RAILWAY PRACTICE

AND

RAILWAY POSSIBILITIES.

BY

W. BRIDGES ADAMS,

ENGINEER.

"DIVIDE, ET IMPERA!"

MAKE A DIVIDEND, AND RULE OVER US!

LONDON:

PUBLISHED BY FREDERICK DANGERFIELD,

[illegible], BEDFORD STREET, COVENT GARDEN.

1868.

RAILWAY PRACTICE

AND

RAILWAY POSSIBILITIES

AS AFFECTING

DIVIDENDS AND SAFETY,

WITH

DIAGRAMS OF ENGINES, TRAINS, AND BRAKES,

BY

W. BRIDGES ADAMS,

ENGINEER.

"DIVIDE, ET IMPERA!"

MAKE A DIVIDEND, AND RULE OVER US!

LONDON:
PUBLISHED BY FREDERICK DANGERFIELD,
22, BEDFORD STREET, COVENT GARDEN.

1868.

TO THE READER.

Nearly twenty years back I published a work under the title of *Road Progress*, treating the general question of Railways and also of the proportions and excess of dead weight to paying load. There is no doubt too large a proportion of dead weight, but the supposition that the dead weight can always be exactly adjusted to the paying load is a fallacy. The Engine and Train must be a fixed load, because it must go and return whether full or empty, just the same as the omnibus and horses, whereas the paying load, whether of goods or passengers, will always be varying. The calculation of accommodation must therefore be for the maximum average, and not the actual maximum. And herein lies a difficulty. The public makes a great outcry, if fifty passengers are occasionally disappointed in a train calculated for five hundred, and so the Directors provide for five hundred and fifty, and the dead weight for the fifty is dead loss as often as the fifty fail to come. And this process goes on till at last trains commonly run half full, and with large engines doing the work of small ones.

As there is a tendency in all large processes to become stereotyped, so it is sought to make all locomotives of one standard, and carriages and wagons the same, unless absolutely impossible. And thus we occasionally find branch lines worked by the same kind of stock as main lines, with an absurd disproportion of dead to paying load. It is convenient to save trouble, but the trouble is saved at a loss.

On suburban lines with trains rapidly following each other, it is practicable to adjust the means more exactly to the end and to have the engine and carriages facsimiles of each other—first finding out the best types. This has been done with omnibuses which have come generally to two standards, for the smaller and larger number of passengers. These are regulated by the time which passengers will wait at the various points to collect the average. If the time be every two minutes and only twelve passengers collect in that time, it would be useless to provide accommodation for forty. If twenty-four collect, then the double omnibus may be applied. But it would be a fallacious comparison to take the dead weight of an omnibus with a full load as against a railway train with half a load. Both omnibuses and trains must occasionally travel half filled. The real question at issue is, whether the trains are unnecessarily heavy, and in addition to that, whether they run with the minimum of resistance to traction, for resistance to traction resolves itself into increased engine power, and that again into destruction of rails and permanent way.

The rapid destruction of rails on railways has become an evil of such magnitude that Engineers have publicly discussed the subject, and the necessity of substituting homogeneous metal for the present laminated structure of wires and ribbands held together by scale, and which separate like woody fibre under the increasing load of engine driving wheels. Some Engineers hold that the remedy is to be found in doubling the cost of rails to get better metal. Others say that ordinary iron rails are good enough if only the rubbing process were stopped, between tires and rails, and the resistance reduced to its possible minimum. Other things being equal, homogeneous rails are no doubt best, and would last for a generation, but so would ordinary rails, were they fairly dealt with.

Railways have grown up something after the fashion of sheep, that always follow the bell-wether and imitate all his actions without enquiring into the reasons. If any bystander puts up a stick when the flock is about to leave the fold, the bell-wether leaps over it. If then the stick be withdrawn, all the sheep continue to leap at the same spot exactly as the bell-wether did. And thus, as the early Railway Engineers went very much on expedient and convenience, the original practice has been stereotyped and only altered in patches under circumstances of necessity, and not always with success. Railway Geometry has not yet been reduced to strict accordance with Euclid, or the vicious practice would not be continued of striving to force longer and longer parallelograms round sharper and sharper curves, as though a tangent working against a curve were the means of preventing impedimental friction, and increasing safety, instead of the direct contrary. Constructors have been spoiled by the facile development of steam power, and trusting to its mere force have disregarded all resistances, forgetting that the force needed foothold or wheelhold by weight, and so rails and wheeltires have crushed under the loads, the term "Permanent Way" has in some cases become a standard jest, and occasionally officials almost think that paying dividends with a closed capital account, is like "making bricks without straw."

We must try back again, and reducing our surplus resistances to the minimum, make the discovery that our steam power will be probably in excess of our needs, so soon as we shall substitute true rolling movement for the sledging vibration that induces physicians to forbid railway travelling to nervous patients.

W. BRIDGES ADAMS.

Blackheath, London, 1868.

RAILWAY PRACTICE AND RAILWAY POSSIBILITIES.

The Rolling Stock of Railways has of late years increased largely in its proportional resistance to traction, by reason of the extended wheel bases of larger carriages and their additional friction between the wheel flanges and rails, needing therefore a stronger and consequently heavier structure to resist the forces of buffing and traction. This again involves the necessity for proportionately more powerful engines, and greater dead weight, to render the increased steam power availing.

The early carriages had wheel bases of six or seven feet in length which increased to eight and nine feet, and now have grown to sixteen feet for four wheel carriages, and thirty feet for those on eight wheels.

The rail curves have also multiplied in number and increased in curvature, especially in town approaches, and the necessity for check rails to prevent the vehicles from running off the line is on the increase, and with these an increase of friction.

On straight lines of rail a given number of carriages may be drawn, but as the curves increase in number and sharpness, so must the number of carriages decrease, or the engine power be increased.

Practically with Goods and Coal trains the necessity for shunting, out of the way of the passengers' trains, limits the load of the Goods to one third less on curves, than would be available on the straight line, even when the train is drawn by the engine; and when propelled, and the wagons are thrust in crooked directions against the rails, the resistance is increased.

It is well known that on a straight line one of the long carriages of the present day may be moved by manual power, but a very slight curvature of the line renders it impracticable.

Friction on the railway is of three kinds. First, the rubbing axle friction. Secondly, what is called rolling friction—*i.e.* the friction between the tread of the wheel tyre and the rail, caused by the varying length of the pathway. Thirdly, the flange friction against the rail edges, caused by pressing a long rigid parallelogram round a sharp curve, the wheels being then always at a tangent with the rails, and with great risk of running off. It is this that wears out tyres and rails, and causes a constant grinding annoyance to passengers, affecting their digestive organs.

The remedy for it is so to arrange the wheels and axles that they will so move laterally to right or left in radial curved lines; that the axles will always point truly to the centres of these curves, each pair of wheels being independent of the others, in order to work irregular curves, and not enforcing both pairs, to exactly the same angle at the same time, which would on an *S* curve be dangerous.

Goods wagons are loosely shackled together and run freely with sinuous movement, the wheels seeking the path of least friction. As this movement would annoy passengers, passenger carriages are closely coupled one to the other, throughout the whole train. Their wheels are thus debarred from seeking the path of least friction, and tyres and bearing brasses are ground away. If the wheels were free to move laterally, the carriages might be close-coupled without mischief, with true radial connection.

The same difficulty that occurs with the vehicles, occurs with Engines and Tenders. The Engine is commonly on six wheels, all drivers, for a Goods Engine, and four drivers and two leaders or trailers for a Passenger Engine, the wheel base being from twelve to fifteen feet in length. The Tender is four or six-wheeled, and has commonly a shorter wheel base. The coupling is so arranged, that there is a constant dispute between Engine and Tender, and the jolting on the foot-plate becomes almost unbearable to the driver and stoker, who therefore close-couple them by the connecting screw as is done by the carriages to obtain steadiness, and the result is, great friction of the flanges and a tendency in the wheels to escape from the rails.

On the great Northern and Chatham and Dover lines, working over the Metropolitan, there have been employed now two years thirty four of the Radial Engines of the writer. The four driving wheels are forward between the firebox and cylinders, and the trailing wheels are placed about twelve feet from the nearest driving wheels, making up the total wheel base of about twenty feet—the frame being lengthened to the same extent. The tank is carried wholly on the trailing wheels with 1000 gallons of water and the load of the engine is so nearly carried on the drivers, that when the tank is empty, it makes a difference of only 3 cwt. less on the driving wheels. As the trailing wheels are radial, and can shift from side to side on a curved line, the engine on one frame works very well round curves, and it would work equally well if two pairs of trailing wheels were applied radially, in which case the engine might carry 2000 gallons of water, and serve for long journeys, with the advantage of running either end foremost without reversing.

One disadvantage of existing Tender engines is that by reason of their faulty connection they are only adapted to run engine first and so require reversing, which is an operation needing time and trouble and turntables, but with an effective arrangement the Tender-Engine would be just as useful in this respect as the Tank-Engine.

The engine draws the train by means of the adhesion of the driving wheels, and according to their load so may steam power be applied, the steam power being about one-fifth of the load on the wheels. Two drivers, or four, or six, or eight may be employed, but the power of the engine must be limited by the number of driving-wheels inasmuch as the load is limited. If 12 tons be the limit to place on two wheels in order to prevent destruction of tyres or rails, four wheels will take 24 tons, six wheels 36 tons, and eight wheels 48 tons. Thus the two-driver engine may use a power of 48 cwt., four wheels 96 cwt., six wheels 144 cwt., eight wheels 192 cwt., or 9 tons 12 cwt.

In proportion as the resistance of the train is diminished, so may the load be increased, always supposing that the traction rods and couplings be sufficient not to break, and in proportion to the facility of traction, so may the dead weight of the vehicles be decreased, without diminishing their proportional strength.

But in increasing the power of the engine by the multiplication of the wheels, we also increase its length, and render it proportionally unfit to work curved lines of rails. We must therefore so arrange the engine that it may be capable of lateral bending, or keep the wheel-bases very short, to prevent friction between the flanges and rails. It will therefore be desirable in some cases to use two engines so coupled together that they will work as one engine, taking care that each engine may describe varying curves and not be so attached together as to make exactly corresponding movements and angles. The rails are irregular and so must be the movement of the wheels to correspond to them.

The construction of engines must vary with the purposes to which they are to be applied, whether for small loads at high speed, or heavy loads at lower speed. High speed requires large wheels, and heavy loads smaller wheels. But in all cases it is essential that the train should follow with the minimum of friction. And other things being equal the larger the floor area of the vehicles the more economical it will be in carrying bulky loads. As a rule it is desirable that wagons should carry every kind of load possible, and the larger the wagon the better it will be adapted for carrying cargoes. For Coals, Cattle, Sheep, Cotton bales, Hay, Staw, Corn, there seems no reason why one class of wagons should not be adapted. Coal wagons would be peculiarly advantageous in preventing cattle disease from spreading. It is quite certain that if only one class of wagon could be used, the "demurrages" would be considerably lessened, and the number of "empties" reduced.

The whole question resolves itself into practical structure. How to obtain the minimum resistance, and the vehicles and engines best adapted for following and hauling. The writer has therefore given various diagrams for the purpose of illustration.

PLATE 1.

Is a diagram showing a train of four wheel carriages on a sharp double or reverse curve. The dotted lines indicate the actual position of the axles and traction rods of existing carriages, all at tangents with the rails. The black lines show wheels, axles, and traction roads, all true to the rails, on the radial system. In the first case there is a constant grinding of the flanges with great noise, and vibration, and risk of getting off the rails. In the latter, there is neither noise nor vibration, the wheels being parallel to the rails, and the cones of the tyres free to play laterally on the irregurities of the rails, without disturbing the bodies, following the path of least friction. The curves are shown on one chain radius, in order to make the difficulty clearer. But at the same time it may be remarked that it is a very important thing in railway working to be enabled to run round sharp curves, to remove carriages from the main lines, saving much ground, and especially at terminal stations, and on suburban lines where land is especially costly. The being enabled to work four chain curves instead of six chains would in many cases economise the purchase of land and buildings to the extent of fifty per cent.

PLATE 2.

Shows a wagon frame on four wheels in plan and elevation, so constructed that in running, the wheels are always parallel to the rails whether on straight lines or curves, and consequently the axles are always at right angles to the rails on straight lines, and pointing truly to the centres of the curves. The Gauge of way is 4 feet 8½ inches, and the axles are 16 feet apart, the total length of the wagon being 24 feet, and the width 8 feet outside, the internal floor area being 176 feet super. To the headstocks and cross trees are bolted strong scroll or bracket irons (*aa*) which carry the frame pendent on the side springs from iron suspending rods (*bb*) with a ball-head and ball-nut working in sockets above and below, and free to move to a considerable angle from the vertical line in every direction, the nuts below serving to adjust the levels. As there are no horn-plates to the axle-boxes the springs may be made of any required width of plate, which is a great advantage, as strong and yet flexible springs may thus be attained. Therefore the springs are five to six inches in width according to the load. They are firmly fastened on the axle boxes by outside clips, the width of the springs passing over a projection of the axle-box at each side and nipping into an angle grove below, and the nuts are screwed down on plates above, lying across the spring on each side the spring-buckle. The springs are formed of plates all lying one on the other at an obtuse angle at the centre, and are thus held firmly together and in line without any hole or rivet through them. The spring buckle is partly sunk in the box and the spring plates rest on the edges of the box. The springs on either side of the wagon are formed into a frame by two flat bars of iron or steel (*cc*) with lips turning down to clip the springs while the ends of the spring plates turn up to clip the bars. Through the ends of the springs and bars, holes are formed, larger in diameter than the suspending rods which pass through them, in order to give free regular movement. The flat bars are formed into cupped sockets round the holes to take the semi-circular heads of the suspending rods, and a brass washer, also cupped, may be placed in the sockets to take and hold a lubricant. On these two flat transverse bars is bolted a longitudinal bar (*dd*) in a line with the carriage centre, pierced with the reinforced hole (*e*) about nine inches behind the axle towards the centre of the frame. The front end of the longitudinal bars turns upwards against the headstock. This forms a lower or turning frame. The upper frame has a transverse iron plate (*ff*) bolted between the diagonals by ends cranking upwards and in the centre of this plate is forged a pivot *g* projecting downwards to pass through the longitudinal bar of the lower frame. Against the headstock is bolted a deep curved plate (*h*) struck from centre of the pivot, and within this works the upturned end of the longitudinal bar (*i*). Thus the wheels and springs are firmly held at the centre and periphery, but with perfect freedom of motion to right or left to suit curves or irregularities of the rails. In an ordinary bogy carriage with a very short wheel base and the central point exactly between the four wheels, the tendency on a curve is for the outer wheels to recoil, and the axles to become abnormal to the curve. But by the excentric position of the centre pivot as shown in the diagram, a caster movement is obtained which causes the outer wheels to advance on the outer curves at the front end of the wagon and to recede at the hinder end, thus placing the wheels parallel to the rails, and the axles true to the curves, and each pair of wheels independently of the other pair to accommodate themselves to *S* curves and irregularities. The wheels will thus be free to follow the path of least friction without carrying the frame and load with them, and without damaging the permanent way. If each pair of wheels were obliged to make the same movement at the same time, counterparts of each other, the result would be a large amount of mischievous friction.

It is obvious that a long wagon passing along a sharp curve will have the centres of the headstocks nearest the outer rail, and if the traction hooks be fixed at the centre of the headstock and one wagon be longer than the other the result will be, cross strains tending to pull the vehicles off the line. With the traction rod free to move to right or left, it will always by the force of traction seek the centre line between the two rails. In the diagram this movement is provided for by a long slot in the headstock, and the traction rod, which is attached to a volute spring at the cross-bar, slides in a slot of the upturned end of the longitudinal bar (*i*) and thus guides the wheels to the right track without interfering with the action of the draw-springs. The free and perfect movement of the wheels and axles is thus provided for. As neither horn plates nor scroll irons are bolted to the sole bars, they are not weakened by bolt holes, and consequently they will be less disposed to hang down at the ends and will be stronger to sustain end thrust.

But wagons require to be arrested and stopped, pulled up as suddenly as possible under fear of collision, and self-acting on inclines in case of the breaking of a coupling. With radial wheels the brake blocks must of course follow the wheels and a block should if possible be applied to every wheel. There is a certain space within which a single wagon may be stopped by brake blocks according to the speed and load, and if the same power be applied to every wagon, a whole train may be stopped in the same space. There are various means of applying power to self-acting brakes but the most certain of all is the power of gravity, for it is always in operation.

The brakes shown in the wagon diagram are four blocks suspended from the hind cross bar connecting the springs together, and without connection with the wagon frame, for it will be seen, that, as the frame rises and falls on the springs, the radial framework rises and falls with it, neither coming in contact with the other. A cross bar (*kk*) connects the two opposite brake blocks together, and to the centre of this bar is applied a gravitation lever (*l*) which has lateral movement at its attachment to allow the radial movement of the wheels. The gravitation lever is held in position vertically by a tie rod (*m*) similarly to a crane jib with facility of adjustment by screwing up the tie rods as the brake blocks wear, and they will wear equally, as the pressure is at the centre between them. The normal condition of these brakes is to be constantly pressing on the wheels with a force proportioned to the length and weight of the lever. As the action of the lever resembles that of steel yard, the weight at the end is very small compared with that at the blocks, and either guard or driver can lift the levers by cords passing over pullies beneath or at the side of the wagons, to the engine or brake van. A single cord descending in bights between each pair of wagons, and wound on a barrel, will thus with a very small force lift the levers of the whole train, the bights of the cords compensating for the lengthening and shortening of the couplings. If the brakes be continous, traction *i. e.* every wheel be provided with a block, a very small pressure will be sufficient to command the train, and a small effort to lift the levers. And, in ascending an incline, if a coupling breaks a way the lifting cord will be severed, and the whole of the brake blocks will instantly press on the wheels before they can reverse their movement.

As friction and concussion are removed by the free movement of the wheels the wagons will be subject to less strain and may be made proportionately lighter, and the engine power required to move them will be lessened by one-third—or one-third more wagons will be moved by the same power while the destruction of tyres and rails from friction will be lessened in the same proportion. The vehicles will become rolling bodies instead of sledges.

The existence of this sledge movement may be thus demonstrated. A double-headed rail, long used in chairs, becomes notched to the extent of half an inch more or less at every chair. When the rail is reversed and the notches are upwards, the sensation of riding over it, is like a Corduroy rod in Canada. But in a week the corners of the notches are worn off. In a few weeks more the notches have become short undulating curves, and in a month or two the rail has become a perfect plane, ground down by the sliding of the wheels to the original depth of the notches. Mere rolling movement would not produce this effect.

In this wagon, buffers are not shown, as they may be of any kind, but the true form of buffer is to shape the wagon end into a curve (elastic or not) struck from the wagon centre, so that the thrust will be true in all cases to the centre line of the rails. This wagon will roll freely round curves of one chain radius, and with perfect steadiness on straight lines. The dotted lines indicate the angles of the axles and wheels on curves.

Plate 3.

Shews a Radial Passenger Carriage constructed similarly to the wagon before described, but with larger and easier springs, and with an external buffer spring arrangement of considerable simplicity. Curved plates of tempered steel are hinged to the external end of the headstock, the curve struck from the pivotted centre of the wheels. The inside ends of the springs are supported on buffers of india rubber against the headstocks, with a space between for the play of the traction rod. As the wheels are free to play laterally to seek the path of least friction, the carriages may be close-coupled together, without inducing flange friction, and the curved buffers will prevent the binding movement on curves, while the lessened space between the carriage ends will considerably diminish the total length of the train, and also the adverse action of high wind. Horn plates are indicated by dotted lines, applied to the diagonal timbers, so as to take the axle, and not the axle box; not for any practical utility, but as a mere contingent safe guard. The wheels attached to the springs by the axle boxes are far more secure and far less noisy than when applied in the usual mode, and as they never form a tangent with the rails, there is less strain upon them than there is on the axles of ordinary road carriages which are attached to a similar mode. The brake blocks are arranged to give free play for rise and fall, in the attachment to the spring cross bars, and there is no jar to the body or passengers.

The frame is 27 feet long by 8 feet wide and will take a body 9 feet wide. With four compartments this will accommodate luxuriously 32 passengers. With five compartments 50 seccond class, or 72 third class in six compartments.

The principle that should govern the fares is, the cubic space occupied. The lining and ornamentation have very little to do with the question. On the above calculation each first class passenger would occupy a floor area of 1053 square inches, second class 674, and third class 466; in an ordinary omnibus the passenger occupies 432 square inches of floor area, or less than half one first class.

American bogy carriages of great length are not economical. They carry one passenger per foot run as their contents, giving about 1270 square inches per passenger, but the space for a stove is included and a large central gangway. For economic arrangement the best plan is, compartments, and side doors, and especially for short traffic and frequent exits and entrances. With only one door at each end, the stoppages at stations would be much prolonged.

Plate 4.

This is a Twin Carriage, formed in two parts, shown for the 5 feet 6 inches gauge, with central headstocks bolted together for convenience of structure, shipment, and removing from the line in case of repairs. It is upon eight wheels, grouped together in fours to give a long and steady wheel base. The total length of the conjoined frames is 60 feet, and the centre can be stiffened if needed by diagonal tie rods trussing from the cross bars. The total width is 11 feet, the total internal floor area 760 feet super. The total wheel base of each groupe of wheels is 7 feet, and the frame is suspended from the springs by scroll irons and long swinging shackles as before described, and not from the sole bars, which thus retain their full strength. Each pair of wheels is connected by plates to the axle boxes, top and bottom, carrying a strong central timber beam between them. On this beam is bolted an iron quadrant frame which is pivotted to the upper frame about 12 inches behind the centre of the two axles. This curved quadrant is made to pass between a pair of horn plates which like the pivot are bolted to the diagonal timbers similarly to the wagon first decribed with the difference that there are four radial wheels at each end instead of two. And there is no guidance by the traction rod, the excentric pivot acting as a caster, so that the movement by the action of the wheel flanges against the rails is true, with the exception of the parallelism of the axles which in so short a wheel base is off little importance. The length between the spring shackles on each side is twelve feet, but to prevent the necessity for the extreme angling of the shackles on sharp curves the springs are pivotted on the axle boxes and the internal ends radiate beneath central clips, which confine them to the frame. The total wheel base is 40 feet, the inner wheels 28 feet, but notwithstanding, the carriage will roll round curves of two chains radius. Such a vehicle would serve equally well as a wagon for bulky goods, or for carrying a large number of passengers or troops, or as a baggage wagon.

The dotted lines show the extreme radiation of the axles on curves, the buffer springs shown at the ends are formed of curved plates and india rubber blocks. The traction springs are volutes, with a radial traction rod sliding laterally in the headstock.

This principle is peculiarly applicable for the large carriages which will soon be in request for journeys occupying days and weeks in the direction of the East, in which travellers will require to sleep and rest and find appliances for occupation. There is no reason why such vehicles should not be as convenient at least, as steam vessels on the ocean, and possibly be more free from vibration. We have scarcely yet entered into the possibilities of railways.

The long carriages of the Metropolitan Railway on eight wheels are provided with radial frames on the Writer's system, to the end wheels, which form a 30 feet wheel base, but as the centre wheels which form an 18 feet base, do not radiate, the result is not so favorable as would be the case with all the wheels radial, on the sharp curves. It would not be possible to work these carriages with a rigid wheel base, on the sharp curves, without considerable risk of getting off the rails. The radial frames and long loose swinging shackles give true guidance with free movement.

The plan in Plate 4 shows the internal mechanism on one half. The other half shews the internal arrangements of one twin body. There is a saloon 13 feet long by 11 feet wide with ample side seats for 14 persons, and middle seats for 14 more, and sliding central doors opening into adjoining compartments by a central passage. On each side the passage are two compartments each 4 feet 6 inches by 6 feet for four seats each. Beyond these on one side of the passage is a lavatory and closets 4 feet 6 inches by 6 feet 6 inches; on the other side a kitchen 4 feet 6 inches by 5 feet 6 inches. Beyond this an open lobby 5 feet by 11 feet for standing, sitting or smoking. All the outer and inner doors are made to slide, so that they may be kept continually open for ventilation in hot weather by day or night. Thus the twin carriage will be conveniently arranged for 64 passengers seated, and with standing room for several more, as well as for servants, and beds can be made up for 44 on the seats and floors of the saloon and compartments, leaving the lobbies and passages unoccupied. There are self-acting lever brakes, with blocks to four wheels which may be applied without labor from the interior, by the servants, at the stations, or in case of emergency to call the driver's attention. Fitted as a troop carriage, this vehicle would carry 168. Twenty carriages forming a gross train, including passengers, of 400 tons, would thus transport a small army of upwards of 3,000 men with the power of a single engine, on a line of tolerable level.

PLATE 5.

Illustrates a radial engine on eight wheels with a solid frame. The driving wheels, 7 feet between the axles, are 5 feet in diameter, and are placed between the cylinders and firebox so as to balance the weight upon them, and for this reason the cylinders which are outside are projected some distance in front of the wheels. The four trailing wheels, 4 feet in diameter, are six feet between the axles and they carry the load of the water and fuel—2,000 gallons—just as a separate tender would, and scarcely affect the weight on the driving wheel whether the tank be full or empty. The radiation of the hind wheels is produced in a very simple mode. The axle boxes are connected together by plates, which are again connected by a curved radial bar working between hornplates, similarly curved and fixed to the inner frame, which is angled to make room for the lateral play of the wheels. A single spring 12 inches wide and six feet in length carries the load of water and fuel. This spring is pivotted in the centre to the upper frame and slides in grooves with brass washers in the lower frame, as it moves on curves. The engine is set out to roll round curves of four chains radius, and will run with perfect steadiness at any practicable speed. The footplate is five feet long by eight feet wide, 40 feet area, which is an important consideration for a driver and stoker on a long journey. The total wheel base is 27 feet. The dotted lines indicate the angle of the radial wheels on curves.

PLATE 6.

Shews a Radial Tender Engine. An ordinary engine is carried on six wheels for the purpose of keeping it steady. With the ordinary tender attached to it, the hind wheel of the engine and the front wheel of the tender are very close together. The lateral friction and the vertical heaving on the springs make the standing on the footplate very rough and unsteady, and so the driver couples engine and tender as tightly as possible to steady them, making a very long frame, apt to get off the rails by flange friction.

The object of the present arrangement is to obtain a steady engine with radial movement to roll round curves of 1½ chain radius. The engine proper is balanced on four coupled drivers 6 feet 6 inches apart and 6 feet in diameter. There are no trailing wheels, but the hind end of the engine is formed into a curve. The tender is carried on four wheels 4 feet in diameter, the distance between being 8 feet base. The curve of the engine is struck from a radius of 6 feet 6 inches, equal to the distance from the central pivot to the centre of the tender. The curve is formed by two strong deep angle irons into a trough, with a central curved slot for a strong bolt to pass through. This trough is overlapped top and bottom between a pair of strong jaws of the tender. Through these jaws passes the bolt, and through a roller which lies in the trough, and bears against two steel plates lined behind with india-rubber. In passing round curves, the tail of the engine works between the jaws of the tender, to the angle shewn by the dotted lines, and the tender works to a similar but smaller angle corresponding to its length, the curved slot permitting the independent movement, the thrust and pull of the engine being always in a straight line between the centres of the two wheel bases. The tender is carried on two side springs on the hind wheels, and on a cross spring on the front wheels, so that the wheels always fit the rails, and the two frames adjust themselves together without any shake or jumping. The coupling of the two frames together in this mode makes the engine far steadier than it would be with trailing wheels under the footplate of the engine. The engine and tender thus become one machine with a lateral bend. It is not to be supposed that an engine can run round a radius of 99 feet at speed, but this engine will run at any speed on a straight line or large curve, and it is a considerable advantage to be able to run round sharp curves, under many circumstances, avoiding the use of turntables. And this engine will run equally well with either end foremost. The dotted lines show the angles taken by the two frames on sharp curves.

PLATE 7.

Is a diagram of a pair of Twin engines so coupled together as to work like a single engine either end foremost. The extreme wheel base is 36 feet. Each groupe of six wheels is disposed between the firebox and cylinders, each wheel base being 7 feet. Each engine is nearly balanced on its wheels, 3 feet 6 inches in diameter, and the fire box ends are formed in curves struck from the centres of the middle axles. Two strong plates are placed, one above and the other below the curved ends, secured together by end bolts and distance pieces, forming them into a frame. Two other bolts with rollers work in the troughs, formed by the curved ends, each engine being able to work independently of the other to suit irregular curves. A foot plate is placed above the connecting plates, covering the wheel space between the two engines, and tanks are carried on the sides of the frames. The pair of engines will weigh sixty tons, equal to a steam power of twelve tons, and with a moderate load of five tons per wheel. The pair of engines would thus be equal to a train load of 150 tons, exclusive of their own weight, up an incline of 1 in 20 and round curves of $1\frac{1}{2}$ chain radius, and worked by one driver and stoker. With the weight increased to 72 tons or six tons per wheel, the two engines would be equivalent to a train of 200 tons up 1 in 20 at ten miles per hour. It is therefore a very simple mountain engine. And if separated, the two engines can each have a radial tender applied, to work two separate trains. In working round a sharp curve the central connecting plates always retain the same position of a straight line between the middle axle centres, the thrust of the engines varying their relative position from the centres towards the sides. The dotted lines denote the position of two engines when in a curve of $1\frac{1}{2}$ chain radius. Of course the wheels may be made of larger diameter, if wanted for greater speeds. The regulator handles may be coupled to work together. There is an ample foot plate, 12 feet by 5 feet.

The wheels of this Twin Engine are of small diameter, in order to obtain greater power with diminished weight of material, but it must be borne in mind that the speed must be proportionately diminished, or the dead weight greatly reduced. Small wheels, heavily loaded, and run at high speeds, are very destructive both to tyres and rails, as well as to Permanent Way. Small wheels lightly loaded may run fast, and may start quickly into motion, but they will have proportionately small power of traction.

Plate 8.

Shows a small engine weighing about 12 tons, carried upon four driving wheels 4 feet in diameter and five feet apart. The weight is balanced on the wheels, and the curved end of the engine is attached to a radial carriage on four wheels 25 feet long and carrying 60 passengers. This arrangement is well adapted for branch lines, as the engine and carriage coupled will work lines of $2\frac{1}{2}$ chains radius, and the engine is equal to the haulage of one first class with 32 passengers, two second class with 50 passengers, and four third class with 250 passengers, total 372. The total weight of this engine, train, and load of passengers, is about 60 tons gross, and it will work a gradient of one in seventy, at 25 miles per hour. The carriages can be of very light construction, and are all radial, so that the impedimental resistance is reduced to the minimum.

This class of engine and carriages will also suit very well to run on rails laid on common roads, where communication from railways to towns or villages is needed at a cheap rate of outlay. On a smaller scale the engines and carriages may be constructed to run round curves of 60 feet radius.

For the purpose of Engines requiring small haulage power, as for Omnibuses, it will probably soon become a practicable thing to use heated air engines in which there is no water required, no possibility of explosion, and no skilled management needed. Omnibuses thus propelled, with a load of fifty passengers, will be able to surmount ascents of one in 20, at a speed of seven to ten miles per hour.

There is a class of railways which has been growing up and increasing in the last few years, which are called Suburban Railways. These are practically the most valuable of all railways, as more passengers per mile travel over them, than over any long railways. In the olden time it was the short stage coaches round London that earned the most money and enabled the owners to make fortunes, which the long stages commonly lost. The suburban lines have an advantage beyond this. The old roads were always subject to competition as are the present omnibus lines, by any one who can scrape together a few hundred pounds. But the suburban line gradually becomes a street, and nothing can cause its traffic to leave it in the way of competition, save the grasping at too heavy fares. No one leaves the Strand to go to the Bank by way of Holborn or *vice versâ*. But if the Strand people were to double their fares, and the Holborn people did not, very soon the traffic would change its route.

The suburban railway traffic is really omnibus traffic, and the things essential to its prosperity are, frequent stations and quick travelling between them without loss of time. To accomplish this, quick stopping and quick starting are absolutely necessary. To do this the minimum of train resistance to traction must be attained by the various means before described and also some means of absorbing rapidly the momentum generated by the rapid motion of the train. One means would be, forming all the stations into summit levels, corresponding in length to the maximum train desired, with a descent on either side, of one in fifty. Thus by skilful management the driver could absorb the momentum in ascending the incline, and land the train on the summit level. And by drawing up the engine on the edge of the descent, the descending weight would instantly be at work to put the train into motion. Otherwise, supposing the whole line a level, large cylinders would be needed if the train were heavy and they involve much dead weight. On a level line the only means of stoppage are the reversal of the engine and the application of brakes to absorb the momentum. The brakes to the engine should be applied by small steam cylinders elevating a curved wedge between the wheels on either side. This would relieve the driver and stoker from the hard and annoying work that takes off their attention from their other business of looking out and attending to the fire, and which thus involves the risk of accidents. It is very probable that the fire will ultimately become a matter of greater simplicity—an arrangement of a large lamp burning liquid fuel, and not requiring a stoker to raise or lower the flame, taking the place of the fuel that needs stoking. When putting the brakes on the engine, and raising and lowering the fire, shall be as simple a matter as turning on or off the steam, the element of safety will be largely increased. But the brakes of the train have yet to be considered.

PLATE 9.

Shews the diagrams of a tender and two carriages in elevation. The axle-boxes of each carriage are connected together by timber bars, bolted beneath by the bolts which secure the bearing-springs on the top of the boxes. If the wheels are radial, these bars may be hinged at the centres by sliding hinges so applied that they will bend horizontally without interfering with the wheel action. To these bars the brake-blocks are hinged, one to each wheel. Cross bars are attached to each pair of blocks, connecting them together at top and bottom. From the centre of the bottom bar a lever is fixed, supported by a curved tie-rod from the top bar, and passing a little beyond the carriage end. This lever and tie bar act like a steel-yard, and, pressing downwards by gravity, bring the blocks into contact with the wheels, with a force proportioned to the weight at the lever end, and its multiplication through the length of the lever, and without any jar, the tie bar curvature acting as a spring muscle. Thus the normal condition of the brake blocks is to be always pressing on the wheels until lifted off. To lift them off, a cord or rod attached to the lever end may be hitched to a hook on the carriage end, and every separate lever in the same mode. And thus the carriage will be free to be moved about when out of use. Or the brakes may be let down to prevent the moving, when off the line, or on a siding.

Every carriage has two levers, and when made up into a train, a continuous cord of sufficient strength passes over the whole train from the engine to the end passing over rollers in a bight between each pair of carriages. In each bight is placed a pulley block with a pendant hook, so arranged that the cord can enter the pulley from the side by a spring catch. To the hook, which has two horns or bars, the links of the gravitation levers are applied, and by the driver winding up or hauling in the cord from the engine, or the guard from the train end, the whole of the levers are lifted and the train is free. It is obvious that the lifting may be performed by a winch at either end, but it is better that the driver or stoker should have it under control than the guard, as the former knows the exact time of application and removal better than the latter, and, if desirable, the cord may be wound up by engine power, only turning a steam cock. On approaching a station the cord is set free by loosening the barrel on which it is wound, and all the gravitation levers drop down with the blocks pressing on the wheels, throughout the whole train, the rollers on the roofs involving scarcely any friction on the cords, being merely long cylinders with rubber attachments to prevent noise.

If the train be working a steep incline and a coupling breaks, it frequently happens that the separated portion obtains back movement and "runs amain" before the guard can arrest it. But with these continuous brakes the moment a coupling breaks, the lifting cord breaks also, and all the blocks instantaneously drop on to the wheels before reverse action can take place, and thus arrest the movement. They are, therefore, essentially *safety* brakes.

It will be seen that the connection of the lifting cord in no way interferes with the buffer action, or the increase or diminution of the length of the train, as the links of the brakes and the bights of the lifting cords can increase or diminish their angles to compensate, and even wagons with loose couplings may be united in the same mode by running side cords, with cross levers, or skewed gravitation levers.

Nor is it absolutely necessary that the whole brakes of the train should be in use at once. Any number of levers may be hitched up, and the lifting cord pass over or by them in a straight line, omitting the bight and pulley.

But for working suburban trains it is important that every wheel should have a separate block, for thus a whole train may be arrested in the same time and space as each separate carriage can be arrested.

When any short wagons are used on lines without sharp curves, the axle box bars bolted below, and which should be slightly elastic, are an important steadiment to the wheels and boxes, and prevent such severe strain on the axle boxes and horn plates as otherwise occurs.

The pressure on the brake blocks must of course depend on the weight of the levers, but a far less proportional weight will be needed, with all the train wheels taking an equal bearing, than when one or two carriages only are provided with brakes. And the guard's separate brake van may be wholly dispensed with, as a piece of useless lumber, unless for luggage on long journeys.

Supposing a carriage to weigh 8 tons with a load of 60 third-class passengers on an incline of 1 in 40, the gravitation to provide for would be 448 lb. With the levers multiplying 14 times the weight required at the levers end would be 32 lb., or 16 lb. each lever. The pulley block with the doubled cord would reduce this to 16 lb. or eight pounds each lever, the force pressing on each wheel being 112 lb. The brake block moving through 1 inch space to clip the wheel would require the lever end to descend 4 inches, involving a movement of the lifting cord of eight inches between each pair of carriages. The difference of diameter between the winch barrel and handle would reduce the total weight lifted by the driver or guard to 8 lb. each carriage.

A 16 inches cylinder engine with 4 feet 6 inches drivers four coupled would easily work a train of 100 tons up and down gradients of 1 in 40. This would be equal to 12 carriages with 720 third-class passengers. The brake pressure required on the wheels would be 5600 lb. and the lifting power to take off the brakes 400, and allowing 25 per cent. for possible friction of the cord, 500 lb. The length of lifting cord to be wound up would be eight feet only. For a ten mile line the double journey might be made in an hour, and with five minute trains upwards of 200,000 passengers might be conveyed in a day of 12 hours over the whole length—if they could be got. And, rightly constructed, not unnecessarily to get out of the repair, a comparatively small number of engines and trains would suffice for the work.

The question of the Brakes is so important and has been so little heeded that it will be well to state it as clearly as possible.

A given pressure on the periphery of the wheels of a single vehicle will arrest it at any speed in the shortest space of time required, safely to absorb the momentum.

If this power be multiplied in proportion to the numbers of the vehicles any number will be arrested in the same space and time.

Uniform pressure destributed over every wheel in the train, will be far more effective than partial pressure destributed with greater force over a small number of wheels, because the whole weight of the train can be made effective instead of a portion, and with far less destructive wear.

The ordinary method of applying brakes is by brake vans, three guards and their vans being employed to a train of fifteen carriages.

The physical power of each guard is applied through machinery, which involves loss of time, to force the brakes of his van into strong contact with the wheels. If the force be sufficient, he can stop the revolution of the wheels, and in such case they will slide along the rails and grind flat places on the tyres, rendering them mischievous and unsafe.

And on the whole, the result in arresting the train is less beneficial, than when the friction between the wheels and blocks does not wholly arrest the movement of the wheels.

As the ultimate resistance or fulcrum to the force applied by the brake blocks is the axle bearing, it follows that violent pressure may heat and damage the bearings, and on this account also the distribution of the force of pressure over a large number of wheels is another element of safety.

The brakesmen use their brakes under signal from the driver, but a certain space of time must be occupied and a considerable exertion of muscular strength take place between the signal and its effect during which time the train continues to run on. This may not signify in the case of ordinary stoppages at stations, to which drivers and brakesmen are accustomed, but it involves considerable risk in sudden emergencies of impending collision, and also in case of the severance of a train on a steep incline by a coupling breaking. In each case such train acquires a reverse movement and great rapidity down hill, and it is frequently too late for any available application of the guard's brakes.

The remedy for these defects is to make the brakes self-acting, pressing instantaneously on the wheels when permitted by either guard or driver, and preferably by the latter, because it is he who first sees the impending danger, and would apply the retarding force if it were at hand, without involving the delay of giving a signal to three or four separate brakesmen.

On an incline, the breakage of a coupling and the separation of a train into two parts, would instantly liberate the whole of the brakes to press on the wheels.

On such a system a train might very well be worked by the driver and stoker without needing the help of the guard, who could thus be left free to his other duties.

With brakes attached to the axles and wheels, and not to the body, there can be no jarring to the passengers.

In the foregoing remarks the writer is merely working out in greater clearness and circumstantiality the principles he advocated in a work in the year 1849, called the "Iron Ways," on which the *Times* remarked, January 25th, 1850:—

"A pamphlet just published, entitled the "Iron Ways," will be read with satisfaction by proprietors of railway shares for its hopeful anticipations of what may be effected towards a restoration of profits by the adoption of light and frequent trains. It also contains a number ot suggestions on the general development of traffic, which in point of ingenuity and completeness, as well as in the faith which they exhibit in the extent to which the public would avail themselves of increased facilities, resemble the original Post Office plans of Mr. Rowland Hill."

The *Spectator*, February 9, 1850, thus writes:—

"So broad, and yet carried out into details, the view propounded in the "Iron Ways" forbids a complex reflex in our crowded space. The main elements are these. The use of heavy engines, carriages that are proportionately heavier, and trains still heavier, beget cost in the work of fuel and apparatus for locomotion, and also in the destructive crushing effect which it has on the permanent works of a railway, especially on the rails and bridges. The view is put forth by a practical man, its reasoning is clear, and the method of attaining the proposed end direct."

It is now four years since the Radial engines of the writer were introduced on some of the lines of the Metropolis, and a paper was read before the Institution of Civil Engineers on that subject. The paper and the discussion are in print, and therefore the writer violates no confidence in quoting from them.

Mr. C. M. Gregory, V.P. (now President of the Institution), "said he had listened with great interest to the papers, and not with the less interest because the inventions brought under their notice emanated from a gentleman whom he had known for twenty-five years as having devoted himself earnestly and honestly to railway improvements. He believed that Mr. Adams's labour had been of great value to the railway world, and the merit of one of his former inventions—the Fish Joint—was now universally admitted. He considered the Radial Axle, when properly applied to locomotive engines, to be a very valuable invention, which might be adopted without any fear, and this conclusion was formed not merely from an inspection of the drawings, but after carefully watching the working of an engine fitted with the radiating axle boxes. A long wheel base had been found of advantage; but that advantage had been hitherto diminished more or less by the retarding effect of friction. Length of wheel base, while giving increased steadiness when running at high speed on a straight line, involved so much friction on curves as practically to prevent the introduction of engines with long wheel bases on railways with very sharp curves, where the existence of steep gradients might make powerful engines especially necessary. He had attended the trials of the 'White Raven,' on the North London Railway, and he rode on the engine and watched the working of the axles with great care for some time. During a portion of that time they ran upon very sharp curves and at very high speed, very nearly, if not quite, 60 miles per hour. The motion round curves was extremely easy. There was none of that grinding which would have taken place with an ordinary engine having a wheel base 22ft. long, but not fitted with some compensating arrangement, still less was there anything like a blow."

Mr. Vignoles said, "that he was happy in being able to corroborate in almost every respect what had been stated in commendation of the improvement which constituted the subject of the paper, and the more so because he thought that the railway world was deeply indebted to Mr. Adams for a great number of valuable inventions of which the public had had the advantage, but which had not always resulted in equal benefits to the author. He was present at the trial just spoken of and could state his full conviction that the action of the machinery realized even more than could have been expected, and he was quite satisfied that there was no recent improvement in locomotives which was likely to be more beneficial than this one, particularly upon the modern system of adopting very sharp curves."

Mr. George Berkley said, "that the results of the experiments with the Radial engine had been fully stated and were very satisfactory."

Mr. T. E. Harrison said, "he looked with the highest respect upon anything that came from the author of the Radial engine, for in all matters of permanent way a great amount of valuable improvement was due to the constant attention which he for the last thirty-five years had given to the subject."

Mr. J. M. Heppel "was present at the experiments with the Radial engine, but the results had been already so well explained, that he had little to add. He would say, in all his experience he never rode on an engine which ran at such speed so steadily and so well. The leading axle not only placed itself normal to the curve, but at the same time brought the middle point truly over the centre line of the rails. He thought it might be reasonably anticipated that great evenness in passing round curves would result from such an arrangement, and he was happy to add testimony to the satisfactory manner in which this expectation had been verified by the experiments he had witnessed."

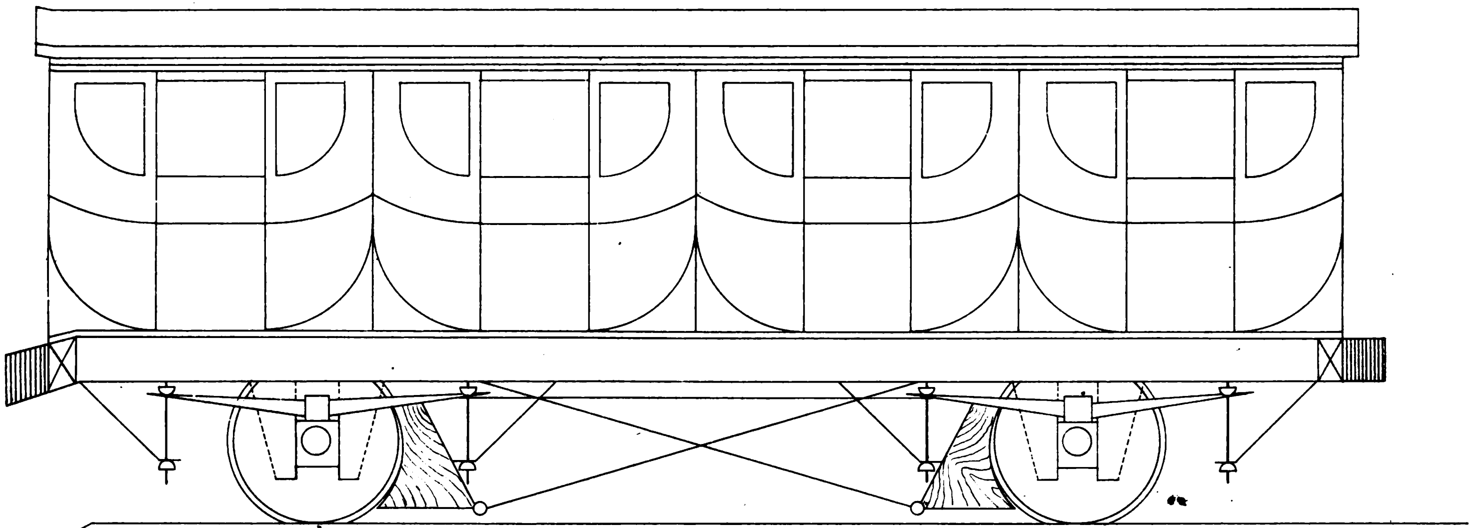
Mr. Hawkshaw, Past-President, "had recently an opportunity of inspecting the improvements of Mr. Adams and of riding upon the engine, described in the paper, from Bow to Camden Town. It was no doubt, important that something should be done to enable locomotive engines to pass round quick curves without those jerks and jumps which sometimes took place in the ordinary class of engines. This had been done to a considerable extent by what was called the bogie, but that plan took up a good deal of room and in some cases interfered with space, which could be better applied to other purposes. He thought Mr. Adams' engine possessed many elements of usefulness which, with a little more care and elaboration might prove advantageous, when locomotive power was applied to pass round quick curves, and as far as he could at present judge it did not seem liable to get out of order."

Mr. William Adams said "as Engineer of the North London Railway he might be permitted to give same particulars of the trial in question. As far as he could judge the down journey was made at the rate of 50 miles per hour and the return journey at rather more than 60 miles per hour. The engine had gone round a curve of 2 chains radius at Poplar without showing any tendency to mount the rails but that was at a slow speed. Curves of 20 chains radius had been gone through at the rate of about 35 miles per hour but it was contrary to custom to pass curves at high speed. He had been to St. Helens to test an engine of that kind on the line for which it was designed. He took a coal train about 7 miles, and on that day some part of the road was in bad order for want of packing; the oscillation of the coal trucks was remarkable. At a speed of 40 miles it was so excessive that the steam was shut off, but the engine was perfectly steady. He had been much surprised at the absence of slipping on the St. Helens' engine and he thought that the absence of slipping was to be accounted for by the spring tires. There was a considerable difference between the St. Helens' engine and any other."

Mr. Bidder, Past-President said "the time had arrived when the institution should address itself to the question of locomotive power and economy. He was glad the subject had been opened by the papers last read. He had not inspected the radial engine himself, but he had received a very favourable report of it."

The fact of thirty four of the Radial Engines of the writer having now worked upwards of two years on the Great Northern and London Chatham and Dover, over the sharp curves of the Metropolitan line, is ample confirmation of the judgment of the members of the Institution of Civil Engineers before quoted.

W. BRIDGES, ADAMS.



Pl. :