Title: Minimum Gauge Railways

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MINIMUM GAUGE RAILWAYS:

THEIR APPLICATION, CONSTRUCTION,
AND WORKING.

Being an account of the origin and evolution of the 15 in. gauge line at Duffield Bank, near Derby; also of the installation of a similar line at Eaton Hall, near Chester; together with various notes on the uses of such Railways, and on the results of some experimental investigations relating thereto.

BY

Sir ARTHUR PERCIVAL HEYWOOD, Bart., M.A.

THIRD EDITION.

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Preface to Second Edition.

In the year 1881, when the Royal Agricultural Society held their show in Derby, it was represented to me that, as many of the members were interested in the cheap transport offered by narrow gauge railways, it would be appreciated if I opened my experimental line at Duffield to inspection during the week.

In order to facilitate the comprehension of the objects of this little railway, the late Secretary of the Society suggested that I should draw up a short descriptive pamphlet to place in the hands of visitors. This was done with success and much saving of verbal explanation.

Thirteen years later, having added considerably to the rolling stock and improved many of the details, I decided to give a three days exhibition, and to issue a general invitation to all interested in the promotion of such lines, at the same time taking the opportunity to revise and amplify the first edition of this pamphlet.

A. P. H.

August, *1894*.

Preface to Third Edition.

Some four years have elapsed since the second edition of this pamphlet was exhausted. During this period I have constructed and equipped at Eaton Hall, Cheshire, a line which has been in regular use since May, 1896, exactly similar to my own at Duffield. This railway having been made wholly for practical purposes and on strictly economic principles, I am in a position to present more reliable data, both in regard to cost and working, than I could obtain from my own experimental line, which has been continually altered and only irregularly worked.

I desire to take this opportunity of expressing my thanks to the Duke of Westminster for the free hand accorded me in regard to the arrangement of all details of the Eaton Railway; a liberty which has resulted in a symmetrical and entirely successful carrying out of the work.

What I am now able to advance will, I trust, amply demonstrate the really solid advantages which, under suitable conditions, may be reaped from the installation of little railways of the kind described.

A. P. H.

July, *1898*.

I.
INTRODUCTION.

At the outset I must offer an apology for making use, throughout this pamphlet, of the first person. I do so partly for convenience of expression, and partly because almost all that I have to advance is derived from my own experience. In doing so I am far from desiring to undervalue the work of others in the same direction. I have, however, little hesitation in saying that, with the exception of the late Mr. Charles Spooner, the able Engineer of the Festiniog Railway, most of those, so far as I know, who are responsible for the design of plant for these small lines have been manufacturers whose productions, though often of fair workmanship, are clearly indicative of a failure to grasp many of the leading principles involved. This shortcoming is the natural result of a want of sufficient time for the consideration of details, and a consequent tendency to imitate established customs in regard to railway work which by no means apply with equal advantage to very narrow gauges, where the conditions involved are wholly different. This is especially true of small locomotive building, the specimens of which evidence in their design not only ignorance on important points, but also a deplorable absence of the sense of well-balanced proportion.

I venture to think that, in the twenty-five years during which I have devoted much of my time to the subject, I have succeeded in bringing to considerable perfection both permanent way and rolling stock suitable for these diminutive lines, and more especially the locomotives, which are probably, for their weight, the most powerful and flexible ever built to work by simple adhesion. Whether this conceit be well founded or no I leave to the judgment of those who may be at the pains to acquaint themselves with the details and result of my work, which has been undertaken wholly as a labour of love with the sole desire to promote improvement in what I believe to be an entirely special branch of engineering. I have never wasted my money on patents, and, so long as p. 8
my designs are not imitated in a bungling manner, I am glad to see them made use of by anyone to whom they may be of service.

It must be understood that I do not here attempt to enter upon the comparative merits of narrow gauge railways generally, but merely to give particulars of what has come within my own experience. To facilitate a comprehension of the conditions under which I have worked, it will be well to explain that I make no pretension to be considered a professional engineer, and that I speak rather as a self-taught mechanic and surveyor.

My father possessed a beautiful Holtzappfel lathe, with elaborate tools for ornamental turning in wood and metal. As a boy of seven or eight I can recall watching him as he worked. At ten years old I was promoted to stand on a box and turn candlesticks, but, a year or two later, a few lessons—the only direct practical instruction I ever had—from an old fishing-rod maker in chasing metal screw-threads begot in me an ardent desire to construct machinery, particularly anything pertaining to railways, for which from my childhood I had an absorbing craze.

By my father’s kindness I, by-and-bye, fitted up a workshop in which the tools were driven by a half-horse steam engine; and at eighteen had completed my first locomotive, weighing 56 lbs., which, with a dozen or so of small wagons, made a fine show on some 40 yards of brass-railed permanent way of 4 in. gauge. Locomotive driving was my hobby when I went up to Cambridge, and many were the tips that I learned in my illicit journeyings on the footplate. The new degree of “Applied Science” had just made its appearance, in which, in 1871, I had the doubtful credit of appearing alone in the first class. Doubtful, because the papers were absurdly simple, and the examiners hardly educated beyond the bare theories of the mechanical processes; for it was long anterior to the days of Professor Stuart and his engineering laboratory, where, by-the-bye, I once remember seeing the “demonstrator” supervising the reduction of a 4 in. shaft on a stout 9 or 10 in. lathe by a young turner whose nervous and thread-like shavings would have ensured his speedy dismissal from any commercial machine-shop.

When I settled at Duffield in 1872, I at once began to put into practice the views I had formed in regard to the possibility of advantageously superseding horse traction, in cases where a traffic, though heavy, was wholly insufficient to justify a more costly railway, by a line of the narrowest and consequently the cheapest gauge compatible with safety. It is to a setting forth of the results of my experiments during the years that have since elapsed, that the following pages are devoted. My claim to a hearing is chiefly based upon having always been my own draughtsman, p. 9
and, for my first two larger locomotives, also moulder, machinist, and fitter. Owing to the increasing number of experiments, and to other calls upon my time, assistance eventually became necessary, and, though I am still conceited enough to keep the more delicate manipulations in my own hands, so far as I can find time to execute them, it has gradually come about that I have seven or eight artisans in the little workshops. Practical acquaintance with every detail both in survey, design, and construction of narrow-gauge railways has given me something of a pull over the professional engineer. Thus it happens that, without the credit of any exceptional ability, I have had advantages that fall to few of acquiring information which I desire to lay before those who are interested in the rapid and economical transport of a moderate annual tonnage.

The first three sections of this pamphlet comprise a brief sketch of the purposes, origin, and construction of my own line. In Section IV. is given a detailed account of the construction, working, and cost of the similar line which I made to connect Eaton Hall with the Great Western Railway. Sections V., VI., VII., and VIII. are more technical, and may be passed over by those not interested in the mechanical details, although it is to the care that has been bestowed on these that my success is chiefly attributable. Section IX. deals, from such experience as I have acquired, with the conditions under which these small railways may be profitably installed. In Section X. I have appended a few further items of possible interest.

II.
OBJECTS OF THE 15 IN. GAUGE.

When, in 1874, I started on the construction of my experimental railway, the more notable narrow-gauge lines in our own country were those of 18 in. at Crewe, Woolwich, Chatham, and Aldershot—the latter a sad failure and the admirable 23½ in. from Portmadoc to the Festiniog Slate Quarries. The Festiniog Railway, which owed its success as a locomotive-worked line to the persistent energy and ability of the late Mr. Charles Spooner, opened the eyes of the transport- p. 10
interested world to the extraordinary capacity of a very narrow gauge. But here the marvel lies in the manner in which the work was adapted to the gauge, not in the suitability of the gauge to the work. No one but an enthusiast would dare to contend that a two-foot gauge was the ideal width for a line employing twenty-ton locomotives and hauling about 100,000 passengers and some 150,000 tons of minerals and goods per annum. If this development could have been foreseen, the selected gauge would doubtless have been wider. Such a traffic, however, is quite outside the scope of this pamphlet, the logic of which is directed to shewing how a much smaller annual tonnage than has been hitherto deemed worthy of a railway may be profitably thus conveyed.

An 18 in. line, such as one of those above referred to, would, if of not more than three or four miles in length and tolerably level, be capable of transporting, with one locomotive, 60,000 tons of minerals annually, reckoning the traffic as in one direction only. There are, however, up and down the country, a number of cases where a traffic of from 5,000 to 10,000 tons is annually hauled between two fixed points over the public highways by a single employer. Such cases may be classified as large mansions, public institutions, mines, quarries, &c. Now it is clear that, unless there is a prospect of large increase in the traffic, it would be absurd to employ for a maximum of 10,000 tons a railway equal to 60,000 tons, and so the question arises:—What is the smallest and therefore the cheapest railway capable of being practically and advantageously worked? This is the question to which I venture to think I can give a reliable answer.

In the year 1874, after various preliminary trials, I determined to construct a line of 15 in. gauge, as the smallest width possessing the necessary stability for practical use, although I once laid down one of 9 in. gauge for my younger brothers, which proved by no means deficient in carrying power.

The stability of this 9 in. line was perfect enough so long as persons did not attempt to ride on the ends and edges of the carriages and wagons, but man being an article of approximately standard size, it is clear there must be a minimum gauge which will be stable enough to be independent of such liberties.

Rolling stock properly proportioned to a 15 in. gauge seems the smallest that will thoroughly insure safety in this respect, and indeed in France the late M. Décauville, who did so much to develop lines of this class, arrived at nearly similar conclusions in adopting a minimum width of 16 in.

It must not, of course, be understood that gauges of such small proportions are to be advocated except where the traffic is unlikely to increase beyond their capacity, and where the material to be moved can conveniently be loaded in moderate sized wagons.

Feeling, however, convinced of the eventual recognition of the utility of lines of minimum gauge, p. 11
I took some pains to become acquainted with what had been already achieved in this direction, with the result that, excepting only the Festiniog railway, where every detail was most ably worked out by the late Mr. Spooner, I found generally both road and rolling-stock constructed as mere imitations of those of the standard gauge, and showing a want of apprehension of the totally different conditions to be satisfied. To endeavour to solve the various problems involved in the successful design of engines, carriages, wagons, and roadway for a minimum gauge is, therefore, the main object of my little railway. The chief ends in view are the application of such lines to agricultural or commercial purposes on large estates, or where quarries, brick yards, and other industrial establishments need better connection with the pier or railway station from which their productions are forwarded. An excellent example of such a line is now to be found in the one I have constructed at Eaton Hall, particulars of which are given in Section IV. There were also problems relating to adhesion and friction, particularly from the narrow-gauge point of view, which I was desirous of solving, some remarks on which will be found in Section VIII.

III.
CONSTRUCTION OF THE DUFFIELD BANK LINE.

The construction of my line of 15 in. gauge was commenced in 1874, and various additions were made up to 1881, when the length laid amounted to a little over a mile, inclusive of sidings. Since the latter date there has been no material extension, but the permanent way and its accessories have been gradually improved.

The line runs from the farm and workshops, up a gradient varying from 1 in 10 to 1 in 12 about a quarter-of-a-mile long, to a level 80 ft. above, where the experimental course is laid out in the shape of a figure 8, so as to admit of continuous runs. This part, somewhat more than half-a-mile in length, has a level stretch of a quarter-of-a-mile, the remainder consisting of gradients, of which 1 in 20 is the most severe. The minimum curve on the main line is 25 ft. radius, but in the sidings some occur as sharp as 15 ft. radius.

The permanent way was at first laid with 14 lb. rails, without fish-plates, spiked to elm and p. 12
Spanish chestnut sleepers fallen and sawn on the premises, 5 in. wide, 2 in. thick, and 2 ft. 6 in. long, set at 1 ft. 6 in. centres. The maximum load did not exceed 12 cwt. per axle, but, although the work was well done, the road was not equal to the weight, and required incessant attention. The line was then re-laid on sleepers 6½ in. wide, 4 in. thick, and 3 ft. long, with various sections of rails, 12 lbs., 14 lbs., 18 lbs., and 22 lbs. per yard. These were all fitted with fish-plates, the joints being on a sleeper. The spacing of the sleepers was varied with the rails, from 1 ft. 6 in. for the 12 lb. to 3 ft. for the 22 lb. section. Any part of this road carries comfortably 25 cwt. per axle. The fish-plates and larger area of sleeper more than doubled the original carrying power of the rails.

Six years being about the life of these small sleepers, it soon became necessary to renew them. Seeing that the rails, owing to the light traffic, remained perfectly good, to have to pull the road to pieces for the sake of new sleepers only was a serious annoyance. I then determined to try a light cast-iron sleeper with the same bearing area. After some years of experiment, a thoroughly satisfactory one was perfected, in which the rail is held to its place by a curved steel spring key that cannot work out. The greater part of the line is now laid on these cast-iron sleepers, which weigh 28 lbs. each, inclusive of the chairs, which are cast on. This pattern has now had some eighteen years’ test, and has proved entirely satisfactory. With a 14 lb. steel rail, the sleepers being spaced 2 ft. 3 in., and at the suspended fish-joint 1 ft. 3 in., the road, under the load of 25 cwt. per axle, requires very little repair, some parts having stood for five or six years without being touched, though constantly run over.

The length of the sleeper is a very material point. It should project beyond the rail a distance of rather more than half the gauge of the line thus the rail is equally supported inside and out. When the projection is reduced, the centre of the sleepers cannot be packed up solid, because the support would then be greatest between the rails, with the result that the ballast below would assume a convex form lengthwise of the sleepers, and thus produce an unstable road. On lines of the standard gauge, if sleepers of this proportion were adopted, and of sufficient thickness to distribute the load more widely without bending, a great saving in repairs would be effected; but it is not likely that any permanent way official will be bold enough to suggest such a radical change. On the Festiniog Railway of 23½ in. gauge, a sleeper 4 ft. 6 in. long has been adopted with excellent results.

A detail of importance in laying rails is that the joints should be opposite one another. For this purpose it is necessary to order a proportion of the rails 3 in. to 6 in. shorter than the rest, according to the gauge and radius of curves. In this way the joints can be kept practically square. A cross-jointed road is not only unpleasant to travel on, but is also exceedingly difficult to set up p. 13
true, particularly on sharp curves.

Steel rails are now almost universally employed, but it is worth attention that on any part of a line that is either very damp or rarely used, iron rails will long outlast steel ones, as every mining engineer knows.

In regard to the most suitable length of rail, I have found 15 ft. very convenient for weights up to 18 lbs. per yard. A good deal depends upon whether the rails come from the makers properly straightened. The longer the rail, the more difficult it is to straighten; as a rule even the most careful specification will fail to bring them on the ground in a fit condition for use. It is a very usual thing to look at rails only in regard to their horizontal truth, but in reality the vertical correction is of far more importance, and, to detect this, the rail must be turned on its side. I cannot too strongly insist on the vital importance of laying only straight and level rails. A good running road can never be made if any humpy rails are laid, and it is quite impossible to subsequently rectify the defect without taking up such rails and treating them under the press. Rail-straighteners should be directed to level a rail before straightening it, that is, to correct it vertically first, then horizontally; the reason being that vertical pressing disturbs the horizontal truth, while the horizontal pressing does not affect the vertical accuracy.

I have employed a rail-press fitted up on a wagon, specially arranged with drilling machine for fish bolt holes, with tool boxes, and a brake. The screw works horizontally, and the rail runs on adjustable rollers at each end of the wagon. The amount of curve is thus readily appreciated by the eye as the process proceeds, while with a vertical screw it is scarcely possible to judge correctly. For sharp curves I use a roller bender of a type I designed many years ago for the use of the Royal Engineers in their field railway experiments. In this machine, which consists of the usual three rollers with the centre one adjustable by a screw, two men wind the rail through, and, except at the extreme ends, effect a perfect curve. This machine, however, is of little use for the ordinary straightening, and, though saving some time on a long curve, is laborious to work. A curve made under the ordinary screw-press is of course really a succession of what are technically termed “dog-legs,” but, unless it be of smaller radius than one chain, these are imperceptible if the successive pressures are not applied more than about 14 ins. apart. By pressing at still smaller intervals it is possible to produce sharper curves of reasonable truth, but I find the rails on such curves work smoother and wear better if bent with the roller machine.

Rails can be laid round moderate curves without requiring to be bent, by screwing up the fish
plates tight and then springing the rail. The extent to which this can be effected depends on the p. 14
weight of the rail and on its length; the longer rail being the more accommodating. It is not advisable to attempt to spring a 14 lb. rail round a sharper curve than five chains, or an 18 lb. rail beyond ten chains radius.

The result of attempting too much springing is that the rails, under the traffic and changes of temperature, work outwards at the joints and make "dog legs" more or less serious. Where the ballast is of a loose dry nature very little, if anything, can be done with springing. I have enlarged upon this subject of rail-laying because it is of prime importance to a good road, and a matter that, on narrow-gauge lines, does not receive the attention it requires.

To return to a description of my line, there are on it three tunnels, two bridges, and a viaduct 91 feet long and 20 feet high. The latter was erected in 1878, as an improvement upon one at Aldershot, put up by a gentleman who induced the War Office to sanction a short experimental line for army transport upon a hopelessly inconvenient and ridiculous plan.

My structure is of pitch pine, and stood for 16 years without repair. It is a trestle bridge, the trestles being so designed that each member is a multiple of the height. The roadway is carried on four timbers; formerly, for a 8 ton engine, 11 in. deep and 8 in. wide; now, for one of 5 tons, 13 in. deep and 3½ in. wide. These are bolted together in pairs, one pair under each rail, the two being kept parallel by stretchers and through bolts at every 5 feet. In each pair the timbers break joint with one another on alternate trestles, the latter being 15 ft. apart, and each timber 30 ft. long. The advantages of this arrangement are two-fold, the timbers can be run forward from trestle to trestle as the work advances without scaffolding or lifting tackle, and, should one trestle sink out of line, the continuity of the upper work checks it, and obviates the dangerous "dog legs" to be almost invariably observed in this class of bridge. The original cost with the lighter timbers was £30, including every item of expenditure—equal to £1 per yard. The average height is 15 ft. The details are arranged to require but little skilled labour, the connections being made entirely by bolts and cast angle-plates. Two carpenters, in five days framed the five trestles including cutting the timber to length; and in three more days, with the assistance of three labourers, the whole was erected and the rails laid ready for traffic. A platform and railing were, however, subsequently added for the convenience of foot passengers, thus materially increasing the cost. When rebuilt in 1894 with stronger timbers, the original trestles were retained.

Where the line crosses field-fences a dyke is dug about 5 to 6 ft. square and 3 ft. deep, across which the rails are carried on two narrow girders, thus effectually preventing the passage of p. 15 cattle, and avoiding both the delay of gates and the expense of side fencing.

The line is properly equipped with interlocking signals and points on a very simple plan. These are for the most part worked from two signal-boxes in telephonic communication.

Particulars of the cost of such a line will be found in Sections IV. and IX. On my experimental course there are six stations, at three of which are sheds for the accommodation of the rolling stock. When the line is used on the occasion of a garden party, a regular service of passenger trains is run, and several times trains of eight long bogie cars, carrying 120 passengers, have been hauled up the gradient of 1 in 20, and up the still more trying one of 1 in 47 situate on a three-quarter-circle curve of 40 ft. radius.

In the year 1894 I exhibited the line to the engineering public during three days. On this occasion a variety of experiments in haulage and shunting were shewn, and for part of each day two trains were run concurrently.

IV.
DETAILS OF THE EATON HALL LINE.

During the exhibition of my railway at Duffield in 1894, one of the visitors was the Hon. Cecil Parker, agent to the Duke of Westminster, who was desirous of laying some sort of light railway from Eaton Hall to the Great Western Railway, three miles distant. It was necessary that the line should be unobtrusive in appearance, of a thoroughly permanent character, yet moderate in cost. The traffic was, as it proved, correctly estimated at from 5,000 to 6,000 tons annually. Here was a perfect opportunity for a practical experiment with the 15 in. gauge, which was ample for five times that amount. I was asked to inspect the route, and subsequently roughly estimated the cost, exclusive of buildings, at about £6,000. I had some doubt at first whether it was possible for me to find time to lay out and construct the whole line and rolling stock myself, but the difficulty of getting special designs effectively carried out by commercial firms at a reasonable cost decided me to undertake everything. It was at my desire eventually agreed that I should have a p. 16 free hand in regard to all the designs, doing the work at cost price and without charge for my own time.

The line will now be generally described, after which some of the more interesting details will be enlarged upon.

The Eaton estate railway connects the Hall with the Great Western Railway at Balderton, 3 miles distant. The total length of line laid is 4½ miles, which includes, besides the main line, a branch ¾ mile in length to the estate works near Pulford, together with several shorter branches to the estate brickyard and other points. The traffic to be dealt with, consisting chiefly of coal, road metal, and building material, was computed at about 6,000 tons per annum. As it was desired that the line should be as inconspicuous as possible, since it had to cross the park and the three principal drives, and the required capacity being small, it was decided to adopt the 15 in. gauge.

The line is laid with steel flat-bottomed rails, weighing 16½ lbs. per yard, and, to reduce repairs to a minimum, these are carried throughout on cast-iron sleepers, 3 ft. long, 6½ in. wide, weighing 28 lbs., and coated with anti-corrosive. Steel spring-keys secure the rails in jaws cast on the sleepers, which are spaced at 2 feet 3 inches centres, and, at the joints, at 1 ft. 4 in. Steel girders, on cast-iron foundation plates, are used for all the bridge-work. Thus no timber whatever is employed in the permanent way, and the depreciation is practically limited to wear of rails.

The rails for the points are rivetted on to flat-topped cast-iron sleepers, and were built up in my workshops, and forwarded ready for laying down. A set of points with seven sleepers carrying them, and with lever, counterweight, base plate, and the necessary rods, weighs about 4 cwts., and costs £7 15s. 0d. All the switches are planed out of the solid, and the crossings are of cast steel. Special cast-iron sleepers are employed on the girder bridges. These are of bar form, having below a cross-piece which is tightened up to the sleeper by two bolts, and which grips the inner flange of each girder. It is thus possible to set the rails to any moderate curve, on straight girders. For crossing roads a short and very strong sleeper, only 2 feet in length, is employed, with jaws fitted to take a second rail on each side to act as a guard-rail to the running one. These sleepers have a concrete foundation, and are packed to the required level with tarred macadam. The spaces are then filled in with the same material, and the road finished to a surface level with the top of the rails with a mixture of tar, pitch, and screenings. The flange space is of course left free; this is 1½ in. wide so as to avoid any chance of the shoes of draft horses jamming therein. The field crossings, to permit of carts crossing the line at convenient points in the various fields, are arranged with a similar double rail, but on a specially strong sleeper of the standard length, p. 17
packed with ordinary ballast.

The ballast is red furnace cinder, 5 to 6 in. in depth below the sleepers. The surface width is 4 ft., and through the park the top of the ballast is level with the turf, the drainage here being effected by a central 4 in. pipe. The appearance is thus that of a narrow garden walk. For the remainder of the route, which is entirely over grass land with a stiff clay subsoil, the ballast is above ground.

The railway is unfenced throughout, and passes from field to field on short open girders with a dyke excavated below, thus preventing the passage of cattle. Two high roads besides the three drives are crossed on the level, and several brooks by girder bridges, the longest span being 28 ft. The line is practically a surface one, there being few noticeable cuttings and embankments. The cost of the earthwork has been £205 per mile. The maximum gradient against the load is 1 in 70, the highest point of the line is 63 ft. above the lowest, and the Eaton terminus is 51 ft. above the junction with the Great Western Railway. The curves on the main line do not run below 300 ft. in radius, but curves of 60 ft. radius, and, at difficult points, of still less, occur at some of the termini and on the branches. At Eaton a large covered coal stove 80 ft. long and 33 ft. wide has been erected, so arranged that the little wagons run in at a high level and readily discharge their contents.

The rolling stock, which is all capable of traversing a minimum curve of 25 ft. radius, is fitted throughout with self-acting coupler-buffers, and all similar parts are interchangeable. It comprises the following:—

One four-coupled locomotive weighing 3 tons in working order, and carrying enough water and fuel for an hour’s running.

Thirty wagons 6 ft. long, 3 ft. wide, 1 ft. 3 in. deep, weighing each 7½ cwts., and holding 16 to 17 cwts. of coal, or 20 to 22 cwts. of bricks and road metal. The sides are of box form and removable, so that the floors can be used as flat wagons for the conveyance of large stones, castings, &c. Fittings are attachable to any wagon for carrying long timber. Also one bogie passenger car 20 ft. long and 3 ft. 6 in. wide, weighing 23 cwts. and seating 16 persons, and one parcel van, to carry 2 tons, of approximately similar construction.

Various other vehicles; among which are a brake van, 6 wagons capable of carrying 1½ tons each, and 2 for 2 tons each. Full particulars of the construction of the rolling-stock, now increased, will be found in Sections V. and VI.

The gross load which the engine, exclusive of its own weight, will haul in regular work is 40 tons on the level, and 20 tons up the ruling gradient of 1 in 70; the speed being about 10 miles per hour. In an experimental trip, however, a speed of 20 miles per hour was attained without undue p. 18
oscillation. This weight of train is by no means the limit which can be hauled on the line, for, on the Duffield Bank railway, the eight-wheel-coupled engine draws far more than this load, and on one occasion took eight bogie passenger cars carrying 124 persons up a gradient of 1 in 47 on which is a half-circle curve of only 40 ft. radius.

The entire cost of construction has been £1,095 per mile, exclusive of sheds. This figure would have been materially less but for the considerable expense attending the extra levelling and turfing required to avoid undue prominence. The cost of rolling stock has been £214 per mile, thus bringing the total outlay to £1,309 per mile.

The annual expenses were computed thus:—	£	s.	d.
Interest at 4 per cent, on gross expenditure	285	0	0
Renewal of permanent way, 4 per cent on £2,000 (25 years life)	80	0	0
Renewal of rolling stock, 8 per cent, on £900 (12½ years life)	72	0	0

Working expenses	£	s.	d.	
Driver	91	0	0	
Brakesman (boy)	26	0	0	
Two Platelayers	99	0	0	
Fuel and oil	39	0	0	
				255 0 0
			Total annual cost	642 0 0

The cost of loading being the same for railway wagons as for carts is not considered. With a minimum traffic of 5,000 tons per annum over an average distance of 2½ miles—equal to 12,500 ton-miles—the cost of transport is almost precisely 1s. per ton per mile; which is materially less than the cost of the cart haulage. The same rolling-stock and staff could readily deal with 40 tons per working day of eight hours—equal, at five days per week, to upwards of 10,000 tons a year. If the traffic were to reach this amount, the cost per ton of transport would be greatly reduced With a more powerful engine and additional rolling stock, such a line is capable of conveying an annual traffic of 40,000 tons.

There are probably many localities in which a diminutive railway like that at Eaton, ample in its capacity for estate requirements and extremely flexible in threading existing buildings, would well repay construction. The unobtrusiveness of so small a line and rolling stock, the relief to the roads, and the convenience of constant connection with the nearest railway, are points which are deserving of consideration where the conditions make such an installation possible.

The laying of the line was begun in August, 1895. The earthwork was already well advanced. On p. 19
account of the large amount of game in the neighbourhood of the line, it was considered wiser to employ no contractor, nor were any men obtainable with a knowledge of such diminutive platelaying. For the first fortnight I worked away myself with beater, rammer, and crowbar, till I had taught a proportion of my staff of 16 the use of these tools, and how to put the permanent way together. My assistant engineer, new to railway work, soon picked up the right ideas of what was required, and in a month, when I had to leave, everything was going nicely. A bonus was paid on every rail-length beyond a quarter-of-a-mile per week completed. This, compared with the fine work done by the Royal Engineers in the Soudan, appears a poor performance, but it must be remembered that we had to bring not only rails and sleepers from our base, but also all the ballast, and that we left our work thoroughly packed, the banks soiled and turfed, the road crossings laid in concrete and asphalte with double rails and special sleepers, the field-crossings for carts made good, the girder bridges and fence bridges (cattle stops) erected, and all points and crossings permanently finished off. About Christmas we reached Eaton Hall, and in the following May (1896) had pretty well finished all the branches.

Of course work done with such care and by the day was costly, and it would doubtless be possible to construct a similar line by contract at two-thirds of the price. But it is a question whether much would have been saved in the long run, for, except the usual platelayers' work, no repairs of any sort have been necessary since completion, nor has any part of the mechanism failed or given trouble; a result not usually attained in contract work.

It may interest those who have similar work to deal with if I explain that in making this line all our material had to be hauled from our base on the Great Western Railway at Balderton. The procedure was as follows:—At the rail-end four 15 ft. lengths of light timber framing 9 in. deep were laid on the bare formation. A train then backed up with eight wagons of ballast, and on top of them four lengths of rail ready keyed to sleepers. The rails were lifted off alongside where they were to be laid, the "tops" of the wagons were removed and the ballast shovelled off on each side. The train then drew away to refill. The length of framing next the rail-end was lifted forward to the end of furthest framing, and so consecutively with the other three, thus leaving between the rail end and the fresh laid framing a space of 60 ft. with the loose ballast lying thereon. Four men with shovels and four with rammers then put the ballast in shape and rammed it solid, and also true to a level given by the engineer. The rails and sleepers were next lifted into place, and the fish plates affixed. The sleepers next the joints were temporarily packed, by which time a p. 20
fresh train had arrived. The process was then repeated. In this manner, with a staff of ten men at the rail-end, a driver and boy with the train, six men loading ballast, three men straightening and bending rails, and three fixing them in sleepers, 60 ft. were laid in about forty minutes, including delays for field crossings and cattle-stop bridges. After a day or two of this work the men were set to packing and finishing what had been laid. With a larger staff the two processes might, but less conveniently, have proceeded at the same time.

The following is a detailed account of the cost of construction:—

	£	s.	d.
Earthwork to formation level	923	18	0
Drain pipes	33	2	1
Rails, sleepers (cast iron), and fastenings	1,814	15	1
Girders and fittings for four bridges and nineteen cattle-stops	143	5	9
Foreman, trainmen, and platelayers	563	5	8
Ballast (red furnace cinder)	337	10	4
Road metal, cement, and asphalte	39	1	7
Fencing at cattle-stops	42	10	2

	£	s.	d.
Sodding in park and finishing banks	224	5	5
Locomotive coal, oil, &c.	17	3	11
Laying water-supply, Balderton, Belgrave, and Eaton	90	8	6
Weigh bridge, Balderton	22	18	2
Tools, huts, carriage of goods, repairs, &c.	248	13	4
Resident engineer	427	5	3
Total cost of construction	4,928	3	3
The cost of rolling stock was as follows:—			
1 four-wheel locomotive, 4⅝ in. by 7 in. cylinders, 15 in. wheels	400	0	0
1 covered bogie parcel van	50	0	0
1 open bogie passenger car (16 seats)	40	0	0
1 covered brake van (4 seats)	25	0	0
28 wagons (load 1 ton) ... at £12	336	0	0
2 special wagons (load 2 tons) ... at £14 10s.	29	0	0
1 rail bending wagon with press and drill	32	0	0
1 platelayers' trolley and tool chest	9	2	0
8 sets timber carriers, and sundries	43	17	9
Total cost of rolling stock	964	19	8
Add construction	4,928	3	3
Total	5,893	2	11

The amount per mile to which the above works out has already been given. I am unable to give the cost of the coal store at Eaton, and of the engine and wagon sheds, although I designed them. They were executed by the estate, and being, for the most part, of the excellence and solidity of the neighbouring buildings, were doubtless somewhat expensive. p. 21

For all practical purposes simple wooden sheds would usually answer every requirement, and the extra amount spent at Eaton on levelling and sodding in the park much more than outweighed the omission of this item. As to the coal store this was altogether a special matter which does not affect the estimate of the cost per mile of this class of railway.

It will be of interest to give the actual amount of working expenses as compared with their estimated amount.

	1896.			1897.		
	£	s.	d.	£	s.	d.
Wages driver and boy	115	3	4	115	12	0
,, platelayers	145	8	8	94	15	8
Locomotive coal	19	15	0	19	17	7
Oil, stores, and sundries	8	1	10	9	7	1
	288	8	10	239	12	4

	1896.	1897.
Tons of material hauled	6,067	5,986
No. days in steam	225	207
Tons hauled per day in steam	27	29

The best Welsh smokeless coal is used, costing about £1 per ton.

From the above figures the following deductions may be drawn:—

The locomotive worked an average of 4 days per week, hauling an average of 28 tons each day, and burning 1¾ cwts. of coal at a cost of 1s. 9d.

Full particulars of the hauling powers of the locomotive are given at the end of this section, where it will be seen that 70 tons a day can readily be dealt with, and that, in an emergency, 100 tons would be quite within reasonable compass.

It is required, at Eaton, that the engine should meet the wants of several independent departments on the estate, and in different directions, added to which only a limited number of men are usually available for loading. In effect, instead of matters being arranged primarily with a view to the economy of the working of the railway, the railway is made an instrument for the economical working of the various departments supplied by it. There is doubtless much to be said p. 22 for the view that, as the driver's wages have to be paid, he may as well have his engine in steam as often as required. But, notwithstanding this easy mode of working the traffic, the cost of haulage is 3d. per ton per mile less than the average cost of carting, including interest on capital as well as working expenses.

I may say that the line is kept in the most admirable order, clean, well packed, and neatly ballasted, and that, under the astute direction of the Hon. Cecil Parker, the Duke's agent, the painstaking Superintendent of the line, Mr. Forster, records with the greatest accuracy the weight of every truck load of goods hauled, and the exact amount of all expenditure on the railway, thus giving a value to this somewhat novel experiment which it would not otherwise possess.

It should be mentioned that the amount expended on platelayers' wages during 1896 exceeded the probably normal sum spent in 1897, on account of the road not having become till the latter year properly consolidated. The cinder ballast, though admirably porous, has proved somewhat deficient in solidity, and the sleepers have required a good deal more packing than should have been necessary.

Since the completion of the line in May, 1896, some additions have been made to the rolling-stock, with a view of obviating the necessity for the immediate unloading of every wagon. There was a strongly expressed idea among the employes that tip wagons would be more serviceable than the box wagons with loose “tops” supplied by me. I have always felt that the greater dead-weight of the former class of wagons in proportion to the load carried, and also their increased cost, heavily discounted their only advantage: celerity in unloading. In order, however, to bring the question to a definite proof, I constructed six tip wagons entirely of steel and cast iron which are fully described in Section VI. In practice these were found to work as well as it is possible for a tip wagon to do, but, nevertheless, the unloading advantages were wholly incommensurate with the drawbacks of greater dead-weight and less capacity. There was the further disability that a wagon of this class could not be used, as can the others, for the conveyance of timber or other bulky goods. In the end I removed all but two, which were left as samples, and replaced them with wagons of the original type.

I conclude this account of the Eaton railway by giving particulars of the trial trips of the small four-wheeled locomotive and of its hauling powers, and also of a test day’s work on time line.

The trials of No. 4 locomotive at Eaton were carried out in Sept., 1896, and the particulars were as follows (all weights being accurately taken on the weighbridge):—

Weight of engine in working order, with two men on the footplate, 3 tons 5 cwt.; weight of brake-van, with two men and a boy, 14 cwt.; pressure of steam throughout trials, 155 to 165 lbs. per sq. in.; ruling gradient between Balderton (G.W.R.) and Eaton, 1 in 70 rise from Balderton to Eaton, 51 ft.; rise from lowest to highest point, 63 ft. p. 23

Trip 1.—Balderton to Eaton, distance 3 miles exactly. To show that engine could haul its guaranteed load of 15 tons gross, exclusive of own weight. Coal train of thirteen wagons and van:—

	Tons.	cwt.	qrs.
Coal	10	10	3
Thirteen wagons	4	18	1
Van	0	14	0
—			
Gross load	16	3	0
Engine	3	5	0
—			
Total weight of train	19	8	0

Time from start to stop, 17 mins.; speed. 10 miles per hour. In all cases trains have to stop dead on a rising gradient of 1 in 100 before crossing the high road one mile from Balderton.

Trip 2.—Eaton to Balderton. To test capacity of engine for fast running. The same train as above, empty. Time from start to stop, 12 mins.; speed, 15 miles per hour.

Trip 3.—Balderton to Eaton. To determine maximum speed at which average weight of train could be run. Gross load, exclusive of engine, 14 tons; time from start to stop, 15 mins.; speed, 12 miles per hour.

Trip 4.—Eaton to Balderton. To test power of engine to haul a long train round the curve of 60 ft. radius on a gradient of 1 in 60, with which the line starts from Eaton. Gross load, exclusive of engine, 14 tons, consisting of 33 vehicles. The gradient was surmounted without difficulty. No time taken.

Trip 5. Balderton to Eaton. To test maximum capacity of engine.

Coal train of 20 wagons and van:—	Tons.	cwt.	qrs.
Coal	14	6	2
Twenty wagons	7	13	0
Van	0	14	0
—			
Gross load	22	13	2
Engine	3	5	0
—			
Total weight of train	25	18	2

Time from start to stop, 21½ mins.; speed, 8½ miles per hour. The first mile, fairly level, was run at 6¼ miles per hour only. The long gradient up to Eaton was run at just under 10 miles per hour, the steam blowing off freely with injector full on and damper three-quarters closed nearly all the last mile-and-a-half. p. 24

Trip 6:—From 1¼ to 2¼ mile posts, chiefly up gradient of 1 in 80. To test maximum running speed with light trains. Load: bogie passenger-car and van only. The maximum speed was attained on passing the 1½ mile post, but fell off slightly after passing the 1¾ post. Time by stop watch, from 1½ to 2 mile post, 1½ mins. exactly. Average speed, 20 miles per hour.

It is to be noted, since the 15 in. gauge is almost precisely one-quarter that of the standard railway gauge, and since possible speed is in direct proportion to gauge, that 10, 15, and 20 miles on the one equal 40, 60, and 80 on the other. Thus the average speed of 10 to 12 miles per hour usually maintained, including the road-crossing stop, by the mineral trains on the Eaton line is considerably in excess of the proportionate speed of similar trains on the standard railways.

In August, 1897, arrangements were courteously made at my request by the Hon. Cecil Parker and by Mr. W. A. Forster, to enable me to test the weight of minerals that could be transported in a full day's work, over the three miles of line from Balderton to Eaton. Care was taken to obviate any delays in loading and unloading, but every truck had to be weighed separately on leaving Balderton, a process occupying about ten minutes with each train. Six trips were run during the day, and 69 tons of coal and road-metal were transported. There were four loaders at Balderton, and two unloaders at Eaton. The trains consisted of 12 wagons and van. The average gross weight, exclusive of engine, was about 17 tons, and the weight of minerals, or paying load, 12 tons. The speed was just under 10 miles per hour for the loaded trains, and 11.5 miles per hour for the empties. The engine left the shed at 8.15 a.m., and returned at 5.45 p.m., with a delay of 55 minutes for dinner. The weather was as bad as possible, slight showers all through the day making the rails so greasy as to necessitate the constant use of sand up the inclines. Time was also wasted in an extra journey for empty wagons, and in other unavoidable delays. About 1 hour 10 minutes was the average time taken over a trip out and back, reckoning to the time of next start. It is thus apparent that, with a little more arrangement, eight trips could have been run in the day. In the earlier trips, the gross loads hauled were only about sixteen tons, increasing later in the day to eighteen and nineteen tons. These larger loads might just as well have been also hauled on the earlier trips and it was apparent that, under less adverse conditions, 100 tons of paying load could have been transported in the day. Only 3 cwt. of coal was burned, including lighting up. The total distance run was 41 miles, and the average consumption of coal per mile, including that burned while standing, was 83 lbs. For Eaton Railway Regulations see Appendix C.

V.
LOCOMOTIVES.

The first locomotive put upon my line was completed in 1875. This engine was constructed, not so much as a model of what a small locomotive should be, as to provide the requisite motive power for the experiments I desired to carry out. No great care was, therefore, observed in the details, and in its construction a good deal of material which happened to be at hand was utilized to save time and expense; this much in excuse of the want of proportion in some of the dimensions, which will be found in detail under the head of No. 1 in the table of locomotive dimensions on page 31.

The boiler was of the launch type, a cylindrical shell with a cylindrical fire-box terminating in tubes. This pattern of boiler, though giving less heating surface for its size than one of ordinary locomotive design, has the great merit of having no fire-box projecting below the barrel, thus enabling the over-hang of the frame beyond the wheel-base to be equalised at each end, a matter of the first importance in small tank engines. Its low first cost and the ease with which it can be kept in order are additional advantages. So well was I satisfied with the working, that in the four boilers since designed for my locomotives I have adhered to the original plan, which was copied from some shunting engines made by Mr. Ramsbottom for the London and North Western Railway. I go so far as to think that, without getting rid of a depending fire-box, no really satisfactory tank engine can be constructed for a small gauge railway unless idle wheels are introduced, a proceeding that cannot too strongly be deprecated. The gradients, which are almost invariably the concomitants of these small lines, make it essential that the whole of the available weight should be utilized for adhesion.

The difficulty of carrying on four wheels a boiler of sufficient length for a more powerful engine, and the unsuitableness of an ordinary six-coupled engine to the sharp curves in which narrow-gauge lines generally abound, led me, in 1877, to work out a design by which the wheel-base of an engine of the latter type could be made to accommodate itself to any required degree of curvature. At this time I was in communication with officers engaged in promoting a scheme for an army field railway, where great power conjoined with perfect flexibility was essential. As the result, I constructed the engine of which the dimensions are given under No. 2 in the table, this being put to work in 1881. While avoiding the complication of the double-bogie system, this engine possesses most, if not all, of its advantages. It is six-coupled in the ordinary way, the axles having outside bearings and cranks. The wheels, of cast steel, are not fixed upon the axles, but each pair is keyed upon a cast iron sleeve, through which the axle passes. The sleeve upon the middle axle is capable of sliding 1 in. in each direction laterally, but cannot revolve upon its axle thus, when the engine reaches a curve, the arc of the rail draws the middle wheels on their sleeve to an amount equal to the versed sine of the arc, without interfering with the rigid position of the axle. The leading and trailing pairs are likewise mounted on sleeves, but here the connection of the sleeve with the axle is by means of a ball joint at the centre, so constructed as to leave the sleeve free to radiate in any direction, but obliging it to revolve with the axle. The middle sleeve is so connected by external hoops and links with the leading and trailing sleeves that, when the former makes a lateral diversion, the two latter are radiated precisely to the required curve, providing it is within the limit of the travel of the middle sleeve, which, in this case, is arranged for a radius of 25 ft. This engine excited considerable interest among visitors to my railway at the time of the Royal Agricultural Show in Derby in 1881, but the opinion was expressed that the arrangement would not stand hard work. A few years later, however, when some officers of the Royal Engineers were trying the engine with a view to adopting the plan on the military railway at Chatham, they subjected it to very severe tests, loading it up steep inclines to its utmost capacity; stopping it with the steam brake almost dead when travelling at various speeds and over the most awkward places; and, finally, giving it a fifty mile run with all the load that could be got together, at an average speed of seven and a half miles an hour, stops being made for water, &c., for twelve minutes in each hour. This was followed, shortly after, by a continuous run with a similar load for an hour and thirty-five minutes, the extreme limit to which the water in the tanks would hold out.

There was no heating of any part during the trials, nor failure of any kind. After eight years' work, chiefly on gradients of 1 in 10 to 1 in 12, where sand has to be used freely, the engine came into the shops to be overhauled. During this time there had been no mishap or breakage whatever, nor had a wheel ever left the rails, except on one occasion in descending the steep incline, when, owing to the slippery state of the rails, and sand failing, the engine slid away and left the road; less than an hour, however, sufficing to get it running again.

On removing and examining, shortly after this, the working parts of the radiating gear, they were found in perfect order, the tool marks being still visible in the ball joints; and in August, 1895, the engine, which was then sent over to do the ballast work on the Eaton Railway, where it worked p. 27
for thirteen months, showed still a clean bill of health. The engine is now rebuilding, and it is proof of the excellence of the radiating gear that this part is being put together again without re-adjustment of any kind. There is thus no doubt of the success of this radiating principle.

This engine is fitted, as already noticed, with a steam brake, which can also be applied by hand but the latter alone is far too slow in action for the abrupt stops necessary on a line like mine.

The space between the frames being occupied by the radiating arrangements, the valve gear is necessarily outside, and, to avoid overhung eccentrics, I designed a modification of one of Mr. Charles Brown's Swiss valve gears, which are also the parents of what is known in this country as Joy's gear. I venture to think that my plan, in which nothing projects below the connecting-rod, is better suited to small engines where the motion is almost always near the ground than any yet produced. The gear is extremely simple, and has worked without any trouble, the only setting required being the adjustment to length of the valve spindles, and the setting of one fixed centre on each side of the engine.

The springs consist of rubber pads placed between the axle-box and the horn-block. They are simple to fit, take up no room, never get out of order, and last many years. I have no steel-carrying spring on any of my stock.

The safety-valve spring is entirely within the boiler, so that it cannot be tampered with or injured by accident.

The connecting-rod brasses are peculiar. In order to avoid the twist to the slide bar when the driving axle, owing to inequalities in the road, fails to preserve its horizontal parallelism with the frame, the brasses are shaped circular, so as to turn slightly in their straps, the latter being bored out in the direction of their length instead of slotted. This plan not only relieves both crank-pin and slide-bar of torsion, but also forms a much more rigid union between the strap and the rod end.

The steam jet is worked by the regulator handle, the valve being so arranged that when the handle is moved beyond the point at which steam is shut off, the jet is opened. A spring stop prevents the jet being opened inadvertently. Thus when steam is put on, the jet is by the same action closed, steam is saved, and two motions are performed in one.

An important point in this, as in all the locomotives I have built, is that the over-hang at the two ends is equal, and the weight also on both leading and trailing axles practically the same, when the driver is on the foot plate. A further arrangement of value is that in all my engines the cranks are counter-balanced. It is impossible to effect the counter-balancing on the wheels, nor, even if feasible, will the result be so good, as counter-balance weights on the wheel are not at the same p. 28
distance from the axle centre as the disturbing weights, and therefore not equable in their effect at different speeds.

This engine was built for tractive power, not speed, and eighteen miles an hour is the highest rate registered over the short straight course available. The previous engine, with 15½ in. wheels, reached a speed equal to 23 miles an hour, the time being in both cases taken over a measured distance with a stop watch. About 11 miles an hour is the usual average speed with passenger cars, which, owing to the severe curves, it is not deemed wise to exceed.

The net cost of the engine under consideration was £309, exclusive of drawings and patterns. At the time it was built a joiner and occasionally a labourer were my only assistants; the work consequently proceeded but slowly, occupying altogether two years and a half. Reducing the time to hours, the whole of my own labour was almost precisely equal to that worked in one year by an artisan, and that of my assistants together to about half the amount. This includes the time occupied in moulding, for all the castings were made on the premises, with the exception of the steel wheels.

The boiler, frame-plates, and some of the brass fittings, were purchased, but the whole of the machine work and fitting was executed on the spot. The cost of all material, the hours of labour and engine power, interest on tools, &c., were all carefully booked, and it will probably not be far from a fair trade price for the engine if 10 per cent, for drawings and patterns, and 20 per cent, for profit, are added to the cost given above, thus bringing the amount to about £400.

The working of the radiating gear of engine No. 2 proving so satisfactory, I elaborated the principle so as to apply it to an eight-wheeled locomotive. (No. 3 in the table.) In this case both of the middle pairs of wheels have the traversing motion already described, but, instead of the leading and trailing wheels being radiated from one central pair, the second pair of wheels radiates the leading pair, and the third pair of wheels the trailing pair, thus forming a mechanism practically equal to a double bogie. By this arrangement an eight-coupled engine is obtained capable of passing round curves as severe as may be necessary. In the present instance, the travel is constructed for a minimum radius of 25 ft. The details of the engine are similar to those of No. 2, but numerous improvements have been effected, into all of which it would be tedious to enter. It may, however, be mentioned that the ends of all the crank pins are boxed in by the connecting and coupling rod brasses, to exclude dirt. A steam water-lifter has also been added, by which the tanks can be filled without delay during frost.

The blast-nozzle is made adjustable by raising or lowering an internal cone. Owing to the steep p. 29
gradient before alluded to, it was impossible to get a fixed size of nozzle that would keep up steam with a light load on the level, without being so contracted as to lift the fire off the bars on the incline.

The boiler fittings have been made as symmetrical as possible, and circular nuts have been substituted for hexagon, as more easy to clean. The water-gauge glasses are put in through the top cock and fastened by a single cap nut, thus doing away with the usual external glands. The steam brake has a 5 in. cylinder, and the rigging is arranged to swing with the traversing wheels.

The locomotive for the Eaton Railway (No. 4 in the table) was built as an example of a four-wheeled engine for use where the traffic was small and the gradient reasonable. With the exception of radial axles, it is fitted up precisely as No. 8. It has not, however, been altogether a success. From the data of its hauling powers, it will readily be seen that there is no deficiency in this respect; indeed, the maximum load handled exceeded all my expectations. In its working, for now nearly two years, nothing has gone amiss, nor has there been any trouble. On the contrary, the engine has on all these points given full satisfaction. But it is with regard to its effect on the road that I have my doubts. The running is steady enough, and 20 miles an hour has been attained without undue oscillation, yet nevertheless the road suffers as it never suffers under the six and eight-wheeled engines. The long and short of my experience is that I should not again recommend a four-wheeler except for very short distances and low speeds. Nothing but the experience I have had with this engine could have impressed so forcibly on me the very distinct advantages of such a radial action as I have adopted in my other locomotives, which enables them to go round a considerably sharper curve than the four-wheeler with an ease and absence of grinding quite remarkable, to say nothing of the saving to the road by the distribution of weight over more points. The relief seems to be by no means so much in the lessening of the weight per axle, which is not very great, as in the increased number of points of support. I am well aware this is not a new discovery, but it has come home to me with a practical force that leads me to insist somewhat strongly upon its importance.

The whole of the foregoing locomotives have been entirely made in my workshops, with the exception of the boilers and steel castings. The former have been chiefly supplied to me of excellent workmanship by Messrs. Abbott and Co., of Newark, and the latter by the Hadfield Steel Foundry Co., of Sheffield.

The last locomotive in the table (No. 5) is now being commenced, and will combine all the advantages of the previous ones in a less costly engine than No. 8 which was built specially with a view to see how powerful and fast travelling an engine could be put on the 15 in. gauge. No. 5,
with its smaller wheel, is not very inferior in hauling power to No. 8, and the expense of the extra p. 30
axle is saved. This is the engine that, if I had to build another for the Eaton Railway, I should certainly recommend in preference to the four-wheeled No. 4.

The wheels of such little locomotives, since speed is no object, should be kept as small as possible, and the stroke should be of the greatest length. The nearer the stroke can be extended to half the diameter of the wheel, the more successful will the engine prove on steep inclines. Good sand-boxes, front and back, of ample capacity are essential, but it is not advisable to fit any steam sanding apparatus, for, owing to the low position of the motion, a good deal of the sand will rebound into the joints and bearings, as I found by experiment.

Cabs on such small engines are to be avoided as unbearably hot in summer, dangerous in case of emergency, and inconvenient at all times on account of the contracted dimensions. A stout mackintosh is cheaper and far better for the driver.

A steam water-lifter is a convenience in frosty weather when the water supply above ground may be frozen up, but in summer the engine tanks get so hot from their proximity to the boiler that the water, which becomes lukewarm in the process of being raised by the lifter, is then very soon at a temperature which makes the action of the injectors precarious.

I may say that in all my locomotives I use Holden and Brooke’s restarting injector, which, after experiment with many types, I find takes the hottest water and is in all ways most reliable. I place brass wire strainers in both steam and water-supply pipes close to the injector, which is invaribly fixed below the tanks, so that when the injector is overheated the water will run through by gravity and cool it; a most important advantage.

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Number, Date of Completion, and Name of Engine.		No. 1. 1875. “Effie.”	No. 2. 1881. “Ella.”	No. 3. 1894. “Muriel.”	No. 4. 1896. “Katie.”	No. 5.
Diameter of cylinders		4 in.	4⅞ in.	6¼ in.	4⅝ in.	5½ in.
Length of stroke		6 in.	7 in.	8 in.	7 in.	8 in.
Diameter of wheels		1 ft 3½ in	1 ft 1½ in	1 ft. 6 in.	1 ft. 3 in.	1 ft. 4 in.
Length of wheel-base		2 ft. 6 in.	4 ft. 6 in.	6 ft.	3 ft.	5 ft.
Number of wheels (all coupled)		4	6	8	4	6
Length over framing		7 ft.	8 ft. 8 in.	10 ft. 9 in.	8 ft.	10 ft.
Overhang at each end		2 ft. 3 in.	2 ft. 1 in.	2 ft. 4½ in.	2 ft. 6 in.	2 ft. 6 in.
Width over framing		2 ft. 3 in.	3 ft. 10 in.	3 ft. 10 in.	3 ft. 10 in.	3 ft. 10 in.
Length of boiler		4 ft. 6 in.	6 ft. 6 in.	8 ft. 3 in.	5 ft. 8 in.	7 ft. 8 in.
Diameter of boiler		1 ft. 10 in.	2 ft. 1 in.	2 ft. 1 in.	2 ft. 1 in.	2 ft. 1 in.
Length of firebox (flue)		1 ft. 9 in.	2 ft. 3 in.	3 ft.	2 ft. 3 in.	3 ft.
Diameter of firebox		11 in.	1 ft. 3¼ in.	1 ft. 3¼ in.	1 ft. 3¼ in.	1 ft. 3¼ in.
Number of tubes (brass, 1⅜ in.)		23	57	57	57	57
Heating surface		23 sq. ft.	70 sq. ft.	91 sq. ft.	53 sq. ft.	80 sq. ft.
Grate area		1.25 sq. ft.	2.12 sq. ft.	3 sq. ft.	2.12 sq. ft.	3 sq. ft.
Capacity of tanks		18 gals.	50 gals.	84 gals.	49 gals.	77 gals.
Working steam pressure per sq. in		125 lb.	160 lb.	160 lb.	160 lb.	160 lb.
Weight in working order		1 ton 3 cwt.	3 tons 15 cwt.	5 tons	3 tons 5 cwt.	4 tons 5 cwt. (?)
Co-efficient of adhesion at 145 lb. mean pressure		3.6	4.7	4.5	4.9 lb	4.3 (?)
Tractive power per lb. pressure in cylinders		6.2 lb.	12.3 lb.	17.3 lb.	9.9 lb.	15.1 lb.
If diameter cylinder^2 = 1, ratio heating surface =		207	425	336	356	381
If diameter cylinder^2= 1, ratio grate area =		11.2	12.8	11.0	14.2	14.3
Load (exclusive of engine) on level.		15 tons.	35 tons.	49 tons.	28 tons.	44 tons.
(These are average working loads which can be considerably exceeded on the easier gradients.)	up 1 in 100	9 tons.	21 tons.	30 tons.	17 tons.	27 tons.
	up 1 in 50	6.4 tons.	14.6 tons.	21 tons.	11 tons.	18 tons.
	up 1 in 25	3.8 tons.	8.3 tons.	12 tons.	6.5 tons.	11 tons.
	up 1 in 12	1.8 tons.	3.4 tons.	4.9 tons.	2.5 tons.	4.4 tons.

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VI.

WAGONS AND CARS

The wagons first put upon my line measured only 4 ft. by 2 ft. inside. It soon became apparent, however, that a gauge of 15 in. could carry with safety a much larger vehicle. In fact it may be taken as a reasonable rule that the floor area of narrow gauge wagons should not be less than four times the gauge in length and twice the gauge in width. I have found such a wagon very handy for light work, but on the Eaton Railway I adopted an over measurement of 6 ft. by 3 ft. with 1 ft. 3 in. depth of side. The wheel base is, in all cases, half the length of the wagon. The larger wagon above described carries 16 cwts. of coal, and from 20 to 22 cwts. of sand, road metal, bricks, etc., and weighs about 7½ cwts., or one-fourth of its total gross loaded weight, *i.e.*, it carries three times its own weight. The axles in this case are 2 in. diameter. For heavier loads I have made the wagons with 2¼ in. axles to carry 30 cwts. which is the standard I have finally adopted; and also with 2½ in. axles to carry two tons. Two of these last were built for the Eaton line, on which logs of timber up to 30 in. square and 60 ft. long have to be conveyed from the G. W. Railway to the Estate works. Each end of the log rests on a “timber fork,” which can be fitted on to any wagon, and in this way, not only timber, but any kind of lengthy goods can be carried with the greatest ease. My resident engineer at Eaton gave me an amusing account of the arrival from Messrs. Handyside & Co. of the ironwork for the coal store at Eaton. This included a number of long and awkward shaped pieces, and the foreman sent by this firm to erect the shed was in despair at seeing the toy wagons provided for the transport of pieces that with some difficulty had been loaded in the main line wagons. To his surprise the 15 in. gauge handled them with far greater facility than the 4 ft. 8½ in., owing to length being no drawback.

My standard wagons are constructed of pitch pine with angle-iron rims, and the box sides are framed together independently of the wagon itself, thus a flat wagon is converted into a box wagon by merely placing this frame upon it. These sides, or “tops” as they have come to be called, are about 15 in. deep, and the wagons being constructed to a standard size, are interchangeable. An iron rim on each enables two or three of the tops to be placed one above another upon any wagon, to give an extra depth. To empty the wagon, two men readily lift off the
top, and, if necessary, turn it over sideways, sufficiently to shoot off the contents; or the load may p. 33
be upset without removing the top. This mode is almost as rapid as emptying a tip wagon, which, though convenient to unload, is a fraud as to capacity, and cannot be designed to carry more than one-and-a-half times its own weight; and even then there is the objection that the centre of gravity is far higher than in the box wagon.

For carrying timber or other lengthy loads swivelling carriers can be placed on any two wagons; and if a greater length is required, these two wagons can be set a distance apart, with or without other wagons placed between them. By adopting the flat wagon as a standard, it is possible to adapt each one to any class of work, without the necessity of keeping a large variety for various purposes. A narrow gauge is said not to lend itself advantageously to the carrying of bulky material, but by loading a train of wagons without break from end to end, I clear hay off land, to which it happens that carts cannot have access, with great despatch. There is, therefore, no valid objection on this score. The cost of these wagons is from 80s. to 85s. per cwt. In the two years the Eaton line has been at work they have proved convenient in every way and show no signs as yet of wear.

In addition to a number of wagons, some of which are fitted with brakes, there are on my line seven bogie passenger cars and a bogie van; also a variety of miscellaneous stock, such as workmen’s car, screw and roller rail-benders, dynamometer car, and various small trolleys. The dynamometer car is constructed to indicate the tractive effort of the engine, the speed, and the distance travelled. The roller rail bender is worked by three men, two of whom work the winch which draws the rail through the rollers, while the third adjusts the pressure to produce the required curvature. The screw bender has two thrust blocks, opposite which works a horizontal screw, which straightens or bends rails with great accuracy, but in long or sharp curves the roller bender is more rapid and efficient, as elsewhere noted.

The passenger stock, which, like everything else, was built on the premises, requires a somewhat more detailed notice. There are four open cars, holding sixteen persons each, two abreast. These are 19 ft. 6 in. long and 8 ft. 6 in. wide, and are carried on two bogies of 1 ft. 6 in. wheel base, the total wheel base being 16 ft. 6 in. A foot brake is fitted to one bogie on each car. The weight of these cars is 20 cwt.; they therefore only weigh 1¼ cwt. per passenger seat, and reckoning sixteen persons to the ton, the proportion of live to dead weight is as 1 to 1. On the main lines it is more than 1 to 5. The cost of these cars, stained, varnished, and lined with linoleum, was £37 each.

In order to demonstrate the capabilities of even so small a gauge, a closed car of the same
dimensions as those already described was constructed, which has doors and windows of the p. 34
usual kind. Lest it should be supposed that the space is unduly cramped, I may mention that a visitor 6 ft. 3½ in. in height, when seated, found ample clearance for his tall hat. The cost of this car was £67, and the weight is 24 cwt. Here the proportion of live to dead weight is as 5 to 6.

As a further test of the capacity of a 15 in. gauge, I have built a dining car and a sleeping car of the same dimensions as the cars already described. The former seats eight persons and carries a suitable cooking stove in a compartment to itself. The latter contains four berths 6 ft. 6 in. long and 1 ft. 10 in. wide, with a lavatory and other fittings. This, though hardly an essential accompaniment to a line under one mile in length, can be utilised as an overflow bedroom for my boys when the house is full of guests. I am unable to state the exact cost of these two vehicles, but exclusive of fittings, it is little, if at all in excess of that of the closed car already quoted. The weights are somewhat greater, owing to the bogie truck frames being of cast iron instead of elm.

A closed luggage van, 15 ft. in length, but otherwise of the same pattern as the cars, concludes the list, and is used to convey luncheons, teas, etc., for large parties, to the station where refreshments are served. The extreme height of the closed cars is 6 ft.

All the wagons and cars are carried on chilled iron wheels, 13½ in. diameter, cast in my foundry. The axles, as has been stated, vary from 2 in. to 2½ in. in diameter, and on to these the wheel on one side is forced by a hydraulic pressure of about 15 tons, while the opposite wheel runs loose to reduce the curve friction. The journals run in cast-iron boxes, which are lubricated by sponges placed in oil receptacles below. The horn-blocks and axle-boxes, with a rubber block between them to form the spring, and a cover to the oil reservoir, are secured together by a single bolt, after the insertion of which no part can come loose. The castings are put together as they come from the foundry, without machining or fitting of any kind, the axle bedding well into the cast-iron box after a few days' wear. For the Eaton railway, however, I bored out the boxes, but have not found any advantage to result. These bearings require oiling only at intervals of several weeks, and although some of them have been in use more than eighteen years, there has been no case of heating or other failure. The cost of each complete bearing, including horn-block box, cover, spring, and bolt, is only 5s., 1s. of which goes for the rubber.

The buffers and couplings are central. A single east-iron buffer, which in the case of the cars is mounted on a spring draw-bar, has a coupler of the same metal hinged to it by a bolt. The latter is self-coupling or not as desired; but, when turned back so as not to couple, the driver can, by bringing the buffers smartly together, cause it to fall and couple up. These couplers allow the p. 35
wagons and cars to be shunted out of the train, when the engine is either pushing or drawing, by a quick manipulation of the points, the hook sliding laterally from its hold as the vehicles diverge on different lines. I designed some cast-steel coupler-buffers of this type lately for the Royal Engineers' 30 in. gauge experimental field railway, near Chatham, which, though for reasons unconnected with their construction not adopted, are reported as the only ones of several types experimented with 'which fulfilled the necessary requirements. In the bogie stock the coupler-buffers are fitted to the bogie, and not to the car frame, on account of the severe curves. In the construction of the wagons and cars almost every part is made to gauge, and put together without fitting.

The aim throughout has been to make the details of all the rolling-stock as simple, cheap, and efficient as possible, which has been principally achieved by adopting designs and modes of construction largely at variance with commonly accepted notions. The totally different conditions under which minimum-gauge lines work, as compared with ordinary railways, renders this possible without any sacrifice of safety or durability.

In Section IV. mention was made of tip-wagons supplied as an experiment to the Eaton line. These consist of steel tubs, U shaped in section, hung at each end on two trunnions riding in cast-iron pedestals, the latter being bolted to an under-frame of channel steel fitted with cast iron ends rivetted in, and so formed as to carry a drawbar with rubber cushions, to the end of which the coupler-buffer is attached. These wagons cost £20 as against £12 for the standard box wagon. They weigh 11½ cwts., and carry about this weight of coal, or a little more. Loaded with coal, they average a trifle under 24 cwt., exactly the same as the box wagon, which weighs 7½ cwt., and carries 16 to 17 cwt. of coal. Thus the paying loads of the two are as 3 to 4 for the same hauled weight. For short distances, where the emptying bears a greater proportional relation to the running time, or where the load must be got rid of in a particularly short space of time, tip-wagons may answer. For such purposes as my experience has had to deal with, they are a drawback, which, as I have previously pointed out, is increased by their inadaptability to the carriage of bulky goods. One of my strong contentions is that, on a small line, to avoid expense in rolling stock, every vehicle should be available for every purpose.

VII. p. 36

THE DUFFIELD BANK WORKSHOPS.

A brief account of my little works will be of some interest to engineers. I have already, in Section I., given an outline of my progress as a mechanic.

I will now describe the machinery by which the locomotives, carriage and wagon stock, and permanent way fittings have been constructed.

The machine-shop contains an 11 in. lathe for wheel turning, cylinder boring, and the heavier work; an 8 in. lathe for surfacing, sliding, and general work; a 7 in. lathe for screw-cutting and fine work; a 4 in. Pittler universal lathe, with a variety of automatic and other fittings, chiefly used for the smaller brass work, such as cocks, glands, lubricators, &c.; a 3 in. sliding and screw-cutting lathe, for very light work; a planing machine to take work 4 ft. by 1 ft. 6 in. by 1 ft 6 in.; an 8 in. stroke double-table shaping machine, fitted for hollow and circular shaping, specially used for machining coupling rods, &c.; a 4½ in. shaping machine with circular motion, for light work; a milling machine; a 9 in. stroke slotting-machine with compound table, for heavy work; a 2½ in. spindle drilling and boring machine; a 1¾ in. drilling machine, for general work; a screwing and tapping machine, to 1½ in. for bolts and to 2 in. for pipes; a cold-sawing machine, to cut iron up to 2¼ in. square; a slot drilling machine; a twist-drill grinding machine; two grindstones, three bench vices, and complete sets of screwing tackle and fitters' tools.

The smith's shop contains two fires, of which one is blown by a fan, and is suited for the heavier work; anvils for ordinary purposes and also for the treatment of angle iron, &c.; a 2½ cwt. gas hammer; a punching and shearing machine; a bench vice, and complete set of smiths' tools.

The erecting shop contains an overhead travelling crane; an engine pit; a 30-ton hydraulic press for putting axles into wheels, crank pins into cranks, testing samples, &c.; a hand screwing and tapping machine to ¾ in. for bolts and to 1 in. for pipes; standards for fitting up frame-plates; a rivet heating forge; two bench vices, and tools for tube extracting and other special processes connected with the construction and repair of locomotives.

The iron-foundry contains a 16 in. cupola worked through a double tuyère by a “Root’s” blower; an overhead travelling crane; a core stove; charge-weighing scales; a large supply of boxes for general purposes, and special ones for cylinders, chilled-wheels, sleepers, gutters, &c., with all p. 37
ladles and other appliances suitable for producing castings up to half-a-ton weight. Especial pains have been taken to turn out chilled wheels (13½ in. diameter), for the rolling stock, of perfect smoothness and of even depth of chill.

The brass foundry contains a furnace, a metal moulding bench, and the usual fittings.

The carriage shop has two lines of 15 in. gauge formed of cast plates bolted together and bedded in concrete, and contains a wood-morticing and boring machine; fitters and joiners’ vices, with every convenience for erecting, finishing, and painting two of the long 20 ft. bogie cars simultaneously, or eight of the standard wagons, according to requirements; all bulky joiners’ and carpenters’ work is also done in this shop.

The pattern and joiners’ shop contains a 5 in. Holtzappfel lathe; and a small circular saw; 2 instantaneous-grip vices; saw tooth-setting machine; and a variety of other special appliances, in addition to a full set of joiners’ tools.

The saw-shed contains a 30 in. circular saw bench; a band saw; a small general joiner; an 11 in. planing machine, and a small emery grinder.

The engine house contains an 8 horse-power Otto gas-engine, of which the water circulation is effected by a small centrifugal pump.

The drawing office is fitted up with the usual appliances, and is in telephonic communication with my house and two of the stations on the railway.

The general stores comprise timber; foundry sand of various qualities; five kinds of pig iron; copper, spelter, tin, &c.; bar, rod, and angle iron; wrought-iron tubing up to 2 in.; bolts, rivets, nuts, and pins; steam fittings of all kinds; every sort of requisite needed in the construction of small railways and rolling stock, and also for meeting house and farm requirements.

The pattern store contains patterns for all the locomotive, carriage, wagon, signal, permanent way, and general experimental work; and for drain grates, gutters, &c. which are supplied from Duffield for my other estates.

The shops are lit by gas, and the 15 in. gauge line runs throughout. The construction, both in wood and iron, is done as far as possible to template, and every endeavour is made to turn out the very best work, which is perhaps the more easily attained in that there are no profits to be considered. At the same time it should be explained that the shops and machinery are, throughout, though good and sufficient for their purpose, in no way models of excellence. Their object is only to turn out the chiefly experimental work required, and the gradual additions that have been made during the twenty-five years of their existence have been done as cheaply as was consistent with efficiency.

Outside the shops are a weigh-bridge for weighing rolling-stock and loads, and a six-ton crane to p. 38
tranship heavy goods from drays to the 15 in. railway.

Adjoining the workshops is the locomotive shed, with rails raised 30 in. above the floor, so as to get more easily at the lower parts of these small engines. It is arranged for two locomotives, and is fitted with an air jet for raising steam, and with a water supply.

The carriage and wagon stock is, for the most part, housed in three sheds at various stations on the main part of the railway, 80 ft. above the workshops.

VIII.

SCIENTIFIC CONSIDERATIONS.

The present section contains the result of experiments and experience on points which, for the most part, are of interest only to those who study the scientific side of railway work. I here take the opportunity of placing on record various considerations, more or less connected with the subject of narrow-gauge railways, of too technical a nature to be mixed up with the descriptive pages. This explanation will account for the somewhat disjointed nature of the statements which follow.

The fact that narrow gauge locomotives are usually required to surmount much steeper gradients than are generally to be found on standard railways, makes adhesion a question of the first importance. It is very generally supposed that the co-efficient of adhesion between a wheel and a rail is a constant fraction of the insistent weight, varying slightly with the molecular structure of

the metals in contact. There is, however, reason to believe that it decreases considerably with an increase of weight. In locomotives of the standard gauge, with from 12 to 18 tons per driven axle, it is generally held that a co-efficient of adhesion of one-sixth is all that can be counted on with certainty. From a number of experiments on the Festiniog Railway, with the results of which the late Mr. Spooner, who himself supported the theory, was good enough to supply me, I found that the load there per driven axle was five tons, the co-efficient averaging about one-fifth. Again, with my small engines that have a load on each axle of from 1.2 to 1.6 tons, the calculated co-efficient is two-ninths, in support of which I give the following experiment, conducted in the presence of two gentlemen belonging to a firm of locomotive builders, when it was under p. 39
consideration to build for military purposes some engines on the plan of the No. 2 described in Section V.

I guaranteed that the locomotive referred to should take a load equal to its own weight up a gradient of 1 in 10 a quarter of a mile long, which then was, in parts, as steep as 1 in 9, with a short curve of half-a-chain radius at the severest part. This was satisfactorily accomplished. The day being dry, I was requested to ascertain what was the maximum load that could be hauled. On reaching four tons, when the start had to be made on a less gradient, the engine barely struggled up, and this was evidently all it could do. When full up with coal and water it weighed at that time 3 tons 6 cwt. During the experiment, however, there were but 3 tons 2 cwt. on the three axles, all of which were coupled. The boiler pressure was 145 lbs. exactly, and, the gross weight of engine and train being 7 tons 2 cwt., the gravity resistance on the gradient of 1 in 10 was equal to 14.2 cwt. The weight of 3 tons 2 cwt. available for adhesion, reduced by a tenth part, which the gradient converts into gravity resistance, was equal to 56 cwt. Thus, without reckoning the curve friction of the whole train and the journal friction of the wagons, both uncertain quantities, the proportion of developed tractive power to load was as 1 to 3.9. This result confirms the probability of the truth of the above assertion. Assuming its correctness, which appears beyond doubt, what is the explanation of increased proportionate adhesion with a decreased weight on the driven axles? The reduced diameter of wheel in the smaller engines might seem to offer a solution of the problem. Experience, however, goes to prove that, if there is any difference, a larger wheel has, with equal insistent weights, a better grip of the rail than a small one. I am of opinion that the weight is directly responsible for the difference. A wheel rests upon a rail on one point, or possibly on a transverse line of which the length is equal to the width of the rail. With a small insistent weight the molecules of the wheel and rail interlock without injury, and adhesion, on the principle of an infinitesimal rack and pinion, is the result. As the weight is increased on the fine bearing area, the molecules become disturbed, and fail to offer so firm a fulcrum. Ultimately they become displaced, and move as rollers between the two surfaces, materially reducing the adhesion. If this theory be the correct one, as is not improbable, the graduated reduction in the adhesion would be accounted for.

That the rolling wheel and rail do actually interlock was demonstrated by Sir Douglas Galton in his experiments on the retarding power of brakes, when he pointed out that, on a wheel becoming skidded, the rack and pinion motion was converted into a series of jumps of the wheel across the microscopic teeth of the rack, with a consequent reduction in adhesion proportionate p. 40
to the sliding speed. In confirmation of this statement I detailed, during the meeting of the British Association at Sheffield, an experiment I made by reversing a locomotive so as to skid the wheels, and ultimately to cause them to revolve in a contrary direction, while descending an incline. With skidded wheels the descent was at a certain speed with backward revolution of the wheels the speed increased rapidly, the effect of the reversal being to cause the wheel to slip over the rail at a speed greater than that at which the engine was moving, thus showing that Sir Douglas Galton’s theory of the adhesion diminishing in proportion to the extent of departure from the interlocking or rolling motion of the wheel on the rail remained consistent even beyond sliding contact, and disposing of the old theory that the loss of adhesion with a skidded wheel was due to the creation of a polished point of contact on the wheel.

Another somewhat curious point in connection with adhesion is the slip of the driving wheels, which is naturally in the direction of causing a greater number of revolutions of the wheels than would be due to the length of rail travelled over. Occasionally, however, I have, in experimenting, noticed that fewer revolutions are made than would suffice to travel the distance as measured on a centre line between the rails. That is, the wheels slipped forward instead of back. This freak is probably due to the outer wheel on a curve slipping forward when, owing to considerable superelevation and a low speed, the inner wheel is the more heavily weighted, the distance then travelled being the reduced length of the inner rail.

I now proceed to explain the basis of calculation of the net loads hauled on various gradients, as appended to particulars of each locomotive described in Section V. The resistance on the level consists of journal friction, tire friction, and locomotive internal friction. Tire friction is practically nil, except on curves and in strong side winds. Journal friction I find, in the case of my small rolling stock, to be covered by an allowance of 10 lbs. per ton. Owing to the numerous curves another 10 lbs. per ton must be added to cover tire friction. A tractive power of 20 lbs. per ton proves quite sufficient to keep the train in motion on the level. It is not, however, enough to start the train on a curve, nor to overcome the inertia due to journal friction when, as on an incline, there is no slack between the wagons, and the whole train must be started at once. After considerable experience I find it necessary to add a further 20 lbs. per ton to the required tractive power. A total of 40 lbs. per ton is thus allowed as a good working equivalent of the frictional resistance of the train.

The friction of the locomotive is a much more complicated question. There seems very little information available on this point. It has been said, in the case of full sized engines, to absorb thirty per cent. of the tractive power, but this is a vague estimate, out of all reason excessive, unless it be intended to include gravity resistance on a steep incline. It is desirable to consider the nature of the various causes of resistance to motion separately. Viewed as a carriage only, the journal and tire friction of the locomotive may be taken at the same amount per ton of its weight as in the case of the trains, namely, 40 lbs. The additional resistance due to friction of the moving parts of the mechanism cannot be calculated as a constant. If the engine is developing but a small portion of its power, the amount will be small; when loaded to its full capacity there will be a large increase of internal resistance, varying, however, in proportion to the accuracy with which it is put together, and the stiffness of the framing. p. 41

Such experiments as I have made show clearly that, when exerting approximately its full power, the total frictional resistance of the engine does not exceed 100 lbs. per ton, and when running light is much less, but in what proportion less I have as yet failed to ascertain satisfactorily. Of this 100 lbs. per ton, from 20 to 40 lbs. is due to journal and tire friction, leaving from 60 lbs. to 80 lbs. per ton as the deduction for internal friction.

I thus conclude that an allowance of 40 lbs. per ton for train resistance, and 100 lbs. per ton for engine resistance, is a basis for calculating the tractive power required on the level that is sufficient under all possible narrow-gauge conditions. In the case of gradients there must, of course, be added the gravity resistance of the engine and train, which is, on a gradient of 1 in 100, one-100th of the gross weight; on a gradient of 1 in 50, one-50th, and so on.

In calculating the tractive power of the engine, the effective pressure in the cylinders may be reckoned at fully nine-tenths of the boiler pressure, on account of the low piston speed.

The above particulars are not to be taken as representative of what can be got out of a narrow-gauge engine in a few isolated experiments only, but of what is well within the compass of daily work.

IX. p. 42

REMARKS ON NARROW GAUGE RAILWAYS.

Up to this point I have merely detailed the particulars of the construction of my experimental railway and of the line at Eaton, giving at the same time the reasons that have led me to adopt certain methods and designs. I now propose, in conclusion, to offer a few remarks upon the application, in this country and abroad, of small railways of 2 ft. gauge and under to do work at present done by means of horses and carts.

The cases in which such lines can be profitably applied may be classed under two heads; the one, where, in a country possessing ports or a system of railways, large establishments, private, public, or industrial, might be connected therewith by a narrow gauge line so as to reduce the cost of transport below that which has to be paid for haulage by animal power on roads; the other, when no roads worthy of the name are available, and the choice is a light railway or nothing. The chief condition of success in both cases is a sufficient traffic between two or more definite points. Military railways, however, must be regarded from a somewhat different standpoint, as the object here is to supply a movable centre as expeditiously as possible with the vast commissariat requirements of an army rather than to study economy. It is not my intention to enter into the pros and cons of small railways for war purposes. Suffice it to say that some countries are ahead of us in the matter, which is one that has, in England, been allowed to drop rather into the background.

Returning to the consideration of cases where a fairly large traffic has to be delivered to a port or railway system, the first question that arises is that of transhipment. Material of any kind can be as effectively delivered on ship-board by narrow gauge railway wagons as by horses and carts, if not better. In reckoning up the cost of transhipment from small wagons on to a railway system—no great matter with proper appliances—it must not be lost sight of that, even if a branch of standard gauge were constructed to many establishments, the large wagons cannot, as a rule, be got up to the point where the material lies, and a preliminary transference in barrows or carts is necessary. With the little wagons it is usually possible to get right up to the place and to load direct, in which case there is clearly no additional expense incurred. It is, further, often forgotten that there is on the standard railways endless transhipment for the sake of economical transport, p. 43
in no way connected with a break of gauge.

Again, a small line can be carried round curves, up gradients, and through confined premises, where a wider line would be inadmissible. In many places the unsightliness of the standard gauge would be objected to, nor can such a line be made very light if it has to carry, as it must, the 7 or 8 tons per axle of a full sized coal wagon (see Appendix A).

The narrow gauge has also the advantage in first cost, and by bringing the small wagons on to a level with the floors of the large ones, or, in the case of minerals, by erecting a simple shoot, the transhipment difficulty may be reduced to a minimum.

It is not well to have gradients steeper than 1 in 40 where avoidable, as difficulty will be experienced in slippery weather; but it is quite possible with suitable engines to work inclines of moderate length, as steep as 1 in 12. The diminution of the power of the locomotive on gradients is also a matter for consideration, the importance of which will be clear when it is stated that if an engine will haul, as it should, in addition to itself, ten times its own weight on the level, it will haul, speaking roughly, only four times its weight up 1 in 50, twice its weight up 1 in 25, and once its weight up 1 in 12. More work can be done if adhesion does not fail, but the above is an approximate working average.

The speed on small lines is not generally a matter of much moment, owing to their usually moderate length. A locomotive that is sufficiently powerful to start a given load, will without difficulty get it along at from 8 to 10 miles an hour. It has occurred to me that a very fair approximation to the reasonable running speed of which any gauge is capable is to be found in estimating that the speed of passenger trains is equal to as many miles per hour as the gauge is inches wide, and, for goods trains, to half that amount.

The permanent way should be made a thoroughly sound job, as it will then cost but little for repairs. Particulars of what is recommended will be found in Sections III. and IV. I am no advocate of portable railways, which may be well enough for hand trains, or even for horse traction, but a locomotive requires a solid and clean road if it is to work to advantage.

It is often possible to carry a narrow gauge railway by the roadside or, as at Eaton, over pasture lands without the necessity of fencing the line in. Fences can be crossed as described in Sections III. and IV., so long as arable land is avoided. Where the route is not wholly the property of the projector of the railway, the requisite way-leave may frequently be leased by paying an annual acknowledgment of from 3d. to 6d. per yard run.

It now remains to show what traffic is required in order that a line of this description may repay the outlay upon it. This may best be effected by drawing a comparison between the cost of locomotive traction on rails and horse traction on roads. The cost of loading and unloading will not be included, as these are the same in both cases. (See also Section IV.) p. 44

Taking the minimum distance apart of two points, between which haulage may be supposed to be required, as one mile, the smallest and cheapest gauge as 15 in., and allowing 2,000 yds. to the mile so as to include the necessary sidings, the cost of the line will be as follows:—

2,000 yds. of 16 lbs. steel rails, cast-iron sleepers, ballast, and laying	£650
Fence bridges, field crossings, fencing, and other structural works; but exclusive of river bridges, tunnels, or other costly requirements	£200
Earthwork, if an approximately surface line … say	£250
One 4½ in. cylinder four-wheeled locomotive	£400
12 wagons to hold 1 cube yd., at £12 each	£144
Extras … say	£156
Cost of 1 mile of line, equipped complete	£1,800

If laid with pitch pine sleepers a reduction of about £100 per mile would be effected, the cost of renewal being correspondingly increased.

The engine would be capable of hauling a gross load, exclusive of its own weight, of 12 tons up a gradient of 1 in 50, which may be taken as a fair ruling gradient for a surface line. This would be equal to an average paying load of about 8 tons; so that, supposing the engine to make one trip per hour, about 60 tons would be moved per day; although, with a double set of wagons and men, 100 tons would easily be handled.

If the engine worked two days a week, or say 100 days per annum, it would have hauled 6,000 tons one mile in the year. A less load hauled on the return journeys need not be taken into account, as this would make no difference in the comparison, such work being practically done without extra cost in both cases.

The cost of the line per annum would be as follows:—

Interest on £1,800 at 4 per cent.	£72
Driver and boy, who would keep the rolling stock and line in order	£100
Fuel, oil, stores, and sundries, at 5s. per day	£25
Renewal of permanent way and rolling stock at 15 years life on £1,200	£80
Cost of moving 6,000 tons one mile	£277

This is equal to about 11d. per ton. Now the same haulage by horses and carts in Great Britain would usually cost about 1s. 3d. per ton, and in this case there is the advantage of being able to haul, if necessary, in other directions if required, which would somewhat reduce the financial advantage of the railway, but still leave it a distinct superiority. p. 45

It is probable that a traffic of 5,000 tons annually over a mile of line is the smallest amount that would repay the construction of a narrow gauge railway, for the estimate has been based upon the narrowest line which can profitably be employed. If the line were longer, the balance in its favour would be greater. This would also be the case if the traffic were greater, and with the maximum amount which the line, using only one, but a larger engine, could accommodate, say 40,000 tons, the concern would be very profitable, for the extra charge for renewals would not be heavy, and the cost per ton carried would be reduced to about 5d. or 6d.

No allowance has been made for way leaves or purchase of land. Should there be outlay under these heads, the cost of transport would be increased accordingly.

In concluding these comparisons, in which it may be thought that the railway is shown in a less attractive light than might have been expected from an enthusiast, I may explain that I am no advocate of ill considered schemes, planned without proper knowledge, cheaply constructed, and carelessly worked. My figures represent thoroughly sound and serviceable plant, kept in good repair. If it is not worth while to go to such expense, then it is not worth while to construct a railway at all. I have been fortunate enough to work my line for twenty years without the slightest injury to a single person of the many thousands that have been carried as invited guests for pleasure, as visitors interested in my experiments, or as workmen on the premises. None of the rolling stock has sustained more than the most trivial damage; and derailments, beyond an occasional mishap in shunting, are unknown. The working of the Eaton line has been equally satisfactory. This immunity from accident I attribute entirely to proper care having been taken to construct every part, not only of the best materials and workmanship, but also with a careful eye to the fitness of each detail for the purpose it has to serve.

That there are many openings for lines of 2 ft. gauge and under, is beyond dispute. But while, already, this mode of transport is largely made use of abroad and in our colonies, a deeply rooted prejudice has hitherto prevented it from gaining a footing in England and Scotland.

Admirable articles pointing out the advantages of light railways have appeared from time to time in the daily press with little or no effect. It is one of the strangest anomalies in the progress of p. 46
civilisation in this country that Great Britain almost wholly refused till lately to countenance such lines. The reasons for this obstinacy are not readily discoverable. Probably the innate conservatism of every Englishman—for there exists here no such thing as liberalism out of the region of politics—has been the principal factor in determining this course of inaction.

Even now that the Light Railway Act has passed, there is little or no movement in the direction of making small lines such as I refer to, and not much in respect of larger ones. Whether, in the future, private individuals will, in their own interest and in that of their neighbours and dependents, lay out money in this way, it is impossible to foresee. But undoubtedly there are many openings for such installations, particularly on large estates, where the possession of the land gives the owner a free hand.

X.
APPENDIX

A

The following letter, which appeared in *The Times* two years ago, is here reprinted as bearing on various points connected with narrow-gauge railways. Special attention is directed to what is advanced under the third head.

LIGHT RAILWAYS.
TO THE EDITOR OF "THE TIMES."

Sir,—The movement in favour of secondary railways has evoked from your numerous correspondents widely divergent views. This want of accord is more apparent than real, and it would facilitate the proceedings of the approaching conference [46] if conflicting opinions could be partially reconciled beforehand.

The causes to which these differences are due may be summarized under three heads:—

1. The absence of a defined terminology of the distinctive kinds of railways.

2. The failure to appreciate that a scheme which is good for one locality is not of necessity the best for all. p. 47

3. The apparently meagre acquaintance on the part of those who state their views with the practical working of any but the standard railways of the country.

Under the first head, some confusion has arisen in consequence of the application of the term "light railway" now to lines of the standard gauge only, and again to narrow-gauge lines also. Similarly with other expressions. It may be pointed out that the term "light railway" is properly applicable and should be confined to a line of standard gauge, of which the entire construction is lighter, cheaper, and simpler than is obligatory where weighty engines, heavy traffic, and high speeds are dealt with. Any line of less than the standard, gauge is correctly described as a "narrow-gauge railway," and such lines, when not of a permanent character, come under the title, simply, of "portable railways," for these are invaribly of less than the normal width. The term "tramway" should be restricted to its modern meaning of a line laid in the metalled or paved surface of a road or street. Finally, the not unfamiliar appellation of "secondary railways" might be fitly adopted as generally descriptive of all lines not amenable to the standard railway regulations of the Board of Trade. It would be well that the conference should pronounce on these points.

In regard to the second head, needless controversy is engendered by attempting to assume that, because a light railway is right here, therefore a narrow-gauge railway is wrong there, or vice versa. In estimating the transport requirements of any particular locality, if connection is to be made with the railway system, the applicability of a light railway, as above defined, should first be considered. By its adoption the use of existing rolling-stock is secured, transhipment is avoided, and the line can be subsequently and without difficulty transformed, if necessary, into a railway of standard construction—advantages for which much may be sacrificed. But as it would be almost invariably essential to build a light railway of sufficient strength to carry the 15 tons gross weight of a standard coal wagon, the permanent way would be of a somewhat costly character, and, in the case of severe gradients, considerable difficulty would arise in providing suitable locomotive power.

Where the impediments in the way of a light railway branch are insuperable, or where the proposed line has no connexion with the railway system, the advantages of a narrow-gauge railway may properly be weighed—such as the smaller width occupied, the sharper curves admissible, the lighter, cheaper, and more easily-handled permanent way and rolling-stock, the absence of much of the unsightliness of a line of standard gauge, the ease with which, in the ease of gauges under 2 ft., the rails can be laid among and into existing buildings, and, lastly, the convenience of being able to load and unload small wagons at the exact point required without p. 48 the intervention of carts or barrows.

In regard to the third head, it may be noticed as a curious fact, that the strong and commendable predilections of English engineers for the standard gauge, whenever obtainable, appear to lead them, where circumstances compel the adoption of a narrower one, to advocate as little reduction as possible. Now, the general result of foreign experience goes strongly to show that narrow gauges exceeding 30 in. approximate so closely to a full-size line as to forfeit, to a considerable extent, the advantages of either system. This attitude is probably due to ignorance of what can be done on the narrowest gauges, for, in spite of the fact that many hundreds of miles of lines of less than 2 ft. gauge are at work abroad, our professional advisers persist in regarding such railways as mere toys. Yet a line of 15 in. gauge has been at work in this country for twenty years, on which thousands of passengers have been carried without a single accident, as many as 120 in one train, over gradients as steep as 1 in 20, the goods traffic being worked in all weathers up a long gradient of 1 in 11 without difficulty. [48]

It would be well that our railway engineers should inform themselves more fully on the subject, as otherwise their valuable assistance, which would insure that narrow-gauge railways were constructed in a solid and reliable manner, will be thrust on one side by the requirements of the times, and the work will be wholly in the hands of the many manufacturers of narrow-gauge plant, whose designs, being chiefly of what is known as the portable class, are, for the most part, ill adapted for permanent locomotive traffic. If so, it is likely that, in the push that may very possibly be presently made for secondary railways, the results will not be so satisfactory as would be the case if the work were carried out under the direction of professional advisers.

Under the same head, attention may be directed to the fact that it is entirely unnecessary to urge the adoption of a standard narrow gauge. The circumstances of each case will decide the most suitable gauge, and it is only where there is a possibility, as in the North Wales district, of a wide ramification of connected narrow-gauge lines that the adoption of a particular standard is of any importance.

I am, Sir, your obedient servant,

ARTHUR PERCIVAL HEYWOOD.

B. p. 49

The annexed letter, published in The Times about two years ago, deals with possible difficulties to be met with by those who make a private line of railway. I brought to bear all the influence I could to obtain the insertion of a clause in the Act which would meet the "public road crossing" difficulty, but without success. The course which I took in the case of the Eaton Railway here detailed may be of service.

PRIVATE LIGHT RAILWAYS.
TO THE EDITOR OF "THE TIMES."

Sir,—May I, through your columns, draw attention to a class of light railway which does not apparently come within the purview of the Bill now before Parliament—that of lines constructed by private individuals or firms for their own purposes? These will usually confer advantage upon the district in which they may be situate by relieving the roads of a more or less heavy traffic, and in some cases by offering facilities of transport to a section of the neighbourhood.

In a proposed route two difficulties may arise. In the first place, land not in possession of the projector may have to be invaded, and way-leaves obtained by a judicious tact in selecting the ground and in approaching the owners, since private interest is properly debarred from invoking compulsory powers. This problem, then, may frequently be satisfactorily solved. The second and more common impediment is the crossing or skirting of highways, and it is to this point that my letter is specially directed. The county and district councils are usually ready in their own interest to permit a private line to cross a road on the level—an over or under bridge is almost invariably impossible by reason of the expense—or to make use for a short distance of waste space by the road side. But—and here is the crux—no permanent agreement is obtainable, because councils have apparently no power to bind their successors in office, and without such guarantee the projector is naturally unwilling to risk his capital when the possible rescinding of the concession would render his entire outlay abortive.

The Light Railway Bill contains, apparently, no provision under which this disability can be remedied, for it is improbable that the Commissioners would take action in respect of a private concern. The above difficulty was lately met with in the construction of a private narrow-gauge line for the Duke of Westminster, which crosses a main road. The matter was ultimately compromised by the insertion of a clause in the agreement to the effect that, should the county council give notice to discontinue the crossing, the Duke should be entitled to appeal to the Board of Trade for arbitration. There is, however, no assurance that the Board would consent to appoint an arbitrator if called upon, but it is very certain that if a provision legalizing such an appeal could be incorporated in the Bill a serious hardship would be thereby removed, and some encouragement given to private persons to embark capital in enterprises of the kind. p. 50

As a case in point, and doubtless there are plenty of others, a quarry owner of my acquaintance is at the present time conveying some 80,000 tons of stone annually by means of traction-engines from his works to the railway along 2½ miles of highway. The road authorities, levying £400 a year for extraordinary traffic, are utterly incapable of coping with the destructive action of the heavy loads, and the roads are in a state of disintegration that baffles description. The proprietor of the quarry would at once set about making a narrow-gauge line at his own expense, with the cordial good-will of the county and district councils and his neighbours generally, could he only obtain some guarantee that the permission to cross and, in some parts, run alongside the road, which to-day would be gratefully accorded, would not be suddenly revoked at a future date.

Perhaps those in charge of the Bill will see their way to give this point their consideration.

I am, Sir, your obedient servant,

ARTHUR PERCIVAL HEYWOOD.

FROM A MANCHESTER PAPER.

According to a correspondent in yesterday’s *Times* projectors of private light railways have hitherto been very chary of risking their capital owing to the precarious nature of their running powers. In nine cases out of ten the light railway proposes to cross or skirt the highways at certain points, and the permission which may be given by one district council in such cases is revocable by the next. This must be so inevitably, for circumstances might well arise under which a level crossing, for instance, would become a public danger. The difficulty might well be met by an appeal to arbitration in all cases of proposed revocation of the running powers; and if the Board of Trade were to undertake to nominate the arbitrator, the projector ought to have no reasonable ground for timidity. The present Bill can only be regarded as proposing to set an example and provide occasional assistance to the construction of light railways. Seeing, therefore, that its chief result, if successful, will be to encourage a more extensive construction of railways, it is important that all obstacles in the way of private enterprise in this direction should be at once removed. The *Times* correspondent suggests that the insertion of a clause providing for arbitration in all cases of dispute with the highway authorities would meet the difficulty.

C. p. 51

The regulations given below, which I drew up for use on the Eaton line, and which have worked very well for two years, may, to some, be of interest.

EATON RAILWAY.

GENERAL REGULATIONS.

1. All persons connected with the Railway shall be held responsible for making themselves acquainted with such of the regulations as apply to them, and for acting in accordance therewith.

2. All workmen on the Estate shall be liable to such fines for infraction of the Railway Regulations as are herein set forth, and as the Estate Office may see fit further to order.

3. All men employed on the Railway Staff shall promptly report any infraction of the Regulations which may come under their notice, or they shall be themselves liable to any penalty which may attach to such offence.

4. All workmen on the Estate are particularly requested to remove any impediment, such as sticks or stones, which they may see on the line; and in case of any serious block, such as a tree fallen across the rails, to give prompt notice to one of the Railway Staff.

5. No wagon or car shall (under a penalty of 1s.) be moved by hand on to or along the main line, except by special arrangement with the engine-driver; and the term “main line” shall be

understood to include every part of the railway not being a siding or within a terminal yard.

6. Hand shunting of vehicles on sidings shall be done carefully, so as to avoid injury to the rolling stock; but no vehicle shall be moved at all except by an authorised person.

7. No vehicle shall (under a penalty of 1s.) be left in such a position on a siding as to interfere with the free passage of other vehicles along adjoining rails.

8. If it is necessary to throw over time weight of any point-lever, this shall be done gently, and the weight shall always be returned as soon as possible to the position in which the white bar thereon is uppermost. Point levers of which the weights are pinned in one direction, shall not (under a penalty of 1s.) have the locking pins tampered with.

9. No material of any kind whatever shall (under a penalty of 1s.) be deposited within a distance p. 52
of two feet from the rail on any part of the main line or sidings.

10. No heavy weight shall be dropped upon the rails or sleepers, and no carts shall cross any part of the line except where a proper crossing of double rails is provided. But in the terminal yards light loads may cross the rails where the ballast is for that purpose made level with the top of the metals. Any unintentional damage to rolling stock or the line shall be at once reported to the engine-driver or foreman platelayer.

11. No unauthorised person shall ride on any part of the train, and those having permission shall, whenever possible, travel in vehicles provided with seats.

12. It is desired that all workmen on the Estate should understand that there exists the same liability to accident on a narrow-gauge line as on one of full size, and that it is only by a similar careful observance of proper regulations that serious mishaps will be avoided.

REGULATIONS FOR YARDMEN.

13. Yardmen shall carefully observe the General Regulations for the safe conduct of traffic comprised in Rules 1 to 12 inclusive.

14. The yardman at each terminus shall clean and oil all points in or near his yard at least once a week, and keep them perfectly free from grit, leaves, etc.

15. In frost or snow the points shall receive daily attention, and great care shall be taken in releasing frozen switches not to strain them. Salt for this purpose, shall, on account of its injurious effect on the rails, be used only as a last resource.

16. Yardmen shall take care that the loads on wagons are securely placed, evenly balanced, and not in excess of the specified weight.

17. Lengthy articles shall be loaded on a sufficient number of wagons to ensure that the ends thereof do not catch against other wagons.

18. All vehicles shall be loaded to the satisfaction of the engine-driver.

19. Yardmen shall give the earliest possible intimation to the engine-driver of the nature and quantity of the material requiring transport from their respective yards, that he may provide the necessary wagons at the proper time.

20. Yardmen shall take care that the wagons and cars are not roughly handled, and shall see that heavy lumps of coal or other material are not thrown carelessly on to the wagon bottoms.

21. The yardman at Balderton shall be responsible for the washing of all wagons when necessary, and the yardman at Eaton shall similarly see to all the bogie cars. Care shall be taken in washing that no water is allowed to run into the axle boxes.

22. Yardmen shall use their best endeavours to get the rolling stock in their respective yards p. 53
promptly unloaded, and also put under cover at night and in wet weather.

REGULATIONS FOR PLATELAYERS.

23. Platelayers shall carefully observe the General Regulations for the safe conduct of traffic comprised in Rules 1 to 12 inclusive.

24. The foreman platelayer shall be responsible for keeping the whole of the permanent way, bridges, cattle stops, banks, road crossings, etc., in proper repair.

25. He shall see that every set of points on the line is kept in good working order, but he shall only be responsible for the oiling and cleaning (as under Rules 14 and 15) of such points as are not under charge of a yardman. He shall report to the engine-driver any set of points not under his personal charge which he finds neglected, as also any defect which he is himself unable to repair.

26. He shall keep clear all road and field crossing grooves, and shall at once acquaint the engine-driver when repair to the surface of any road crossing is necessary.

27. At least once a week he shall walk over the whole length of the main line and sidings, observing carefully that the keys, bridge bolts, fish bolts, and sleepers are in order.

28. He shall, at the same time note, and as soon as possible rectify, all loose sleepers, crooked rails, and defective superelevation.

29. He shall pay particular attention to the prompt repair of all parts of the line marked by the engine-driver as defective, but, independently of such notice, he shall be responsible for detecting defective places.

30. In regard to any special repairs, or other emergencies of the traffic, he shall be under the direction and obey the instructions of the engine-driver.

31. When any part of the line is under repair, care shall be taken that the surface of the rails is kept clear of ballast grit, and that the free passage of trains is in no way obstructed.

32. When it is necessary to remove a sleeper, a red flag shall be set up between the rails in such a position that the engine-driver can discern it from a distance of at least 150 yards in each direction. Such flag shall remain until the line is made good. On no account shall the engine or a loaded wagon pass over any rail from which a sleeper is removed.

33. If from any cause it is necessary to remove a rail, or otherwise block the line, the foreman platelayer shall previously notify the engine-driver, and arrange with him a convenient time for the work to be done; and without such notification the line shall under no circumstances p. 54
whatever be so blocked. A red flag (as directed under Rule 32) shall remain exhibited until the line is clear.

34. No platelayer other than the foreman shall be authorised to undertake any work interfering with the free passage of trains.

35. If, for ballasting or other purposes, wagons are left by the engine-driver at any point on the main line, such wagons shall on no account be subsequently moved by hand to any other point on the main line, except by special arrangement with the engine-driver.

36. The platelayer's trolley shall under no circumstances be left standing on the main line and when not in use, or unattended, the trolley shall always be put at a safe distance from the line, with the wheels padlocked.

37. The foreman platelayer shall report to the engine-driver any case of material found deposited within two feet of the rail, and likewise any other infraction of Regulations which may come to his notice.

REGULATIONS FOR ENGINE-DRIVER.

38. The engine-driver shall be responsible for the efficient working of the line, and shall use the utmost promptitude in dealing with the traffic as notified to him by the yardmen.

39. He shall be responsible also for the care of the locomotive, rolling stock, and fittings appertaining thereto, any defect in which that is beyond his own power to rectify he shall at once notify to the Superintendent, with whom any further responsibility in regard to such defect shall then rest. But the washing of the wagons and cars shall be done by the yardmen as set forth under Rule 21.

40. He shall, further, be responsible for the proper oiling of the axle boxes, spring slides, swivelling forks, and bake gear of the whole of the rolling stock; and shall on no account run on the train a loaded wagon having a hot axle box or a bent axle.

41. He shall see that all rolling stock is kept, as far as possible, under cover at night and in wet weather.

42. He shall watch carefully that the whole of the line and its accessories are kept in thorough working order, and shall direct the foreman platelayer in regard to any part requiring attention.

43. He shall put down white mark pegs, of which he shall at all times carry a sufficient supply in the brake van, at all points of the line which he may notice to be in special need of repair.

44. He shall arrange with the foreman platelayer, as set forth under Rule 33, in regard to the time of execution of any work requiring the blocking of the line.

45. He shall promptly enquire into, and report to the Superintendent, any case of material left p. 55
within two feet of the rails, as also any other infraction of the Regulations which may be brought to his notice. He shall take care that Rule 11, in regard to passengers by the train, is strictly observed, and shall allow no person to ride on the engine without permission of the Duke or from the Estate Office.

46. He shall carefully observe the following County Council Regulations in regard to crossing the public roads, and shall be personally liable to the County and District Councils respectively for the consequences of any infraction thereof:—

(*a*) Every train about to cross the road shall be brought to a stand at a point not less than 10 yds. therefrom, and the brakesman shall proceed to the centre of the road with a red flag, and shall, as soon as any approaching vehicles have crossed the railway, wave the said flag as a warning to distant vehicles and as a sign to the engine-driver to proceed and shall continue to wave until the whole of the train shall have passed over the road. After dusk a red lamp shall be used in place of a flag (but a green light shall be momentarily shewn to the driver when the road is clear).

(*b*) No train shall cross the road at a greater speed than five miles an hour, nor shall any train impede the traffic along the road further than is necessary for the crossing thereof, which shall in no case exceed three minutes.

(*c*) Every train crossing the road shall be in charge of a competent engine-driver and brakesman, and shall consist of not more than twenty-five vehicles, exclusive of the engine.

47. He shall take care to run no train without a brake-van at the rear end, and a brakesman in attendance.

48. He shall at all times whistle before putting his engine in motion, and also on approaching all road crossings, termini, and other points where a warning may be desirable. He shall, during fog, proceed with the utmost caution, particularly in crossing roads, and shall be ready to stop promptly where cattle may be upon the line.

49. He shall approach all facing points with caution, especially after dark, and shall see that his train is well under control in descending inclines, particularly the gradient by the Eaton cricket ground.

50. He shall cross the Great Western Siding at Balderton only when the yard gates are closed, and at dead slow speed, and shall be personally responsible for any mishap resulting from neglect of this rule.

51. He shall perform no fly-shunting with the engine pushing, and in draw-shunting he shall p. 56
proceed with the utmost caution.

52. He shall take care to avoid injury to the rolling stock from shocks, careless usage, or foul shunting.

53. He shall, between September and February inclusive, carry on the train all necessary lamps ready trimmed.

54. He shall take care that the breakdown tackle is always kept ready on the brake van in case of emergency.

55. He shall under no circumstances leave his engine with the steam up without the hand-brake hard down, the lever out of gear, and the cylinder cocks open.

56. He shall take care that the spark arrester is kept effective; the sand boxes full, and that, in conveying passengers, condensed water is cleared from the cylinders before starting.

57. He shall keep his engine in good working order, clean, and smart; executing all necessary repairs at the earliest opportunity.

58. He shall keep a careful watch that point-lever weights are left in the right positions, and that the white bars thereon are kept clearly painted.

59. He shall notify to the Superintendent at the earliest possible time any requirement for the rolling stock or line, such as coal, stores, material for repairs, oil, waste, etc., etc., and shall keep such booked records of the working as are required.

60. He shall impress upon the brakesman the following orders

(*a*) To travel always in the brake-van; to keep a sharp look-out and promptly put down his brake should occasion require, or on receiving a signal from the engine.

(*b*) To carefully watch the loaded wagons, and in the event of any part of the load appearing unsafe, to signal at once to the engine-driver to stop the train.

(*c*) To carry always on the van a red flag, and, between September and February inclusive, a hand lamp ready trimmed, which latter, in travelling after dusk, shall shew a red light at the back of the train.

(*d*) To perform shunting operations with caution, taking care that all point-lever weights are left in their proper position.

(*e*) To keep his van clean and smart, washing it when required.

(*f*) To carefully observe such of the Railway Regulations as apply to the brakesman’s work.

SIGNALLING REGULATIONS. p. 57

61. The engine-driver shall give three short whistles when he requires the brake-van brakes to be put down, and one short whistle when they are to be released. When he requires facing points to be set for the main line he shall give two, and for a branch or siding three medium whistles. A whistle continued for several minutes is a call for assistance, and workmen within hearing should at once proceed to the spot.

62. A red light is a signal to stop; a green light, to proceed cautiously; and a white light, to go a-head. In shunting, a green light, if waved up and down, is a signal to move a-head; if from side to

side, to back.

63. It is important that all persons having to do with shunting operations should understand that if an engine is either in contact with no vehicles, or has vehicles both in front and behind, it is said to go a-head when it moves chimney first, and to back when it moves fire-box first. If in contact with vehicles at one end only, it is said to go a-head when it draws and to back when it pushes such vehicles, without regard to its own direction.

D.

The following rather neat parody, which appeared in a London evening paper at the time of the passing of the Light Railways Act, expresses a very reasonable doubt, in which I fully share, as to the specially beneficial effect of the measure on agriculture. Fortunately, the Act has been taken very quietly, and such schemes as have been promoted will, for the most part, be of considerable general advantage. Certainly there are some cases in which farmers would be the gainers by a light railway, but these are an infinitesimal proportion of their whole number.

THAT TIGHT LITTLE, LIGHT LITTLE

“Non si male nunc et olim
Sic erit.”

You farmers, who lately
Have suffered so greatly
From agricultural depression,
Shake off gloom and sorrow,
A brighter to-morrow
Will dawn in the course of the Session.

By no relaxation
Of rates or taxation,
By a certain sure-never-to-fail way,
Through Government’s pleasure
To bring in a measure
For giving some districts a railway:
A tight little, light little railway,
A nice little, light little railway,
O think of the joy
Of that exquisite toy,
A tight little, light little railway.

Your wheat may grow cheaper,
The pay of your reaper
May rise to a figure outrageous;
The weather may lay all
Your crops, and your hay all
Be ruined by tempests rampageous;
Your stock mayn’t grow fatter,
But that does not matter,
Except in a bargain and sale way:
What are these to the blessing
Of really possessing
A tight little, light little railway?

(*Chorus.*)

You may not have a fraction
Of produce for traction,
Not a stone’s weight to put in a wagon,
Not a horse in your stable,
No bread on your table,
Not a shoe to your foot, not a rag on:
All this would be frightful
Were it not so delightful
To see in as-slow-as-a-snail way
The trucks all go gliding
From track into siding,
From siding to track on your railway.

(*Chorus.*)

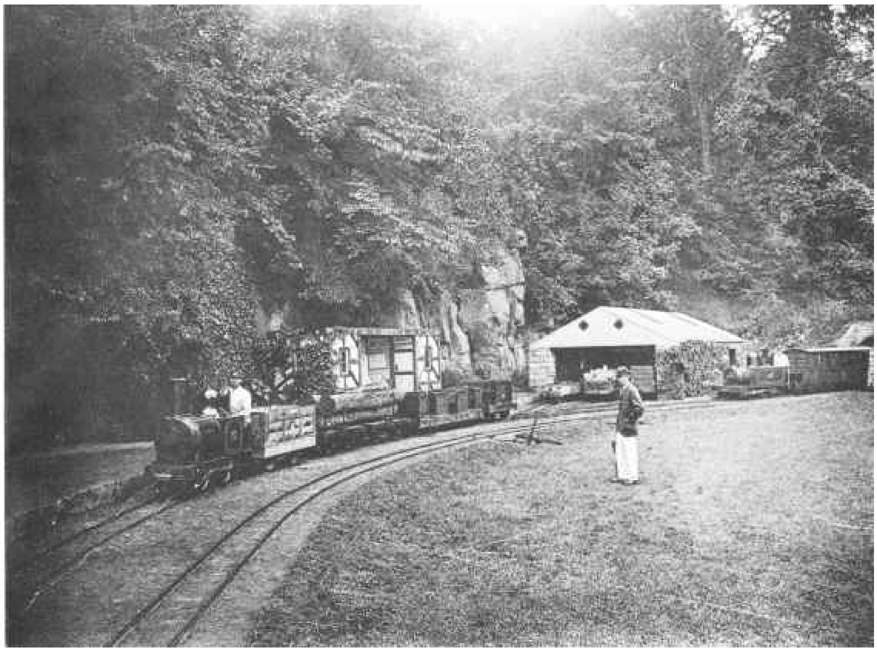
Then, oh *fortunati*
Agricolæ, wait, aye
Wait, for the clouds to roll by you:
Your troubles are over;
To-morrow, in clover,

   You’ll laugh at the ills that now try you.
“*Ex machinâ Deus*
Is coming to free us,
   Not in an old-fashioned or stale way.”
Let this be your chorus—
“A future’s before us;
   Three cheers for the light little railway!”

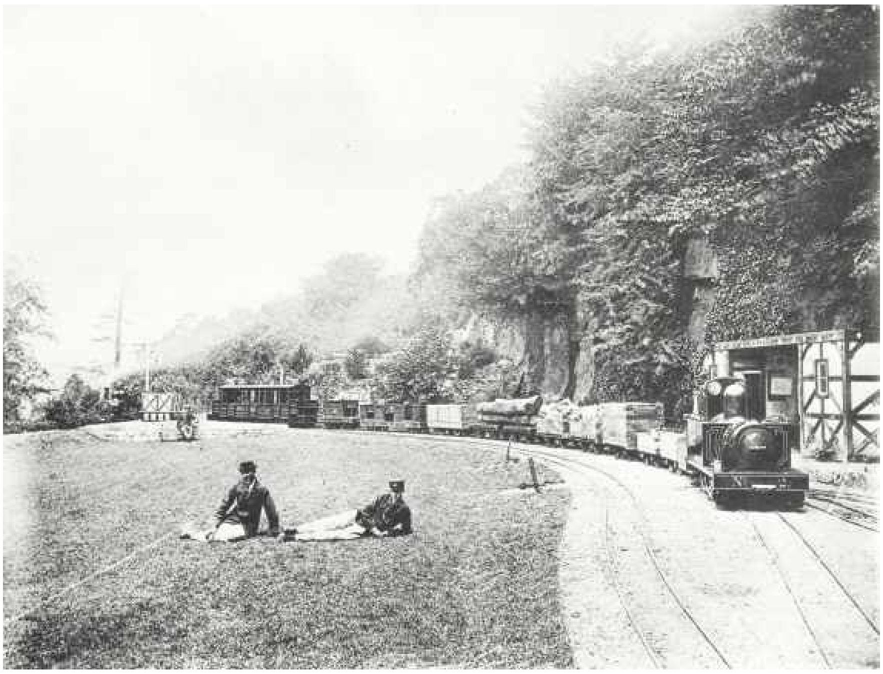
(*Chorus*.)

PLATES.

Tennis Ground station, Duffield Bank Railway.



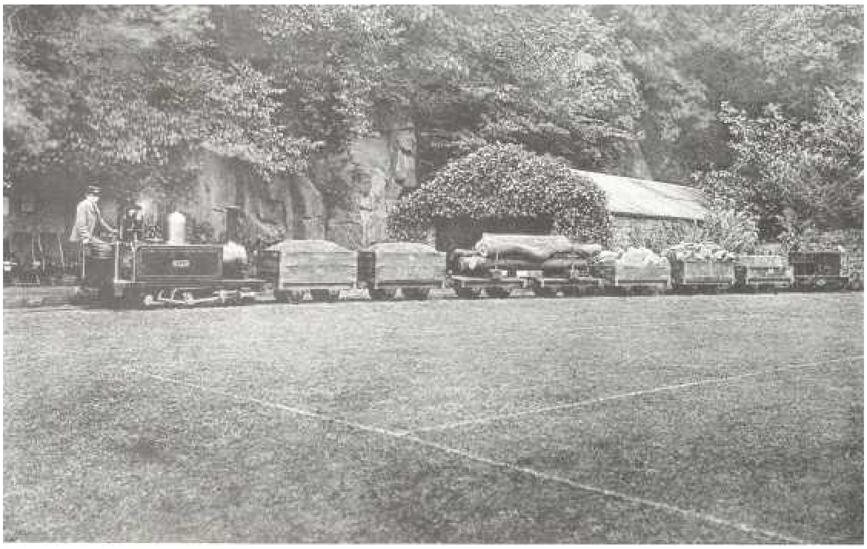
Tennis Ground station, Duffield Bank Railway.



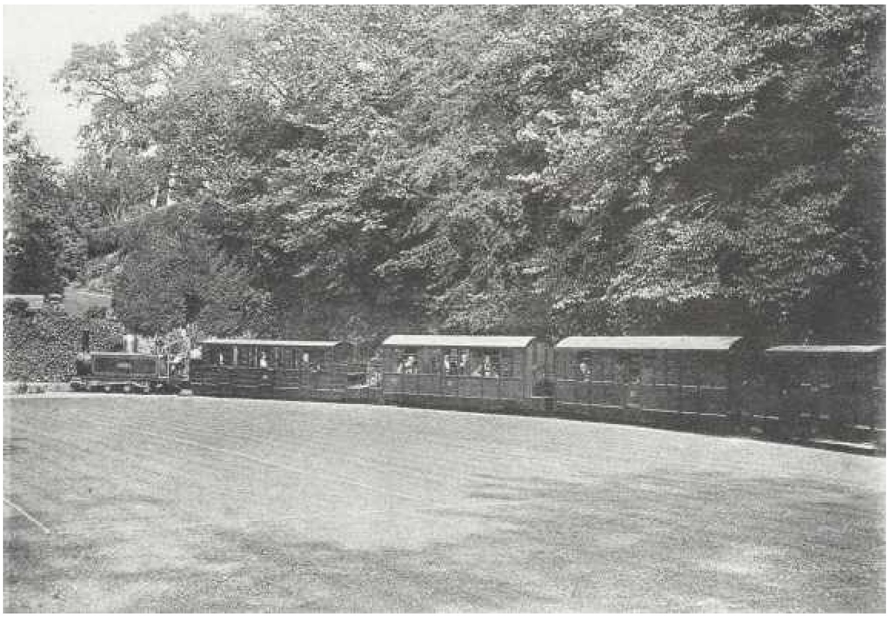
Viaduct, Duffield Bank Railway.

Curve, 25 feet radius, Duffield Bank Railway.

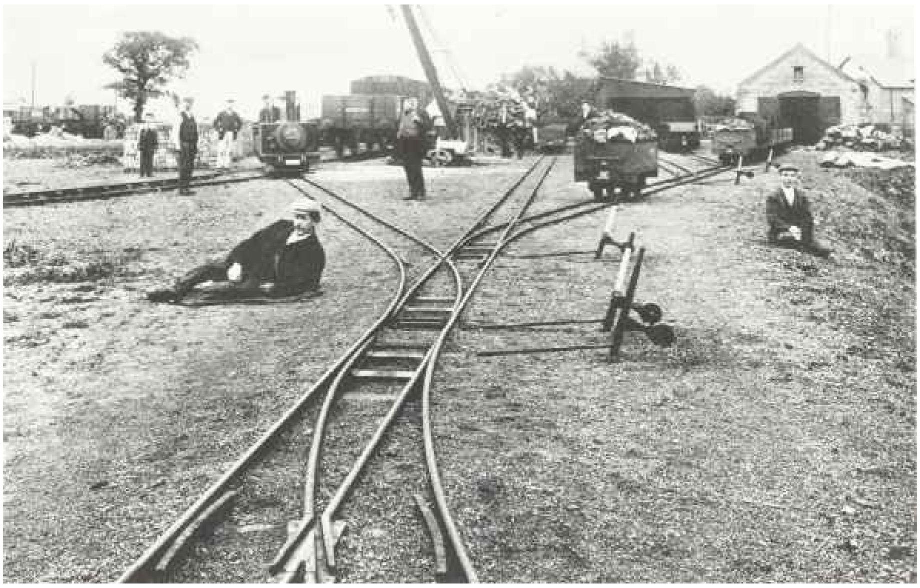
Engine No 2 and Goods Train, Duffield Bank Railway.



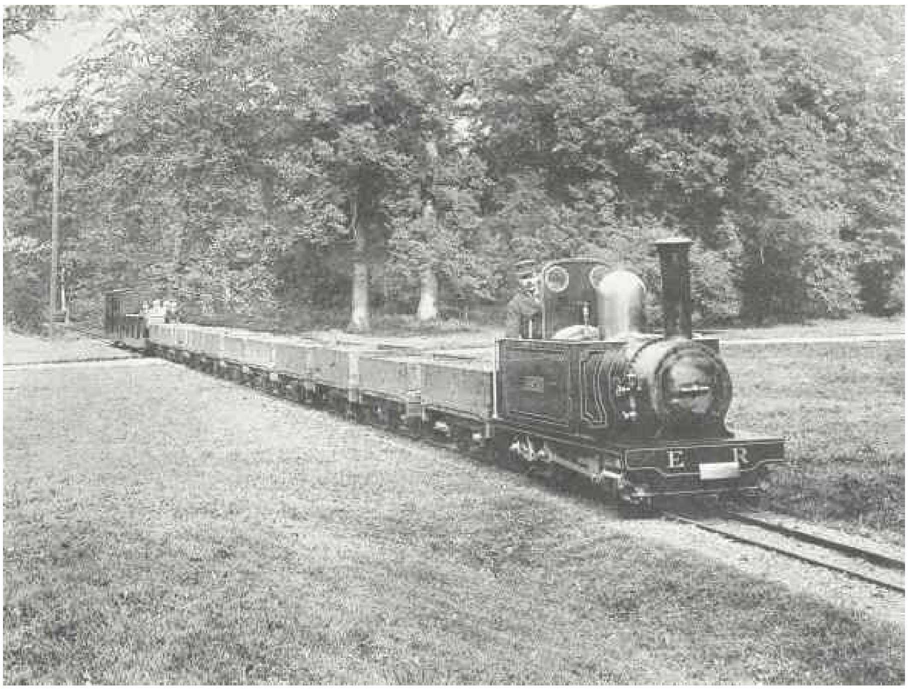
Engine No 1 and Passenger Train, Duffield Bank Railway.



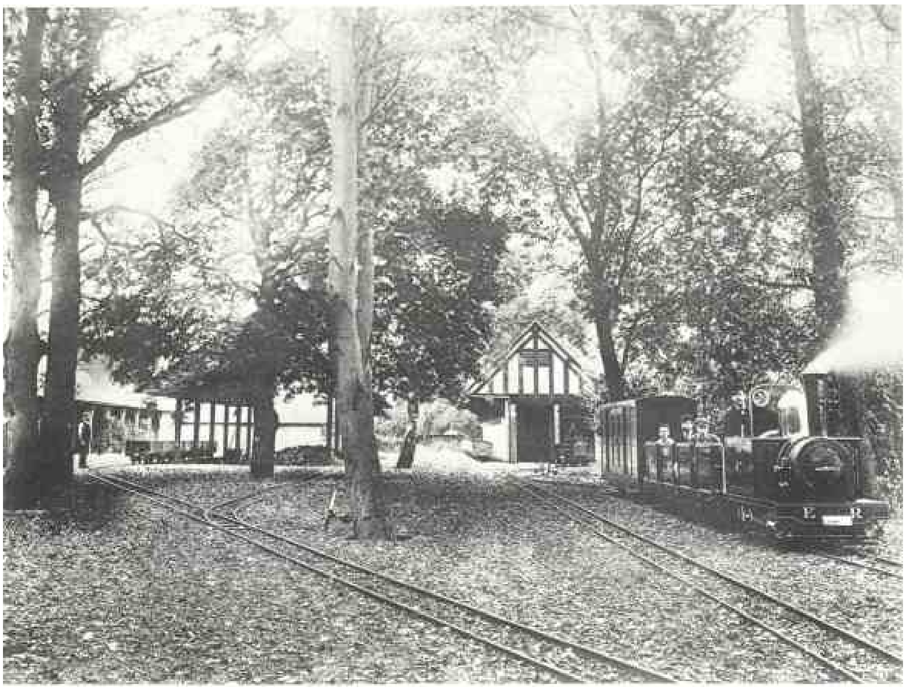
Balderton Junction—Engine and Waggon Sheds, Eaton Railway.



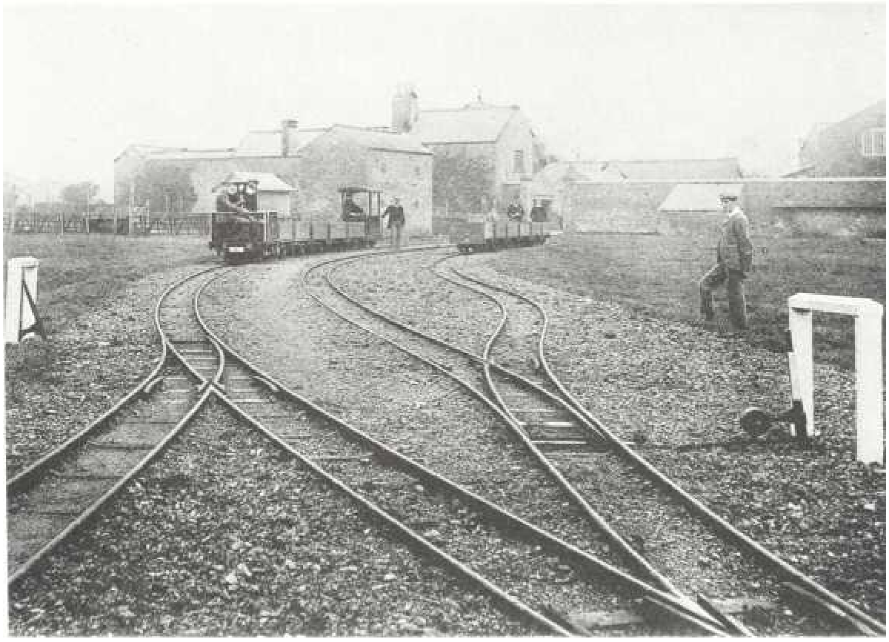
Engine No 4 and Train, Eaton Railway.



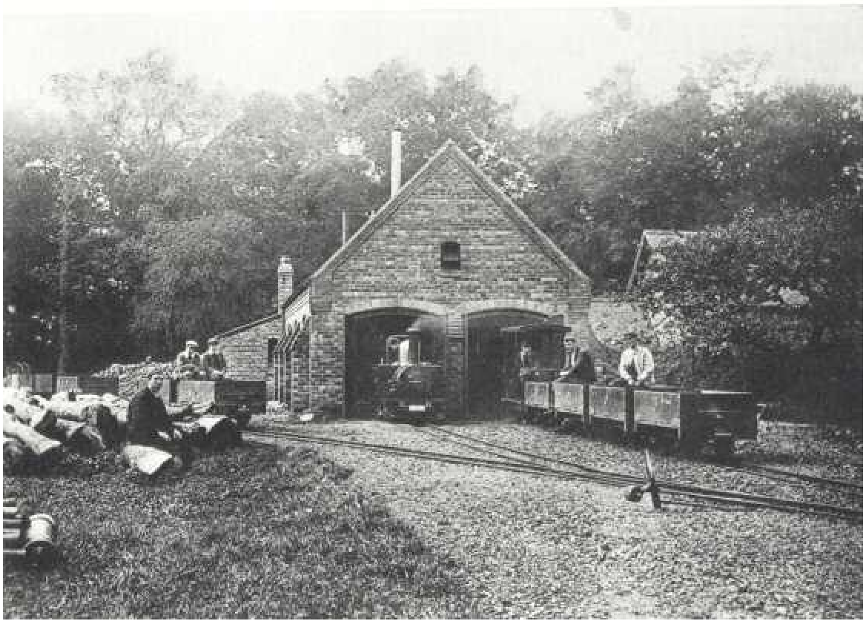
Eaton Terminus—Coal Store and Carriage Shed, Eaton Railway.



Estate Works Sidings, Eaton Railway.

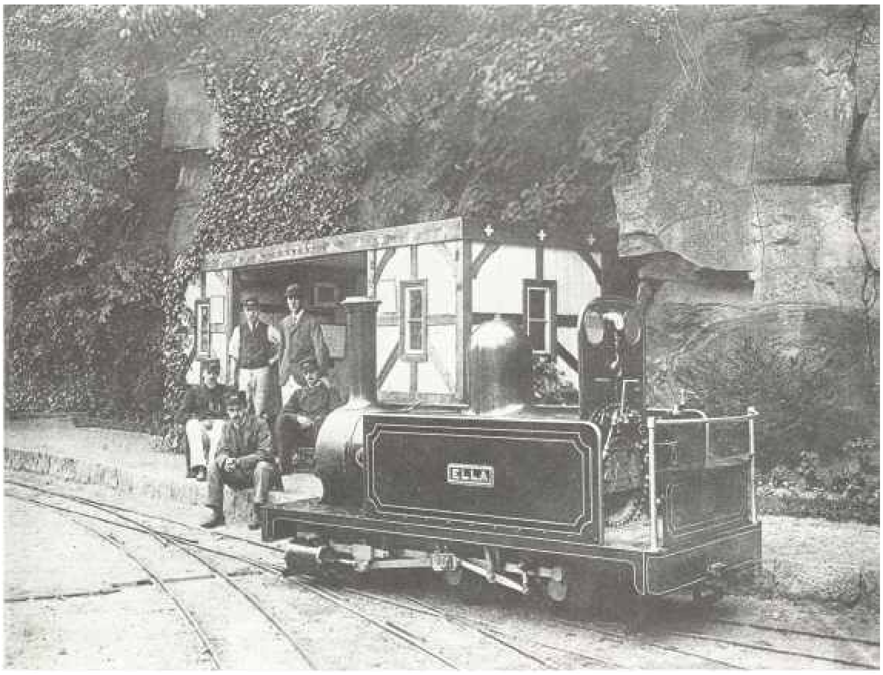


Belgrave Engine Shed, Eaton Railway.

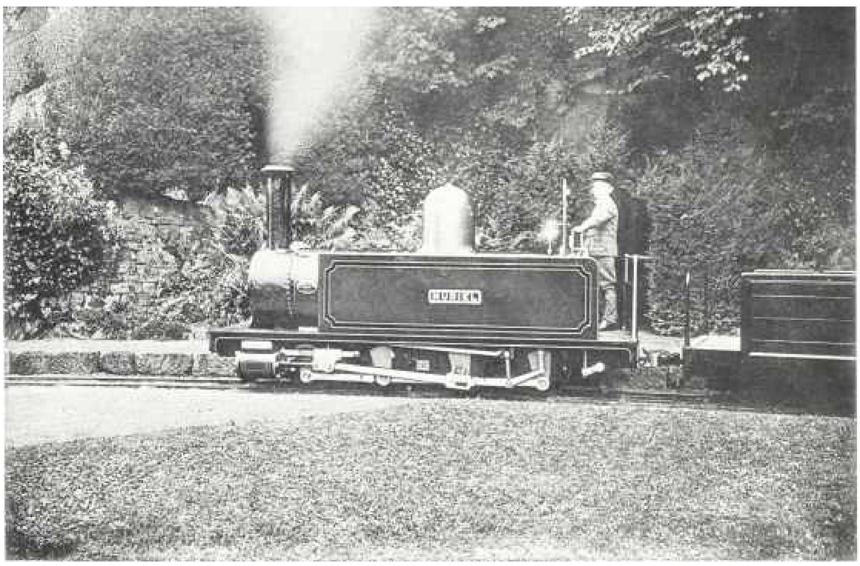


Engine No 1, Duffield Bank Railway, 1874.

Engine No 2, Duffield Bank Railway, 1881.

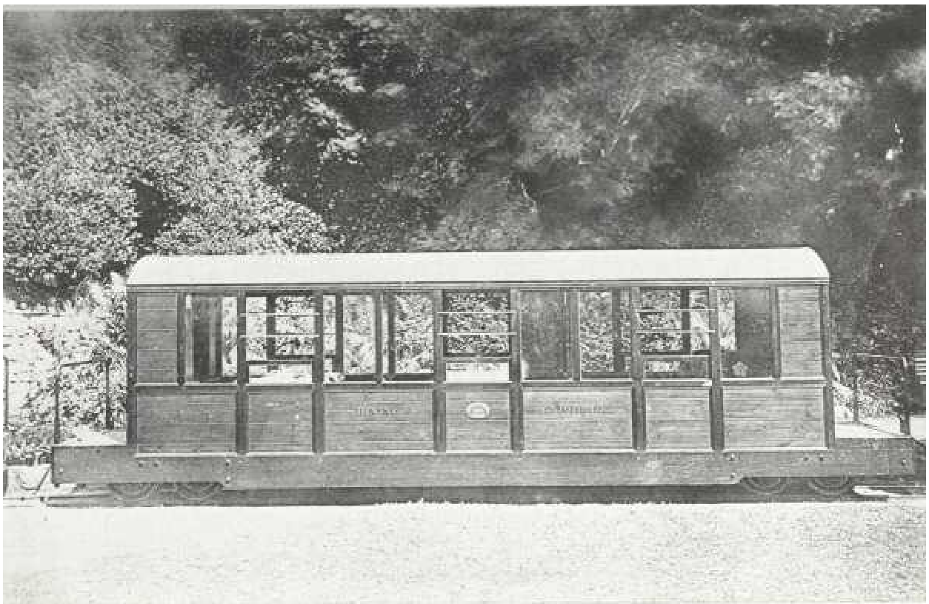


Engine No 3, Duffield Bank Railway, 1894.

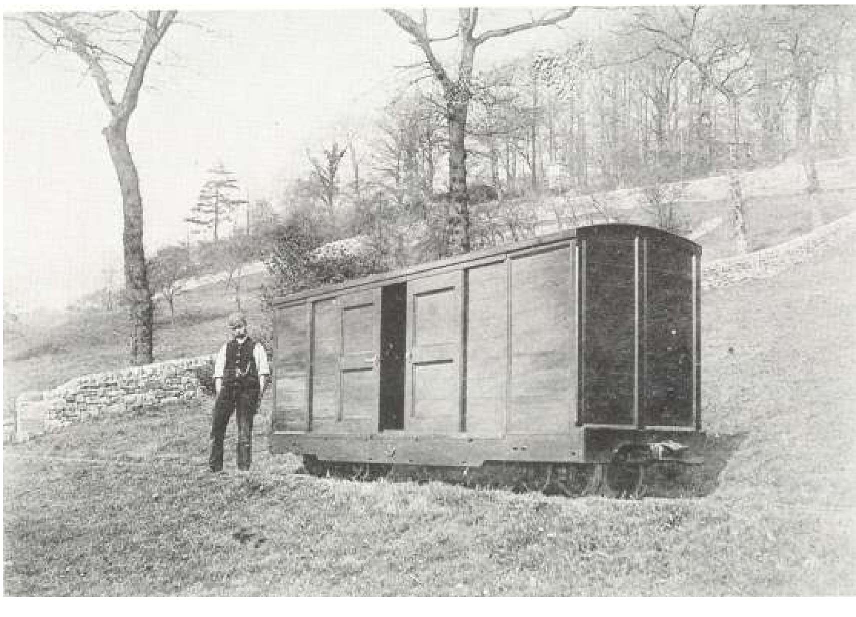


Engine No 4, Eaton Railway, 1896.

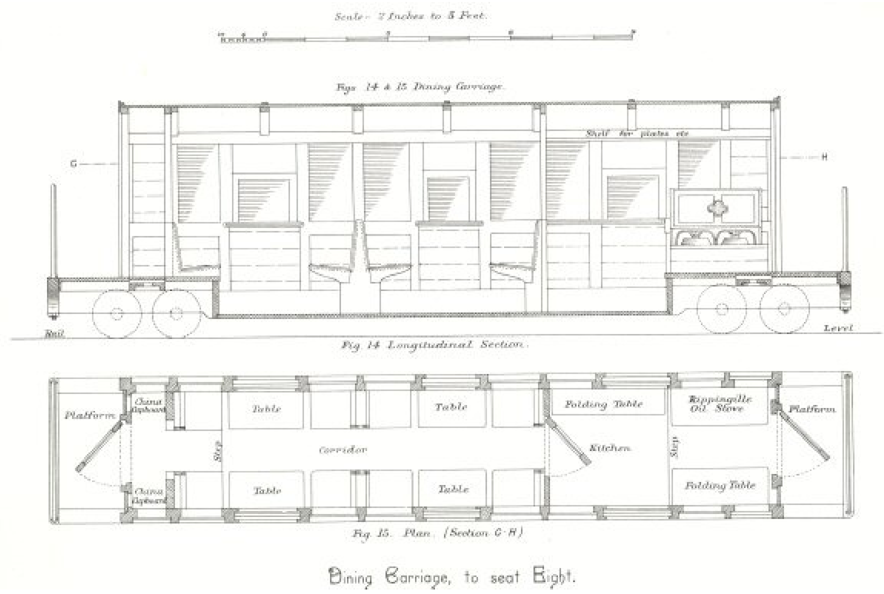
Dining Car (to seat eight), Duffield Bank Railway.



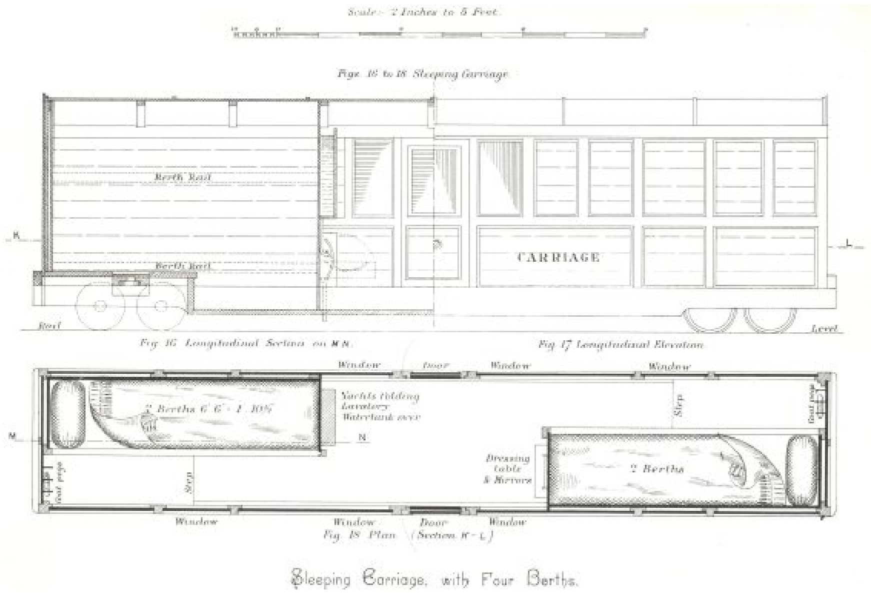
Parcel Van, Duffield Bank Railway.



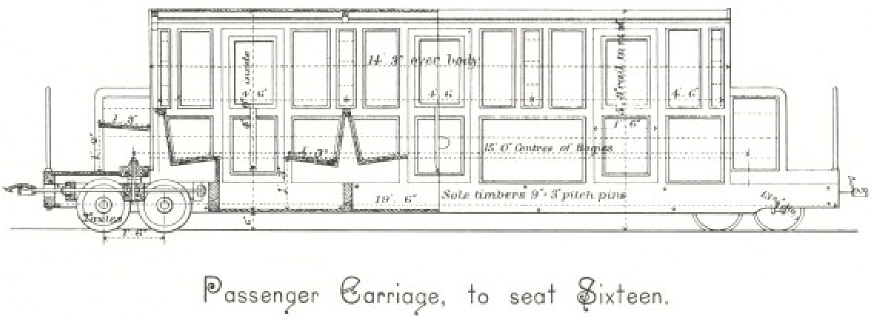
Arrangement drawing of Dining Carriage to seat eight.



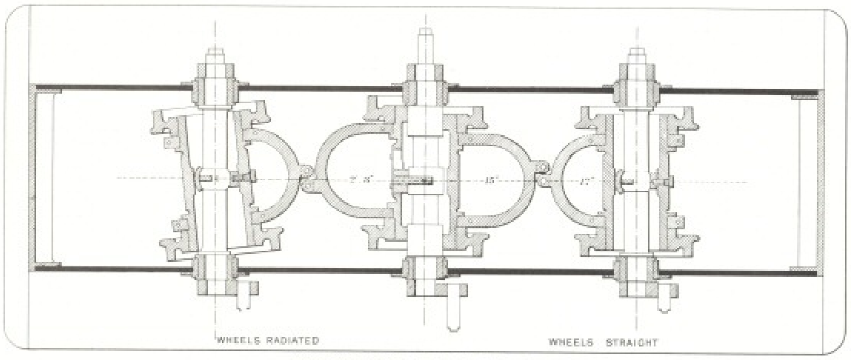
Arrangement drawing of Sleeping Carriage with four berths.



Side elevation of Passenger Carriage to seat sixteen.



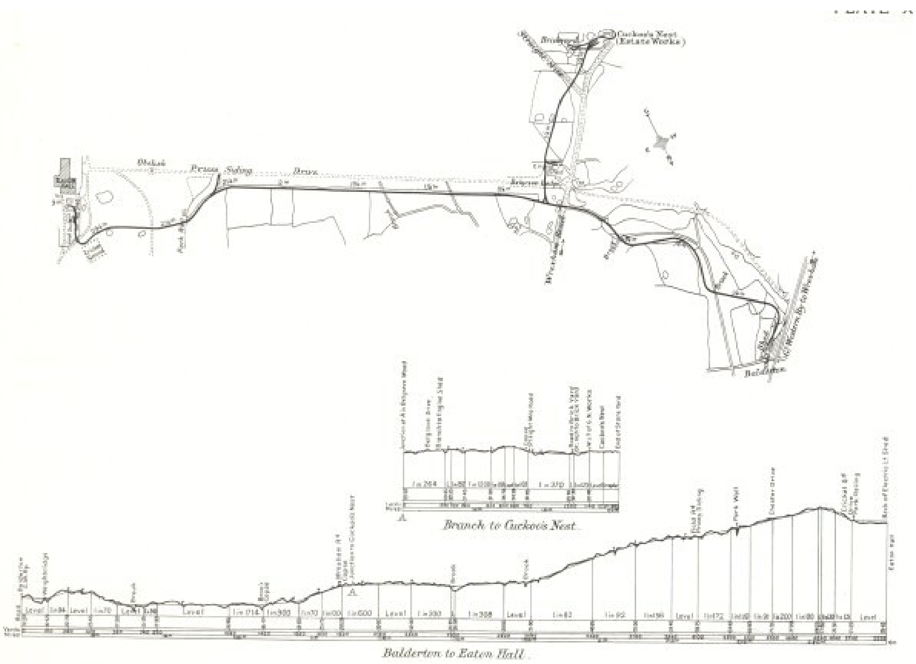
Arrangement of Radiating Wheels on six-coupled engine No. 2.



SECTIONAL PLAN OF RADIATING GEAR.

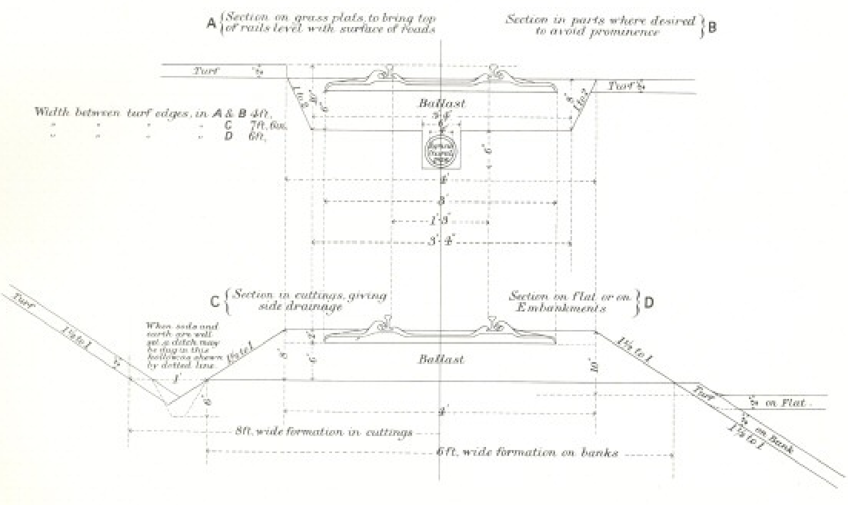
Arrangement of Radiating Wheels on Six-coupled Engine No. 2.

Plan and Section of Eaton Railway



Plan and Section of Eaton Railway.

Cross Sections of Eaton Railway



Cross Sections of Eaton Railway.

FOOTNOTES

[46] The then approaching Board of Trade Light Railway Conference.

[48] The Duffield Bank Railway is here referred to.