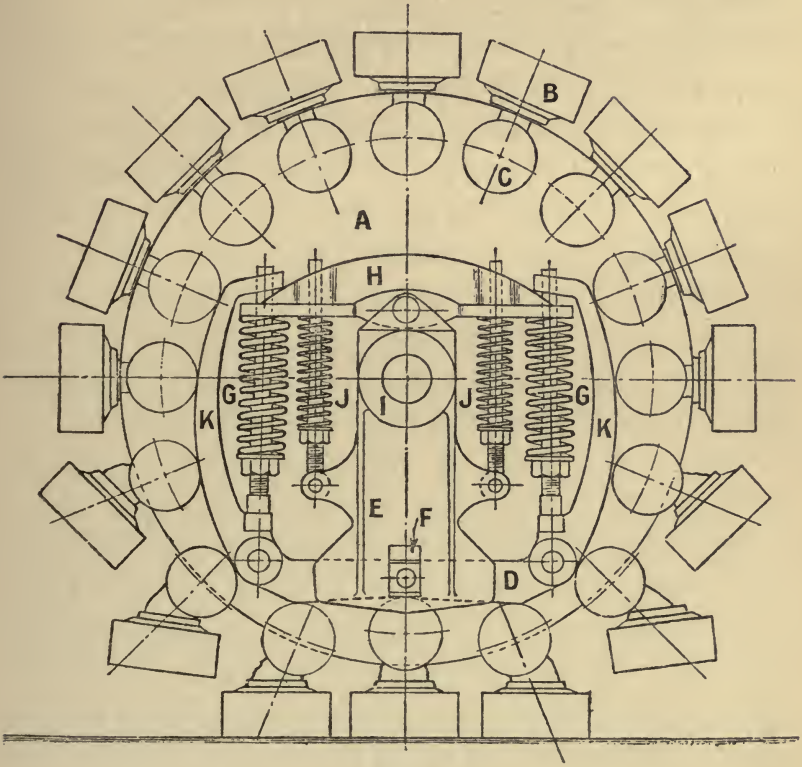

Fig. 3.

A is a disc keyed or fastened to the driving axle; mounted in the disc are sixteen sliding spokes, and on the outer end of each spoke is a foot, **B**, pivoted by a ball-and-socket joint so that it can turn to any reasonable angle to suit the surface of the road. On one side of each spoke, and projecting beyond the disc, is a small wheel, or roller, **C**. The spokes are drawn inwards by springs (one to each spoke) on the other side of the disc, radiating from the centre. These springs are not shown in the drawing.

Mounted on the axle-box **I** is a rail, **D**, pivoted to a flat plate or guide, **E**, forming part of the axle-box; the pivot of the rail is free to rise and fall in a slot, **F**, in the plate **E**. The rail **D** supports the engine or vehicle by two springs, **G**, pressing against a top lever, **H**, pivoted to the top of the axle-box **I**. The two inner springs, **J**, only serve to steady the top lever, **H**. Two guides, **K**, are provided to lead the rollers **C** under the rail **D**.

The whole of the levers and springs mounted on the axle-box **I** come flat against the disc **A**, so that the rollers **C**, which project from the disc **A**, are arranged round the guides **K** and the rail **D**, as shown.

The disc **A**, carrying the spokes, rollers, and feet, revolves, but the axle-box **I**, with its dependent lever, guides, rail, and springs, does not revolve, with the result that a roller starting from, say, the top of the disc, strikes on the guide **K**, and gradually forces the sliding spoke outwards, thereby enabling the foot to turn on its ankle-joint by its own weight as it comes down, and to drop with its flat surface on the road, the roller then passing under the rail as shown. The bottom of the rail is slightly arched, as shown by the dotted line, so that the varying height of the rollers caused by the spokes being sloped or upright is neutralized, and the soles of the feet present a uniform level surface to the road.

Practically the Pedrail system places feet on the ground, each foot supporting a roller on edge, and a short rail, supporting the load, is *levered* along by the spokes over the rollers.

In an ordinary railway a rail is laid down and wheels are run over it; in the Pedrail, wheels, or rollers, are laid down and the rail is run over them. The principle is the same, only the railway is inverted. The sliding spoke represents the horse's leg, or lever, and each leg is pivoted by an ankle-joint to its foot.

By turning the railway upside down, the parts coming in contact with the road are broken up into a number of comparatively small feet, which can twist in *varying* directions as required. Previous attempts at endless railways have failed owing to the attempt to place the *rail* next the ground. The rail, presenting a *long* cumbersome surface to the road, did not lend or adapt itself to the varying inequalities of the road surface, and hence caused endless breakages and repairs.

In Fig. 3 three feet are shown in contact with the road, and it will be seen that as the Pedrail moves forward one of these feet is lifted up before the corresponding foot at the other end of the rail comes down; in other words, each Pedrail has two and three feet alternately on the ground, and if this is combined with the four-wheeled-driven traction-engine already described (*i.e.* four Pedrails), the number of feet on the ground per engine would never be less than eight, and might be twelve, or an average of, say, ten. Each of these feet on a full-sized Pedrail is about 9 inches in diameter, the feet being circular on plan to admit of their turning round when turning corners, etc.

Compare this surface contact of 10 feet, each 9 inches in diameter, with that obtained in a two-wheel-driven traction-engine, as shown in Fig. 4, in which the point of contact is quite small and inadequate. By using four Pedrails the proportionate surface adhesion is so enormously increased that the slipping of the driving-wheels, so well known as the great traction-engine problem, would in the Pedrail system be practically an impossibility.

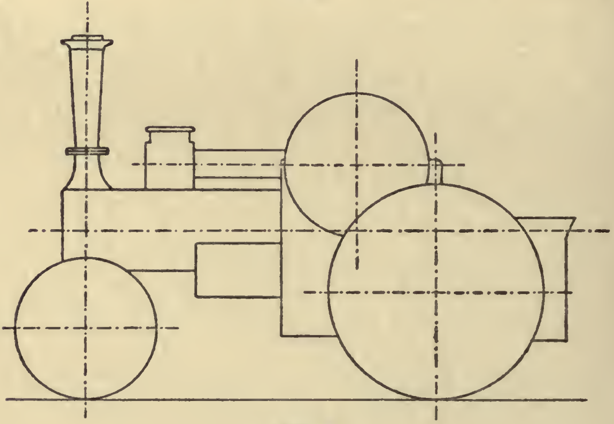

FIG. 4.

Attention is here drawn to a theory, which the author believes has not hitherto been advanced, viz. that a wheel in rolling on the road compresses the road by what may be described as a series of *infinite gradations*, aptly illustrated by the *squeezing* action of the ordinary mangle. In other words, a road that would be strong enough to support a given weight spread *simultaneously* over a large area is unable to withstand the pressure which attacks it *piece-meal*. In Fig. 5 the shaded portion represents the section of a soft road that has been squeezed into a wedge-shaped wave in front of a wheel. It is clear that the compression of the road particles is greatest at the point **A**, and therefore that the density of the wedge-shaped wave lessens from **A** to the point **B**, where it is theoretically softest. The wheel in rolling, however, commences its attack on the road at this softest point, **B**, *gradually* creeping forward inch by inch and *mangling* it down to the density of **A**. Compare this with Fig. 3, in which there is *no rolling motion on the road at all*, and in which no wedge-shaped waves are possible; the rolling movement is in the inverted railway at a higher level. The feet come down at intermediate *intervals*, each foot covering a *large surface simultaneously*, and they act like rammers, falling and rising almost vertically. Even with the *same area* of contact the supporting power of a road is thus very different when subjected to a *ramming* as compared with a *rolling or mangling* pressure.

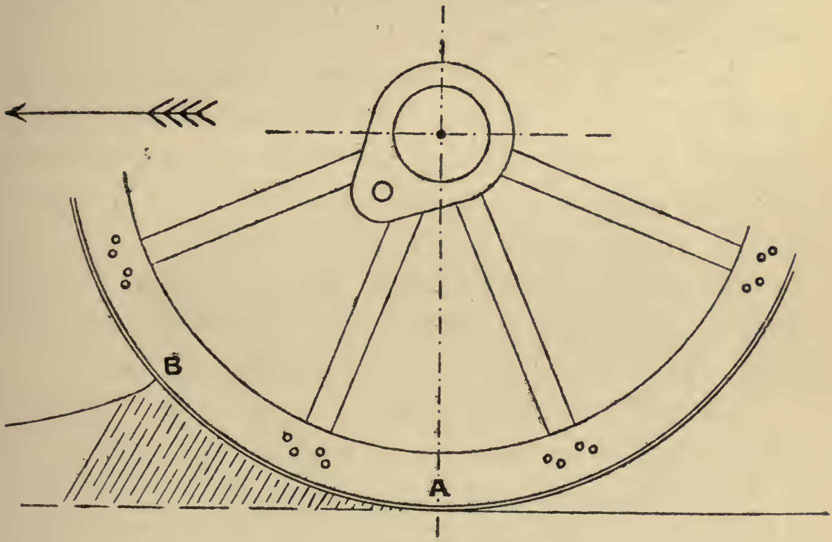

Fig. 5.

Moreover, any one foot alighting on a sufficiently hard projection in the road would lift the other feet off the ground, and increased weight would thus be concentrated on the projection; but if, on the other hand, any one foot comes down over a depression of moderate area in the road, no weight comes on it at all, as the adjoining foot or feet sustain the weight.

An ordinary wheel would bump down into the depression and make it worse.

Here we have a very important result, viz. that the action of the Pedrail tends to beat down the projections without increasing the depressions in the road surface. In other words, a process that, so far as levels are concerned, would actually tend to *improve the road!*

The author foresees a future for the principle of the Pedrail as applied to steam rollers, which, as is well known, at present tend to *roll* the road into waves.

Another important feature in the Pedrail is the arrangement of springs. In an ordinary traction-engine, even if fitted with some kind of spring arrangement, the wheels, axles, and axle-boxes, etc., representing some tons of weight, are *destitute* of springs, *so far as their own weight is concerned*, the remainder of the engine being mounted on springs resting on, or dependent from, the axle-boxes.

Of course, the ideal position for the spring medium is between the wheel, or Pedrail, and the road surface, as in pneumatic tyres on bicycles, cabs, carriages, etc. This spring medium is usually limited in elasticity, and a further and more elastic spring is generally provided under the vehicle body or bicycle saddle. The necessity of improved spring mounting and also increased surface adhesion led to some very important experiments with rubber tyres on traction-engines, carried out by the Indian Government in 1873 to 1875, under the superintendence of Colonel Crompton, who afterwards read a valuable paper on the subject at the Institution of Mechanical Engineers at Glasgow, in August, 1879. Although at the time the results were considered highly satisfactory, rubber tyres for traction-engines have not come into general use, partly because of the great cost and partly because, being an elastic *material* instead of an elastic *mechanism*, it was found impossible to control the *direction* of the elasticity.

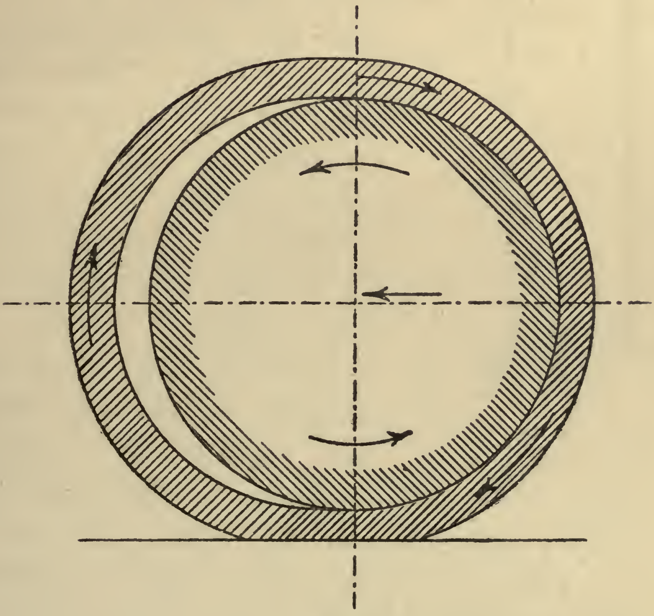

Fig. 6.

The rubber became stretched horizontally under the wheel, as shown in Fig. 6, thus "bagging out" in front of the wheel, and this also led to a creeping action of the rubber round the inner metal tyre, so that the ring of rubber wore away *inside*, and became too large and loose on the metal tyre. Clips or metal armouring were found necessary outside the rubber to prevent this, and also to prevent undue wear of the external surface of the rubber; but these did not work well under the conditions shown in Fig. 7. These experiments have led the author to the conclusion that what is required is an arrangement that will admit of considerable *vertical* elasticity, but in which no *horizontal* elasticity is possible.

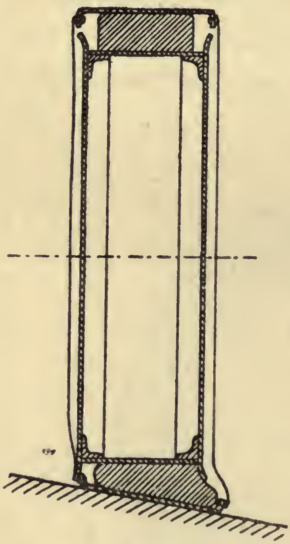

Fig. 7.

As already explained, two kinds of springs are generally used in road vehicles—one of limited elasticity, viz. the rubber tyre, and a second and much more elastic spring between the vehicle body and the axle. It stands to reason that as much as possible of the total mechanism should be *above* these second and more elastic springs, and that the parts actually *below* them should be reduced to the smallest possible weight and size commensurate with the necessary strength.

In an ordinary traction-engine the parts below the springs amount to *tons*, and these parts are destitute of springs, but in the Pedrail the only parts *below* the springs (see Fig. 3) are the rail and the two or three feet actually on the ground, with their attendant spokes and rollers.

By introducing rubber pads between the soles and shoes of the feet, as described later, even these parts are mounted on a spring medium corresponding to the rubber tyre; and the fact that the whole of the rest of the mechanism, including even the disc, the axle, and the axle-boxes, are hung on the second springs, constitutes an important gain in spring-mounting which must tend to greatly increase the life of the engine.

As already mentioned, the life of an ordinary traction-engine is commercially about four or five years, whereas many of our railway locomotives have been running for thirty or forty years. The author sees no reason why, with an adequate arrangement of springs, the life of a road engine should not assimilate itself more nearly to that of the railway locomotive, and this should prove a very important gain as regards working expenses.

It may also be mentioned here that lubrication, which forms so important an element in reducing wear and tear, has received very careful attention, the numerous working parts, in the Pedrail especially, being lubricated by a simple arrangement of one or two annular oil-chambers round the disc communicating with all the movements. These oil-chambers are easily and quickly filled, and hold a sufficient supply of lubricant for a long journey. All the working parts are enclosed in dust-tight, sheet-iron covers, with the exception of the sliding spokes and the ankle-joints, which are dealt with specially.

The author found it practically impossible to protect the sliding spokes from dust or grit, and seeing that they must necessarily be lubricated to prevent undue wear, and that the lubricated surfaces are so close to the road, it appeared certain that some dust and grit must necessarily adhere to the lubricant on the spokes, and thus be carried into the sliding-spoke bearings. This would undoubtedly sooner or later "scotch" the spokes and jam the mechanism. To obviate this the author introduced ball bearings to the sliding spokes, since experience with bicycle and other ball bearings has amply shown that they are not materially affected by grit. Rotary ball bearings are, of course, well known, but the author believes that ball bearings have not hitherto been applied to a reciprocating movement.

The difficulty consisted in preventing the balls from shaking or falling to the wrong end of the groves, which would not only make them ineffectual, but would prevent them rolling, and thus cause them to wear "flat-sided" and out of shape. This difficulty has been overcome by a simple mechanical arrangement which automatically sets the balls in their right places once in every revolution, and this is supplemented by the introduction of spring clips which hold the balls in their correct positions during the movements. The arrangement has been tested in actual practice; it works very satisfactorily, and does not appear likely to get out of order or give any trouble.

It does not require much discernment to see that the construction of the feet of the Pedrail required very careful consideration and design. It is only when we attempt to copy it that we fully realize how beautifully a horse's ankle-joint or fetlock is formed to fulfil the purpose for which it is required.

In the Pedrail feet the conditions, although not unlike, are yet not similar. The feet are not required to pass each other when stepping forward, as they travel over the top of the disc, on a principle aptly illustrated by the Manx Coat of Arms.

Provision is, however, required for the varying distances between the feet, according to the slope of the spokes or radius lines in relation to the tangential line of the road surface. It also is evident that if three feet are held rigidly in a line on the ground and with the weight of the engine pressing on the top of them, it would be impossible for the Pedrail to turn a corner.

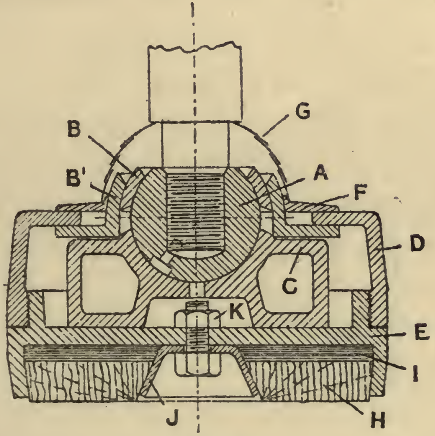

Fig. 8.

A description of Fig. 8 will best illustrate how the required conditions have been carried out.

On the end of each spoke is a ball, **A**, which works between two cup-shaped blocks, **B** and **C**. The upper block is made in two parts, **B** and **B′**, one inside the other, which gives a better movement and more lap over the ball than would a single one.

The blocks **B** and **C** are held together by an outer covering or shoe, **D**, into which is screwed the sole **E**.

The screw admits of any wear of the parts being taken up, and the sole is prevented from unscrewing by a cotter and split pin, not shown in the drawing. All the parts are circular on plan, and it will be noticed that the blocks **B** and **C** are smaller in diameter than the shoe, so that they are free to slide about to a certain extent *inside* the shoe. Noise is prevented by a ring of leather secured round the block **C**.

The ball-and-socket movement thus obtained represents the ankle-joint, and the sliding movement enables the before-mentioned varying distance between the feet when on the ground to adjust itself. When turning corners two of the blocks, **B**, **C**, slide *sideways* in the shoes, and the ball of the third shoe (if on the ground) pivots.

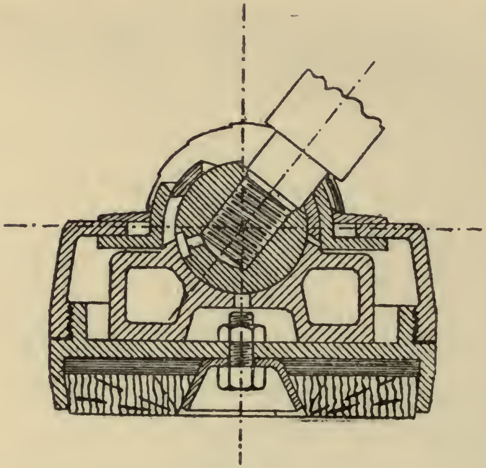

FIG. 9.

Dust is excluded by the flat ring **F**, surmounted by a series of metal rings (forming a hemisphere, **G**) which telescope over each other with the movement of the ankle-joint, as shown in Fig. 9, or, if preferred, a leather anklet can be used for the same purpose. A mixture, preferably of castor-oil and black lead, inside the shoe should serve to keep the parts lubricated for several weeks, and would also keep the leather supple.

The sole of the shoe **E** has a cone-shaped flange, inside of which are hard wooden segments, **H**, pressing against a rubber pad, **I**, pierced with holes to allow of compression. The segments are easy and cheap to renew when worn, and are held in place by a centre cone, **J**, fastened by a nut and split pin, **K**. The rubber pad **I** takes the place of the rubber tyre as the *first spring medium.*

The parts are put together in such manner that nothing can possibly work loose—a very necessary provision.

Reference to Fig. 3 will show that the feet are held tight against the disc when travelling over the upper half, but are free to swing on their ankle-joints round the lower half. The object of this arrangement is to utilize the well-known fact that the upper half of a wheel travels so much faster than the lower half. The movement of the ankle-joint is a combination of centrifugal force checked in its horizontal forward velocity, and this force acts against the swing, due to gravity, of the shoe itself when free to turn on its ankle-joint; the result being that the shoe should always fall on its sole.

Another very important feature in the Pedrail must not be overlooked, viz. the *oscillating rail.* To return to our prototype, a horse when stepping on to rising ground shortens its leg by bending its knee. It will be noticed that the rail **D** (Fig. 3) is *pivoted* at its centre to the plate **E**, and when one of the feet steps on to rising ground the rail and other parts take the position which in its extreme possible angle is shown in Fig. 10, with the result that the spoke shortens to suit the altered level, and what is more—*to go one better than the horse!*—the spoke, or leg, at the other end of the rail *lengthens*, and thus continues to carry its share of the total weight. In effect the oscillating rail forms an *inclined plane* on rollers, well known as *the* best mechanical means of running a weight over an obstacle with the minimum of power.

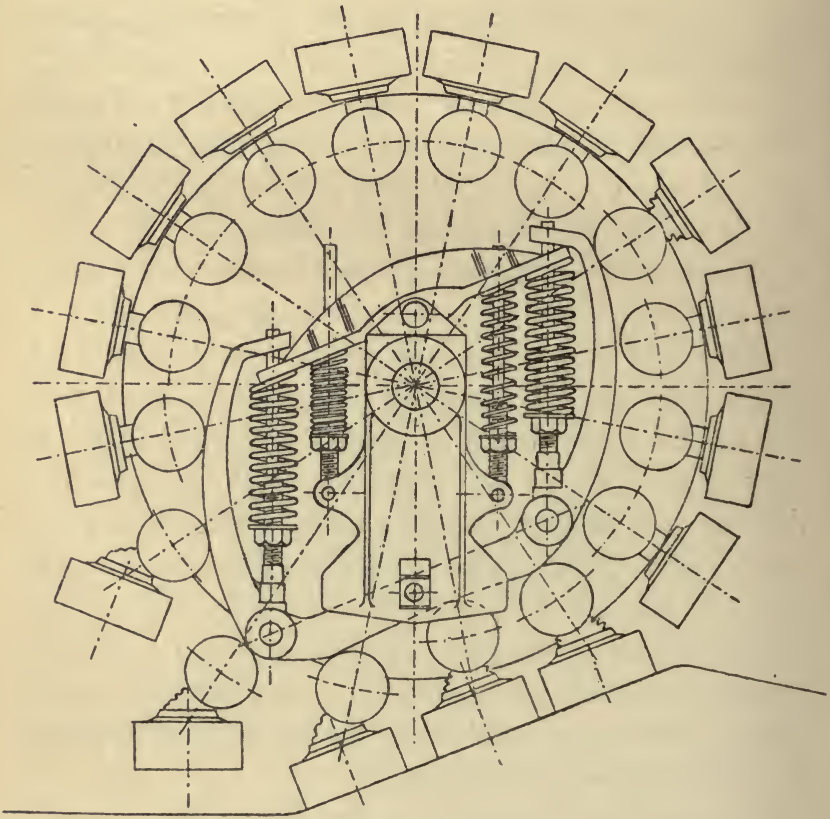

Fig. 10.

CHAPTER IV.

ROLLING STOCK.

THE author has dealt at some length with the Pedrail, for the reason that it forms the main basis of the whole system, not only for the propelling power, or engine, but also for the rolling stock, or wagons. It is well known that traction-engine haulage according to existing practice does undoubtedly cause undue damage to the roads, especially in wet weather. This is partly caused by the somewhat barbarous system of obtaining adhesion by fixing cross-bars or strips on the driving-wheels which actually cut down into the surface of the road, but how large a proportion of the damage is caused by the heavily laden *wagons*, each wheel of which is grinding down the road surface by "*infinite gradations*," according to the theory already explained, is not generally recognized.

If only to minimize damage to the roads, the adoption of Pedrails for the wagons would be amply justified, but there is another and equally important reason, viz. the reduced "road-resistance."

As already stated, "road-resistance" varies so enormously according to the state of the road, the weather, the size of the wheels, the weight on each wheel, and the speed of locomotion, that it is practically impossible without actual experiment to form any correct estimate of its effect under any specified conditions, no record of results based on actual experiments in which *all* the governing factors have been taken into account being at present forthcoming.

From the table of results compiled partly from data by Colonel Crompton (then Lieutenant Crompton) and quoted by Mr. John Head in his splendid paper on Steam Road Locomotion in 1873, it may be assumed that road-resistance under average conditions is about ten times that on rails,[1] and this assumption is supported by Telford and

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[1] Extract from Treatise on the "Rise and Progress of Steam Locomotion on Common Roads," by John Head, 1873.

"The following table, compiled partly from data by Lieut. Crompton, and partly from other sources, will show the resistance of smooth rigid wheels in pounds per ton on different surfaces :—

On very good pavement	35 lbs.
On good macadam	60 ,,
On ordinary macadam	90 ,,
On newly laid gravel	200 ,,
On soft grass land	300 ,,
On newly laid metal	440 ,,
On a well-laid railway with moderate gradients ...	8 ,, to 10 lbs.

From which it appears that even when the road is in the best order, the rolling resistance is about 8 times that on rails. With the road in an ordinary state, it is from 10 to 12 times, while on newly laid metal, the rolling resistance becomes nearly 50 times that on rails. As almost all roads contain inclines of 1 in 20, or 1 in 30, and as many of them contain inclines of 1 in 10, it will be seen that the actual pull required to move 1 ton over many portions of macadamized roads amounts in some cases to more than 100 times that on a railway with moderate gradients. The difficulty of obtaining sufficient adhesion, and the wear and tear caused by rigid wheels without springs, have from time to time led to the trial of various devices for overcoming these defects, but extended experience seems to show that a rigid wheel, with wrought-iron diagonal bars on the periphery, is the cheapest driver, and that in many cases it is sufficiently reliable for the class of work for which road locomotives are usually required. At the same time, a great demand exists for a reliable 'flexible' wheel for use under certain circumstances where the 'rigid' wheel is almost useless."

Babage's data quoted in Professor Hele-Shaw's paper before referred to, but it does not appear that the size or width of the wheels, the weight on each wheel, or the speed have been taken adequately into consideration in the conclusions arrived at. There can be no doubt that road-resistance on a yielding surface increases very rapidly by, and *out of proportion* to, any increased *weight* on the wheels, and for heavy haulage this demands serious attention.

Assuming, however, that the proportion of ten to one is correct, a traction-engine of sufficient power to pull 25 tons on an average road would pull 250 tons if the load were on rails, though the small diameter of the rollers, or rail-wheels, in the Pedrail would no doubt tend to a small increase of friction. Taking all the conditions, however, carefully into consideration, it may be assumed as a very safe and moderate estimate that the adoption of Pedrails on the wagons will reduce road-resistance by at least half (or a proportion of two to one instead of ten to one), and possibly much more. This would mean that an engine of equal power would pull at least double the load, or an engine of half the power would pull the same load.

The proposed Pedrails for the wagons (see Fig. 11) would require to be somewhat differently designed, owing to the absence of motive, or lifting, power in the legs or sliding spokes, which would necessitate inequalities and obstacles in the road being surmounted entirely by the action of the inclined plane or rail. It will be noticed that the rail is therefore longer and more gradually sloped at the ends, and that the guides leading the rollers under the rail consequently slope inwards in a somewhat triangular shape. The two springs shown are adjusted to carry a little more than the weight of the wagon when *empty*, and there is an arrangement under the frame of the wagon by which the power of a second pair of springs pressing on the centre of the rail can be easily adjusted on the principle of the steelyard *to suit the load in the wagons.* This latter arrangement is so simple and easy and has such conspicuous advantages that it seems somewhat extraordinary that it is not already in general use.

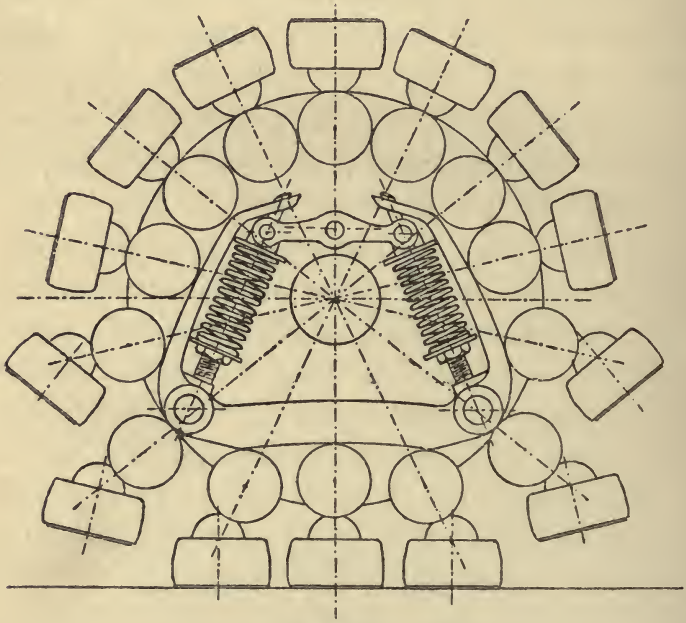

Fig. 11.

Fig. 12 is a side elevation showing the general arrangement of a wagon, and it will be noticed that under this system each wagon is divided in the middle by a special form of hinged joint, so that the front and rear portions become what may be called *two-wheeled wagons*, but which in the absence of wheels may be better described as the *Single-axle System.* This arrangement has many advantages ; the Pedrails can all be larger in diameter and of uniform size, as none of them are required to lock under the wagons when turning corners ; also, being of uniform size, they are interchangeable, and a few spare Pedrails at headquarters can be substituted bodily for any others requiring overhaul or repairs.

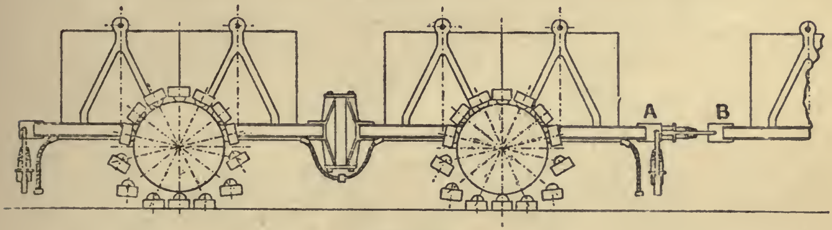

FIG. 12.

In fact, this interchange of parts forms an important element in the system, as spare sliding spokes, feet, and other details can be carried on the train, and readily substituted for any *parts* requiring attention or giving trouble *when on the road.*

The main advantage, however, of the single-axle system is, that it enables a long train to turn round a sharp curve or corner. A comparison of Figs. 13 and 14 will best illustrate this. Fig. 13 shows the position that the wheels of two four-wheeled wagons would assume when turning round in a circle in the direction shown by the arrow, with an ordinary draw-bar coupling between the two wagons hinging at **J**. It will be noticed that the *near* front wheel, marked **A**, of the first wagon and the *off* hind wheel **B** of the second wagon are travelling on nearly the same curve; in other words, the hind axle of the second wagon is practically the whole width of the wagon *nearer* to the centre of the curve. In a third wagon this loss on the radius of the curve would continue in the same proportion, so that in a long train of these wagons it would be impossible to prevent the rear wagons from running on to the pavement or into the hedge or ditch at the roadside. In ordinary traction-engine practice this difficulty is obviated by limiting the number of wagons and taking a wide sweep with the engine when turning corners, but, inasmuch as *long* trains form one of the axioms of the new system, it is evident that some better means of guiding the long train round corners is required.

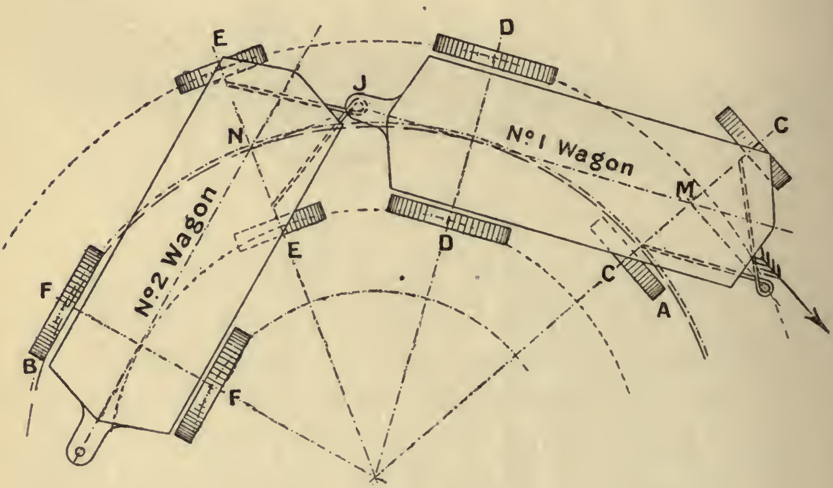

FIG. 13.

This is obtained in the single-axle system, as shown in Fig. 14, in which, as explained in the next paragraph, the wagons follow each other in *exactly the same tracks,* and it is evident that by this system a train of any length—barring side-skidding of the Pedrails—can be taken round any corner. It may also be pointed out that the Pedrails give so large a surface contact for adhesion that the danger of side-skidding with a train of any reasonable length is practically *nil.*

It has been proved theoretically and by actual experiment that if a vehicle or a train of vehicles travels in a curve round any given centre, each axle must necessarily radiate from that centre.

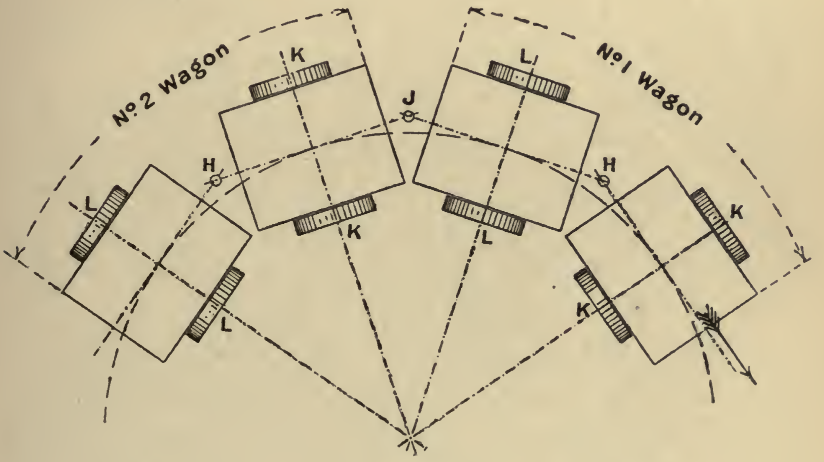

Fig. 14.

This condition is fulfilled in Figs. 13 and 14, but with this difference—that, whereas in Fig. 14 each *axle* radiating from a common centre is at the *same distance,* or radius, *from that centre,* in Fig. 13 it is evident that the fore-carriage axles **CC** and **EE** pivoting at the points **M** and **N** must *necessarily* be *further* from the centre than the rear axles **DD** and **FF**, or, in other words, they are travelling in each case in another track, or radius.

In Fig. 14, the axles being equidistant from the centre, the wheels are travelling in the same tracks, and this result is obtained by the special form of hinged joint (already mentioned) at **H**, which, being placed *equidistantly* from the front *axles* **KK** and the rear *axles* **LL** of each wagon, admits of the necessary geometrical conditions being fulfilled. The same result could be obtained in a four-wheeled wagon by pivoting *both* axles, but it would involve so many mechanical complications that the single-axle system is preferable.

The hinged joint **H** must not be confused with the ordinary draw-bar coupling **J** between each *wagon*, which is the same in Figs. 13 and 14, and it will be observed that in Fig. 13 the coupling at **J** enables the fore-carriage axle **EE** of No. 2 wagon to follow in the tracks of the rear axle **DD** of No. 1 wagon.

It may here be pointed out that if any coupling or joint (**J** or **H**) is moved *towards* the axle *preceding* it, the train will follow in a *decreasing* radius; and *vice versâ* if any coupling or joint is moved towards the axle *following* it, the train will follow in an *increasing* radius. This principle is utilized in the interchangeable draw-bar system explained later.

The most important feature, however, in the rolling stock, and perhaps even in the whole scheme, is what may be described as the *Wagon-body System.* It will be noticed that the bodies of the wagons are fitted with lifting-straps (Fig. 12), and that there are two bodies, or boxes, to each axle. These boxes are loose, and can be lifted off the frames of the wagons, the latter being built practically in skeleton form. The boxes shown in Fig. 12 are 6 ft. long (resting transversely on the wagon-frames), 3 ft. 9 ins. wide, and 3 ft. high. The sizes are arranged partly to suit the most convenient width of wagon for road work, and partly to provide that four of them shall comfortably fill an ordinary railway truck. There are projections or dowels on the bottoms of the boxes, which fit inside the frames and also serve to keep the bottoms dry when the boxes are standing on wet ground. These projections fit into the *tops* of the boxes, and they can therefore be piled one on the top of the other when filled with light and bulky goods, so that each axle may be loaded to its full carrying capacity, and haulage of unnecessary dead weight thus be avoided. Moreover, some of the frames can be made 3 ft. 9 ins. longer, in order to carry *three* of the boxes in a row instead of two, as shown.

It must not be supposed, however, that the boxes are confined to the above arbitrary sizes or shapes; they can be 7 ft. 6 ins. × 3 ft. on plan, or 7 ft. 6 ins. × 6 ft., or 11 ft. 3 ins. × 3 ft., and so on, or loose, flat platforms without sides can be used instead of boxes. Some of these platforms could be fitted with turn-tables, so that very long goods, such as baulks of timber, could be laid along *two* wagon-frames, and some of the upper tiers of boxes could also have sides sloping outwards for loading hay, straw, or market-garden produce, or open crates could be substituted for boxes. In fact, it is evident that, provided the projections or dowels are made to a common standard, the shapes and sizes of the boxes, platforms, or crates, can be varied to an almost unlimited extent to suit the goods traffic of any district; except that, if the sides slope outwards they would not be so suitable for fitting in railway trucks, and would probably only be used for local traffic.

It may be mentioned here that the second experimental engine or locomotive has been built and tested by the Syndicate before mentioned, and will be fully described in a later chapter, but the wagons, although fully designed, are not yet built.

For the present it is sufficient to state that this No. 2 engine is mounted on Pedrails, and includes a crane of sufficient power to lift the wagon-boxes up to a total weight of 4 tons, and to transport them along the road wherever required. The jib of the crane is telescopic, so that it can be shortened to pass under bridges on the road, or extended to a sufficient height to load or unload the upper tiers of boxes on the train. This use of the extended crane-jib is only intended for lighter goods, owing to the extra leverage on the jib; but, apart from this, the heavy goods would naturally be loaded in the lower tiers of boxes. The crane-jib slues round a half circle, so that the locomotive can travel parallel to, and alongside, the whole length of the train, and load or unload wagon-boxes wherever required.

The hinged joint **H** (Fig. 14) in the centre of each wagon is so designed that, whilst rigidly preventing the frames from tipping up on the single axles (even against the stress of a powerful brake), it yet admits of a free hinge action when turning corners, and *also* allows the two axles to oscillate in opposite directions, to an almost unlimited extent, when passing over uneven ground. The front and rear halves of each wagon, including the *two halves of the hinged joint*, are exactly alike in every detail, and are thus interchangeable. For instance, two rear halves, or two front halves, can be easily turned round and joined together to form a complete wagon.

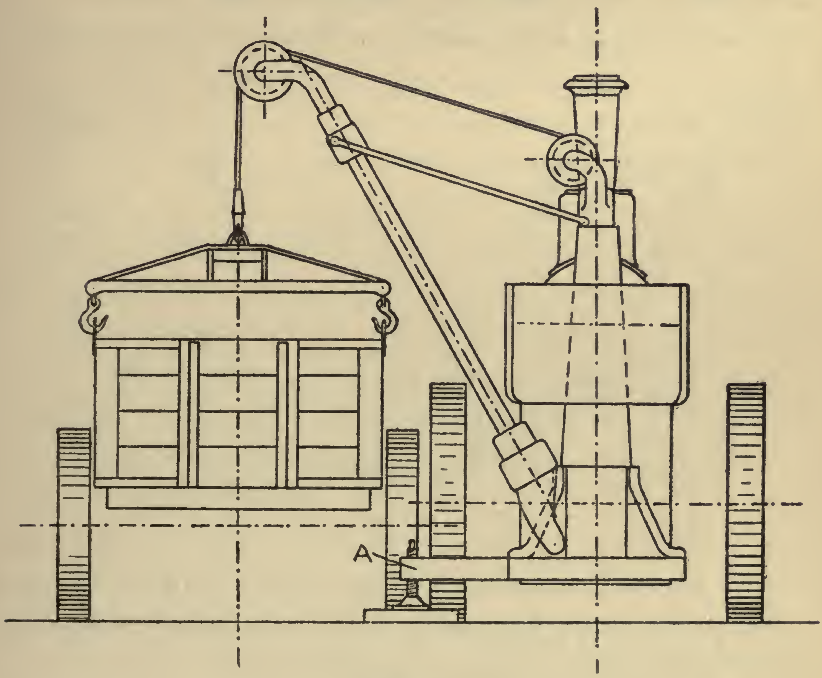

Fig. 15.

This would be a convenience in the very likely event of portions of two wagons requiring repairs, as the other halves of the wagons could be used whilst the repairs are being effected. The method of loading and unloading the wagon-boxes is illustrated in Fig. 15, and it will be seen that the sliding-screw strut at **A** prevents the load on the jib from tipping the locomotive over.

Fig. 16 illustrates the method of transporting the wagon-boxes to or from the wagons. The box is first landed on the ground, then the locomotive approaches it near enough to attach the two short chains at **B**, the box is then lifted by the crane a few inches from the ground, and the two short chains prevent it from swinging about and disturbing the equilibrium of the locomotive. It is also plainly desirable, when travelling with the box hanging behind, to have it close to the crane-post, as shown, and thus to reduce the leverage of the back weight as much as possible.

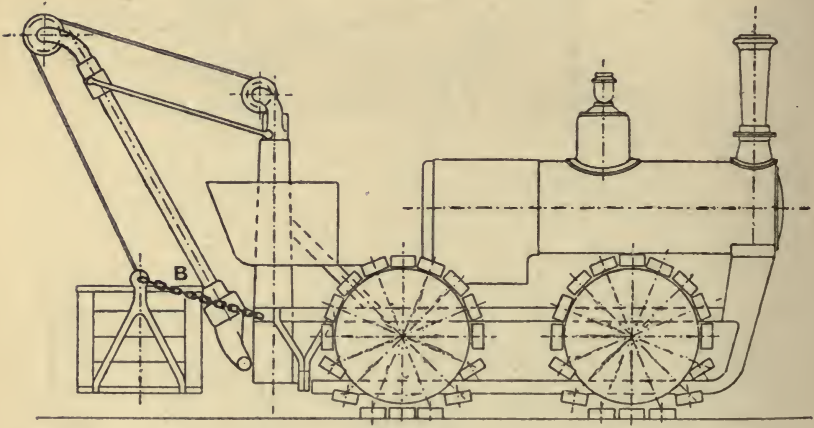

FIG. 16.

In order that the locomotive may be spared the strain of starting the whole train at once, each draw-bar contains a strong volute spring. This not only avoids all jerks in starting, but each wagon, being started separately, helps, by its own volume of weight in motion, to start the next.

It will be noticed that there is a draw-bar hanging at *each* outer end of the wagon, and it should be explained that the *hinge* end of each draw-bar has a funnel-shaped coupling and draw-bar pin in the centre of the hinge. This not only makes the outer ends of the wagons alike and interchangeable, but when two outer ends come together *either* draw-bar can be used, the unused one hanging loose, as in Fig. 12, and the wagoner can therefore couple his wagons to pivot at **A** or **B** (Fig. 12), alternately or otherwise, at *any* part of the train, as he finds by experience will best serve in turning corners, or in the event of side-skidding or other causes rendering this necessary. The draw-bars being all in duplicate, the train can be pulled from either end as in railways, and the difficulty of turning a long train round in narrow roads or at termini is thus avoided. Another great advantage of the wagon-box-and-crane system is that the skeleton wagon-frames need never be uncoupled during transport, and the boxes being lifted off bodily by the crane at termini, etc., *shunting of wagons is absolutely abolished.*

The locomotive with a wagon-box slung behind can be backed into narrow embayments and spaces, where shunting operations would be impossible.

Also the wagon-box can be landed at varying *levels,* such as on the platform of a goods station or on the ground as required, and as each wagon-box is fitted with a hinged side-door, goods can be trucked by hand into the wagon-boxes at the same level as that in which the goods may happen to be stacked or stored.

The author estimates that the power and adhesion of No. 2 engine will be sufficient to pull a *long* train of wagons (if mounted on Pedrails) on level roads and over easy gradients. Moderate gradients might also be surmounted by using the second or slow-speed gear of the engine, but it must be borne in mind that the use of Pedrails, although reducing road-resistance, does not reduce the pull, due to gravity, up an incline, and for steeper gradients, with long and heavy trains, some further provision is required. This is met by a powerful winding-drum and rope mounted *centrally* in the tail of the engine-frame. All traction-engines are fitted with winding-drums, but they are mounted on the road-wheel axles at the *side* of the engine, and involve a cumbersome process of putting in locking-pins, blocking the wheels, and other arrangements not suitable for frequent use. The winding drum on No. 2 engine is mounted on a *separate shaft*, it is operated by simply moving a lever on the foot-plate, and is quite independent of the Pedrail driving-gear.

The plan of operations is as follows: The locomotive proceeds up the hill, taking with it two or more wagons, according to the gradient, and leaving the loose end of the wire rope passed *under* these wagons and attached to the foremost wagon left behind. The limit of the rope, say seventy yards, having been reached, powerful brakes are applied to the front portion of the train, and it is used as an anchorage for winding the rear portion after it. This process is repeated till the hill is surmounted. In turning curves up a hill it is evident that the process must be repeated at shorter intervals than seventy yards. It may be pointed out that the brakes are applied on the wagons of the front portion as well as on the engine, and as all are mounted on Pedrails the large surface adhesion and weight thus obtained provides ample anchorage for the winding operations. It is, of course, understood that, whilst the front portion of the train is proceeding up the hill, the brakes are applied to the rear portion, and not removed until the front portion is "anchored." A light permanent brake prevents the winding-drum over-running when paying out slack rope.

When descending hills the wagons are controlled by pneumatic brakes[1] worked from the engine, and being thus under the control of the driver, he is not only able to prevent the wagons over-running each other and zig-zagging down the hill, but also to prevent *over*-application of the brakes by the wagoners, and the consequent waste of steam power in pulling a train down-hill, an occurrence that might easily happen, especially with long trains.

By a simple arrangement of links the *same* brakes can also be applied *by hand* when the engine is uncoupled from the train. These hand-brakes are designed so that they can be operated from *either* side of the train, and without requiring the wagoners to incur the dangerous risk of standing inside the track of the Pedrails.

When descending hills additional hand-brake power can be applied by the wagoners to the *rearmost* wagon, thus materially supplementing the provision against zig-zagging already referred to.

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[1] The author is indebted to Mr. Alfred Holt for this suggestion.

CHAPTER V.

NO. 2 ENGINE.

THE design and construction of an engine to comprise so many new features was necessarily a lengthy business. The drawings of No. 2 engine were commenced about October, 1899, but it was not until more than two years later that the author was in a position to invite Professor H. S. Hele-Shaw, LL.D., F.R.S., etc., to witness, and report on, an actual trial. Professor Hele-Shaw is too well known in engineering circles, as an authority on Road Locomotion, to need any introduction, but the author, at their first meeting, was agreeably surprised to find him already "primed" on all the main features and advantages of the Pedrail!

The explanation, though not unusual, is interesting. It is not the first time that two minds, working independently at the same problem, have arrived at the same conclusions almost simultaneously. In this case, each had constructed models, which were curiously alike in their main principles, although not equally complete in details, and it should be recorded, that if Professor Hele-Shaw had had sufficient leisure to prosecute his study of the problem more effectually he would, in the author's opinion, have arrived at a solution.

The Professor's previous study of the Pedrail principle was, however, not wasted—it had one good result: time was not required for consideration and discussion; he was in a position, on witnessing the trial of No. 2 engine, to *at once* write the following somewhat remarkable report in its favour:—

REPORT ON THE DIPLOCK TRACTION-ENGINE.

University College, Liverpool,
January 29, 1902.

The President of the Institution of Mechanical Engineers in 1898 stated in his inaugural address that the annual train-mileage in this country had increased during thirty years from 200 millions to 350 millions, and remarked that our iron roads are the arteries and veins of the nation. It is not surprising that the great development in our main lines of traffic has led, during the last few years, to a general awakening in this country to the necessity of improving our means of road locomotion, and it is now generally realized what immense possibilities there are in this direction.

In presenting this report, I think it best to separate the motive power and general construction of the Diplock Traction Engine from Mr. Diplock's substitute for an ordinary wheel which he has named a "Pedrail." The traction-engine itself contains a number of improvements, and at least two important departures from anything which has been hitherto successfully accomplished. The Pedrail, however, constitutes, in my belief, the successful solution of a walking machine, which, whilst obviating the chief objections to the ordinary wheel running upon the road, can be made to travel anywhere where an ordinary wheel can go, and in many places where it cannot. At the same time, it has the mechanical advantages which have made the railway system such a phenomenal success. It constitutes, in my belief, the solution of one of the most difficult mechanical problems, and deserves to be considered as an invention quite apart from any particular means by which it is actuated, whether it is placed upon a self-propelled carriage or a vehicle drawn by any agency, mechanical or otherwise.

General Features.

Design.—Commencing with the general structure of the engine, boiler, and framework, I may remark that, considering the radical departure from all previous ideas, the whole presents an admirable example of the highest class of design, and reflects the greatest credit on both the makers and designer.

Boiler.—The boiler seems to have most satisfactory steaming capacity, which is not only attained by ample proportions and good design, but by the special introduction of the latest feature in modern locomotive practice, viz. the use of cross-tubes in the fire-box; and it may be remarked in passing that the way in which these cross-tubes are arranged and attached seems to me admirably calculated to strengthen the boiler, as well as to enable cleaning and repairs to be easily effected.

Engines.—With a working steam-pressure of 160 lbs., the engines—which are compound—must give, at a not unreasonable speed, at least 108 I.H.P., the cylinders being respectively 6½ in. and 10 in. diameter, with a 10-in. stroke.

Bye-pass.—The bye-pass valve, enabling the driver to admit high-pressure steam to the low-pressure cylinder for starting purposes, contains an entirely novel feature. The novelty consists in the absence of seated valves in the steam-chest, and in the fact that, with one slide-valve and the movement of one lever, the engine becomes single-acting, with both cylinders at high pressure, exhausting direct into the funnel. In doing this, it may be stated that the highest possible pressure on the low-pressure piston would not rise to above about 5 tons, so that there would be no danger of excessive strains.

Crank-shaft and Bearings.—The arrangement of the crank-shaft and four bearings is such that the bearings are quite close up to the cranks, whilst the driving pinions between the two centre bearings being in the middle of the crank-shaft instead of at the end, as they mostly are, seem to me to ensure sufficient stiffness and accurate engagement in the gearing, a most important consideration. I believe I am correct in saying that this is the only traction-engine in which the pinions are between the cranks, and the bearings close up on each side of each crank; indeed, throughout the whole engine, all the driving gear are between bearings on short shafts without any overhang.

Absence of Back-lash.—A very important novelty is the arrangement of the *position* of the gear-wheels in relation to the springs, by which the spring action is utilized to ensure the entire absence of back-lash in the gear. It is well known that the great wear and noise of the gear-wheels in ordinary traction-engines is caused almost entirely by the constant hammering of the gear-teeth due to back-lash.

Speed.—The gearing is so arranged that at the slow speed the ratio is 29·6 to 1, and the fast speed 14·2 to 1; thus the actual speed on the road would be—

Fast-speed gear at 400 revolutions per minute = 5·02 miles per hour.
" " " 320 " " " = 4·0 " "

With slow-speed gear, the speeds on the road would be about one-half the above, and the construction of the engines; the allowance of guide-block surface and of glands, etc., is such that 400 revolutions per minute may be considered a reasonable value for a life of many years.

Simultaneous Driving.—The way in which all four wheels are driven simultaneously so as to give the maximum pulling effect by means of elastic connection, is in itself sufficient to mark the engine as a most valuable departure from common practice. Hitherto this driving of four wheels has never been successfully achieved, partly because of the difficulty of the turning of the steering-wheels, and partly because, until the present invention of Mr. Diplock, the front and hind wheels would act against each other, a defect at first experienced and overcome by the inventor in his first engine. This is one of the most interesting features of the engine.

Triangular Spring Frames. — The most important point, however, not even excepting the simultaneous driving, is the arrangement of triangular spring frames. This invention is so ingenious that it would require drawings to explain, but it may be said that it enables the axles to take every possible movement in meeting an obstacle, or in passing over rough ground in a way that could not be believed unless actually witnessed. I do not think there has ever been a traction-engine made in which the axles are enabled to take even a small proportion of the movements of the Diplock Engine without interfering with the gearing or wheels. The latter result is partly ensured by the use of a spherical bearing upon which the wheels work and in which the axle turns.

Winding-Drum.—A winding-drum is provided for winding wagons uphill in a way that I will refer to in dealing with the actual trials, but this winding-drum itself has some important features which show that it has been carefully designed, and not merely attached as a sort of after-thought, and I have no doubt that it could be used, if necessary, for assisting the engine itself (in the very unlikely event of its being unable to move on soft ground), by using an anchor.

Crane.—Another remarkable feature of the general structure is the provision of a crane which takes the rope up the centre of the pillar, so that it is always in line with the top pulley in turning the jib. The crane is provided with a telescopic jib, with a short length for heavy loads and capable of being lengthened out for light loads. A crane-strut, so as to insure stability and stiffness in raising a heavy load is another important feature of the crane. I have witnessed the operation of the crane in lifting a load of more than a ton, and found the jib worked in swinging very easily and smoothly. I am informed that the crane is designed to lift four tons.

I have devoted a good deal of space to the engine and framework, because they would ensure in themselves an excellent traction-engine, far superior, I believe, to any one in existence, even if ordinary wheels were used; but I now come to the part which will doubtless excite more general attention, viz. the Pedrail.

The Pedrail System.

I should like to say, before commencing to discuss the details of this invention, that as a result of long study of the problem of the wheel upon the road, and as a careful observer of the behaviour of motor-wagons and traction-engines, I had previously come to the conclusion that the ordinary wheel had reached the utmost limits of its possibilities for purposes of heavy traffic. If this be admitted we are driven to the conclusion that some form of walking machine (in which the heaviest loads could be carried, and an enormous tractive force obtained, without entailing the destruction of the road surface, upon which the machine rests) is the only solution of the problem. I knew, of course, that there were great mechanical difficulties to be overcome, and that the solution must be essentially of a practical nature, involving numerous details. Hence, when I went into the details of the Pedrail, and saw how in every direction Mr. Diplock had grappled with these mechanical difficulties and had successfully surmounted them, I realized that there was every hope of ultimate success.

It would be idle to ignore or minimize the great difficulties which have prevented engineers from attaining success with any form of walking machine. These difficulties have hitherto prevented any successful results being obtained, although numerous attempts have been made in this direction; and therefore I have looked forward with very great interest to the trials of which I give an account at the end of this report. I will state at once that before seeing Mr. Diplock's invention I had come to the conclusion that if this mechanical problem could be solved, it must have an enormous future, and I will so far anticipate my remarks as to say that, after witnessing the trial of this system, I believe that Mr. Diplock, by his invention of the Pedrail, has secured a means which makes it possible to draw a load not merely over roads, but over agricultural land, fields, and plains, and even to climb mountains. In a word, not only has he, in my belief, a tractive agency which makes his vehicle able to traverse the worst possible roads without the slightest difficulty, or to pass over ordinary roads in any weather without doing the slightest injury to them, but that he has solved the problem of a self-propelled vehicle and traction-engine which is absolutely independent of roads at all. The possibilities which open up before the mind are such as would carry me beyond the sober language of an engineer's report, but I am prepared to assert my belief that the Pedrail is destined to revolutionize our ideas upon road traction and road transport generally.

I will now proceed to a very brief statement of its salient points, and to answer the chief doubts which may be raised concerning its practical success.

Design of Pedrail.—The Pedrail may be briefly said to consist of a rail somewhat in the form of an inverted heart, round which passes in succession a number of small wheels or rollers each carrying a circular foot. Imagine a number of steel spokes to be all that remains of the ordinary wheel, each of these steel spokes having one of the rollers with the foot attached mounted on it. When the engine drives the axle carrying the spokes, these feet are placed in succession upon the ground with the roller upwards. The lower part of the heart-shaped rail slides upon the roller which it finds beneath it, until it has passed off the roller, which is then picked up and carried over to the front part of the rail in order to take its place again in supporting the vehicle.

The essential feature of the invention consists in breaking up the surface contact of each Pedrail with the road into a number of feet, the feet being free to tilt in *varying* directions to suit the inequalities of the road, each foot carying a roller for the rail to slide over. Moreover, this rail is not rigid but oscillating, and automatically forms an inclined plane for mounting upon or running off the rollers when they are raised above their normal level by the feet encountering obstacles in the road.

There are four Pedrails, corresponding to the four wheels, and the self-contained nature of the Pedrail is shown by the fact that the Diplock Traction-Engine can either be fitted with four Pedrails or four wheels.

Inasmuch as each Pedrail has three circular feet each 11 inches in diameter in contact with the ground at once, the weight of the engine is spread over no less than twelve feet, each one of which presses upon the ground with an area immensely greater —probably as much as ten times greater—than that of all the wheels taken together on a hard road.

Upon a soft road all comparison between wheels and the action of these feet really ceases. The wheel cannot roll except upon a geometrical line of contact, anything in excess of this can be proved both theoretically and experimentally to involve a rubbing and grinding action, whereas the contact of each of the feet of the Pedrail is absolutely free from all slipping action, and attains the absolute ideal of working, being merely placed in position without sliding to take up the load, and then lifted up again without any sliding to be carried to a new position on the road.

Answers to Possible Objections.—The first and most important objection to be raised to the Pedrail is its complex nature. This is not apparent from the outside, as it is neatly cased in, and nothing but the moving feet are visible.

Engineers, however, have long realized that *complexity* does not necessarily mean *complication*, and that the higher the scale of invention the greater the necessity for complexity in a machine; that no machine which performs a difficult mechanical process can be expected to be simple, and hence the tendency of all invention is not in the direction—as is erroneously thought—of simplicity, however simplified the externals may be, but in the direction of attaining a higher result by more perfect mechanical devices.

The Pedrail imitates, with modifications suitable to a mechanical device, that most complex of all structures, the living animal, and it is not to be wondered that the solution of this mechanical problem has required an ingenuity and fertility of resource by Mr. Diplock which must be described as little short of marvellous.

Having, I think, disposed of the theoretical objection to complexity, I now turn to the question of its practical efficiency. There are two ways in which this must be answered: first, by a due consideration of all the details; secondly, by the results of actual trial. Dealing here with the former, I will briefly point out that the chief danger arises from three causes:—

1. The unavoidable presence of dust in the summer and mud in the winter upon the exposed working parts of any road vehicle.

2. The danger of weakness in parts of a complex structure and liability to break down, and also excessive wear.

3. Costliness.

1. It may be at once said that the whole of the working parts, with the exception of the projecting square steel spokes (which work in and out from a central box) and the rollers, are absolutely dust and dirt proof, and are lubricated automatically from one central supply chamber, which holds a surplus supply of oil. The square spokes work in and out upon reciprocating ball bearings of the most ingenious design, and even these spokes have special provision of renewable dust-proof plates round them.

The feet, which naturally have to work in the dust and mud, have a beautiful ball-and-socket joint, enabling them to take any position in treading upon a stone or projecting obstacle. This ball-and-socket joint is protected from dust by a steel cap, after the form of the joint of a shell-fish, and may be called a "crustacean" joint. The feet themselves are filled with tallow and black lead to act as a lubricant.

No attempt has been made to have ordinary lubrication to the rollers; they are bushed with gun-metal bearings, in which are inserted graphite plugs. An examination of one of these rollers after a trial showed that the graphite lubrication answers admirably, and apparently would act nearly as well, however dusty the state of the roads.

2. Concerning the possible weakness of parts, it is enough to say that there is no working part that does not admit of sufficient strength to ensure satisfactory working, and that screw adjustment for wear is provided throughout, even in the ball-bearings of the sliding spokes.

3. Concerning the costliness, there is no doubt that the first Pedrail has been an expensive article, but there is the most important of all considerations in regard to its future manufacture, viz. the repetition of similar parts. There is no doubt that all the parts of the Pedrail (except the rail) consist of comparatively small pieces, which can be turned out by automatic machines, and many parts even stamped complete. It would be going too far to say that the Pedrail could ever be made as cheaply as an ordinary wheel, yet I venture to think there is nothing about it that prevents its ultimately being made at a comparatively low cost.

Trials.

On January 8th, I visited Stoke in order to see the actual trial of the engine, and as my report is already, I fear, of great length, I will condense this portion as much as possible.

The actual traction-engine rested on two Pedrails in front and two ordinary traction-engine (temporary) wheels behind, and proceeded to mount the steepest hill in the neighbourhood. The points which struck me immediately were: (1) the marvellous ease with which it started into motion, and (2) the little noise with which it worked. I have never witnessed a traction-engine, under any circumstances, move as quietly and with so little noise as the Diplock Engine, nearly the whole of the noise appearing to arise from the two hind wheels. This fact speaks volumes, because noise is an immediate indication of vibration and wear of the working parts.

Another thing which I noticed was the difference in the behaviour of the feet and wheels. The feet did not in any way seem to affect the surface of the road. Throwing down large stones the size of the fist into their path, the feet simply set themselves to an angle in passing over the stones, and did not crush them; whereas, the wheel coming after invariably crushed the stones, and, moreover, distorted the road surface.

Coming to the top of the hill, I made the Pedrail walk first over 3-in. planks, then 6-in., and finally over a 9-in. balk, and photographs taken at the time tell more plainly than any words can do the behaviour of this extraordinary invention under these circumstances. One could scarcely believe, on witnessing these experiments, that the whole structure was not permanently distorted and strained, whereas it was evidently within the limits of play allowed by the mechanism.

As a proof of this, after having its photograph taken, the Diplock Engine walked down to the works, and I then witnessed its ascent of a lane, beside the engineering works, which had ruts 8 in. or 10 in. deep, and was a steep slope. This lane was composed in places of the softest mud, and whereas the wheels squeezed out the ground in all directions, the feet of the Pedrail set themselves at the angles of the rut where it was hard, or walked through the soft and yielding mud without making the slightest disturbance of the surrounding ground.

The engine then manœuvred itself satisfactorily to its berth, where I witnessed experiments with its crane.

Final Conclusions.

The impression which the trial left on my mind was that the Diplock Engine—especially with the slight modifications in various ways which the inventor is about to introduce—is destined to play a part in road locomotion, and, indeed, in locomotion off roads altogether, which can scarcely be conceived. I came away from that trial with the firm conviction that I had seen what I believe to be the dawn of a new era in mechanical transport. I am absolutely satisfied, after a perusal of Colonel Crompton's able reports on the previous Diplock Traction-Engine, that if that engine could pull successfully 87 tons, the new Diplock

Engine with Pedrails attached would be able to draw behind it, on the level road, from 150 to 200 tons, and probably even more, for I feel perfectly certain that a pull of more than 10 tons could be obtained on the draw-bar. Of course, this load of 200 tons could not at once be pulled up a hill, but so complete are the hauling arrangements of the winding-drum, that it would be quite possible to take a few of the trucks first, and rapidly haul up the remainder in series, thus attaining upon ordinary roads, even by doing this, an average speed of more than three miles an hour.

I do not profess to have a sufficient knowledge of financial matters to express an opinion upon the apparently well-worked out scheme of Mr. Diplock for collecting and distributing goods and agricultural produce. I do feel, however, competent to say that the mechanical details which he has worked out, and the way in which he proposes to handle the units in his system, are not only practical, but that the operations can be effected very simply and rapidly with the minimum of hand labour, and I know that in this part of England, where I have been frequently consulted about such matters, there would be great scope for the system which he proposes.

I will, however, say in conclusion that it is not in any one or other distributing system that I should look to a great future for the Diplock Engine, but I feel assured that the use of the Pedrail System (in conjunction with many of the features of the Diplock Traction-Engine) is *the real solution of one of the greatest difficulties which will be met with in developing self-propelled traffic.*

(*Signed*) H. S. HELE-SHAW.

The photographs referred to in the report are reproduced in Figs. 17 and 18.[1] These photographs were both taken without the engine being moved, and serve to illustrate, though not to its full extent, the elasticity of the axle and Pedrail movements. The off hind wheel

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[1] See Frontispiece.

remained in hard contact with the ground (Fig. 17), notwithstanding that the off Pedrail was mounting a considerable obstacle, the tilting effect on the main frame being well shown in Fig. 18. It should be mentioned here that the Pedrail and axle movements of No. 2 engine are designed to maintain hard contact of all four wheels or Pedrails with the road when any one wheel is mounting an obstacle not exceeding twelve inches in height, and the ankle movement of the feet is designed to mount a succession of steps, rising not more than about four inches each, up to a total of twelve inches, without requiring the feet to strike each step evenly. They will work equally well under the conditions shown in Fig. 19.

With larger Pedrails greater obstacles could be surmounted, but the author was of opinion that 12 inches was sufficient; in fact, even 12-inch obstacles are not frequently met with on our main roads!

It will be seen from Fig. 17 that the hind axle was mounted temporarily on ordinary wheels. These were borrowed from No. 1 engine, it being deemed advisable not to build more than one pair of Pedrails for a first experiment.

The second pair is being built, but the wisdom of deferring their construction has been amply demonstrated by the number of improvements of detail introduced into the latest design. Amongst these improvements may be mentioned the reduction in number of the spokes and feet from sixteen to fourteen in each Pedrail, the number of feet on the ground at any given moment being the same as before; the lubrication arrangements have been greatly improved, and the castings and fittings generally

January 8th, 1902.] NO. 2 ENGINE. [FIG. 17, *to face p.* 70.

straightened and simplified. Moreover, the feet are each to be increased in size from 9 to 11 inches in diameter, thus adding *fifty per cent.* to the area of surface contact and support.

One very important result has been achieved : by way of an experiment, the feet of one of the first Pedrails were soled with rubber. The rubber was of ordinary cab-tyre quality, arranged in segments with strips of wood between (see Fig. 18), the rubber thus coming into actual contact with the road. The rubber not only seems to stand admirably, but to keep itself clean even when traversing the most muddy roads. The strips of

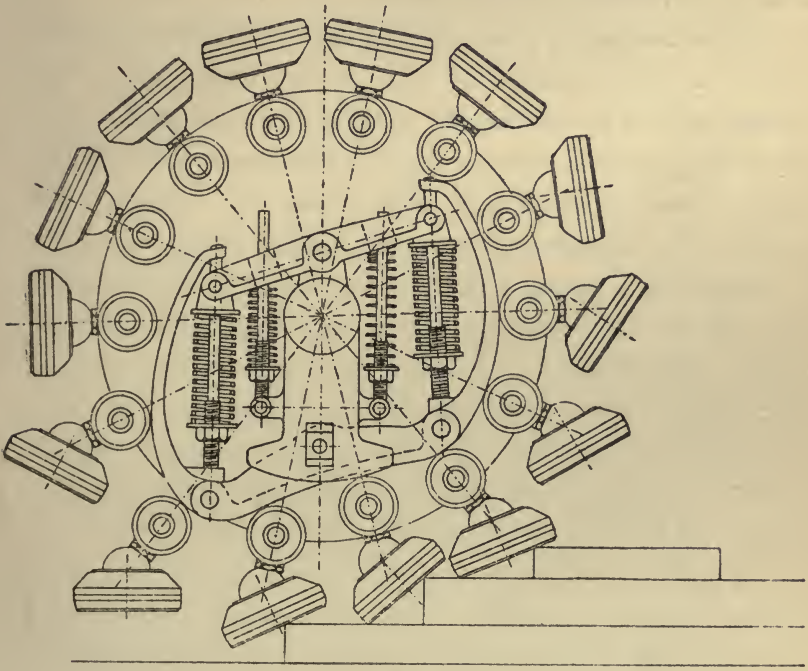

FIG. 19.

(*The Pedrail takes exactly the same position, only reversed, when stepping off the steps.*)

wood are intended to break up the surface of the rubber, and thus prevent suction. The explanation of the excellent results obtained is in the fact that the feet come down vertically, and the rubber is thus only subjected to a "buffer" action instead of the "mangling" action of rubber tyres already mentioned.

If an extended trial justifies the application of rubber soles to the Pedrails of the engine and wagons, the result will be to reduce the wear of the road surface to a vanishing point; moreover, the difference between the cost of rubber tyres and rubber soles is enormous. The rubber for traction-engine tyres (being subjected to the "mangling" process) has to be about 4 inches thick, and of the best quality, costing from £250 to £300 per pair; whereas for "Ped." soles pure rubber is not suitable, the buffer action necessitating an admixture of other material to harden the rubber, and a much smaller quantity being required; the result is, that the cost of soling an entire Pedrail will not exceed £5!

The feet are designed so as to admit of these segments being easily and quickly renewed, even when on the road, and the author foresees the possibility of the rubber-soled train being able to travel on *snow* (especially if the engine is fitted with a plough), it having been ascertained by the experience of motor-cars that snow does not "cake" on an elastic rubber tyre.

Perhaps the greatest hindrance to the progress of "road locomotion" is in the fact that all experiments, to serve a really useful purpose, require to be carried out in full size on an actual road, and consequently at a very high cost and risk of loss. In most other branches of mechanical research, valuable experiments can be carried out in model form, but not so in regard to road locomotion, for the reason that it is practically impossible to reproduce the varying conditions of a road surface *in miniature* to correspond with the scale of the model. Another reason lies in the fact that the laws of friction and dynamics would almost appear to vary out of proportion to the scale of the experiment.

A good example of the latter was obtained in the Pedrail; the author had constructed a quarter full-sized model, which was subjected to the most severe tests, one test being to run it at varying speeds (such as would correspond to twenty or thirty miles an hour with a full-sized Pedrail) on surfaces of wood, corrugated rubber, and very uneven "virgin cork." In all these tests the model worked perfectly, the feet especially turning on their ankle-joints by their own weight, so that they fell with their soles horizontally presented to the imitation road surfaces.

Professor Hele-Shaw, on witnessing these model experiments, expressed doubt as to whether the dynamics would work as satisfactorily in a full-sized Pedrail, a forecast that was certainly justified by the result.

At the first trial of No. 2 engine and Pedrails, in the autumn of 1901, it was found that, although the weight of the feet or gravity force (as opposed to the centrifugal and other forces) was sufficient to make the feet fall horizontally at speeds up to three miles an hour, they did not always come down flat on their soles at four miles, and altogether failed to do so at five miles an hour. The difficulty of devising any mechanical means of controlling the movements of the feet was partly that it must be dust and mud proof, but principally, that any arrangement that would cause the feet to come down on their soles when travelling forwards would cause them to come down on their *sides* when travelling backwards, as in Fig. 20.

This led to the author's further invention and patent to control the feet by the movements of the *rollers*, through a light *friction-clutch*, it being observed that the rollers revolve in an *opposite* direction when the engine is travelling backwards, thus *reversing* the movement and preventing the feet coming down on their sides. The friction-clutch is necessary owing to the facts, first, that the rollers continue to revolve *after* the feet are landed on the ground, and secondly, that the feet must be free to

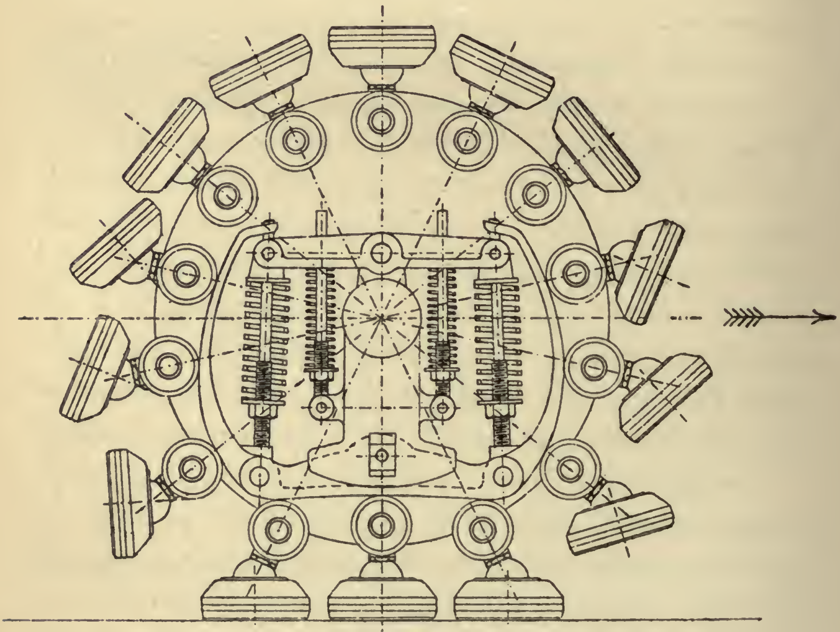

FIG. 20.

turn *against* the action of the friction-clutch when the inequalities of the ground require them to do so.

The solution of this problem being thus arrived at, it only remained to choose the best mechanical details to carry it into practical effect. These were ultimately supplied with the assistance of Messrs. Kerr Stuart and Company's general manager, Mr. J. W. Hartley, whose practical experience and suggestions, throughout the construction of No. 2 engine by the firm named, contributed very greatly to the successful result obtained.

The friction-clutch arrangement and the necessary alterations in the internal mechanism of the feet are shown in Figs. 21 and 22, in which **A** is the roller and **B** is the friction-clutch, turning the spindle **C**, which communicates the movement to the cogwheel **D**, through two sliding racks, **E, E** (Fig. 22). Attached to the cogwheel **D** is a hinged finger, **F**, which, pressing against the sliding-block **G**, as shown in Fig. 22, turns the foot to the angle required. The extent of the angle is regulated by the size of the opening at the end of the ball **H**, and the finger **F** is hinged to admit of its taking the position shown in Fig. 21, when the inequalities of the ground require the foot to move to its extreme angle *sideways*. The sliding-block **G** is centralized in the outer shoe by three radiating springs, one of which is shown in the illustration.

The above may be considered an ultra-refinement of mechanism for a road locomotive, and it should therefore be pointed out that it is adequately protected from dust, mud, and *all undue strains* by being *entirely* encased in the strong steel spoke; and further, that the details of the mechanism are so arranged that their strength and durability are far in excess of any strain that can possibly be brought to bear on them by the light friction-clutch, which is, however, of sufficient power for the purpose required.

The great importance of this latest improvement lies in the fact that it admits of the Pedrail being run at any reasonable speed, and thus appears to open the door to the application of its benefits to a very wide field, including wagons, vans, motor vehicles, omnibuses, and especially *tram-cars,* of which the last-named *would no longer require any tram-lines!* and with regard to this it may be mentioned that Colonel Crompton, in his paper on

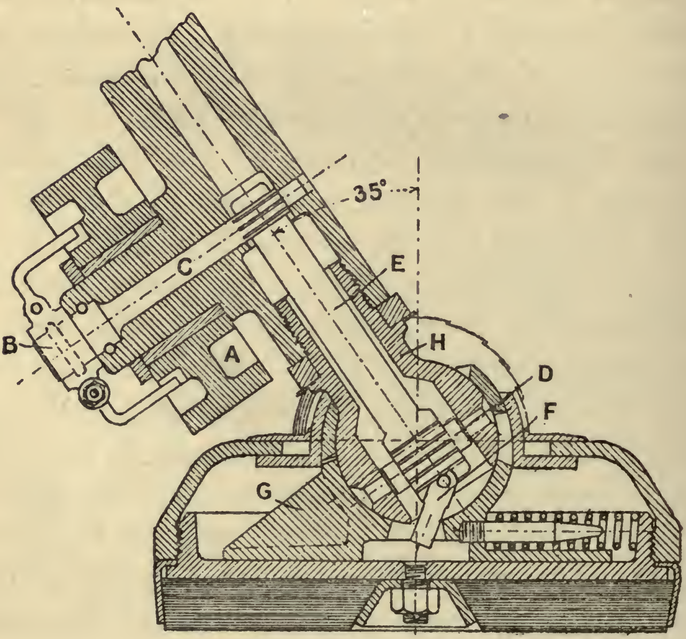

FIG. 21.

Street Traffic, demonstrated that if tram-cars could turn out and pass each other, and other vehicles, instead of being tied to a tram-line, the carrying capacity of our most crowded streets would be doubled.

Before passing on to another chapter, it is desirable to refer to the size and weight of No. 2 engine, as the author has been subjected to some criticism on this head, the main argument being that, having regard to its superior hauling power, a lighter engine would be more serviceable, especially in crossing weak bridges. The question of weak bridges is dealt with in a later chapter, but it may be here pointed out that the scheme is based on the necessity, from an *economical* point of view, of long and heavy trains for the main or trunk routes, thereby

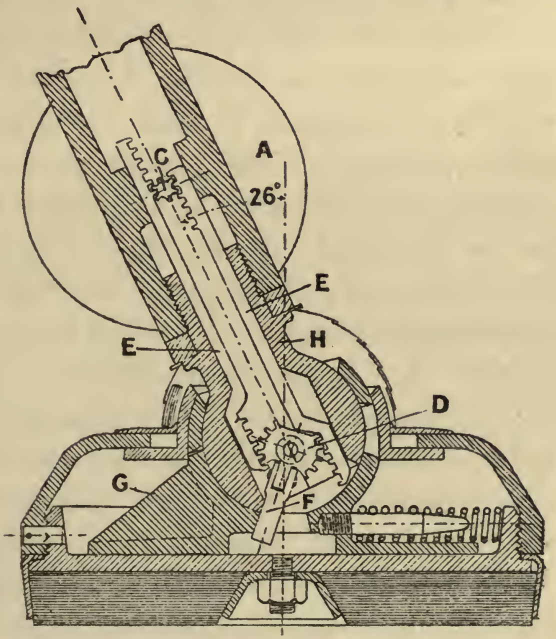

FIG. 22.

requiring powerful engines; moreover, the wagon-body system cannot be adequately dealt with unless there is sufficient weight in the engine to maintain the equilibrium of the crane, when lifting wagon-boxes up to the standard limit of four tons. There is, however, nothing to prevent lighter engines from being built in the future for other purposes.

The motive power of the engine is supplied by the ordinary locomotive fire-tube type of boiler, and is coal-fired, as the author did not consider it desirable, with so many experiments in hand, to further complicate them with any motive-power novelties;[1] moreover, he has always been of opinion, and up to the present has seen no reason to change his views, that the *elasticity* of steam places it far ahead of any other form of power at present utilized for road-locomotive purposes. No doubt the quantity of water required is a disadvantage, but the author does not hesitate to express his belief that at no distant date means will be found to condense the steam and re-use the same water constantly, the engine being so designed that no lubrication beyond that of the steam itself will be required in the steam passages. This would result in only pure distilled water—free from grease, lime, and other matter—being used for filling the boilers, only a small quantity would be required for replenishment of waste, and boiler troubles would then become practically unknown.

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[1] The experiments have, however, shown that liquid fuel is desirable in the next engine, for many reasons.

CHAPTER VI.

THE PROS AND CONS OF COMPLEXITY.

In an elaborate and mechanically complex system of road haulage such as described, the questions of labour, supervision, repairs, and capital outlay, all demand due consideration. The test of a scientific solution of the problem, however, does not lie in its simplicity and low first cost, but in its efficiency and earning power, combined with a general suitability to the times in which it is introduced and the work to be performed.

In the scientific and mechanical progress of the present day the tendency is *all* in the direction of increased complexity, perhaps even too much so, as the technical education of the labour to control, repair, and work these complex mechanisms is not keeping pace with the strides of invention. No better example of this can be cited than the invention and perfection of the Linotype machine, which, with its mass of beautifully delicate mechanisms, is rapidly superseding the old and laborious process of setting up type by hand. Yet the linotype for many years required two classes of labour, one to operate, and the other to look after the machines, and it is only after much printed discussion and publications that it has been gradually found possible to concentrate the requisite knowledge of both branches in one individual. The excuse for this digression is in the fact that the same difficulty will probably arise in the introduction of scientific mechanism for road-haulage purposes, and it is quite possible that in the early stages of development it will be found necessary to employ skilled fitters capable of adjusting and supervising the machinery, and *to teach these men how to drive.*

The driving of a road train is by no means a simple matter, for, irrespective of the fact that the driver has to watch and control his fire and the usual steam and water-gauges, lubrication, etc., it must be remembered that the road is common to other forms of traffic, including uneducated and restless horses. The driver has to foresee and provide for extra steam for climbing steep gradients, and for extra water in his boiler to keep his fire-box cool when descending long hills; he is hampered by more or less impossible legal restrictions, and has to stop and re-start his heavy train, often at a moment's notice, when signalled to do so. He must be a man of ample resource, ready to tackle and surmount innumerable difficulties caused by greasy roads, heated bearings, and all the other vicissitudes common to heavy haulage, and added to all this he has, owing to the absence of guiding-rails, not only to keep a sharp look-out ahead, but also to look after the *tail* of his train, and see that it is not pulling down a stray house or fence, or committing some other damage behind him, to say nothing of fouling overhead telegraph wires and bridges.

Some of these difficulties could be considerably reduced by establishing telegraphic communication between a guard or wagoner at the tail of the train and the engine-driver on the footplate, and this would without doubt be desirable in the case of long trains.

Experience has proved that railway drivers do not make good traction-engine drivers, possibly because the conditions are too similar and yet so widely different. The practice hitherto has been to pick out a handy man and train him as a driver, and, ordinary traction-engines having been built with a massive strength out of proportion to the power of the engine, the result, although somewhat crude, has been fairly successful. It will be seen, however, from Professor Hele-Shaw's report that No. 2 engine gives, at 400 revolutions per minute, an I.H.P. of 108, and the effective force obtained from this comparatively large power can not only be multiplied by nearly 30 in the gearing down to the road wheels, but the power itself can again be practically doubled for short emergencies by using the special form of by-pass valve. If the extreme force due to this combination were all turned on at once, without due discretion, a serious breakdown would result, especially with an adhesion of the Pedrails almost amounting to their being "anchored," and with an unusually complex mechanism intervening between the "anchor" and the power. It is therefore evident that the problem of the driver, to suit this higher plane of conditions and mechanism, must be *faced*; he will require to be, not only a fitter, having had a thorough training in the "shops" and a sound practical experience as an *engineer*—of the railway express locomotive standard—but he will also require a *special* training in the dynamics and other conditions of road-locomotion work.

It will probably be found in practice that the best plan will be to employ a skilled fitter as wagoner or steersman, and a first-class traction-engine man as driver, the latter being carefully cautioned about using the higher sources of power at his command, and working in conjunction with the fitter. With these men as a nucleus, it would be possible to gradually train an efficient staff of drivers, the raw hands in each case beginning with an empty engine, and gradually taking on more wagons, and travelling longer distances, future drivers being recruited entirely from the *shops.*

The problem of complexity of mechanism as affecting wear and tear must next be considered, with a view to showing that increased intricacy of machinery does not by any means necessarily entail extra working cost; in fact, the experience of railways tends to proof in the opposite direction. The first-class locomotive of to-day is a veritable triumph of complexity, as compared with the historic "Rocket," and yet the safety and absence of breakdowns on our railways is too well known to need comment. It is only traction-engines that have remained comparatively in the "Rocket" stage.

The author will have failed in his object if he has not succeeded in demonstrating that the problem of the road locomotive is much more complicated in detail than that obtained on railways, and it therefore stands to reason that such a problem *is not to be solved by any simple means.* Traction-engine builders have hitherto met their difficulties in this respect solely by making each part of the engine strong enough and heavy enough, in proportion to the load hauled, to as it were *slam* itself through or over its obstructions, and under these conditions it is not surprising that they have found that any addition or improvement involving complexity has only resulted in an increased need for repairs.

How is it possible, under these conditions, for the scientific solution of the problem to be even *commenced*, seeing that the mechanical intricacies *have never been carried far enough* to eliminate the first *cause* of the breakages?——Go to the root of the problem, remove the *cause* (even if it necessitates the introduction of complications that may afterwards prove unnecessary), for it is clear that——THE TRUE REMEDY IS, TO GO IN BOLDLY FOR SUFFICIENT MECHANICAL ELABORATION TO ENABLE THE TRAIN TO AUTOMATICALLY "ABSORB" AND ACCOMMODATE ITSELF TO EVERY OBSTACLE AND DIFFICULTY IT MEETS WITH, AS IT WILL ONLY *then* BE POSSIBLE, *under smooth running conditions*, TO ACCURATELY ASCERTAIN WHAT UNNECESSARY COMPLICATIONS——*can be left out!*

The author is of opinion that improved mechanism will eventually lead to *reduced* repairs, but he has considered it wiser, in the tables of working cost set out in a later chapter, to estimate for the usual percentages, and this notwithstanding that the percentage is reckoned on a much larger capital outlay, and that much has already been done towards simplifying the renewal of wearing parts, such as the soles of the feet and the rails of the Pedrail, also by taking up wear as much as possible by screw adjustment, and by abolishing back-lash in the gear. Without doubt, great improvements in these respects may be reasonably anticipated in the future, but it is only by *continual* examination and adjustment, and by *forestalling* possible breakages, that repairs can be reduced to a minimum, and it is principally with this object in view that so many parts have been made interchangeable. It should be an easy matter to arrange that every part can be left at home in turn at very frequent intervals for overhaulage and repair by a staff of men, *specially trained and employed for this purpose alone.*

And herein lies the answer to possible objections to mechanical complexity; it is the neglected pin-hole leak that eventually becomes a torrent, and a higher plane of mechanism thus *demands* an elaborate system, not of repairs, but of *overhaulage such as has never before been attempted or required.*

In other words, no train should be allowed to start its day's work except in such a state of *newness* as to practically eliminate all risk of working parts *commencing* to rattle or hammer. Only practical experience can decide how often a train should be overhauled to ensure these conditions; but to err on the safe side, the author would advocate that, at least during the earlier stages of trial, no train should be allowed to travel for more than two consecutive days on the road, and that every third day should be devoted entirely to overhaulage and repairs, this being combined with a free use of interchangeable parts, those left behind receiving attention during the intervening days.

The engine and wagon-frames would require to be so designed, and the mechanical, lifting, and other special appliances so arranged, that every part could be expeditiously "got at," the driver and other attendants of the train *assisting in the overhaul.* This last condition would possess several advantages, the "train gang," having been with the train on its journeys, would be acquainted with any parts requiring special attention, and would soon learn to mark them and see that they were not overlooked, also by assisting the skilled home experts, the "train gang" would be themselves *learning* the best and quickest methods of temporarily dealing with any mechanical breakdown or difficulty that might occur on the road. The chief advantage, however, would be in always associating the same gang with the same train; they would become acquainted with its "little whims" and peculiarities (engines are very like animals in this respect, and require to be humoured); responsibility would be localized, and a feeling of *esprit de corps* possibly engendered between the rival train gangs, which should be encouraged in every possible way by rewards and promotions. Such a result could not well be obtained if the train was always on the road, when the "gang" would be on duty for a somewhat arduous ten or twelve hours' "shift," whereas the overhauling or comparatively slack days at home would provide the necessary intervals of rest.

The next question that naturally arises is, how is this elaborate and expensive system of overhaulage to be paid for? *And herein lies the real strength of the system.* The earning power, as shown in figures in a later chapter, is so largely increased that it will pay for almost any demand on its resources. It is not only that the same weight and power in the engine will pull a heavier train than hitherto, but by mounting the wagons on Pedrails the power required to haul a given weight will be very largely reduced; the advantage is thus both ways, the effective power is increased, and less power is required to do a given amount of work. The large saving of power, per unit of work, should effect a correspondingly important saving in fuel and wages, and this in turn admits of the payment of the increased interest and depreciation caused by the necessarily much larger capital outlay than is usual on rolling stock; but here again the advantage is two-edged, so far as depreciation is concerned, for it is clear that, if the life of the engine and rolling stock is prolonged (as it undoubtedly will be) by the new system of overhaulage, combined with the extreme elasticity of the mechanism, the annual percentage for depreciation can be proportionately reduced.

This is quite apart from the fact that the wagon-body and crane system, already described, would *alone* pay for the extra cost of overhaulage by avoiding delay in loading and unloading, and thus enabling considerably more work to be accomplished in two days than would otherwise be possible in three.

Lastly, as regards capital outlay and also repairs, one very important feature must not be overlooked, viz. that under the Pedrail system the train takes its own railway about with it, and it is thus *rolling stock and permanent way combined.*

To compare the Pedrail train with ordinary railway rolling stock is to put the comparison on an absolutely untenable basis, the only true comparison being with the rolling stock plus (at all events to some practical extent) the permanent way, and this with the further economical advantage, that under the Pedrail system the "permanent way," being self-contained in the train, *comes home for its repairs!* instead of being spread over endless miles of country.

As an example of capital outlay it may be mentioned that the construction of the Lancashire and Yorkshire Railway cost over £60,000 per mile, and the London and North Western Railway over £50,000 per mile, whilst Mr. Alfred Holt, in his pamphlet on Plateways, estimated the cost of construction from Liverpool to Manchester at £38,500 per mile, and although light railways are now built at a much lower cost, the capital outlay must in any case be considerable, involving a heavy annual charge for *interest*, to say nothing of the great annual cost of *keeping the permanent way in repair.* A light railway at best, moreover, does not enable trains to deliver from door to door, neither can the track, once put down, be removed or the outlay reimbursed.

The plant of a Pedrail "Branch" would consist entirely of sheds, a few machine tools, and the rolling stock, so that if the traffic of any district falls away and proves insufficiently profitable, the cost of moving to another district would be merely nominal.

The wagon-body system has also another very important feature, in the fact that the wooden boxes, platforms, and crates are separate from the rolling stock, and being cheap, can be multiplied with very small capital outlay as compared with the cost of spare goods wagons on our railways, which, including steel frames, axles, wheels, brakes, buffers, and couplings, must represent a very large amount of *dead* capital.

A still further advantage is, that under the Pedrail system even a breakdown *does not block the line!*

CHAPTER VII.

SCHEME, DEPÔTS, COLLECTION AND DISTRIBUTION.

HITHERTO the author's description of the system has been mostly confined to the mechanical details of the problem, for the all-sufficient reason that no other course is properly open to consideration until the practical mechanical difficulties are at least in a fair way of being surmounted.

The railway problem, however, was not solved by the invention of the locomotive alone, but by the combination of the locomotive with a number of new ideas and inventions, due, in great part, to the genius of George Stephenson, and comprising rails, bridges, tunnels, embankments, stations, points and crossings, and all the innumerable details that go to make up a gigantic system that has spread itself over, and become the great civilizer of the world; nor would the above combination of engineering features have sufficed without the marvellous commercial organization that has grown up with it, and by its division, and endless subdivision, of management and superintendence has enabled an army of workers and an enormous mass of detail to be accurately and economically controlled.

The author lays stress on the experience of railways as tending to show that the road-haulage problem is also not to be solved by any one invention, but by a *combination* of mechanical arrangements forming a complete system and accompanied by sound commercial organization, instead of the "rule-o'-thumb" methods that have hitherto prevailed; most of the eight thousand traction-engines now working in the United Kingdom being at present owned by small jobbing men, who work from "hand to mouth," with insufficient capital and little or no commercial training.

It is not advisable, or even possible, at this stage to set out the details of a commercial system which must necessarily develop itself by degrees, and will probably vary very considerably according to local conditions, but the following are the main features proposed:—

1. The establishment of a number of "branches," each branch to undertake the haulage work of its locality, and to be controlled by a "District Centre," the latter being in turn controlled by one chief or "Head Centre."

2. The best possible engines and rolling stock to suit the work of each locality.

3. The concentration at one "Factory Centre" of all large repairs, technical supervision, and the purchasing of plant, coals, stores, and other materials at wholesale prices.

4. The classification of goods at various rates on the system adopted by railway companies.

5. The establishment of fixed routes in each locality which will be traversed by the road trains at *regular* intervals; no change in the routes or dates to take place without being duly advertised beforehand in the localities concerned.

6. The establishment of innumerable "depôts" along the lines of route, from whence full and empty wagon-boxes can be distributed and collected in the immediate neighbourhood of the depôts.

7. A special system to enable the accounts and statistics of each branch to be kept at its District Centre with the minimum of clerical staff.

The number of District Centres would probably not exceed ten or a dozen for the United Kingdom, and of these one would be the Head Centre.

The establishment of one Head Centre would secure general uniformity of management, prevent overlapping of District Centres, and would also enable staff, plant, and rolling stock to be concentrated where most required, not only to meet the exigencies of commerce varying at long intervals in different districts, but to supply the demands of agricultural transport, fluctuating according to seasons and districts at very short intervals.

The Head Centre would control all financial and capital arrangements, and would also form a convenient Court of Appeal for the settlement of any friction arising at the District Centres.

The main object of the District Centres would be to *decentralize* the commercial working of the scheme, each District Centre being a complete and separate business in itself, invoicing its transactions to and from the other District Centres, though all would report to the Head Centre, and all deal separately with the Factory Centre.

The establishment of one Factory Centre would be mainly with the object of standardizing the mechanical plant at the earliest possible date. The importance of this cannot be exaggerated; it is only when most of the parts can be stamped complete that interchangeability and minimum cost of manufacture will be attained. The author would advocate manufacturing by contract with established engineering firms as much as possible, the Factory Centre being mostly (but not entirely) reserved for repairs, the concentration at one centre enabling a high-class technical staff to be retained for the technical supervision of the District Centres, and also for designing and supervising the plant built by contract.

Each branch would require a branch manager (corresponding to the station-master on railways), and an engineer foreman, in the overhauling and repairing sheds, who would be responsible to the factory technical staff. Discipline in the branches would be maintained by travelling inspectors reporting to their District Centres.

Book-keeping at the branches should be minimized by a free use of manifold books, the counterfoils passing to the District Centres, where the accounts should be kept. This would leave the more highly paid managers and foremen at the branches free to attend to their practical duties instead of (as so often happens) keeping accounts that would be much more efficiently and quickly dealt with by clerks at the District Centres, and at a cost of less than half the salaries.

It may be mentioned that a special system of book-keeping has been prepared, combining the principle of the "clearing-house" with the abolition of all subsidiary books. The system admits of unlimited expansion, localizes ledger errors, and greatly simplifies stock-taking, but its main advantage consists in its providing the machinery for checking the working cost of the various departments in detail or totals as required by the management.

The foregoing must not be considered an Utopian development of a paper scheme. The scheme itself can be started and tested experimentally with *one branch*, but it is only by carefully mapping out the future that confusion and great waste of capital can be avoided during the *transition* from one or more branches to a larger and more complete organization.

It will be seen from this treatise that the numerous patent rights already granted to the Syndicate have practically secured a monopoly of this road-haulage system for many years, and this monopoly will be invaluable during the experimental stages and the *working out* of the scheme, not so much with a view to finance or profit-earning, as to prevent a competition springing up which might (whilst, perhaps, unable to establish a useful system itself) yet hamper the development of the parent scheme on a really sound and lasting commercial basis. A healthy competition later would, however, be beneficial when the parent scheme has been properly organized.

It does not follow that the establishment of a "branch" necessarily entails the train or trains of that branch travelling on the same route every day, the Pedrail system admitting of different routes being mapped out for different days to an almost unlimited extent. On sparsely populated agricultural routes the traffic might be insufficient to support a train more than once a fortnight, or even at longer intervals, but provided regular dates are fixed and known, the farmers will soon learn to save up their produce for the cheap and convenient Pedrail train.

With regard to possible traffics in agricultural districts, the author was astonished to find, on making inquiries through reliable sources, that the existing average *weekly* traffics "in and out" at twelve typical rural stations, in purely agricultural localities in the home counties, amounted to as much as 500 tons for each station. Seeing that more than twenty such stations could be dealt with by one branch, there does not appear to be any likelihood of insufficient traffic offering, at all events, in the home counties; and in the manufacturing localities, where the conveyance of raw and manufactured material is so large, the possibilities are enormous.

Moreover, it should be borne in mind that in any well-considered scheme, which may ultimately become of even national importance, those outlying localities which may not be even self-supporting, yet contribute to the general result much on the principle of the penny post.

The establishment of the depôts forms a very important, in fact an essential, element in the scheme, as it deals with that most difficult of all the axioms, viz. the collection and distribution of traffic *off* the lines of route. In large towns the depôts should be two or more in number, and so situated that, whilst they can be reached by the trunk or main route trains without unduly inconveniencing the town traffic, they may yet admit of the collecting and distributing engines, hereafter described, having only a short distance to travel to reach every part of the town; and there is nothing to prevent a main route train being divided into two or more sections *outside* the terminal towns, each section being taken separately by the engine to its respective depôt, thereby avoiding long trains in crowded streets.

With regard to the towns situated along the main routes, and not at termini, it would no doubt be possible in most towns to avoid passing through the main streets by making the route and establishing the depôts along the outskirts of the towns as much as possible.

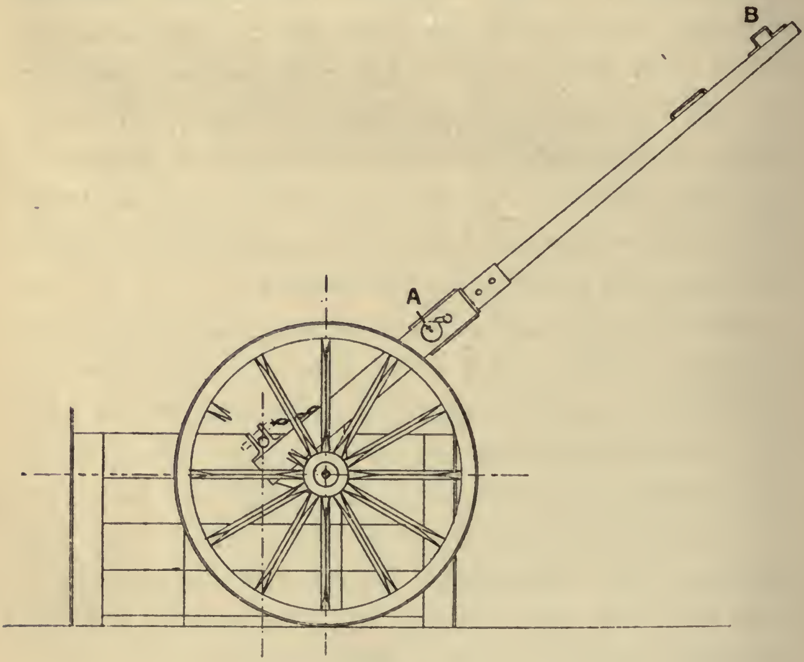

Fig. 23.

The *country* depôts would be stationed at existing farmhouses and villages along the lines of route, and would be practically agencies to collect and distribute full and empty wagon-boxes in their immediate neighbourhood, and here it may be pointed out that, with a possible daily variation of the lines of route, the depôts can, in the course of years, as circumstances admit, be increased in number *until every paying acre of land in the kingdom be brought within a commercial distance of its depôt!*

The empty wagon-boxes would be conveyed by a very simple horse frame, as shown in Fig. 23, which also shows the method of lifting a wagon-box off the ground, the horse being taken out of the shafts, and the box levered up a few inches by pulling on the ends of the shafts with a short rope. A pall on each side at **AA**, Fig. 24, keeps the box from swinging about "en route," and a light crossbar at **BB** can be slipped across the shafts to enable the boxes to be *man-handled* for short distances on level roads.

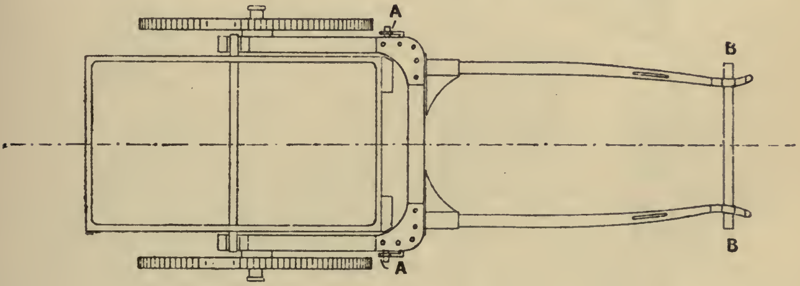

FIG. 24.

An open frame on wheels could also easily be designed with some screw arrangement to lift the *full* boxes when not too heavily laden, and these frames could be loaned to, and horsed by, the farmers in country districts for a small fee.

In order to deal with heavily laden wagon-boxes in larger quantities and in town or country, a cheaper and more completely efficient system would be required. This is supplied in the collecting and distributing, or *depôt* *engines.* These engines have not yet been designed in detail, but their general arrangement is shown in Figs. 25, 26, and 27, such arrangement being, however, subject to any modifications that may be found necessary in actual practice.

Fig. 25 is a side elevation, and Fig. 26 a plan of a "depôt engine." The fore part, or driving mechanism, is separated from the hind part, or carrying-frame, by a special form of steering hinge joint, somewhat on the principle of the wagon hinged joint already described, but with the addition of a worm segment at **AAA** which enables the engine to be steered as shown in Fig. 27. This hinge joint is so arranged that whilst it keeps both halves of the main frame from tipping endways, it yet allows them to freely oscillate crossways when passing over very unlevel ground, the requisite spring movements being amply provided in the *Pedrails.* Thus the necessary steering and oscillating movements being in the frames,

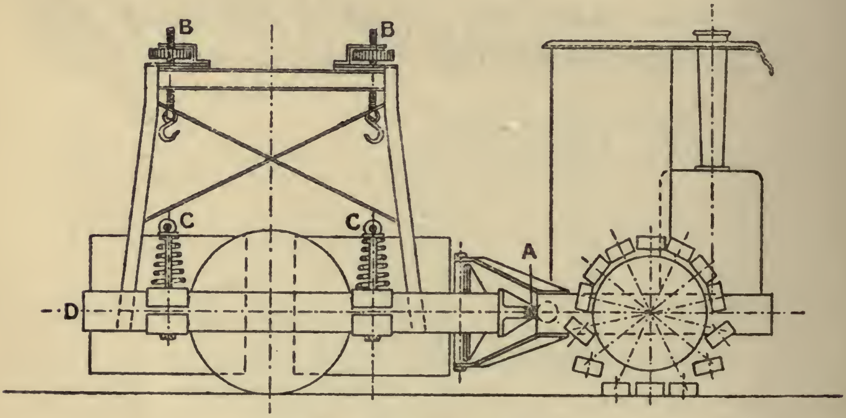

Fig. 25.—Depôt engine.

and the spring movements in the Pedrails, the driving-axle itself is free from all three of these movements in its relation to its frame, with the highly important result, that the axle *bearings* can then be mounted *rigidly* in the frame, this result in its turn reducing the connection of the axle with the motive power to the minimum of mechanical simplicity. There is also the further advantage that the Pedrails can be of any diameter, as they are not required, when turning corners, to lock under the frame, the latter being steered instead of the axle.

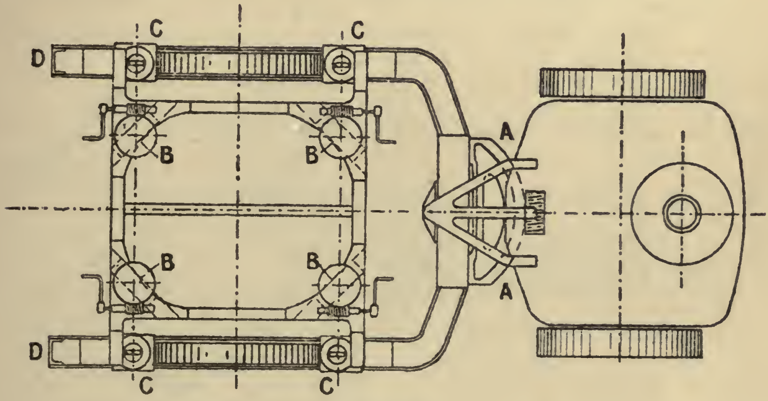

Fig. 26.

The hind part, or carrying-frame, is a kind of cage entirely open at its rear end, and with wheels for town use or Pedrails for country use mounted in the sides, each on a short separate axle, the interior of the cage being thus left free for carrying the wagon-boxes, as shown in Fig. 25.

In the top of the frame are mounted four worms and worm-wheels, **B**, operating on four powerful vertical screws. The handles of the worms can be easily reached by men standing on the side frames, and the combination of worm and screw mechanism provides ample power for lifting the loaded boxes by hand.

Assuming that a box is standing on the ground, the frame is backed over it, and the box or boxes lifted a few inches by means of chains dependent from the worm screws until a crossbar can be passed through the lifting straps of the box, the projecting ends of the bar being then lowered on to the four springs, **C**, mounted in the sides of the frame. Palls, as in the horse frame, prevent the boxes from swinging about, and a light movable crossbar from **D** to **D** ties the frame ends from spreading when travelling on the road.

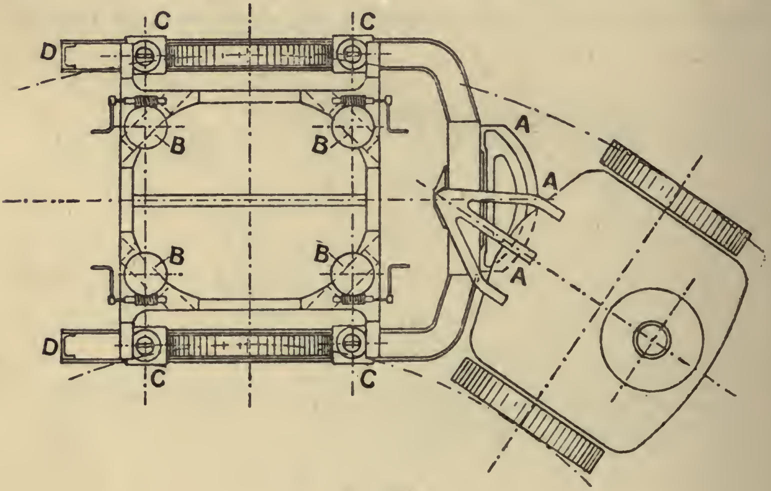

FIG. 27.

There is no practical or mechanical difficulty in designing and constructing these depôt engines, and it will be seen from the description that with practice, the whole operation of picking up or of dropping a wagon-box should not exceed *a few seconds.*

Moreover the depôt engines would be classed under the Light Locomotives Act of 1896, and thus be enabled to travel at speeds up to ten or twelve miles an hour, if required, especially when empty; this is important, as it would enable one of these engines to serve two, three, or more depôts, and thus working in advance of the trunk route train to maintain its supplies without requiring a depôt engine to be entirely supported by the probably insufficient traffic of only one depôt. Reserve engines at the branches could be sent out in exchange for those at the depôts, so that each engine could be overhauled in turn, at frequent intervals, on the system already explained.

It does not appear that there should be any practical difficulty in fitting hydraulic or other compact weighing apparatus on the lifting mechanism of the trunk route, or the depôt engines, or in fitting the engines with mileage indicators. These would not only be extremely useful for statistical purposes and "costing" accounts, when comparing one branch with another, but would provide an accurate and reliable means of preventing the trains being loaded with tonnage in excess of what is being paid for, and also of preventing the customers from being overcharged, as the crane and wagon-box system enables the goods to be weighed without necessitating any additional lifting operations.

The main advantage of the system, however, is in the fact that the boxes can be loaded in the farmer's field, the hold of a ship, the manufacturer's warehouse, or elsewhere, as required, conveyed from thence to any destination by road, or to the railway, and again thence, by another Pedrail train to the ultimate destination, *no unpacking or rehandling of goods being required throughout the entire transport*, the boxes being specially designed in sizes to suit the dimensions of an ordinary railway truck.

It is only by thus abolishing rehandling, and by reducing the stoppages for loading and unloading to a matter of *seconds*, that the cost of collection and delivery can be reduced to that absolute minimum, the want of which has hitherto barred all real progress in the problem of cheap and efficient road transport.

CHAPTER VIII.

COMMERCIAL MAXIMS, LEGAL PROBLEMS, AND GENERAL CONCLUSIONS.

It is evident that the *ultimate* development of a scheme, such as outlined in the last chapter, would be colossal, and would require to be financed in *millions*, but the system possesses the great advantage that it can be started and thoroughly tested in embryo form with a *moderate capital*, and, unlike a railway, no heavy outlay on permanent way is necessary before the earning power commences.

Although the capital should be sufficient to ensure a thorough test of the system in all its commercial and mechanical details, as applied to one or more branches, and to uphold the validity of the patents, yet the author would strongly deprecate any very large capitalization at the outset, or any attempt to at once establish the scheme on a large scale.

Experience *must* be obtained first, and whilst this is being acquired, the progress must necessarily be slow and the profits meagre; once, however, a nucleus organization is established on a sound working commercial footing, finance, and the multiplication of the branches should be comparatively easy.

Apart from philanthropic reasons, every scheme to be commercially successful should share its benefits, to as large an extent as possible, with its customers. This is not only sound morality but it is also sound business, the experience of the leading Co-operative Stores, Halfpenny Papers, and similar concerns, having amply demonstrated that the adoption of this principle ensures an enormous turnover, with a corresponding increase of profit to the original shareholders.

The author is therefore of opinion that the future increase of capital should be obtained as much as possible, by the *co-operation* of the farmers and customers in the neighbourhood of the new branches, rather than by over-capitalization at the start. This would give them an interest in the prosperity of the concern, and might be so arranged as to secure certain *co-operative advantages*, without requiring them to take a direct trading risk in the fluctuations of profit.

For instance, Registered Bonds, in multiples of say £10 might be issued, bearing interest at five per cent. per annum, and secured by a floating charge on the undertaking, the registered bondholders being entitled (on depositing their bonds with an established trustee agency), to claim a ledger credit for transport charges up to say half the amount of their bonds, and being *also* entitled to a substantial rebate on the transport rates; the latter being, however, strictly subject to a prompt *monthly* settlement of their ledger credits.

Some such course, although fully open to criticism and amendment, would possess many advantages; the risk of loss caused by bad and outstanding debts would be minimized and the liberal and material benefits conferred by the bonds, would soon make them of a *local* market value, free from the wire-pulling of Stock Exchange manipulations; the latter condition being easily secured by making residence in the district a necessary qualification to registered ownership.

Moreover, local ownership of the bonds, would be the best of all means of overcoming local prejudice; even the ultra conservative county magistrate, and the typical fox-hunting squire, would learn to look with an indulgent eye on an innovation that, whilst providing him with a safe and remunerative investment, improved the capital and annual value of his land.

It is well known how the strenuous, and even violent, opposition to railways developed eventually into a general recognition of the enhanced value of land, because it was *near a station!* How much more so would this be the case, if it were once demonstrated that the agricultural land value depended for its very *existence* on the Pedrail train!

As regards local prejudice, it should be borne in mind that in most country districts, one long train a day (or perhaps at longer intervals), would cause much less obstruction to other forms of traffic, than the numerous horses and wagons by which the transport is at present conducted, and in which the drivers generally adopt the habit of taking up the middle of the road, leaving the horses to keep a sharp look-out, whilst they indulge in a comfortable sleep!

Compare these conditions with those of the Pedrail train, where a responsible driver at one end would be in telegraphic communication with a guard or wagoner at the other, and where all the attendants would be drilled by strict discipline to assist other forms of traffic in passing the train from *either* end.

It stands to reason that if a cheap and efficient system of transport is established, those counties not adopting its benefits *will be left behind in the race for existence;* and herein lies that most powerful of all inducements, viz. self-interest, to compel local authorities to give every possible facility to the new system, even to the extent of rebuilding weak country bridges.

The author has endeavoured to show in this treatise, that by minimizing vibration, and by spreading the weight of a train over as large a surface area as possible, most of the *existing* highway bridges could be safely utilized for steam transport, but something more than this will eventually be required; the experience of railways having proved that a continuous *increase* of weight and of tractive power, has been found necessary to obtain the ultimate *minimum* of economical conditions, with the result that the railway companies have strengthened and rebuilt their bridges accordingly.

With local self-interest enlisted in the scheme, may it not be assumed that the history of railways will repeat itself in road trains, and that those county councillors and other local authorities not responding to the new conditions will be unseated by the local ratepayers?

The author has based his scheme on existing conditions, legislative and otherwise; but it should not be lost sight of that it will only be by educating public opinion to the possibilities of still greater economies of transport that legal and other restrictions can be removed, and the productive power of the land utilized to its fullest and highest extent almost irrespective of distance!

Without doubt, progress in the scientific development of road-transport has been sadly hampered by legislative restrictions; these restrictions have to a certain extent been justified by the many somewhat crude mechanical attempts to solve the problem (especially in the early years of steam) without sufficient regard to the fact that the highways were constructed for the benefit of the public, and not exclusively for separate individuals.

It is the old story, however, of trying to effect by specific Acts of Parliament, what might have been accomplished much more efficiently by public opinion, backed up by a proper enforcement of the existing rights under common law.

The finicking interference of the Locomotives Acts has tended more than any other cause to retard the *removal* of the very objections that the Acts were designed to frustrate.

There is, for instance, a fine "Gilbertian" flavour about the 1865 Locomotive Act in this respect, especially in the provision introducing the man with the red flag, a condition that had to be repealed in a subsequent Act, since it was found that the red flag frightened horses more than did the locomotive! A similar fate awaited the clause providing for a man to assist horses in passing by walking sixty yards ahead of the engine, it having been entirely overlooked that his assistance was equally required to aid horses overtaking the engine from behind!

Imagine an Act of *Imperial Parliament*, in 1878, defining in inches the *mechanical* details of a wheel! and that, had it not been for a clause introduced into the Light Locomotives Act of 1896 (eighteen years later!), giving power to the Local Government Board to vary these conditions, the Pedrail (designed expressly to minimize damage to the road surface), would have required another special amendment Act to render its use legal!

It is this want of foresight, or rather the difficulty of anticipating *future* inventive progress, that makes it practically impossible for an Act of Parliament to deal sensibly with the details of mechanical locomotion. An Act framed to control a 14-ton locomotive, is found later on to apply its restrictions to say a child's perambulator, or it entails some equally absurd result.

Although in the Locomotives Acts of 1896 and 1898 more enlightened views have prevailed, there is still plenty of room for further improvement, and there can be little doubt that the real interests of agriculture and commerce would be best served by abolishing the existing Locomotives Acts altogether, and by substituting a short provision to the effect that self-propelled locomotives shall not unduly damage the roads or bridges, or cause undue inconvenience to other users; the Local Government Board or some other *central* authority being appointed to define, and from time to time to *amend*, all details in such manner that every improvement or invention can be (by a short trial licence, if necessary) *promptly* and economically dealt with on its individual merits.

Failing such an Elysium, it becomes necessary to examine how far the existing Locomotives Acts affect the *introduction* of the proposed scheme, and here the author has much pleasure in stating that his scheme can apparently be at all events started, and its advantages tested and demonstrated without any special amendment Act being required.

It does not appear to be just, that heavy loads can be taken over bridges by horses with immunities not possessed by the *same loads* when hauled by a locomotive, and there are many other restrictions as to size, weight, hours, etc., that would be better removed, especially in regard to future development, but the bridge risks might, for the present, be covered by insurance, and the removal of hampering restrictions may safely be left to the weight of future public opinion when the advantages of the system have been duly demonstrated.

Under the Locomotives Act of 1898, the Local Government Board have power to restrict local bye-laws, and the Act specially directs that they "*shall* have all proper regard to the necessities of through locomotive traffic and of persons who own or use locomotives." This is, undoubtedly, a very important concession, and should do much to remove the difficulties that have hitherto prevented the establishment of any general system.

The principal "blot" in the 1898 Act appears to be in section 3, stating that a locomotive shall not draw more than *three* loaded wagons without the *consent* of the local authority, and the Act does not appear to provide any power of appeal to the Local Government Board against this restriction.

It therefore seems that it will be necessary, in order to start the scheme, to first find some enlightened local authorities covering a sufficient area in which to establish the first "branch." The author does not anticipate any great difficulty in this respect, especially in the Liverpool and Manchester districts, where the valuable trials of heavy motor vehicles, carried out during recent years by the Liverpool Self-Propelled Traffic Association, under the presidency, and with the support, of Lord Derby, have already educated local opinion to the full recognition of the great advantages to be obtained by developing some efficient system of road transport.

It should be observed that the section of the Act referred to specifies three *loaded* wagons, and does not appear to place any limit to the number of *empty* wagons that may be hauled! It would therefore seem feasible to stimulate the "consent" of any recalcitrant or tardy local authorities by making up a train of nine or ten wagons, and only loading three of them; of course charging higher transport rates in proportion, and leaving it to interested local ratepayers to hold indignation meetings until the obstruction to cheap transport is removed!

In the next chapter the author has endeavoured to show that it will be possible to transport goods, inclusive of profit, at an average rate of one penny per ton per mile, and that an even lower rate may be hopefully anticipated in the future, but it would obviously be unwise to commence with a rate below say twopence per ton per mile, or even threepence.

Errors of judgment, commercial oversights, and mechanical breakdowns, are bound to occur with a too constant frequency whilst the staff is being trained and educated in that most efficient, but at the same time, that most expensive of all schools, practical experience.

Moreover, it may, and probably will, be found necessary to redesign and reconstruct the plant, especially in the early stages, at somewhat frequent intervals, and this can only be done by building up an ample reserve fund out of surplus profits.

Further than this, is it not daily becoming more evident (as compared with the experience of our forefathers) that in these times of expanding inventive progress, a business that is dependent on mechanism, and which is living up to its income in dividends, is really living beyond it? And is it not clearly essential for such an establishment, that it should possess such ample reserves as will enable it to adopt the latest ideas, and if necessary to construct new and up-to-date plant, instead of allowing itself to be displaced by some newly formed concern which, whilst possessing free capital, yet lacks the important advantage of an established organization and connection?

It stands to reason, however, that change of standard patterns should, as far as practicable, be only at *long* intervals; there is no greater mistake (one only too common amongst enthusiastic inventors) than to fritter away the capital of a young concern in endless improvements. The whole question really resolves itself entirely into a matter of sound judgment; too much care cannot possibly be exercised in deciding on the first or the subsequent standard patterns, but once adopted they should be adhered to; a saving of even 5 per cent. in working expenses should not justify an immediate change, but one of 20 or 25 per cent. might do so.

It is the opinion of many engineers that our railway companies made a mistake in building their own plant; for this entails not only an increase of capital outlay, due to the absence of competition, but it also necessitates *continuous building* to keep the men and works employed, and thus prevents that necessary *pause*, which ought to take place for due consideration of any change of standard patterns; moreover, the temptation with continuous building to constantly introduce trifling improvements is almost irresistible. The ventilation, however, of new ideas and inventions *should* be continuous, and any suggestions by the staff and employés in this respect should be most generously recognized and encouraged.

The author has endeavoured in this chapter to set out a few general conclusions, amongst which may be mentioned, in passing, the desirability of employing men of the Royal Navy Reserve and sailors, in other words, the "Handy-man," as affording (for dealing with heavy weights) the best material for wagoners and train attendants; but the real success of the system will mainly depend, as in every other business, not on the mechanical features, or the commercial and other details, but on that most important of all elements in the scheme, *the selection of the right men to manage it.*

CHAPTER IX.

ESTIMATES.

Some one has said, "Give me figures and I will prove anything," and there is so much real truth in the statement that, in presenting a chapter on "Estimates," the author does so with all due reserve.

Although it is possible to *reason in figures*, the results so obtained must necessarily be limited to the establishment of *theoretical probabilities*, and never more so than in a pioneer system which by its very nature absolutely precludes any reference to previously ascertained data, for the simple reason that such data do not yet exist, except, perhaps, in a general way or in minor details.

One fact, however, seems evident, viz. that the scheme proposed cannot fail to effect very considerable economies as compared with the *absence* of any general highway transport system; and with this proviso the following estimates will at least serve a useful purpose, if only as a guide to future possibilities.

Before framing any estimates of working cost, it is necessary to form some idea of the probable—

1. Cost of each engine and train of wagons;
2. Distance to be traversed per train per day;
3. Tonnage of the goods that a train will convey.

1. It would be obviously useless basing the estimated future cost of each engine and train on what it has cost to build the existing engines and Pedrails, owing to the well-known great reduction in cost that takes place when manufacturing in quantities.

The author has been at some pains to arrive at a trustworthy estimate, taking into consideration the actual known cost of the existing engines, and allowing for reduced future cost. On this basis he is of opinion that it will be found possible in the comparatively early stages of the scheme to build and fully equip each engine and train of eight wagons, for a sum not exceeding £5000; and that, by establishing standard patterns and making a larger proportion of the parts (especially the Pedrails) in pressed steel, a reduction in this figure may be reasonably anticipated in later years.

2. As regards the distance a train will travel in a day, it may be assumed that, with loading and unloading time reduced to an absolute minimum, and with the train and train-gang only travelling two days out of three, it should be possible to run for, say, 10 hours at an average speed of 3½ miles per hour, or 35 miles per day. This distance could of course be exceeded if the Locomotives Acts were amended as regards speed.

3. It is difficult, if not impossible, at present to arrive at a conclusion as to the tonnage that may be hauled in a Pedrail train. It will depend on two conditions, neither of which has been yet subjected to a practical test. When No. 2 engine is mounted on four Pedrails (the second pair is now being built) it will be possible to measure its full hauling power and establish the first condition.

Meantime, judging from the experiments carried out with No. 1 engine, the greatly increased engine-power provided in No. 2, and the fact that the latter will be mounted on four Pedrails instead of on four wheels, the author has arrived at an estimate that No. 2 engine should give on a level road a horizontal draw-bar pull of about 10 tons, and this opinion is confirmed by Professor Hele-Shaw in his report.

The other condition referred to is as to the amount of horizontal tractive force required to haul a train of *wagons* mounted on Pedrails. On railways the tractive power required is 8 to 10 lbs. per ton of train, on common roads it is 80 to 500 lbs. per ton, and on tramways about 35 to 40 lbs. After much careful consideration, and allowing for the fact that the flanges of tramway wheels in gritty grooves cause heavy friction, the author ventures to express the opinion that the horizontal tractive force required to move a Pedrail train will eventually prove to be about 30 lbs. per ton of train and load.

Taking 10 tons as the possible draw-bar pull of No. 2 engine, and dividing it by 30 lbs. as representing train resistance, the somewhat startling result is produced that it may be possible, on a level road, with No. 2 engine to draw a Pedrail train weighing a total of *seven hundred and fifty tons!* and with larger engines and stronger bridges even this result might be eclipsed.

Setting these figures on one side as being for the present purely imaginary, it is a fact that No. 1 engine has moved more than 80 tons without either engine or wagons being mounted on Pedrails, and with an engine and boiler power about one-third of that provided in No. 2. It therefore appears evident that it should be possible to deal with a Pedrail train of *one hundred and sixty tons* gross weight, not only on level roads, but also on moderate gradients, and the author has therefore adopted this figure in compiling the following table of estimated working cost:—

FUTURE PRIME COST OF AN ENGINE AND EIGHT WAGONS, SAY £5000.

Estimated Working Cost.

	£	s.	d.		£	s.	d.
Depreciation, at 10 per cent. per ann.				25 per cent.	1250	0	0
Overhaulage and repairs, at 15 per. cent. per ann. ..							
Fuel, water, lubrication, and sundries, 4 days per week, at £1 per day					208	0	0
Driver	0	10	0	per day			
Steersman	0	5	0	„			
Two labourers	0	8	0	„			
Wagoner	0	7	0	„			
Four days per week, at	£1	10	0		312	0	0
Total per annum exclusive of interest, profit, management, and contingencies					£1770	0	0

The above figures are based on the assumption that every third day will be devoted to overhaulage and repairs, the driver's and attendants' wages on these days being therefore included in the £1250 item.

The eight wagons would comprise sixteen axles, each carrying an average of 6¼ tons of goods or 100 tons of goods in all, leaving 60 tons for the weight of the empty train.

The train mileage per day is estimated at 35 miles.

Taking the above figures as a basis, the following approximate results are arrived at:—

		£	s.	d.
Working cost of train per day	$= \dfrac{\pounds 1770}{208 \text{ days}} =$	8	10	2
Cost per train-mile	$= \dfrac{\pounds 8\ 10s.\ 2d.}{35} =$	0	4	10¼
Cost per ton-mile with full load	$= \dfrac{\pounds 8\ 10s.\ 2d.}{35 \times 100} =$	0·583 pence		

or about *three-fifths of a penny per ton-mile.*

With ¾ loads the figures would give 0·778 pence per ton-mile.
" ½ " " " 1·166 " "

Given such figures, however, it may be assumed that full loads will be almost constant, especially in the manufacturing districts, or, as an alternative, that with nine or ten wagons, an *average* of 100 tons of goods will be maintained.

With regard to the 25 per cent. set aside for depreciation, etc., it should be noted that this is equivalent (on a train working two-thirds of the year) to *thirty-seven and a half per cent.* as compared with a train working full time. Moreover, the 10 per cent. for depreciation would "write off" the train in ten years, whereas, with one-third of the year devoted to repairs, and with an elastic mechanism reducing shocks to a minimum, there is every reason to believe that the life of the train will extend to twenty years or even longer.

The following calculations are interesting :—

1. A train conveying 100 tons, 35 miles in a day, at 1*d.* per ton per mile, would earn £14 11*s.* 8*d.*, or a surplus over working cost of £6 1*s.* 6*d.* per day, or £1263 12*s.* per train per annum (208 working days) for management, fixed charges, contingencies, and profit !

2. 100 tons, taken 35 miles, on 200 days, would repre-

sent 700,000 ton-miles, which, if charged at 2½*d.* per ton-mile, would provide more than sufficient to pay the entire working cost, management, and repairs, and also to refund the whole capital outlay plus 5 per cent. interest *in one year.*

It will be observed that these calculations do not include the depôt engines, and it does not seem possible to arrive at any really trustworthy estimate of the rate per ton to be charged for collection and delivery off the lines of route. It is, however, evident that it could not in any case amount to more than a few pence per ton to be added to the through rate, and must certainly be very far below the present cost of rehandling and horse-haulage.

In concluding this treatise, it only remains to mention that the average existing railway rate for distances up to 35 miles, including terminal charges, appears to be about 4*d.* per ton per mile. "Terminal charges" are for stations, management, etc., and do not include collection or delivery.

As compared with 4*d.*, a rate of 1*d.* would be a reduction of *seventy-five per cent.!*

Horse-haulage rates vary, according to districts, from 10*d.* to about 1*s.* 6*d.* per ton per mile, and in sparsely populated districts, with scanty loads, and a possible rate of as much as 2½*d.*, a corresponding reduction (75 per cent.) would be obtained even on the lower figure!

Even though only based on "theoretical probabilities," the foregoing estimates are sufficiently striking and emphatic to speak for themselves. They do not appear to require any comment.

FINIS.

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