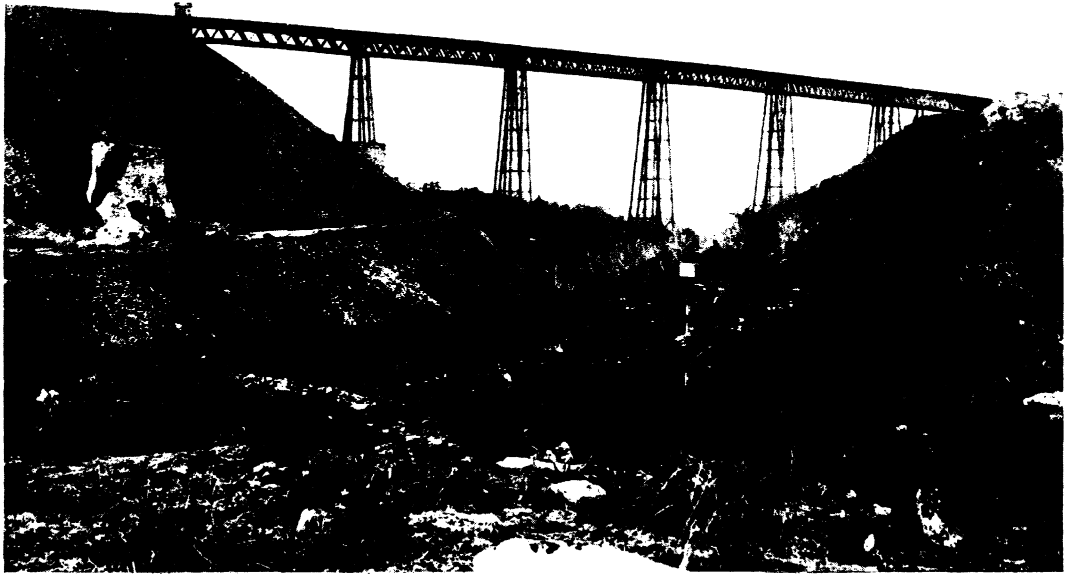
THE RAILWAYS OF GREAT BRITAIN



MELDON VIADUCT, SOUTHERN RAILWAY

[Frontispiece

THE RAILWAYS OF GREAT BRITAIN

BY

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ILLUSTRATED

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PREFACE TO FIRST EDITION

I HAVE to express my most sincere acknowledgments to a great many gentlemen connected with various British railways, and with the Chemin de fer du Nord in France, for the help which they kindly gave me, either by showing me things personally, or by giving me facilities of different kinds, or by supplying photographs.

M.

August, 1913.

PREFACE TO PRESENT EDITION

SINCE the first edition of this work was published in 1913, so many changes affecting British railways have taken place that it has had largely to be re-written. These changes made a rearrangement of chapters desirable, and this has been carried out. The consideration, too, of various railway problems has been carried further.

The general idea is, as before, to present in intelligible form suitable for the lay reader a not too detailed account of most of the more prominent departments of railway activity in this country, the intricacy and importance of which have always exercised great fascination over many minds.

British railways having come into existence early and having always had a very large public to serve, have had exceptional opportunities for keeping themselves efficient and progressive. While they have on the whole provided a service fully equal to that found in any other country, they have in many respects fallen short of their opportunities.

If then a study of British railways reveals a certain solid efficiency, largely due to the great amount of capital originally put into them, there is unfortunately another side of the picture which is by no means so satisfactory and which also receives attention. From the earliest days the administration of railways passed into the hands of a hierarchy of professionals who, apparently in order to secure a quiet life for themselves, very quickly introduced and firmly established a spirit of such intense conservatism and unwillingness to consider new ideas upon their merits that the history of the technical development of railways has in too many directions been a history of strenuous resistance to reasonable improvements. As the position of the railway hierarchy left them judges in their own cause and, as the general public is so ignorant of technical railway questions that it is almost impossible to rouse public opinion on any technical subject except to some extent in connection with safety appliances, progress on railways has been extremely slow.

The hierarchy has not, of course, endeavoured to hold up what may be called routine improvements—that is to say, little developments that must in the nature of things suggest themselves to men who pass their lives doing some one particular kind of work—but large, far-reaching changes have usually been much delayed or altogether prevented. To be precise, the following list of some of the more important questions affecting railway development may be given, together with the way in which they have been treated by the railway hierarchy :—

Block Signals.—Introduced slowly and unwillingly under great pressure from the Board of Trade, resistance to this reform being finally broken only when it was enforced by law.

Continuous Brakes.—Ditto.

Use of Superheated Steam.—Question ignored for many decades and nothing done till the matter had been worked out in Germany. In consequence, many millions of tons of coal wasted.

Acceleration of Express Trains.—Whole question boycotted.

Making up of Lost Time.—Question ignored, huge waste caused thereby and a decided element of danger introduced.

Improved Rail-joints.—(Rail-joints are more imperfect than any other part of a railway.) No serious attempt ever made to find a remedy for the defects in ordinary rail-joints.

Introduction of Third Class Sleeping Carriages.—Question boycotted.

Some of these questions are further considered in the body of this work.

There is no reason to suppose that railway officers individually are less progressive than other people. I believe that many of them deplore the inertia of the railways as much as I do. But in an elaborate organization like that of a railway, the members of the official hierarchy who dislike change for its own sake have enormous opportunities for obstruction, and there is no doubt that what may be termed the " machine " has a firm and deadening grip upon the railways.

I am deeply indebted to many gentlemen connected with British and various foreign railways for much help which they have been so kind as to give me either by showing me things personally, giving me facilities of different kinds, supplying photographs, or reading proofs.

No attempt has been made to describe the railways outside the four groups.

The passages relating to trade unions were written before the outbreak of the general strike of May, 1926.

M.

June, 1926.

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CHAPTER I

IN whatever direction we look we find that the progress of civilization is forwarded by the genius of inventors, the enthusiasm of pioneers and the enterprise of capitalists, but just as no important development can be started without these things so surely is its progress hampered and thwarted by the obstruction of officialism, and the crude plunder of politics. In these respects it is perhaps not surprising to find that the story of railways differs little from that of any other branch of organized human activity.

Directly any big concern is started it must from the nature of the case be staffed by a number of officials and clerks. Perhaps the first instinct in human nature is to surround itself or its business with a ring-fence and to make every effort to prevent the entrance within this barrier either of the person or of the ideas of anyone who is not both by profession and in mentality of a piece with itself. As people of enterprise and originality are rare this means that the dead weight of officialism is usually thrown against developments or improvements of anything more than a routine character.

Officialism is much the same wherever it is found. Differences of environment produce slightly different results in the fighting Services, the Civil Service, and in large public companies, but the heart of the matter is always the same.

The ideal which officialism of every kind everywhere seeks to achieve is a quiet life for itself; and, to secure this quiet life, it is always striving so to arrange things that they will for ever afterwards run themselves, thus absolving the directing officials from accepting any responsibility and from the trouble of thinking out any desirable developments. This of course does not mean that no one of energy and independence is ever found in the official ranks. Notoriously men of energy and independence are, and have always been, found there. But usually any considerable reform in the working of a Government department or of a large public company has to command the assent of so many different people, each one of whom practically holds the power of veto, that considerable reforms rarely take place unless the case for them is so obvious and so overwhelming that obstruction is swept away and they practically impose themselves. But for this to happen the case in favour of reform must be clear indeed.

One great obstacle to many kinds of reform is the difficulty of getting the advantages, which the reforms in question offer, understood. Practically the only subjects for reform on which it is possible to rouse a formidable amount of public opinion are those which offer direct pecuniary advantages to the public; technical or semi-technical questions of the first importance are so little understood that it is almost impossible to rouse enough public interest in them to bring about the application of the pressure which is required to get anything done. Officials in quest of a quiet life refuse to move only so long as they find that immobility secures for them the absence of discomfort which they desire.

When agitation for reform reaches a pitch which makes it less uncomfortable for them to give way than to remain immovable they capitulate at once. To such an extent indeed is reform where officialism is concerned simply a matter of applying the requisite amount of pressure that by far the greater part of human progress (or, for that matter, of human retrogression also) seems to be due to the action and reaction of forces which come into existence from causes so simple as to be practically blind.

As regards politics it is with regret that they must be mentioned at all. It is a calamity that politics should have anything at all to do with the working of railways or with any other matter that is essentially economic in its nature. But as things are economic matters are everywhere so much distorted by the attempts which are made to subordinate them to politics that to endeavour to write about railways without any reference to politics would be futile. At the present time the economic situation of practically the whole world reflects the sickness of democracy.

Almost everywhere democracies, mostly new, misled by their own ignorant desires, and lending a ready ear to disturbers of the peace who promise them ease and plenty from a supposed inexhaustible fund of wealth belonging to anyone but themselves, which has no existence in fact, are living on such realizable capital as they can lay their hands on, and storing up for themselves a future in which the only means of avoiding famine will be to accept less wages for more work than they ever did before.

Railways suffer from these two sources of trouble in very much the same way as all other branches of organized human activity suffer from them. We shall frequently have occasion to notice the baneful effect which one, or the other, or both together, have exercised upon the development of railways from the earliest days to the present time and to regret the delayed introduction or the total absence of many reasonable improvements which have been blocked on their account.

In working a railway there are three parties concerned—the public, the shareholders, and the railway servants—and, for the best results to be secured, the interests of all three must receive due consideration. If, from one point of view, the interests of the three parties are divergent, and one may undoubtedly secure some temporary profit at the expense of the others, a broad consideration of all the facts shows that such a triumph brings with it no lasting gain, and that the interests of all three parties are really identical. If, for instance, rates and fares are made so low that the shareholders receive no dividends and the railway servants inadequate pay, then no more capital is forthcoming for developments, the railway servants do their work badly, and the service provided is in consequence certain to be a bad one. If too much is distributed in dividends to the shareholders, or if the railway servants receive excessive pay for performing an inadequate amount of work, analogous evils arise, which shortly affect that party also, which in the first instance profited at the expense of the others. It is, therefore, highly desirable for everyone concerned that this community of interest should be recognized; and it is certainly a bad thing that any one of the three parties enumerated should be in a position to starve the others for its own supposed benefit.

So long as it is desired to preserve competition, or some semblance of competition, between railways in the same country, private ownership is a necessity, and the question of State ownership does not arise—at least not the question of the State ownership of all the railways. When, and if, it is definitely decided that competition is undesirable or unattainable, a new set of conditions are met with, and one of the barriers to State ownership has been removed.

Under State ownership the State takes the place, which, under private ownership, is held by the shareholders, and in theory there is no reason why State railways should not be worked on the same principles as railways owned by non-competitive private companies. One school of thought, indeed, which favours State ownership, does so on the ground that the railways would still be worked on commercial lines, only with greater economy and efficiency. This school may be called the commercial school. They see certain obvious causes of waste, which tend to increase the cost of privately owned railways, such as the existence of what they consider an unnecessarily large number of directors and high officials, and sometimes two trains running where one is enough. They think, perhaps, that rates are too high and that the energy of the companies is misdirected. They therefore favour State ownership because they see the advantages that would be possessed by a single administration in reducing waste and being able to direct its energies into the most economical channels, unhampered by competition. They may also think that a State department, being the servant of the whole nation, would be less avaricious and fairer in its charges than are private companies. But the views of this school would be almost as well met if the railways, instead of being taken over by the State, were united under a single private company, which would be bound to grant new facilities to the public every time it increased its dividends.

The political school of thought, on the other hand, which favours the nationalization of railways, ranges from those persons who have a sentimental objection to the existence of any large monopoly in private hands, through the social reformers, who consider that the working classes do not receive a fair share of the good things of life, and that the existence of a large body of organized or organizable work-people, directly employed by the State, would be a convenient means of bringing pressure to bear towards effecting in a peaceful manner that redistribution of wealth which they desire, to the anarchists, who, working on the same lines as the social reformers, but with different ends in view, conceive that, under State ownership, the railwaymen might be easier to influence than they now are, and that a large and united body of Government servants, thoroughly aware of their power, might, if they could be worked up into a state of sufficient discontent, be very effective allies for the purpose of over-throwing all existing institutions. The aims, therefore, of all the people composing this class are essentially not economic aims; they have not necessarily any desire to increase the efficiency of railways as a means of transport, but, being dominated by ideas, the fulfilment of which they regard as of paramount importance, they wish to turn the railways to account in promoting their ideas, without in any way considering what the other effects of State ownership would be.

In theory then, the commercial and political schools have nothing in common, though, as a matter of fact, the people who favour the nationalization of railways are not sharply divided into one school or the other, but often look to securing greater economy and efficiency concurrently with the introduction of social reforms affecting the railway servants. This often really means that they hope to mix up business with philanthropy—a proceeding which, to say the least of it, is not likely to have good results. But, whatever the views may be of those people who desire the State ownership of railways, there can be no doubt at all as to the first result of such a reform, and that would be immensely to increase the power of the railway servants. As Government servants, all under one employer, they must be far easier to organize than they are at present, and the united pressure which they could exert on a Government department, by means of their voting power, must be immeasurably greater than the pressure which they can now exert upon the different companies, which are not amenable to direct pressure from votes at an election. Moreover, the officials of a Government department, because they are practically irremovable, would have even less direct interest in the finances than have the officials of a company, and must therefore have less desire to take the trouble to resist unreasonable demands on the part of the railway servants.

In case the railways were nationalized, it is quite likely that some economy would be sought in reducing the salaries of the principal officers. It is probable that the principal officers of British railways at the present time receive salaries a good deal higher on an average than those paid to the principal officers of any State-owned railway on the Continent. The chief advantage of paying adequate salaries appears to be that it induces in the recipients a feeling of self-respect, and in their subordinates a tendency to look up to them, which might otherwise be absent. The reason sometimes put forward that good salaries attract the best brains, although superficially attractive, will hardly bear serious examination. Upon railway work practically every one enters in early youth, long before he can have formed any real estimate of his own abilities, and when the remote chance of eventually occupying one of the positions to which fairly large salaries are attached can scarcely be regarded as an inducement to adopt the profession. And, like many other occupations, the railway service does not offer any particular facilities for a specially good brain to make itself felt. Those fortunate persons who have made their way to the highest positions would probably be the first to admit that their success has been due to a hundred accidents of influence or luck, and that for each possessor of a good brain who has reached a high position, there are a score of others, equally gifted, who have been left behind. It is probable that a reduction of the salaries attached to the principal positions would not mean that less capable men would be secured, but that these men would have less influence than is now the case.

In 1907 a certain unrest, which had for some time been apparent in the railway world, came to a head, and there were threats of a strike, which might perhaps have attained some magnitude. The exact degree of seriousness in the situation was a matter of great uncertainty. Some people thought that the situation was very serious indeed, and others were of opinion that no strike of any importance was in the least likely to occur. However that may be, the representatives of the companies and of the men each agreed to meet the Board of Trade officials, and an elaborate scheme of conciliation and arbitration was drawn up and accepted on the spot by all the big railways, except the North Eastern (which "recognized" the men's unions and had different arrangements). The servants of each company were divided into a number of classes, for each of which a Conciliation Board (composed of representatives of the company and of the men) was appointed. The men were not at liberty to elect representatives who were not in the service of their own railway. These Boards were to endeavour to settle any dispute which might arise. If they failed to do so, the dispute was to be referred to a Central Board, representing the company and the whole of its servants. If, here again, no agreement was reached, the matter was to be referred to arbitration. A considerable number of claims were put forward by the railway servants and in some cases settled by the Conciliation Boards. In the case of some companies the claims were referred to arbitration, and the men were generally awarded certain small advances in wages and slightly improved conditions of service. Partly owing to the small benefits which they received under the conciliation scheme, partly because under it the claims of the different companies were treated in different ways by the different arbitrators, partly because the scheme (not unnaturally) took some time to get into working order, and possibly also, it is to be feared, because the trade-unions never attempted to give it a fair trial, the men were dissatisfied by it, and the dissatisfaction thus engendered was at least the ostensible cause of the strike of August, 1911, during which perhaps as many as 150,000 men were for a short time on strike together. The object of the strikers on this occasion was apparently to force the railway companies to negotiate directly with the officials of the various trade-unions, to which a considerable proportion of railway servants belonged.

Now, one of the greatest difficulties in devising efficient machinery for the settlement of disputes between the railway servants and the companies is that of ensuring that this machinery shall be used only for the purpose for which it has been called into being, and particularly is this the case where trade unions are concerned. Though a considerable proportion of railway servants belonged to trade-unions, the larger number did not belong. The trade-union officials were always wanting the railway companies officially to recognize their existence, and to negotiate directly with them on matters which concerned the union's own members. If the companies had agreed to do this, it is probable that they would thereby have increased enormously the strength of the unions, because those railway servants, who held aloof from the unions, would have been likely to join in large numbers if the unions had become the recognized channel of communication with the companies. Rightly or wrongly, the companies (except the North Eastern) were reluctant to raise up bodies so powerful as the unions would have become if the great majority of railway servants belonged to them. If it were reasonably certain that the policy of the unions would be directed by the unconstrained good sense of the majority of their members, and if there were any real assurance that the members would agree to be bound by any and every settlement reached by the leaders, there would be great reason for encouraging powerful trade-unions to come into existence. But, unfortunately, it is notoriously the case that neither of these conditions can be relied on to obtain in practice. Trade-union leaders often have strong political leanings, and make use of their positions to further their own political ideas, and it has for long been quite common for trade unionists to repudiate settlements made on their behalf by the officials of their unions.

A point on which the railway companies lay much stress is that, as they are answerable for the safety of the travelling public, they must be absolutely unfettered as regards the men whom they choose to promote to occupy the most responsible positions, and in the maintenance of discipline. The same is the case in matters of policy. For instance, one of the complaints of the men is that, owing to the policy of using bigger engines, which haul trains much heavier than was formerly the case, the number of engine-men required is proportionately reduced, and promotion in this department is retarded. This is, of course, the old story of that increasing efficiency of machinery, which, here as everywhere else, bears very hardly upon the labour which it displaces, but is, at the same time, essential to the increased prosperity of the community, by the very fact that the labour which it displaces becomes available for other productive purposes; the process of adapting this labour to these purposes is unfortunately a slow and painful one, and it is in no way surprising that the unoffending victims of the process should give vent to the bitterest complaints. But to give the trade-unions facilities for opposing a policy which is to the public advantage is, to say the least of it, undesirable.

The report of the Royal Commission, appointed after the strike of August, 1911, to inquire into the working of the conciliation scheme of 1907, accepted the views of the railway companies as to the undesirability of such recognition being granted to the trade-unions as would enable the unions to interfere in questions of discipline and policy. The fact that the report was signed by all the members of the Commission, including those whose sympathies would under no possible circumstances be adverse to any reasonable demands made by the trade-unions, justifies in the completest manner the attitude taken up by the railway companies on these points. But, when this is said, there is no reason whatever for assuming that railway servants may not, like other people, have real grievances, and, as it is fairly plain that no Government will ever be able to allow a general railway strike to go on to the bitter end, on account of the suffering and annoyance which would thereby be inflicted on the public, there was urgent need for giving the railway servants suitable means of calling attention to any grievances to which they might consider themselves subject. With this in view, the Commissioners suggested certain simplifications in the conciliation scheme of 1907, which in effect amounted to the abolition of the Central Conciliation Boards; and the proposals of the Commission, with few modifications tending to give the men greater facilities for presenting their case, were accepted by both sides. The question of the recognition by the companies of the men's unions, which threatened to bring about a fresh strike, was settled by allowing the men's secretary on the Conciliation Board to be a person not in railway employ, so that a trade-union official might hold this position. Questions of discipline and policy were, however, excluded from the scope of the Conciliation Board's activities.

It is probable that a cause which contributes much to such discontent as exists is want of sympathy with their subordinates on the part of some of the railway officials. As industrial and commercial concerns get bigger and more complicated, the gulf which divides the official and his subordinate widens, perhaps inevitably, and innumerable causes of friction arise through want of sympathy and understanding on the one side, and ignorance and inability to state a case on the other. To these are added suspicions of nepotism and undue influence, in a large proportion of cases possibly groundless, but none the less irritating because they are not disproved. This state of affairs can hardly be considered to be the fault of any one in particular, but is rather one of the unfortunate results of modern industrial conditions, for which it is to be hoped that time will bring a cure.

When on the outbreak of war the railways passed under Government control the question of the recognition of trade-unions appears at once to have been settled by the unions being recognized by the Government. At the time of the railway strike of 1911 the unions did not comprise a majority of the railway servants but from that time onwards great efforts were made by the unions to increase their membership with the result that by the outbreak of war by far the greater number of railway servants appear to have been members of one or other of the different railway trade-unions.

This does not necessarily argue any spontaneous movement by the railway servants to join the unions, as in the present state of the law a small determined minority have such great powers of applying intimidation to any unorganized majority, however large, that much more force of character than the average human being possesses is necessary to resist the pressure of the organized minority.

This is not the place for re-telling in detail the melancholy tale of blackmail extorted from a bleeding country by trade-union action, during and after the war. The most that can be said in extenuation of the railway unions is that they were no worse than a large number of other trade-unions, and a large number of profiteers of many other kinds besides. It must also be remembered that to a very considerable extent their proceedings defeated their own object, as indeed they necessarily must do, by automatically reducing the purchasing power of money. But, even when allowance is made for this, there is no doubt that the action of the trade-unions was successful in causing a large amount of the nation's capital to be realized or pledged, and distributed in wages to the working classes, thereby increasing the amount of capital consumed during the war, and reducing that available for the carrying on of industry and the maintenance of civilization.

It is probably wrong to attribute a great deal of blame to the general body of the railway servants for the deplorable deeds that were done in their name by the trade-union organizers. I have already pointed out that it is impossible to consider railways apart from politics. Going back to first causes it is pretty clear that the root-cause of the unrest throughout the world is that things have not yet accommodated themselves to the enormous material change wrought by the advent of the industrial era.

Up to the present time the only method evolved on a large scale whereby the interests (or supposed interests) of the working classes can be represented when it comes to bargaining on behalf of large numbers of men with other people representing large concentrations of capital is by trade-union organization. This would be very well if the workmen had any real idea of the economic facts controlling the situation, and if their representatives confined themselves to putting forward proposals in accordance with these facts. What, unfortunately, really happens is that almost the only people who have sufficient energy and enterprise to take the trouble to run a trade-union at all are a small number of fanatics (usually half-educated or over-educated people and often quite unconnected with the trades the members of which they are supposed to represent) who find trade-union organization a most convenient means of forwarding their own political ideas, which are as little concerned with the welfare of the people they are supposed to represent as they are with the real facts of the situation. By means of the frantic and insane energy of people of this type the law has been so rigged as to assure to them every facility for organizing gangs of bullies who, under the protection of the law, are practically entitled to break the heads of any workmen who resist them, and so ensure by intimidation any action on the part of the workmen which cannot be ensured by cajolery. Obviously civilization cannot last where such conditions are in force, but the above is, I believe, no fanciful picture of the existing state of affairs.

In these circumstances the pay of the railway servants in common with that of most classes of workmen was, during and after the war, continually forced up; a system was introduced of paying all railway servants in any particular grade the same wages, no matter how much or how little work they were called upon to do, and immediately after the war an eight-hour day for all railway servants was also introduced. During the war passenger fares had been increased by fifty per cent, but goods rates had not been altered, and such losses as the railways incurred were regarded as war expenditure and shouldered by the nation. The next step was an attempt by the trade-unions permanently to fasten upon the community the obligation to continue paying the railway servants at the highest rates reached no matter how much the purchasing power of money might increase. In endeavouring to enforce this claim the railway trade-unions called the great strike of 1919, which for a day or two practically paralyzed all the railways in the country. The claim was eventually compromised by an undertaking on the part of the Government that, no matter how much the purchasing power of money might increase, no railway servant should in future receive payment on less than a given scale, which corresponded roughly with twice his pre-war wages, and that a bonus graduated in accordance with the current value of money should be paid in addition.

So far as I am aware the exact details of the bargain were never published, but the result was that the railway companies were permanently saddled with an expenditure on wages far more than double their pre-war expenditure. So long as Government control of railways continued (which was not very long) and the country remained solvent all went merrily, but when Government control came to an end the question of how these hugely increased wages could continue to be paid became and remains acute.

In the period immediately following the armistice, when the whole country was committed to an orgy of waste, and its affairs were conducted as if an inexhaustible supply of wealth existed for financing any scheme that the Government thought fit to ask Parliament to sanction, the Ministry of Transport was set up and the first idea appears to have been to nationalize the railways. With the return of the first flickerings of financial sanity it was quickly perceived that the nationalization of railways was first and foremost one of the items in the programme of those revolutionary politicians who desire to encompass the downfall of civilization. These people quite clearly hope to turn all the public services into engines for directly distributing so much of the capital of the country as it may be possible to seize, in the form of hugely inflated wages, with the very definite object of dissipating as much wealth as possible, then leaving the country to face famine, and so inducing famine riots on the largest possible scale.

Nationalization having been decided against, a bill on different lines was introduced and in August 1921 was passed into law.

Railways from the time of their first introduction have not ceased to develop continuously as regards their relations with the public, with the railway servants and with one another. These developments have been brought about partly by the railways themselves and partly by various forms of persuasion or pressure from outside. One form of development in particular has been very noticeable almost from the time when railways came into existence and that is the tendency of small units to coalesce and so form bigger units.

As a general rule little opposition to this process had been experienced, but in certain cases, especially during the years immediately before the war, the desire of railways to combine with one another outran the willingness of Parliament to sanction such combinations. During the war, for the whole of which period the railways were under Government control, all ordinary development ceased, but very great alterations due to the war itself and to circumstances directly consequent upon it were introduced, and at the end of the war things were in a position which made some sort of broad settlement, recognizing and sanctioning certain war-time developments and laying down the lines along which future developments were to proceed, if not imperative, at least desirable.

Among the matters with which the Railways Act deals three are of outstanding importance. They are the grouping of railways, the provisions with regard to charges, and those relating to the wages and conditions of service of the railway servants.

As has just been remarked the grouping of railways is a process which has been going on almost from the time when railways came into existence. It is chiefly owing to the haphazard way in which British railways came into existence that measures were not taken from the beginning to form the railways into large groups with districts entirely to themselves as was done in France. As it was promoters of railways were from the beginning encouraged to build fresh lines in districts already served by other railways. Nothing had been properly thought out and the idea seems to have been that this system would encourage competition and so prove of advantage to the country. When things had once been set going on this principle it was found impossible to abandon it, and the continual amalgamations that have taken place had, up to the outbreak of war, done very little towards giving to each company a well-defined district of its own.

The Railways Act is a great step forward in the process of amalgamation, but in the matter of allotting to each group a well-defined district of its own it does practically nothing, and in the tangle of lines belonging to the different groups there is very little simplification to be observed in comparison with the former tangle among the lines belonging to the different companies.

Though the unregulated way in which British railways came into existence is no doubt the most important reason for the present absence of clean-cut geographical edges it must be remembered that Great Britain is not a country that would be easy to parcel out satisfactorily even if a complete fresh beginning could be made. A long, straggling, country with the capital near one corner and many thickly populated industrial districts very irregularly scattered in various directions would not in any case present facilities in any way comparable with those found in France for the establishment of a really neat system of railways.

France indeed occupies an altogether special position in this respect among all the principal countries of the world. France is not very far removed from being circular in form, and Paris is near enough to the centre of the country to render possible a most convenient arrangement of main-lines radiating evenly in all directions; this arrangement is yet further assisted by the three great commercial centres of Lille, Lyons and Bordeaux lying in such a manner that the main-lines thither from Paris fit in quite naturally with the general scheme of radiating main-lines.

Beyond all this the preponderantly agricultural character of the population of by far the greater part of France causes an extremely even distribution of population outside the few great industrial and commercial areas. When to these advantages is added the fact that the French railways were from the beginning planned as one connected whole it is not surprising to find that they are much better arranged than those of any other big and populous country.

Germany, where the natural facilities for laying out a satisfactory system of lines are not much less than is the case with France, is actually far worse off than France because at the time when railways came into existence and for many years afterwards a large part of Germany was in the hands of the rulers of a great number of small independent States and no attempt was made to plan the railways so as best to serve the country as a whole. Any difficulty that might have existed on this score in the way of allotting districts to each of a number of railway administrations was in pre-war Germany overcome by the unification of the Prussian lines under a system of nationalization, which arrangement in turn put so much power into the hands of the Prussian administration that it was practically able to dictate orders to the railways of the smaller States. The Prussian Minister of Public Works was practically the dictator of the whole German railway system. The political arrangements in Germany before the war rendered the nationalized railways entirely immune from the conditions which in democratic countries make it impossible for the State to work railways at a profit.

In the United States in the same way the absence of centralized regulation at the outset has produced a railway system in the thickly populated part of the country as complicated as that of Great Britain.

It is then in France alone that a combination of favourable circumstances has given the country a really well-arranged system of railways, each with its own district which in hardly any case overlaps the district of any other railway. If the Railways Act has failed to achieve so neat a division in Great Britain there are adequate reasons to explain the failure, and although the British arrangement cannot compare with the French in well-planned completeness, it is France alone among the big countries whose system is greatly superior to that of Great Britain.

As regards charges the Railways Act contemplates a complete revision, the new charges to be so adjusted as to assure to the railways, with good management, a revenue sufficient to pay reasonable interest on capital. Earnings in fact are to be adjusted to requirements, not requirements to earnings. It may here just be remarked that a principle so much at variance with the conditions of terrestrial existence would seem to have little prospect of achieving success and we may then immediately pass on to a consideration of the question of wages and conditions of service.

The arrangements prescribed for settling questions regarding wages and conditions of service practically amount to leaving them to be decided between the railways and the various railway trade-unions. In the first place any proposal brought forward by the management or by the men of any group is to be settled if possible by direct negotiation between the management and the elected representatives of the men. If no settlement is effected by this means there is an appeal first to a Central Wages Board composed of eight representatives of the railway groups and eight representatives of the trade-unions, and from them a further appeal to a National Wages Board.

The only difference between the Central Wages Board and the National Wages Board beyond the fact that the latter has an independent chairman is that in the case of the latter two representatives appointed direct by either side to the Central Wages Board are replaced by four representatives of the users of the railways. But as the sympathies of the four bodies nominated to appoint one representative each are such that on any controversial question their votes are certain to be equally divided, what difference there is between the two bodies is almost entirely one of appearance. It is true that the National Wages Board, which is the final court of appeal, has an independent chairman, whatever that may be worth; but the existence of this gentleman is the only scrap of independence visible about the whole arrangement, and it is only very hopeful people who will think that anything at all will be settled by a system so vicious.

To begin with the arrangement is calculated to drive the whole of the railway servants into, and keep them in, one or other of the unions, which have hardly shown themselves to be bodies to whom questions vitally affecting the prosperity of the country can safely be entrusted. Then, while it is fair enough to begin by attempting to settle any question that may arise by direct negotiation between the interested parties it is obviously entirely wrong in principle to constitute the Central and National Wages Boards, which are judicial bodies, from partisans (though this system is one beloved alike by officialism and by revolutionary politicians, and always when possible practised by both in their own interests). Clearly the right principle is to recognize that the interest of the public is the first thing that counts in the matter of running the railways as in everything else, and the people who should give the final decision are representatives of the public unconnected with either party to the dispute. The members of the Central and National Wages Boards might very properly appear as witnesses or advocates before such a body, but to give to partisans of either side the right to sit as judges in their own cause, and to each side the power to neutralize the proposals of the other and to prevent anything from being settled except on the basis of a compromise in which the interests of the public are likely to be ignored, cannot be regarded as a satisfactory arrangement. The result of the first attempt of the railway companies to be relieved of part of the burden of paying the railway servants the very high wages promised them during the period of Government control well shows the futility of hoping for any reasonable adjustment by means of the arrangements laid down in the Railways Act.

In 1923 the position was that, in accordance with the agreement reached between the Government and the railway trade-unions, the railwaymen were receiving wages very much higher in proportion to those they received before the war than was the case with the great bulk of the working classes (except those engaged in trades like building and printing, or those in the civil or municipal service, who, like the railwaymen, find themselves able, temporarily at least, to corner their respective occupations). The workmen in these sheltered trades, who are in reality drawing tribute from the rest of the population, are of course a constant source of irritation and unrest for the less favoured members of the community.

As almost the only hope of reducing transport charges was to reduce wages, the railway companies made an application for a reduction of enginemen's wages. The reductions suggested were on a scale much smaller than would have been necessary to restore the pre-war balance between these wages and those of the working classes as a whole. The arbitration went to the National Wages Board who sanctioned only a small portion of the reductions applied for, and even these were not accepted by the men without a strike. The trouble about this business of pay and conditions of service is that the whole situation is put out of perspective by the purely political and perfectly unrealizable idea that it should first of all be decided what are reasonable wages and conditions of service and then charges should be so regulated as to produce enough money to pay for them. This idea underlies the whole conception of "standard revenue" which is the foundation upon which the Railways Act is built. It assumes that when it has once been decided how much revenue is to be raised it is only necessary to fix charges high enough and the revenue will be forthcoming.

It is hardly necessary to point out that this is a complete delusion. People will go on using the railways just so long as they find it worth their while doing so and no longer. There is for all kinds of traffic without exception some limit to the charges that the users of the railways are able to pay. If charges are raised above the limit applying to any class of traffic this traffic simply ceases to pass and the revenue to be derived from it, far from being increased, ceases altogether. The truth of course is that there is in the nature of things no such thing as a minimum standard of living below which wages must never be allowed to fall. Wages corresponding to such a standard can be paid if earned, but not otherwise, and railwaymen, just like everyone else, though they may for a time contrive to arrange things so that they can live on the nation's capital, must in the long run accept approximately what their work is worth.

In a huge and complicated system like the economic life of a big country there is of course no accurately adjustable standard for measuring precisely the economic wage of any class of workmen. Some must frequently get a little more and others a little less than a perfectly accurate measurement of the value of their work would allot to them.

It is probable that for some years before the war railwaymen's wages were somewhat lower than should have been the case in view of the value of their work. The value of money had been steadily, if slowly, falling since the beginning of the century, and while most other trades had been free to adjust their prices to the current value of money, railway charges could not easily be altered, so that both railway servants and railway shareholders were somewhat worse off than they should have been in comparison with other categories of workmen and other categories of shareholders.

Now things have gone the other way to an enormously greater extent as regards the workmen whose privileged position can be maintained only so long as the rest of the community consent to continue being bled to provide them (together with the workmen in other sheltered trades) with wages much higher than their services are worth in the open market.

It must also be observed that the Railways Act which practically (not of course explicitly) guarantees the railway servants double their pre-war wages, guarantees to the shareholders only their pre-war dividends, thus carrying a step further that war against thrift which threatens to engulf civilization by constantly reducing the supply of fresh capital available for productive purposes.

Competition, when it really exists in what may be called a free state—*i.e.*, unhampered by limiting conditions explicitly or tacitly arranged between the competing parties—undoubtedly stimulates the spirit of enterprise, and tends to the introduction of all sorts of speculative improvements. Some of these may involve waste in the same way that a proportion of all enterprising speculations end in failure; but the public gain, due to the success of the remainder, which, but for competition would never have received a trial, may far more than compensate for the waste involved in the failures.

For some reason which is difficult to fathom, the railway companies in the past always spread abroad the legend that a large amount of keen competition existed between the different companies, which involved them in heavy expense. Keen competition no doubt existed in very early days for the territory which the different companies desired to serve, but competition of this kind has from the nature of the case, long dwindled into insignificance.

Beyond this such competition as has existed has been chiefly in the form of a certain amount of more or less surreptitious bidding against one another by rival canvassers for goods traffic. For some years before the war this form of rivalry had, by agreement between the companies, been reduced to very small proportions. In passenger charges no serious competition (at any rate not openly avowed competition) has ever existed and as regards facilities the companies have usually been so much terrified of provoking competition that the existence of two or more companies serving the same places has had the very decided effect of preventing the introduction of reasonable improvements. It is safe to say that any competition that has existed between British railways in the lifetime of the present generation has been a matter of very small importance.

When the question of the new grouping of the railways was being debated a great deal was heard of the savings that might be expected from the elimination of competition. Actually things have turned out if anything rather the other way as regards the elimination of competition. What gave verisimilitude to the suggestion that great savings were possible was the fact that the lines of the different companies were in many parts of the country very closely interlaced and in such a way as to make a large amount of competition possible. It is probable that the question was considered of redistributing the railways between different groups in such a manner as to leave each group with a district of its own from which the lines of all the other groups should be excluded.

The difficulties of such a scheme were apparently found to be too formidable and the arrangement which has been made merely provides for the grouping together of the various companies, all the companies in each group retaining the whole of their lines however closely they may intersect the lines of any other company belonging to another group. In these circumstances the possibilities of competition for traffic between the same places are but little less under the grouping arrangement than they were before. The groups, moreover, being bigger and more powerful than any of their constituent companies, would appear to be, if anything, more likely to engage in competition than the old companies showed themselves to be. This however is not saying much, for, as already remarked, such competition as there was between the old companies amounted to very little.

While large savings due to the elimination of non-existent competition are certainly not being effected, there are nevertheless considerable possibilities of economy from grouping. For one thing it is far easier for a single authority to introduce all sorts of cross-country services than it used to be when these services had to pass over the lines of several different companies; then again a single authority in control of two routes between the same places should undoubtedly be able to pass more traffic over the two routes than two separate authorities, each one controlling a single route, could do.

British railways have spent large sums for providing facilities which have no necessary connection with actual railway transport. In no part of the world do the railways confine themselves to the business of transport by rail. In undeveloped countries they sometimes practically administer whole provinces, and are directly concerned in almost every form of activity there prevailing. Though in settled countries the relative importance of railways is not so great, they invariably extend the field of their operations to a greater or less extent outside the mere working of their lines. They provide road transport to carry passengers and goods to and from their trains, hotels for the accommodation of passengers, and warehouses for goods, docks and harbours to give connections between their trains and sea-going vessels, and, very often too, lines of steamers of their own. In Great Britain they also, as a rule, manufacture the greater part of their own requirements in their own workshops. British railways are remarkable among those in settled countries for the extent to which they have carried outside activities, and, not unnaturally, in a sea-girt country like Great Britain these activities are primarily in connection with the sea. It is manifest that a concern, which possesses railways on land, vessels on the sea, and docks and quays to connect the two, is in an extremely strong position for keeping in its own hands any traffic that it may once secure. British railways have not only done their best in this manner to secure and keep for themselves existing traffic, but have shown great enterprise in developing new routes. There is hardly a railway of any size in Great Britain which does not, either directly or through a subsidiary company, possess a considerable fleet; all the more accessible ports of the coast of Europe are served by the steamers of some railway company or other; the railways run many steamboat services between different points in England and Ireland; and, if the railways have no actual share in the ownership of the great ocean lines, the London, Midland & Scottish and the Southern stand respectively in very close relation to the shipping interests of Liverpool and Southampton.

Owing to the policy, which has been pursued in England, of allowing a railway to be built anywhere, where a reasonable demand existed, by anyone who would undertake to do it, the number of different companies, which came into existence, was very great. Many of them were gradually absorbed by the bigger companies, but till the Railways Act of 1921 came into force a large number of minor companies still existed, of more than a few of which most people did not know the names. And this was not all, for the lines worked by the larger companies comprised many sections built and owned by independent companies, and there were also the numerous lines owned jointly by two or more of the big companies. Over nearly all these the traffic was given through rates and fares, which had to be apportioned between the various companies, which owned and worked the different lines. This apportionment was a work of great complication, and, to carry it out, a central body, independent of all the beneficiaries, became practically a necessity. The body on whom this gigantic labour fell was the Railway Clearing House, an institution which has grown up with the railways themselves, and, perhaps for this reason, performed, and still performs, its work with such mathematical precision as to give its clients the nearest approach to complete satisfaction.

In the years before the War the question of the development of canal traffic came very much to the fore, and a Royal Commission was appointed to investigate the matter. Many people are under the impression that, if canals were properly developed, they would at least provide a means of transport for minerals and non-perishable goods consigned in bulk much cheaper than railway transport. In various Continental countries canals are much more highly developed than they are in Great Britain, and a large proportion of the traffic of such countries as France and Germany is carried over the inland waterways. It must not be forgotten, however, that the natural facilities for inland water-borne traffic are in many parts of the Continent much greater than they are here in Great Britain, owing to the existence there of great navigable rivers, and to the flatness of large areas of country, which makes the construction of canals easy, and much reduces the difficulties of keeping them supplied with water. Instead of navigable rivers, Nature has provided Great Britain with a much longer and more convenient coast-line than her Continental neighbours possess, and this extra length of coast-line far more than compensates for the very small amount of navigable river which she has. But, while Great Britain is naturally much less well suited than some other countries for the inland carriage of goods by water, a still more formidable obstacle to the development of canals is found in the conditions of trading which obtain in this country. The inland transport of commodities in bulk has been reduced to very small dimensions. Almost all commodities and articles of commerce are stored or warehoused in bulk at some large centre (very often a big port, whither they have been brought by sea, either coastwise or from foreign countries), and the smaller points of distribution throughout the country are kept supplied from these large centres with small consignments sent off exactly as they are wanted by trains travelling at considerable speeds. Now, canal transport is necessarily slow and best suited to the transport of goods in bulk—*i.e.*, it is just the opposite of what British traders have grown accustomed to—and any considerable increase of canal traffic would have to be accompanied by a change in the conditions of trading which are now current. This must obviously be so difficult to effect that, unless some great economic advantage could confidently be looked forward to from increasing the amount of canal traffic, it would probably be better to spend any money that might be available upon further development of the railways in preference to spending it on canals.

It is interesting to look towards the future and endeavour to decide whether railways are likely to be an enduring phenomenon or whether, when they have served their turn, they are likely to be displaced by some more perfect method of transport. The essential advantage of a railway is that it provides a means whereby vehicles can be moved with an extremely small expenditure of power in comparison with their weight, and this is due to the hard and smooth surface offered by the rails. It is safe to say that no means will ever be discovered which will present any advantage worth mentioning over a railway in this respect. In addition to the advantage of the very small amount of power required to move the vehicles, a railway offers the further very great advantage of complete control over the direction of movement—the vehicles cannot deviate from the line of the rails and no steering is necessary. It may be assumed, therefore, that no system of transport can ever be much cheaper to work than is a railway. The only kind of system which could possibly compete with railways would be one which was much cheaper in first cost.

There are three possible media by which transport can be carried on—land, water, and air. While it is perhaps not impossible that some form of single-rail arrangement, worked by rolling stock swung below it, or kept upright above it by means of gyroscopes, might be much cheaper to build than an ordinary railway, especially in mountainous regions, it is most improbable that any such arrangement would offer advantages which would make it worth while adopting it generally in any country already well supplied with railways of the ordinary kind ; and, even so, it would merely be replacing one kind of railway by another. Some kind of automatic guiding seems absolutely essential for land transport carried on in bulk ; as this is very well supplied by rails, it seems hardly possible that rails will ever be dispensed with ; and, in view of the very great efficiency and safety of the ordinary system, it is difficult to see how this system could ever be exchanged for another.

Water transport possesses, of course, in favourable circumstances, advantages with which railways cannot compete. Where Nature supplies the waterway, the first cost involves nothing but the provision of boats and landing-stages. Water transport is, and was from remotest antiquity recognized to be, the most natural means of transport, and this gave it a long start of railways ; and the construction of canals and the deepening of the courses of rivers, the natural developments of water transport, were available for facilitating such transport long before railways came into existence. In spite of this, railways had in most cases no difficulty in catching up and out-distancing the inland waterways as avenues of traffic, and even the Royal Commission on Canals, who desired to see a development of the British canal system, did not venture to suggest that this could be carried out without a State guarantee. In these circumstances it hardly looks as though railways were in much danger of being permanently superseded by any method of inland transport by water.

There remains the possibility of the development of air transport. As with sea transport, the first cost would be confined to providing the vehicles and landing-stages, and great possibilities of economy present themselves. But the many obvious difficulties in the way of carrying on a large, regular, and frequent traffic by way of the air need not be enlarged upon, and the possibility of effective competition with railways by means of air vessels is probably remote.

So far, then, as it is possible to look ahead, there seems little likelihood of railways losing their importance. As time goes by no doubt more and more perfect methods of moving and controlling trains will be evolved, but as far as the actual railways are concerned, there is a good prospect of their usefulness continuing for centuries.

CHAPTER II

THE system of management of British railways presents many points which are open to criticism. The shareholders, who are the actual owners and the people whom the financial results principally concern, must, from the nature of the case, delegate their powers of control to a committee. This committee is the Board of Directors, who are supposed to be elected by the shareholders. In point of fact, the Board, to all intents and purposes, elect themselves. The directors periodically retire by rotation, but it is the rarest thing in the world for any director who offers himself for re-election not to be re-elected by acclamation. If any director retires or dies, the Board simply nominate his successor.

In theory the Board of a railway consists of persons of good business ability, who, possessing the great advantage of wide experience in other matters besides railways, have at the same time enough special knowledge to have a definite opinion in all matters of policy, and to enable them to exercise effective control over the railway officers. Now this the Boards can hardly be expected to do when the circumstances are considered. There are, no doubt, a good number of first-rate men of business on the Boards of the different railways, but these gentlemen are nearly all notoriously engaged in other business pursuits, which must leave them little time which they can devote to the work of railway directing, and they are frequently deficient in special knowledge of railways. The consequence is that the officers, who really do devote their time to their work, and are adequately paid for so doing, find themselves—beyond having to keep within certain financial limits—subject to hardly any effective control, and have, as a rule, practically a free hand.

A railway in fact, like any other big business, is not really managed by its proprietors, but by experts, who may, and very often do, have little or no pecuniary interest in it.

One of the proposals put forward in connection with the reorganization of railways after the war was that representatives of the railway servants should be given seats upon the Boards of Directors. The proposal, having presumably been found impracticable, was eventually dropped, but not before the confusion of thought of some of its advocates and the deliberate intention of others to use it for the purpose of squeezing money from the shareholders, had been made abundantly clear. As things are the pay of the railway servants is a first charge upon the earnings of a railway. The shareholders can in no circumstances receive anything at all until the whole of the railway servants have received the whole of their wages. Though it is no doubt in the long run not merely advantageous, but essential, in the best interests of the railway servants that the shareholders should not be deprived of a suitable return upon their capital, there is not, practically speaking, the least chance that representatives of the railway servants if they were put into a position of control over the finances of a railway company would be willing or indeed able to use their powers for any purpose other than to pay the largest possible amount in wages. In any sort of commercial undertaking indeed the only way in which equilibrium can be maintained between the interests of the workmen and of the shareholders obviously is that that party whose remuneration is not a first charge on revenue shall have financial control of the undertaking. There is not, theoretically at least, any reason why this party should not be the workmen.

Though the practical difficulties are usually found to be insuperable, there is in principle no objection to any business being run entirely by workmen on borrowed capital if interest on the borrowed capital is a first charge on the earnings of the business, that is to say if interest on capital is paid before the workpeople get their wages. Under conditions such as these the usual position would merely be reversed, and the party having financial control would still be obliged to let the other party live; but if the party with financial control were further given the power of helping itself to as much as it liked before the other party got anything at all, it is particularly unlikely that this other party ever would get anything.

If the railway servants are to appoint directors without the working of the railways becoming impossible it must be under some scheme of profit sharing. Every time the men were paid there might, for instance be set aside a sum proportional, according to some agreed scale, to the sum disbursed in wages, and strictly earmarked for paying dividends. This would of course involve reducing wages if at any time there were not available a sum to be set aside for the payment of dividends sufficient to meet the requirements of the agreed proportion between the two. That is to say there would have to be a real partnership in which both parties would share alike.

There is in any case a rather serious technical objection to the appointment of serving railwaymen to the Board. In their capacity of directors they would be the official superiors of the officers of the line and in their capacity of railway servants they would be subordinate to the officers of the line. This objection might be overcome by making only retired railway servants eligible for seats on the Board.

It is a commonplace that the capital which has been laid out on British lines is much greater proportionally than that which has been laid out on any other railways in the world. The expenditure per mile of the South Eastern & Chatham was nearly £100,000; of the London, Brighton & South Coast about £67,000. Various reasons are given to account for the great first cost of the railways. British landowners are said to have demanded exorbitant prices for their land; legal expenses are said to have been excessive. Without being concerned to examine these allegations, which are certainly to some extent true, we must not forget, when complaint is made of the very large amount per mile which British railways have cost, that a mile of railway in Great Britain is, on an average, a much more valuable thing than a mile of railway in any other country. There is no country in the world where, in proportion to mileage, there is so much double, and even quadruple line, and, when the cost per mile is spoken of, a mile only counts as a mile, however many lines of rails there may be running side by side of each other. British railways, again, are exceptionally well provided with rolling-stock, the stations are unusually numerous, the signalling arrangements are adequate for coping with a very rapid succession of trains, sharp curves and excessively steep gradients have generally been avoided, there are few level crossings, the lines are enclosed in the most elaborate and expensive manner, and the permanent way of all the big companies is tolerable, and much of it is really good. So, if British railways have cost a great deal (nearly £50,000 a mile on an average) to build and equip, they have, on the other hand, a very large earning capacity, and, owing to the generally high (if somewhat varying) standard of their equipment, they are, all things considered, cheap to work.

Railways, whose capital expenditure has been small, may achieve good results on a small volume of traffic economically conducted; but, for British railways, which have spent so much capital, and have been built to cope with traffic on a large scale, to have any chance of paying well, it is essential that their turnover should be very large. This being so, it often appears as though too much attention were given to keeping down the ratio of working expenses to gross receipts, while not enough was devoted to endeavouring to secure the highest possible ratio of net receipts to paid-up capital.

Thick as the traffic already is in Great Britain, there are few existing lines which could not accommodate a great deal more than they actually do accommodate, and, if a considerably increased volume of traffic could be secured, it would not matter if the ratio of working expenses to gross receipts did go up. A turnover of £1,250,000, with working expenses at 84 per cent, produces the same profit as a turnover of £1,000,000, with working expenses at 80 per cent. In ordinary circumstances, moreover, the greater the total volume of traffic, the cheaper it is to work. In many places, where existing lines are capable of carrying more traffic than they now have to deal with, it might be very well worth while reducing charges and spending money in giving increased facilities in order to secure a greater turnover.

The theory of the financing of public companies, like railway companies, is that the capital consists partly of debentures (which are technically loans) and partly of shares. The debenture-holders receive interest at a fixed rate upon their holdings, and, so long as this is forthcoming, are not entitled to interfere in any way in the management of the company, which is the property of the holders of the shares. Ordinary shares are moderately speculative investments, and, as such, sometimes fail to satisfy either those persons, who desire above all things a regular return upon their money, or those who desire shares the value of which may fluctuate sharply. In these circumstances a practice arose of dividing each ordinary share into two parts, one of which (preferred ordinary share) was to receive the whole of the dividend due upon the undivided share up to so or so much per cent, and the other (deferred ordinary share) anything that might be available beyond the dividend upon the preferred share. The stability of the preferred share was thus assimilated to that of debentures, while most of the speculativeness attached to the undivided shares was transferred, and in a higher degree, to the deferred shares. An objection to stock splitting from the point of view of the welfare of the company is that, if the value of the deferred shares falls very low, it is possible for anyone, by the investment of a comparatively small amount of capital in these shares to acquire a disproportionately large measure of the controlling influence, which the voting power attached to these deferred shares confers on their possessor ; but the risk of this is considerably diminished by the fact that it is always arranged that the holder of a large block of shares has proportionately much fewer votes than would attach to the same holding distributed among a number of small investors.

One of the innovations introduced by the Railways Act is that a very largely increased volume of statistics is to be furnished. For many years the question of railway statistics has been a matter of acute controversy. In some parts of the world elaborate statistics have for long been compiled, in other parts the very minimum has been done.

The case for statistics is that they increase knowledge. Suitably compiled statistics indicate exactly what is going on in each branch of railway work, and they enable comparisons to be made between the results achieved in different places, inefficient arrangements or slovenly work to be detected, and steps to be taken for producing better results in the future.

On the other hand statistics cost a good deal to compile, and must be intelligently used if they are to produce good results. Hard and fast comparisons, for instance, drawn between two sets of conditions which may quite easily contain differences which the statistics do not reveal may in the hands of a rigid bureaucrat, lead to the commission of injury and injustice. So there is really a great deal to be said on both sides of the question. Under the Railways Act of 1921 Great Britain is to become a highly statistical country so far as the working of her railways is concerned; the schedule to the Act shows no less than nineteen sets of returns which are to be rendered periodically, in addition to those before required (which since the Act of 1911 have of themselves amounted to a not inconsiderable volume).

The fixing of rates and fares is the most important and also the most difficult question connected with railways. Owing to the enormous part railways play in present-day life, and the almost absolute dependence which everyone is obliged to place upon them, any unfairness in their charges must have the most serious results, while at the same time the number of different considerations, which have to be borne in mind in endeavouring to decide what constitute fair charges, make the problem one of the greatest difficulty. It is clearly ou of the question to attempt to fix fares in accordance with the actual expense incurred by the railway company in transporting each passenger. Hardly two consecutive miles of any railway have cost exactly the same sum to build, the prices of different kinds of engines and carriages vary, the railway companies' profits vary with the number of passengers carried in any particular train, and with the number of trains run over any particular line, and so on. Then there are questions of public policy to be considered. A railway, being a State-sanctioned monopoly, cannot be left free to fix its charges in the same way as a private business can be left free. Many branch lines in remote parts of the country, without much traffic, must be sources of very little profit to the companies, but the railways may not try to recoup themselves by charging specially high fares on lines of this kind, as this would inflict special hardships upon the people who use them, and, it is considered, would conflict with the duty of the State as far as possible to ensure that none of its citizens is subjected to special disabilities. On the other hand, it is of great importance to enable workmen, whom modern conditions have forced to live in localities remote from their places of work to go backwards and forwards at very cheap fares. Railways, as well as other concerns, can afford to give a reduction on a quantity, and the cheapness of workmen's tickets is to some extent compensated by the great numbers of workmen who travel. But besides workmen, many other kinds of passengers get the benefit of this principle to a greater or less extent. Chief among these are the season-ticket holders, who, if they travel a great deal, get very large reductions on what they would have had to pay as ordinary passengers. Railway companies love the season-ticket holder. He is often a man of substance, whose living on the line means much more profit than his own season ticket brings; he travels at regular, and, therefore, convenient, times, and, once firmly established on the line, is likely to remain there.

So, hardly any attempt is made to fix fares in accordance with the expense incurred in building the line, the ordinary fares being almost always exactly in proportion to the distance, but the principle of granting a reduction on a quantity is met with in a variety of forms. Beginning with a small reduction on the double fare in the case of some return tickets, the principle is carried to greater lengths in the matter of week-end tickets to certain selected places; excursion tickets, issued when large numbers of people may be counted on to travel in a manner which makes their transport very economical, are cheaper yet, and tickets for workmen's trains, when the conditions of excursion trains are reproduced in a higher degree, probably cheapest of all.

As so few people have any money to spare, it is always found that the great bulk of travellers gravitate to the cheapest class. The only really effective way of preventing practically the whole travelling public from utilizing the cheapest class is to abstain from running carriages of this class on fast trains. In England this measure is very little adopted, and railway managers have long had to face the problem of what to do with the first and second-class carriages. The Midland long ago abolished second-class carriages, and this example was followed to a very large extent by other companies, so that the second-class has almost been crushed out of existence, but the problem of the first-class is a different matter. It is recognized that some means must be provided for people who desire it to secure, by the payment of a higher fare, a greater degree of comfort and privacy than is afforded by an ordinary third-class carriage. The only real questions appear to be how much extra fare is to be demanded, and how the extra comfort and privacy are to be provided. The principal objection to the present arrangement is the great difference existing between the first- and third-class fares, which to the minds of most people is far greater than the difference in the accommodation given in the two classes. But, as the cost to the railway company must be approximately in proportion to the space occupied by the passenger, and a first-class passenger gets nearly twice as much cubic space reserved for him as a third-class passenger, it would be necessary, if first-class fares were much reduced, to effect also a reduction in the space offered, which would seriously diminish the already too small attractiveness of the first-class.

At intervals very faint protests are raised against the British system of not registering luggage when it is conveyed by train. As the protests never seem to attract any attention worth speaking of, it looks as though most people were quite satisfied with the present arrangement, which is certainly rapid and convenient, and, although luggage is theoretically more likely to be lost or stolen if it is not registered, the extreme rarity with which anything of this kind happens in England effectively disposes of the fancied advantage of registration from this point of view. Practically every other system, indeed, adds seriously to the trouble of a journey at each end, and, even if registration, as practised on the Continent, makes it slightly less likely that the luggage should get lost outright (which, moreover, is very doubtful), it is only necessary to read the correspondence columns of the newspapers to be speedily convinced that it is very far indeed from preventing thefts from taking place *en route*. In America, if a traveller is so unwise as to be travelling with his own luggage, the difficulties of securing it on arrival at his destination are often considerable, and if the arrival takes place late at night, the chances are that he will be told that he cannot have it at all till the following morning.

If the fixing of passenger fares is a complicated matter, the complications encountered in fixing goods rates are greater still. From the point of view of a railway company, one passenger is very much like another—each passenger finds his own way to the station, buys his own ticket, gets into the train by his own motive power, when there occupies the same amount of space as each of the other passengers of his class, and at the end of the journey alights of his own accord and goes about his business. But with goods it is very different. A consignment may weigh a few pounds or may want a whole train to convey it; it may, or may not, be perishable and require to be sent off and delivered at express speed, it may want special care in loading, transit, and unloading, it may have to be sent in specially constructed vehicles, and it may be packed in a manner easy to handle or the reverse, and so on. The trouble and expense, therefore, involved in transporting equal weights of goods varies within far wider limits than is the case with passengers, and goods rates are naturally graduated far more finely than are passenger fares, while the principle of granting a reduction on a quantity is yet more firmly established.

For the purpose of charging rates, goods were up to the year 1920 divided into eight classes. For the first 20 miles the rates on goods belonging to each of these classes varied from about 1d. to 4.30d. a ton a mile; if the distance exceeded 20 miles, the rates per ton per mile for each of the next 30 miles were somewhat lower; if the distance was more than 50 miles the rates for each of the succeeding 50 miles were lower still, and they were lower again for each mile beyond 100. (These rates did not include terminal fees, fees for loading, unloading, etc., nor, in the case of the lowest rates, the use of wagons.) They were, in each case, the maxima that could be charged by law, but these maxima were by no means always charged in practice. Moreover very large numbers of things, in which there is a considerable traffic, were given rates lower than the class-rates which they would otherwise have been called on to pay.

This scale of rates effectually prevented the railways from making charges higher than were therein authorized. But, up to the time of the passing into law of the Railways Bill of 1913, it was not held that the companies had the power of increasing up to the maximum limit, or indeed at all (unless there were very special justifying circumstances) any existing rate lower than the maximum, and very few increases were in fact put into force. Under the Act of 1913 the railways now possess this power, but may use it only to recoup themselves for expenditure incurred in raising the wages and improving the conditions of service of the railway servants.

Any experimental reduction of rates on British lines has therefore always been very difficult, owing to the fact that, if the reduction failed to produce the hoped-for effects, and it was desired to put the rate up again to its former level, the railway company might be called upon to justify the increase before they put it into force. This did not, however, prevent the North Eastern from putting into operation for certain mineral traffic a sliding scale of rates, which appeared to work well and give satisfaction. The rates rose and fell automatically, according to whether the trade in the minerals concerned was good or bad. The North Eastern, which had its own district to itself, no doubt had facilities for making experiments, which other railways did not possess.

Besides everything else, railway rates are fixed with due consideration for " what the traffic can bear." That is to say, certain luxuries and articles of considerable value are quite frankly called upon to pay more than the actual cost of their transport, together with a fair profit, would amount to. This is to some extent a matter of public policy. It is manifest that, if goods of this kind are obliged to pay more than their share, other kinds of goods need not pay their full share, and, if these other kinds comprise the necessaries of life, the cost of living may thus be artificially cheapened. From a purely economic standpoint such a state of affairs is no doubt deplorable, but certainly it plays some part in the fixing of rates.

Rates, again, are frequently arranged so as to increase the area whence supplies are brought to a given centre. To effect this, the rates on commodities despatched to this centre are often very little more, if they come from great distances, than if they come from comparatively short distances—the difference in the rates is, at any rate, much less than the difference in the distances. As the actual transport—apart from terminal expenses—must cost the railway a sum more or less proportional to the distance traversed, there can be no doubt that the commodities which come from furthest off receive in a manner preferential treatment, but, the area of supply being increased, the consumer gets a greater choice, and in this manner the public interest is served.

These are perhaps the most important general principles on which rates are fixed. But beyond them a great many factors come into play, and rates are determined upon a close consideration of all the facts of any given case.

A discussion, which is constantly arising, is upon the question whether the railways, in order to secure the carriage of goods, which they would otherwise not get at all, are justified in carrying them at rates lower than those at which they carry the same sort of goods, which must in any case pass over their lines. If it is a question of utilizing the rolling-stock for a very small return, or leaving it idle, it may be more profitable for the railway to accept very low rates indeed in order to earn something on its capital instead of nothing. And as, by hypothesis, if the railways did not grant the low rates, rates equally low would be granted by some other means of transport—for instance, steamers—it can hardly be contended that the goods in question receive, in this manner, unduly favourable treatment.

The principle of giving a reduction on a quantity has often led to very bitter complaints against the railways on the part of persons who fail to supply large consignments, or who are refused a reduction because they deliver their consignments to the railway company in such a form that only a comparatively small amount can be transported in each vehicle used. To judge from the newspapers, complaints in regard to the rates charged on British railways for the carriage of farm produce are more frequent and bitter than those in regard to anything else. It is said that foreign farm produce gets the benefit of rates so much lower than those granted to British produce that the former receives an undue preference in the markets of this country. In vain do the railways point out that, if British farmers would supply consignments as large as those coming from abroad, and packed in a way which would enable them to load a wagon to its full capacity, there is absolutely nothing that would cause them so much pleasure as to give the British producer rates as low as those of which the foreign producer receives the benefit. Apparently, the British producer will neither pack his goods in such a manner as to make them easy to handle, nor join with his neighbours in providing large consignments. The farmers go on complaining of the rates and the railways go on complaining of the obstinacy of the farmers, and there the matter seems to rest. It is, perhaps, possible that there is sense on both sides. The position of the railways is certainly clear and intelligible, and it is by no means unlikely that the British farmer gains more by avoiding the expense of elaborately packing his goods, and by being able to send off small quantities at any moment he finds convenient, than he loses in the extra railway rates. But, in the circumstances, he cannot reasonably expect to receive the benefit of the same rates as apply to foreign goods, which are forwarded under conditions much more onerous to their consignors.

During the war goods rates were not increased but during the year 1920 they were largely increased on two occasions. According to a report of the Rates Advisory Committee to the Minister of Transport the second increase raised them "to amounts approximately on an average 112 per cent above the pre-war figures." The increases imposed were not uniform but varied from 100 per cent upwards. These were temporary expedients introduced in the hope of diminishing the Government's liability on account of the guarantee that dividends equal to those earned in 1913 should be assured to the railway companies up to August 15, 1921, when Government control was to terminate. In the Railways Act which became law in August 1921 it was laid down that these charges were to remain in force for two more years unless different arrangements had been come to in the meantime. This Act contemplated a complete recasting of the system on which railway rates are charged. It set up a new body called the Rates Tribunal, giving the Tribunal something like a clean sheet on which to make a fresh start. In effect the task before the Tribunal is, after hearing evidence, to fix a completely new set of charges for the transport of goods, in accordance with certain principles contained in the Act the chief of which are:

(1) The elimination as far as possible of exceptional rates. Such exceptional rates as are approved to be not less than 5 per cent and not more than 40 per cent below the corresponding class-rates;

(2) The division of all rates so as to show how much is charged for the actual carriage and how much for each of the various terminal services;

(3) The scale of rates to be so arranged as to allow the railway to earn "with efficient and economical working and management an annual net revenue equivalent to the aggregate net revenues in the year 1913 of the constituent companies and the subsidiary companies absorbed by the amalgamated company" together with certain additions to cover interest on fresh capital invested since 1913.

Various reductions have been made in railway rates since these rates were put up to the highest point reached.

At the time of writing the Rates Tribunal is engaged, in accordance with the terms of the Railways Act, in settling a permanent schedule of charges.

CHAPTER III

In Great Britain the gauge of the rails—that is to say the free space between them—is and always has been 4 ft. 8½ in. on standard gauge lines. In other countries where the standard gauge is used the interval between the rails is not often the rails are laid slightly wider than this. In France always exactly 4 ft. 8½ in., which is equal to 1.435 metres; from the beginning the gauge varied from 1.435 metres to 1.450 metres. At the present time the most usual figure is, I believe, 1.440 metres except on the Paris-Lyon-Mediterranée where it is 1.450 metres.

It does not appear that the spacing of the two wheels upon the axle is varied in accordance with the gauge of the rails, but the rolling stock is allowed to run more loosely on the wider gauge. This may possibly account for the very noticeable difference between the motion of rolling-stock on the P-L-M. line and the motion of rolling-stock on other French railways. On the P-L-M. in my experience the vibration of the vehicles is less than on other lines but the oscillation is greater. I believe that on one or more French railways within the last twenty years the gauge has been slightly tightened up for the purpose of reducing oscillation. In Germany for many years the lines were laid a little wide of the strict 4 ft. 8½ in., but some time before the war it was decided to adopt the standard of 1.436 metres, to which most of the German lines now presumably conform.

There is a great deal of difference between permanent way which is perfectly safe, and permanent way which, besides being safe, is really good. The former is the indispensable minimum, universally attained in this country, but it is only necessary to travel about on the different lines to discover that some approach the latter standard much more closely than others. The extra expense necessary to lay down permanent way of the latter class is considerable, and though, regarded as an investment, it is sure in the end to bring in a handsome return, railway companies sometimes shrink from incurring it. In comparison with a merely safe permanent way, a really good and well-kept permanent way enables an engine to haul heavier trains with the same expenditure of fuel, occasions less wear and tear to the rolling-stock, is pleasanter to travel upon, and cheaper to maintain.

In early days various forms of permanent way were tried, but now for a long time the only sort of road used in Great Britain is the familiar one in which the rails are supported in chairs fixed to transverse sleepers, and secured to the chairs by means of wooden keys. Except for one thing, this form of road seems to be as good as any that could be devised. That one thing is the joint connecting the ends of the rails, and this—a weak spot in any kind of permanent way—is, perhaps, slightly more troublesome in a chair road than in a road laid with flat-footed rails. In a perfect road the joint would be as strong as the rest of the rail, and there would be no bump as the wheel passed over it. There is no reason at all to suppose that this problem of discovering a satisfactory rail-joint is insoluble. Inventors by the score have produced new forms of joint, but, as is so often the case in the matter of new inventions connected with railways, official interest and encouragement have been withheld and nothing has been done. Ordinary fishplates are still almost universally used, the only important difference between the different kinds being that some are longer than others. As the longer ones work with a more advantageous leverage, they are somewhat the more efficient, but, whereas when flat-footed rails are used, as in America and over the greater part of the Continent of Europe, it is possible to use fishplates of any required length, in British roads the presence of chairs used to support the bull-headed rails makes it difficult to use any but quite short fishplates. Practically all that is now done in England to increase the strength of the joint is, in some cases, to lay the sleepers on either side of it nearer together than the rest of the sleepers are laid, and to use extra big sleepers in these positions. No fishplates, however, which are now employed anywhere provide anything like a perfect road, and the rail-joints are one of the things connected with railways which are still conspicuously defective. Three-quarters of the fatigue of travelling is due to the endless succession of bumps, of which imperfect rail-joints are the cause, and a large part of the wear and tear of both road and rolling-stock is due to the same thing.

Fishplates are designed so as to make the joints as strong as the rails which they connect together, and, theoretically at least, when the joints are in good order, the form of the wave-like depressions made in the rail by the trains is almost exactly the same when they pass through the joint, as it is at every other point in their paths. But, however this may be in theory, in practice the unpleasant bump of each wheel as it crosses each joint is always more or less perceptible.

In old days the rails were made of wrought iron, but, now for a long time, steel has been the only material employed. Steel is made in different ways—almost always by some variety of the " open hearth " process—but the object of all is, of course, to produce a metal of the required hardness and toughness ; this result is attained partly by attention to the chemical composition of the metal, and partly also by arranging that, while its temperature is between certain limits, it shall undergo an adequate amount of compression between the rolls of the rolling mills. Rail steel is iron which contains small quantities of other elements—carbon is the principal hardening agent, and there are also various other things, which have more or less valuable effects. The amounts of all these ingredients have to be very carefully regulated, as, in almost every case, an excess or deficiency would have very undesirable results. A good many endeavours have been made to produce steel which will cause the rails to take longer to wear away than is now the case, and, for this purpose, variations are made in the process of manufacture, some of which involve the use of an additional ingredient like chromium or nickel. There is no doubt that some of these special steels show great resistance to wear, and in particular places, where the wear of ordinary rails is excessive, offer considerable possibilities of economy.

Since the inception of railways there has been a continuous tendency toward the employment of longer and longer rails, and of late this tendency has been a very marked one, the length in many cases having been increased from 30 ft. to 36, 45 and even 60 ft. (and in France to nearly 80 ft.). This, of course, correspondingly decreases the number of rail-joints, though, as the intervals left for the expansion of the rails by heat have to be increased, the ends of the rails may get a little more knocked about. If it were not for the necessity of allowing for expansion, it would be a fairly simple matter to weld together the ends of adjoining rails, and so get rid of rail-joints altogether; and, who knows but that some genius may arise who will discover a steel alloy which does not expand when heated?

The bull-headed rail, in almost universal use in Great Britain, has two heads; the upper one is large and heavy and so designed as to allow it to be much worn away before it is sufficiently weakened to render it no longer serviceable; the lower one, equally broad, has less depth, and serves to support the rail in the chairs. The total depth of a heavy modern rail is usually about 5¾ ins. The rails are laid to lean inwards, with an inclination of 1 in 20 so as to correspond to the conical shape of the wheel flanges. For curves of large, or fairly large, radius, the rails are not bent, and, in reality, form series of tangents to a circle.

The weight of the rails, though at first sight the most important element in the strength of the road, is really, within fairly wide limits, a matter of minor concern. On main lines, rails weighing, when new, anything from 90 lbs. to 100 lbs. a yard are employed, and, as they may all be worn down to well under 80 lbs. a yard, and still be capable of supporting the heaviest trains, there is in all cases a wide margin of strength. There are, however, certain places like the Forth Bridge where specially designed rails of weight greater than 100 lbs. a yard are in use. The greater the weight and strength of the rails, the greater the factor of safety; and the weight and strength of those used in British roads compares not unfavourably with the weight and strength of those used in other countries. As a considerable part of the metal of a flat-footed rail is utilized to form the broad foot, which adds very little to the rails' stiffness, bull-headed rails would appear to be stronger, weight for weight, than flat-footed rails. Nevertheless, the weight per yard of the bull-headed rails used in Great Britain is generally greater than that of the flat-footed rails used on the Continent, and about the same as that of the flat-footed rails used on some of the best laid lines in the United States. Other United States lines have, however, rails weighing considerably more than 100 lb. a yard. On the Continent the maximum stress to which rails may be subjected is generally somewhat less than is allowed in Great Britain, and is roughly in proportion to the smaller strength of the rails, but in the United States the rails are allowed to undergo maximum stresses at least 30 per cent greater, weight for weight, than is allowed in Great Britain.

It must, however, be pointed out that the apparently greater strength, weight for weight, of the bull-headed rail is by no means universally admitted to be a fact. In Germany in particular the view is strongly held that, weight for weight, the flat-footed rail is considerably the better of the two. In Europe the factor of safety is in any case so large that from the point of view of safety the matter is of little practical importance, and, as the bull-headed rail is evidently easier to roll on account of its greater compactness of form, it might still be the more economical to use, even if the form of the flat-footed rail were demonstrated to be the more correct.

Some years before the war it became apparent that there was in practice so little difference between the advantages offered by the different sections of rails most generally in use in Great Britain that standard sections of rails of different weights might be designed with a good prospect of their being widely used. This was therefore done, and at the present time rails of these standard designs are in general use.

The best British permanent way has always been celebrated for its solidity and the smooth running which it affords. The reason for this is not far to seek, and is found in an ample margin of strength in the principal elements that go to make up the road. The wheels of the train are supported upon the rail, the rail rests upon the chairs, the chairs are secured to the sleepers, and the sleepers are embedded in the ballast. Good ballast is, therefore, the first necessity for a good road. It must be thick enough properly to distribute the weight of a passing train over the whole subsoil, elastic enough to give the smoothest possible running, binding enough to prevent the least horizontal movement of the sleepers, and of such a nature as to retain no moisture in itself, and to allow rain to drain off rapidly. The sleepers must rest firmly on the ballast at both ends, but not in the middle, so that each one supports its full load without any tendency to swing like a see-saw round a fulcrum; they must be big and strong enough to support the loads put upon them; elastic enough to deaden vibration; and impervious to wet so as not to rot. When all these conditions are assured, the chairs and the rails, which they hold, stand on a really satisfactory base, and the train hums along serenely. Of all the various materials of which the very important ballast is composed, none is so well-beloved of the permanent way engineer as clean, hard, broken stone, which possesses in a high degree a combination of the desirable qualities enumerated, and, although expensive, is almost always worth using on lines where the traffic is heavy. The bottom layer of ballast is usually composed of large heavy stones, carefully packed by hand.

When railways were first introduced a great deal of experimenting with different forms of permanent way was necessary before it could be decided which were the most practical forms to use. Patterns of rail which should give great stiffness, together with enough bearing surface for the wheels above and the supports below, were by no means at once evolved, while the most advantageous method of laying the sleepers was up to comparatively recent times, a matter of controversy. Longitudinal sleepers will probably never again be used, except in special places, but for a long time the supposed advantages of affording continuous support to the rails led to their being extensively used in some parts of the world, and the proverbially smooth running of the old broad gauge trains on the Great Western is sufficient evidence that a very good road can be constructed with them. The comparatively unwieldly longitudinal sleepers are, however, much more difficult to lay and to renew than are the easily-handled transverse sleepers, and there are several other advantages of some value possessed by the latter. As each transverse sleeper is secured to both rails, it is a most effective means of preventing the road from spreading, whereas logitudinal sleepers have to be specially braced together at intervals for this purpose. Then, one of the first requirements for a good permanent way is that the drainage of water should be complete. Transverse sleepers offer no hindrance to efficient drainage, but longitudinal sleepers, by pressing down the ballast immediately underneath them, tend to prevent the free escape of the rain which falls between the rails.

In British permanent way the sleepers used are unusually thick and heavy, but not so closely spaced as is customary in foreign countries, where flat-footed rails are in use. Owing to the comparatively high price of timber in Great Britain, it is almost always found economical to impregnate the sleepers with creosote, which process about doubles their life without nearly doubling their cost. The use of creosote has another important result, as it has the effect of giving the sleepers a life approximately as long as that of the rails which they support, so that, when the sleepers are worn out, the rails are worn out also, and both can be renewed together at one operation.

The almost universal use of chairs in Great Britain is to some extent due to the softness of the wood, of which the sleepers are made; the wood is generally white fir. The softness of the sleepers makes it necessary to give the rails a greater bearing surface on the sleeper than would be provided by flat-footed rails, and so chairs are interposed for the purpose. Flat-footed rails can, indeed, be provided with an augmented bearing surface without the use of chairs, if flat steel plates are laid between rail and sleeper. Steel plates are, however, almost as much of a complication as chairs, while they are without the great advantage, which the latter have, of allowing the rails to be taken out and replaced quickly and easily. They are also rather inclined to clatter.

An important point in the construction of a solid road is to fasten the chairs as firmly as possible to the sleepers. There is always a very small amount of play between the two, but much can be done to reduce this play to the smallest limits. One of the best arrangements so far adopted is in use on the Great Western. The chair is cast with serrations below, which engage with corresponding serrations on the sleeper, and is fixed down under a pressure as great as it will have to bear in service by means of two bolts which pass through the whole thickness of the sleeper, with heads underneath it, and the upper ends, which protrude above the chairs, are secured by nuts. (Quite recently the Great Western has abandoned this fastening and adopted the fastening with three screws—one outside and two inside—which is now standard in this country.)

The enormous numbers of sleepers required on the railway makes the question of their supply an important one. If there are 80 to 100 million sleepers in use on the railways of Great Britain, the effect of a small reduction in price, or increase in durability, might be considerable. In this country wooden sleepers are nearly always used, and there is no doubt that creosoted wooden sleepers combine in a high degree the qualities required for making a first-rate road—toughness, elasticity, and little tendency to shift their position. But wood is by no means the only material of which sleepers can be made. Iron or steel sleepers can be employed, and possibly some form of armoured concrete sleeper will be found to possess advantages. Iron sleepers, though not used to any appreciable extent in Great Britain, are widely employed in some parts of Europe, while in tropical countries they are often indispensable, owing to the attacks which insects make upon wooden sleepers. Metal sleepers are generally made somewhat in the form of an inverted trough. They are, of course, quite thin, and therefore, unless the metal is very tough, they are liable to crack. The friction against the ballast is very much less than that of wooden sleepers, so that they are much more liable to shift their position, and it is not nearly so simple a matter to fasten the rails to metal sleepers as to wooden ones. There are, therefore, considerable difficulties in the way of adopting metal sleepers, and there is certainly no immediate prospect of this being done on a large scale in this country. But it is always possible that circumstances might arise which would make metal sleepers so much cheaper than wooden ones that there would be a great inducement to employ them.

A very good idea of the enormous magnitude of the work of keeping the railways supplied with sleepers is got by paying a visit to one of the places where the sleepers are received, stored and prepared for use. The Great Western has a large establishment of this kind at Hayes, from which the eastern parts of the system are supplied, though there are several points where similar work is carried on for supplying the districts which are not within easy reach of Hayes. The Hayes establishment is immediately beside the main line, and lies on the bank of a canal by which the sleepers are brought to it in barges. On being unloaded from the barges, they are built up into long stacks, which gradually attain a height of some forty feet beside the canal, and slope away to a height of some twenty feet or so on the landward side. The building of the stacks is facilitated by this slope, which enables the sleepers, as they are unloaded and hauled to the top of the pile beside the canal, to be lowered by gravity on the further side. A sort of wooden shoot, fitted with rollers, is used to help in this operation. It is laid on the top of a stack, anywhere it is wanted, and the sleepers are made to slide down it. The full capacity of the yard is about 300,000 sleepers, enough for about 140 miles of single line; they are left in the stacks to season for six months or more. The tops of the stacks are made accessible from the ground, without the use of ladders, by stairways made of sleepers, which are arranged to project some two feet from the stack. It is inadvisable for persons who are liable to suffer from giddiness to attempt to mount these stairways.

The sleepers, before being creosoted, are prepared in a machine tool of special construction, which planes the seatings for the chairs and bores holes right through the sleeper when bolts are to be used. This is done before the sleeper is creosoted, in order to allow the creosote free access to the various incisions. The sleepers are now loaded on to trucks, which run along a narrow gauge line to the creosoting cylinder. Each cylinder is some 70 ft. long and 6 ft. in diameter, and will hold about 300 sleepers at a time. When the sleepers have been run into the cylinder the end is securely closed up, and the air in the cylinder exhausted by means of an air-pump. When a high vacuum has thus been created, the creosote, which has previously been heated to a temperature of about 120 degrees F. to make it sufficiently liquid, is admitted into the cylinder from an adjoining tank, and a large quantity is at once absorbed by the sleepers. The amount thus absorbed is, however, not enough, and after the cylinder has been completely filled with creosote, a force-pump is set to work, which, in the course of an hour or so, thoroughly soaks the sleepers with creosote till each has absorbed about 3½ gallons, or 37 lbs. The force-pump is then stopped, the unabsorbed creosote run back into its tank, a fresh vacuum created, which cleans off the surplus creosote from the outside of the sleepers, and the process of creosoting is complete. All that now remains to be done before the sleepers are ready to be sent out for use is to take them to a shed where the chairs are fastened on accurately to gauge. They are then loaded onto the peculiar long low four-wheeled trucks on which they are sent out wherever they are wanted.

Besides sleepers of ordinary wood, the Great Western Railway uses a small number made of various Australian hard woods, which require no creosoting, and, though considerably dearer than the ordinary kind, give promise of having so much longer a life as to make their use economical.

The rails, owing to the heavy moving loads, which are constantly passing over them, and to the strains due to the application of the brakes, are practically always creeping—

i.e., very slowly moving along lengthwise in the direction of the traffic. This movement is very irregular in amount, but it is often necessary to readjust a line every few months. The readjustment is fortunately a fairly expeditious process. The keys are knocked away from three or four rail-lengths at a time, the fishplates are loosened, and the rails moved back to their proper places by a gang of some twenty-five plate-layers, and made fast again in a few minutes. A more mysterious, and often more troublesome affection of the permanent way, is the tendency of the running surfaces of some rails not to wear away evenly, but to work into corrugations ; these may easily become so pronounced as to make it necessary to replace an otherwise quite serviceable rail on account of the rough running which it causes. The noise, too, which is caused by corrugated rails may be very objectionable, and in some places has been sufficiently annoying to people living in houses adjoining the railway to make it necessary to replace the rails for this reason alone. The corrugations, which generally occur at intervals of a few inches, appear most capriciously—sometimes all the rails for a considerable distance may be affected, sometimes only one here and there. And the reason for the appearance of the corrugations is most uncertain. Some engineers are convinced that it is due to faulty rolling of the rails—they surmise that the rail is allowed to get too cold before it is put through the last set of rolls, so that the surface becomes case-hardened, and is not homogeneous with the rest of the rail. The manufacturers probably do not concur in this view. Yet another trouble connected with the rails is that, under the stress of traffic, they tend to get bent permanently in a vertical plane—each length of rail gets higher in the middle than at the ends. This deformation proceeds very slowly, and, though it sometimes happens that it is necessary to take the rails out and straighten them, this is only done exceptionally. Deformation of this kind is sometimes sufficient to impart to the rolling stock a slight heaving motion, which is quite perceptible, at any rate upon the engine.

The provision of improved crossings is a matter to which some attention is now being paid. Ordinary circumstances, wherever the path of one rail crosses that of another, space is left to give a passage to the flanges of the wheels, with the result that the bearing surface is not continuous, and the wheels are exposed to blows of considerable violence, which are not at all good for them, or for the vehicles which they support. The advantage of the ordinary system of crossings is that there are no movable parts, and therefore there is no necessity for setting the rails in one or other direction for the different trains. But, by introducing a certain number of movable parts it is possible to eliminate the vacant spaces, and, although this increases the complication, it is probably worth while to get rid of the heavy blows to the wheels, which ordinary crossings involve. An advantage of such an arrangement is that the paths of the rails at diamond crossings can be set at a much more acute angle to one another than can be done with safety at ordinary diamond crossings, where it is not permissible to have crossings flatter than 1 in 8.

For the satisfactory working of a railway it is necessary to have efficient means of controlling the trains besides engines of sufficient power and suitable design for hauling them. The two principal factors in this control are the signals and the brakes.

The theory on which railway traffic is generally conducted is that every line is divided up into a number of lengths, upon each of which there is never more than one train at a time. This constitutes the so-called "block system." Each length is under the control of a signalman, who permits no train to enter it unless it is unoccupied, and each signalman is in constant communication, by means of electrical instruments, with the signalman who controls the length of line on either side of the length which he himself controls. There is thus a complete chain of control from end to end of the line. A train cannot start from the terminus till the signalman in charge of the starting signal has been informed by his colleague in the next box down the line that the previous train to leave the terminus has passed beyond that box, and the colleague in turn will not allow the train to proceed into the section at the entrance of which he is stationed, till he has received similar information from the signal-box next beyond his own. So, at the beginning of every length into which the line is divided, there is placed a signal, which can assume a horizontal or a slanting position instructing the engine driver respectively to stop or to proceed ; and this signal is moved by the signal-man in charge in accordance with the information which he receives from up and down the line.

This is the general scheme for the control of the trains. In practice the arrangements are somewhat more complicated. In order to give the drivers adequate notice of the position in which they may expect to find the stop signal—which is known as the " home " signal—another signal, known as the " distant " signal, is placed some half-mile away from it, and this signal is never lowered unless the home signal is lowered also. A driver, therefore, who finds the distant signal in a position which allows him to proceed may go ahead with full confidence. If the distant signal is at danger he passes it, but prepares to pull up, if necessary, at the home signal. At stations and various other places there may be one or two more stop signals at intervals beyond the home signal—known as the " starting " and " advanced starting " signals. In this case the distant signal is not lowered unless all these stop signals are lowered also. On any section of the line where they exist it is of course possible to protect one train with each of them, and so in certain circumstances more than one train at a time may be admitted to that section. On a double line, where all the trains run in the same direction, and there are no points or crossings, and the only danger that has to be guarded against is that of one train's catching up another, it is quite a simple matter to keep the distance between them, but where there are points, and it is necessary to prevent the trains from meeting one another, the arrangements necessary to ensure safety become more complex. The signals and points are then connected together in such a way that no signal can be lowered to allow a train to proceed until all the corresponding points have been correctly set for its passage, and those on neighbouring lines so set that no vehicle can be turned from them on to the line over which the train is to pass.

For the proper working of the block system reliance may be placed either upon the combinations of the brains of the pairs of signalmen, whose consent is necessary before any signal may be lowered, or the safeguard thus provided may be supplemented by a mechanical device which makes it impossible for any signal to be lowered for a fresh train to proceed until the last train which has passed that signal has got under the protection of the next signal further on. The apparently greater protection conferred by the latter arrangement is reduced by its being necessary to provide means whereby the apparatus worked by the train itself may be put out of gear if it goes wrong and the signal gets stuck at "danger." Instances have been known of the signalman's forgetting that a train has passed and locked the signal at "danger," and, when in point of fact the signal was working properly, supposing that it had got stuck, and releasing it with the emergency key. Irregularities, however, are so very rare in either system of block working that both systems must be considered quite satisfactory in practice. Less perfect, as several recent accidents have shown, are the safeguards at stations, where one signalman sometimes has it in his power to admit by mistake more than one train at a time into a section.

The British system of signalling is probably the simplest and most complete of any now employed. Practically all the signalling on the running lines is done by means of only two patterns of signal—both semaphores—and the only difference between them is that the stop signals have square ends and the warning signals have fish-tail ends. The considerable variety of forms of signal found on some Continental railways is absent, and the indications are to that extent less confusing.

In most cases the signals are moved by human agency, but it is also possible to make use of various systems whereby the movements are brought about by the trains themselves, and no signalmen are required. This is effected by means of electric currents, which pass along sections of the rails, and are short-circuited by passing trains. For this purpose the different sections are divided from one another at the required intervals, by insulated rail-joints. Arrangements of this kind are quite suitable for those parts of the line which pass through open country, but at junctions and big stations it is of course impossible to dispense with signalmen. But here also much may be done, by the interposition of electric or pneumatic power, to lighten the signalmen's work, and so reduce the number of men whom it is necessary to employ. With ordinary mechanical transmissions the exertion of pulling over a lever in the signal-box is considerable, and in large boxes, where a great many movements are made in a short time, a man's powers are limited by the actual physical exertion entailed upon him. Where electric or pneumatic power is used for doing the work of moving the points and signals, the little levers which set the power to work can easily be moved with one finger, and any reasonable number can be arranged so close together that the signalman in charge need hardly move from his seat. His work then becomes more analogous to working a typewriter, and the hard bodily exertion of an ordinary signal cabin is absent.

In some places the low-pressure pneumatic system of working points and signals is in use. In the open country, where there are no points or crossings, the signals are entirely self-acting. They are normally held in the "line clear" position by compressed air from a main running alongside the line; when no train is in the section protected, the compressed air is admitted under a diaphragm by the agency of an electric current. This current, in these circumstances, passes along the rails and completes the circuit in such a manner that a valve admitting compressed air under the diaphragm is held open. When a train enters the section, the current is short-circuited through the wheels and axles of the carriages, and no longer serves to hold the valve open. This has the effect of exhausting the air under the diaphragm, and the signal goes to "danger" by gravity.

Where there are points as well as signals to be worked, the power is supplied by compressed air, but it is set in motion by a signalman's pulling over levers very much in the ordinary way, though of course with much less effort. The levers in the signal-box can, in the first place, be shifted by the signalman for only a part of their full stroke; this partial movement admits compressed air at a very low pressure—about 7 lbs. per square inch—into a pipe, along which this compressed air reaches a valve situated close to the signal or points to be moved. The valve then opens a passage for another supply of compressed air—at about 15 lbs. a square inch this time—to enter the cylinder which works the points or signal. When the movement is complete this fact is notified to the signalman by the compressed air, which has brought it about, returning along a pipe of its own to the signal-box and completing the movement of the lever (except when the signal goes to "line clear," when it is not considered necessary to arrange for this indication to be given). Only then can movements be effected of other levers, which are interlocked with the first lever. The levers and interlocking arrangements occupy quite a small space, and are therefore more convenient than the ordinary arrangement, and the point-rods and signal-wires are replaced by iron pipes, along which the compressed air passes; a number of moving parts are thus done away with. These are some advantages to set against the rather large number and intricacy of the pipes. But the greatest advantage of the arrangement is undoubtedly the relief from physical exertion which it affords the signalman, with the result that this relief to his body can hardly fail to increase the alertness of his mind. The amount of relief is realized when, at a place like Clapham Junction, one sees the points set, with practically no exertion at all, for a cross-over road over some half-dozen other lines.

Ordinary visual signals leave very little to be desired in broad daylight; they are slightly less perfect at night, when colour, and not shape has to be depended on. Possibly something may also be done by means of flashlight arrangements to differentiate signals by night. In some cases in order to differentiate the distant signal by night an orange light has been substituted for a red one as the "danger" indication for the distant signal. One advantage of this is that an orange light is far easier to see than a red one. Where this has been done the semaphore has also been painted orange. But when, owing to fog or falling snow, neither shape nor colour can be distinguished, some method other than the ordinary has to be employed. The only one that has so far been brought into habitual use is the system of signalling by means of detonators. When a fog comes on men are stationed by the signal posts to watch the indications of the signal and warn the drivers if it is against them by placing on the rail detonators which explode with a loud report when the engine passes over them. If rather rough and ready, this is a fairly effective method of control, and, though trains are frequently delayed when there is a fog, accidents are very rare. But there are great inconveniences connected with fog-signalling in this manner. Elaborate precautions have to be taken that there shall always be a sufficient staff of men available at short notice, and, when every care has been taken, the fog may come on so rapidly and unexpectedly that some time elapses before they can reach their posts. Then, standing out for hours in the fog is neither a healthy nor a pleasant occupation for the men, while the companies are put to considerable expense. Fogs are fortunately not common enough to make it worth while making very elaborate arrangements for coping with them. The most effective way of signalling in a fog is certainly by arranging that the position of each signal shall be repeated to the driver, as he approaches it, either by audible signals in the cab of the engine or by an indicator before his eyes. Owing to the expense of the necessary mechanism and the general sufficiency of the existing system of signalling, only a few isolated experiments have been made with appliances of this kind, though in some parts of the world the driver is warned if he passes a distant signal at " danger " by the sounding of an alarm whistle in the cab.

The Great Western has, however, gone further than this, and has on some parts of its lines adopted a system whereby there are given to the driver in cab audible and visible indications of the position of the distant signals. This apparatus consists of a box fixed to the side of the cab containing a whistle blown by steam, an electric bell and a window, in which is displayed either a blank surface or the word "danger." It is a comparatively easy matter to arrange that, if the signal is at "danger," a warning should be given to the driver, but it is not sufficient if the signal is at "line clear" that no indication should be given—some definite indication must be given also when this is the case. In the Great Western apparatus, if a distant signal is at "danger," the whistle is blown and the word "danger" is at the same time displayed, while if the signal is at "line clear" the bell rings; and, in each case, the indications continue till the driver himself stops them. The indications are given from a ramp laid between the rails, which, as the engine passes over it, is struck by a shoe fixed under the engine. So long as the "danger" indication has to be given, an electric circuit on the engine is interrupted when the shoe strikes the ramp, and this interruption sets the whistle blowing and causes the word "danger" to be displayed. When, however, the "line clear" indication has to be given, an electric current is passed through the ramp, the effect of which, as the shoe strikes the ramp, is to neutralize the interruption of the circuit on the engine and furthermore to set the bell ringing. When this system was first introduced it was left to the driver to apply the brake when the "danger" indication was given; but now, when this happens, the brake is put on automatically by the apparatus itself.

At some signal-boxes where rail-circuits are in use there are plans of the lines controlled, on which the actual position of each train at any moment is shown by means of discs, which can turn red or white. If a train is on any particular rail-circuit, the discs corresponding to the beginning and end of this circuit are red—otherwise they are white. This device is very useful for locating trains in foggy weather.

On railways, particularly electric railways, where trains follow one another at very close intervals and the block sections are very short there is a tendency to replace the ordinary arrangement of distant and home signals by three-position signals. The three-position signal usually consists of a semaphore, which when in a horizontal position means "stop," when pointing diagonally upwards means that the line is clear for one section ahead, and when in a vertical position means that the line is clear for two sections ahead.

It has lately been discovered that electric lights can be made powerful enough to be seen at long distances even in bright sunlight. It is therefore not impossible that before very long semaphores will be largely replaced by coloured light signals visible alike by day and by night .

On single lines the problem of ensuring the safety of the trains is in some ways different from the problem which presents itself where the line is double. Measures must be taken not only for preventing one train from catching up another, but for preventing trains, which are travelling in opposite directions, from meeting. The simplest means of attaining this result is to allow only one engine at a time to be upon any given line, and in the case of very small branch lines it is sometimes possible to arrange that this shall be the case. But when one engine does not suffice, arrangements have to be made for the same principle to be extended in such a way that the line is divided up into a number of sections, upon each of which there can be only one train at the same time, whether it is travelling in one direction or the other. This can obviously be brought about by not allowing any engine to enter any particular section unless the driver is in possession of some token, generally a staff or tablet, of which only one exists. And this is the principle that is adopted. As, however, it is sometimes necessary to despatch more than one train in the same direction successively, a single token is not sufficient, so, while maintaining the principle, certain modifications have to be made in practice. The difficulty is met in various ways. One solution of the problem has been evolved, which is very complete. A considerable number of tokens are provided, the possession of any one of which gives a driver the right to proceed onto the section to which it has reference. There are, at the stations at each end of the sections, holders, to either of which any number of the tokens can be secured, and these holders are connected together electrically in such a way that no token can be removed from either end unless the whole of the tokens are at that moment in one or other of the holders, and only one token can be removed at a time; no fresh token therefore can be removed from either end till the one which is out has been returned to one holder or the other.

When a train passes the end of a single line section without stopping, there is a certain amount of difficulty in dropping the token which gives the right to pass over the section just traversed, and picking up another for the section ahead. Tablets attached to iron loops are sometimes used, and the firemen and porters become so expert at passing their arms through the loops and catching the tablets upon the shoulder while the train is travelling at something like 40 miles an hour, that very little time is lost in slowing down. A more perfect apparatus is used in some places, for which the tablets to be exchanged are enclosed in leather pouches which are hung to the engine and to a standard close beside the line, and one tablet is dropped and another picked up simultaneously, by means of appropriate catches, without any reduction of speed.

The British signalling system, worked as it is by highly trained men, offers a high degree of security, and it is seldom indeed that, through any fault of the enginemen, the indications of the signals are not given effect to. For ensuring the trustworthiness and experience of the drivers and firemen it would be difficult to imagine a more thorough training than these men are obliged to undergo before the lives of the passengers are given over into their keeping. As a rule they enter the service of the railway company as boys, and spend some years in the running sheds, cleaning the engines which come in dirty from their work. This makes them familiar with every part of the engine, and, at the same time, they have opportunities of observing the fitters and boiler-makers carrying out any repairs which may be necessary, and they are brought into close contact with the drivers and firemen actually in charge of the engines, from whose experience they are able to some extent to profit. After some years the cleaners are promoted, as vacancies occur, to be firemen, first on shunting engines and then, progressively, on engines engaged on more and more important work, till eventually they attain to the express passenger engines. All this time they are gradually getting better and better acquainted with the lines, over which they will have to work as drivers, so that, when they are eventually promoted to that rank, many years' experience of travelling over the railway has fixed in their minds the position of every signal and every other detail which they must know so as to work their engines with safety and efficiency. Besides this, they are from time to time examined by a doctor to ensure that their health is good, and their eyesight and hearing are also carefully tested at intervals. The eyesight test generally consists of counting, with either eye, varying numbers of black dots a fifth of an inch square on a white ground, which are displayed at a distance of 15 feet, and there are further tests for ensuring that the men possess good colour vision.

The signals are the means of conveying instructions to the driver, but when he has his instructions he must also have the means at his disposal for carrying them out, and bringing his train to a stand at short notice, if necessary. The difficulty of doing this increases much more than in proportion to the speed at which the train is running, and very rapidly-acting and powerful brakes are an absolute necessity for ensuring the safety of trains that are at all fast. The adoption of continuous brakes, more than any one other thing, has made high speeds possible, and instead of the train's being brought wearily to a stand by hand brakes on the engine and guard's van, as was formerly the case, the driver now, by a motion of his hand, puts on the brakes as gently or as hard as he likes, from end to end of the train. Of all the numerous systems of continuous brake evolved by inventors, the Westinghouse and the automatic vacuum alone are used in Great Britain. They both depend for their working on a pipe which stretches from the engine to the last vehicle of the train. In the case of the Westinghouse brake the pipe is filled from an air-pump on the engine, with compressed air at a high pressure, and the brake is applied by reducing this pressure, so that if the couplings break and the train divides, the compressed air is liberated and the brake goes on automatically. In the case of the automatic vacuum brake there is normally in the train pipe a vacuum, which is produced by an ejector on the engine, and the brake is applied by reducing or destroying the vacuum. In this case also, therefore, the rupture of the couplings has the effect of applying the brake.

Certain special difficulties are encountered in the braking of very long trains and of very fast trains. The trouble with regard to very long trains comes from the fact that, as the brakes are applied from the engine, which is at the head of the train, it is desirable for them to act rapidly enough to take effect upon the vehicles in the rear of the train before these vehicles have had time to press forward upon the front vehicles, upon which the effect of the brakes is first felt.

To meet this difficulty arrangements have been devised with both systems of brake whereby the required modification of pressure in the train pipe is greatly accelerated by valves on each vehicle providing supplementary entrances for atmospheric air (in the case of the vacuum brake) or exits for compressed air (in the case of the Westinghouse brake).

In the case of very fast trains the difficulty arises from the fact that to achieve the greatest possible retardation it is necessary first of all to apply the brakes with a force which, if not reduced as the speed falls, causes the wheels to skid. This difficulty is not of much importance with the vacuum brake with which the pressure can be reduced at will without its being necessary to release the brake. But to reduce the pressure in the brake cylinders of the Westinghouse brake it is as a general rule first of all necessary to release the brake altogether. The difficulty is met by fitting the brake cylinders of vehicles intended to run very fast with a sort of safety-valve which gradually exhausts the compressed air in these brake cylinders down to some predetermined pressure and then shuts.

In Great Britain there are few descents long, steep, and curved enough to offer any serious difficulties, but in some parts of the world, notably in the Alps and Rocky Mountains, the speed has to be kept so low for so long together that special measures have to be taken to ensure safety. The difficulty arises from the fact that ordinary continuous brakes, after having been applied for some time, have a tendency to leak off, and have to be released preparatory to being applied afresh. This operation takes an appreciable time to carry out, particularly if the train is a very long one, and during this interval, if the brakes were taken off altogether, the train might get out of control. So supplementary devices of different kinds have to be employed. In America the exhaust from the brake cylinder of the Westinghouse brake is fitted with a "retaining valve," which can be put into or out of operation as required. When in operation it acts in the same way as a safety-valve, and, when otherwise the brake would be released altogether, allows only so much compressed air to escape from the brake cylinder as will still leave in the cylinder a pressure of 10 or 15 lbs. a square inch.

A great deal of the traffic passing over British railways is controlled from points where information regarding the traffic of some particular district, or even of the railway as a whole, is received and tabulated. Controllers posted at these points are kept constantly informed of the position of all the traffic moving or to be moved over the lines for which they are responsible and of all empty rolling-stock in their districts, and so possess facilities for gaining a comprehensive view of the changing phases of the traffic situation which can be secured in no other way. Thus continously supplied with the necessary information they can take the most appropriate steps for remedying any irregularity in the working of the traffic that may occur, or for dealing with any unexpected incident or with any sudden alteration in, or addition to, the traffic that may become necessary; they are also in the best position for carrying out other supervising duties such as distributing empty rolling-stock, arranging for the train-men to be relieved when their period of duty has expired and keeping a record of the whereabouts of particular kinds of rolling-stock of which only limited quantities exist.

The Midland was the first company to institute a system of train control. This took place in the year 1908. Before very long other companies began to follow the Midland's example and soon the greater number of companies had installed control arrangements on a more or less extensive scale. The arrangements adopted by the different companies were by no means of a uniform character but contained considerable differences as a result of the different conditions found upon different lines or of the different views of the officers of the different companies who designed the installations. While, for instance, certain companies' schemes embraced the whole line, other companies considered it desirable to introduce the system in certain congested areas only. In some cases only the goods traffic was controlled, in others part of the passenger traffic also ; in some cases the district controllers had almost a free hand while in others they had constantly to be referring for instructions to the central control-office, and so on.

The machinery of control consists first and foremost of a system of telephones by which the different points from which reports are required communicate with a control-office situated at some spot convenient for its purpose. From these points reports of the running of the trains and of traffic waiting to be moved, together with any other information that may be required, are sent in at stated intervals so long as no circumstance arises to affect the regular flow of the traffic, but in case any incident occurs that is likely to disturb or modify this regular flow it can be reported at once.

In the control office is a large and elaborate map of the lines in the controlled district, showing, besides the running lines, the position and capacity of all the loops and sidings and giving all particulars that the controller may require for carrying out his duties. As reports of the positions of the different trains are received they are recorded by means of pegs stuck into the map or clips attached to metal bars representing the controlled lines. The pegs or clips hold cards of different colours corresponding to the different categories of trains controlled, and on each of these cards are entered particulars of the train which it represents such as the number of the engine working it, the number of wagons of which it consists, its starting-place, its destination and the time at which it was due to begin its journey. With all this under his eyes the controller has little difficulty in seeing at once the best way of dealing with any conditions that may require his intervention and can immediately telephone appropriate instructions to any part of his district.

The control system has resulted in considerable economy both of labour and rolling-stock. The weak points of any scheme of working soon become apparent to any one who thus secures such a comprehensive view of it, and the elimination of either permanently, or temporarily, unnecessary trains becomes a simple matter.

To ensure the smooth working of the control system, it is of importance that the trains should be correctly reported. For this reason, therefore, there are displayed on the sides of the brake-vans, in large letters, certain code signs, which indicate the identity of the train—its time of departure from its original starting-point and its destination. The rather ugly large figures, too, with which some engines are now numbered, play their part in making it almost impossible to misread the number of the engine.

CHAPTER IV

The steam locomotive is a highly specialized machine working under conditions very different from those affecting all other kinds of steam engines.

To begin with the engine and the road over which she runs are really intimately connected parts of the same machine. The road is by no means perfectly even and rigid. It sinks as the weight of the engine comes onto it, keeps on sinking or rising as the train passes along it in accordance with the variations in weight which at each moment it has to support, rises as the last vehicle of the train passes off it, though not so much as it originally sank, and after this gradually resumes its original level. The road is thus elastic and adapts itself to the varying stresses put upon it. The wheels on anything like a decently laid line always retain contact with the rails. If the resistance to sinking of every part of the road were always exactly the same and if at the same time the road were perfectly elastic, it would be possible to do without springs between the axle-boxes and the frames of the engine, but it is of course impossible to lay down a road of the requisite perfection and springs are always employed. The sometimes rather ample swaying movements to which rolling-stock is subject are confined to the spring-borne portions of the rolling-stock. The wheels, except for tremors when passing over the rail-joints, are not subject to any disturbing movements other than those due to the sinking or rising of the rails, and those which the small amount of play left between the flanges and the rails leaves them free to make.

Not only are the road and the springs elastic but the engine herself, travelling as she does over a road not perfectly level, and round frequent curves, has to be elastic also. The wheels are dished outwards so as to give them a small amount of elasticity while the frames of the engine are constantly bending a little one way or the other. Any bending of the frames of course has a tendency to throw the bearings out of truth and the broader and the more rigid the bearings the more likely are they to run hot. In a locomotive of ordinary design there is of course no room for very large bearings, but even if there were it would for this reason still be desirable not to employ them.

Both the weight and the size of the engine are strictly limited —the former to what the road is able to bear, and the latter to the dimensions of the tunnels, bridges and platforms (the loading-gauge). On British main lines the weight on any one pair of wheels is usually limited to about 20 tons with the result that if more weight is required for adhesion it is necessary to connect one or more pairs of wheels to the driving-wheels by means of coupling-rods. Owing to the strength and solidity of British permanant way the limit of weight of 20 tons or so for each axle does not unduly hamper the locomotive designer, but with regard to limitations due to the fixed structures the position is not so good, as British loading-gauges were mostly settled at an early period in the history of railways when the importance of ample head-room was not understood. In these circumstances the height was limited to 13 ft. 6 ins. in England and 13 ft. over a great part of Scotland while the breadth does not usually exceed 9 ft.

In most foreign countries where the standard (4 ft. 8½ ins.) gauge of the rails is employed the loading-gauge is both higher and wider. The principal trouble is experienced in designing express engines with very big boilers; and it is just these engines that require the greatest steaming capacity. Big boilers have to be placed with the centre-line high above the driving-wheels and when these wheels are of large diameter as in express engines it is necessary to raise the boiler to such a height as to bring the line of the top of the boiler almost up to the limit of height permitted by the loading-gauge. A loading-gauge 13 ft. 6 ins. above the rails permits the use of a boiler with a greatest external diameter of 7 ft. together with 6 ft. 6 ins. driving-wheels, and, though these dimensions have not quite been reached the designers have very little in hand. (This question is further considered in another chapter in connection with the broad-gauge lines of the Great Western Railway.)

On account of limitations of weight and space locomotive boilers have always had to be built with a large number of small tubes surrounded by the minimum of water space, and worked at a much higher rate of evaporation than the boilers of stationary engines.

Though the locomotive is, as we have seen, subject to certain special limitations due to the conditions under which she works, these conditions also confer certain special advantages. The efficiency of locomotive boilers is increased by the vibration of the engine as she travels along, this vibration tending very strongly to shake the steam bubbles free from the metal surfaces on which they are formed and to cause them at once to rise to the surface of the water.

The locomotive, working as she does in the open air and usually in a violent wind caused by the rapidity of her own motion, has all her bearings and rubbing parts most efficiently air-cooled. The whole weight of engine and train act as a powerful fly-wheel and very effectively damp down any irregularities in the working of the machinery.

A question that has provided many people with food for thought is why railway vehicles do not oftener come off the road. With all the millions of wheels on all the hundreds of thousands of miles of railway that exist in the world a clear case of derailment without some very sufficient reason indeed is almost unknown. On really well-kept lines where the train hums along mile after mile with perfect smoothness this state of things is not particularly remarkable, but that the case should be almost the same on lines of weak construction and faulty upkeep is hardly less than marvellous. Each wheel of a train is no doubt steadied by the other wheel upon the same axle, each pair of wheels by every other pair on the same vehicle, and each vehicle by the ones before or behind it; moreover there is not normally any strong force at work except in a direction parallel to the rails.

But granting all this, everybody has at times been shaken about in such a manner as to make the inch or so of flange that prevents the wheel from mounting the rail seem a perfectly ridiculous safeguard. I remember a journey of forty miles or so on a railway on the Continent of Europe during most of which I was hardly able to remain on my seat. I have even on one or two occasions when travelling upon the engines on first-class European main-lines felt the engine when travelling between sixty and seventy miles an hour give a leap, or a series of leaps, so considerable as to make it seem impossible that any springs in the world can have sufficed to prevent the wheels from lifting themselves off the rails. In the western part of the United States I have travelled at speeds up to perhaps forty miles an hour on an engine which shook so much as to give the impression that the whole machine was about to fall to pieces. And yet neither on these occasions nor, no doubt, on hundreds of thousands of others in the experience of millions of other people does there appear to have been any danger whatever. Even contractors' engines, the very short wheel-base and overhanging outside cylinders of which offer the smallest possible degree of stability, running along lines of grotesque unevenness and complete want of solidity, appear to leave the rails very seldom.

Up to quite recently there was no generally recognized way of describing shortly and clearly the wheel arrangements of engines. An ingenious and simple plan, suggested I believe in America, now supplies the deficiency. According to this plan, every engine is regarded as having leading, driving, and trailing wheels, and is described by simply writing down the numbers of wheels in each group, one after the other, a o being written in case the engine under consideration does not possess uncoupled leading or trailing wheels. Thus an 8-wheel, four-coupled engine with a leading bogie is written 4-4-0, and a 6-wheel, six-coupled engine 0-6-0; and so on.

Both railways and steam engines of a sort existed before anyone seems to have thought of running locomotives on a railway. The first experiment of this kind on a fairly large scale took place in 1825 with good results on the Stockton and

Darlington railway. From this time onwards the successful working of railways with steam locomotives was assured.

Up to about 1840 the locomotives were very small and the fairly rapid progress which was made in their design was largely in the matter of eliminating certain glaring defects. There was, for instance at first no satisfactory valve-gear, the forward or backward eccentric engaging the valve-spindle through a V-shaped attachment called a "gab"; and the pull of the engine was transmitted through a draw-hook attached to the back of the fire-box.

In the middle '40s the question of whether the broad or the narrow-gauge should be standard in Great Britain led to a good deal of rivalry between the Great Western and other lines, resulting, among other things, in the building by both parties, of what were at that time very large express engines. There is no doubt that so far as the design of these engines was concerned the broad-gauge people had the better of it. Both parties adopted large single driving-wheels but, whereas the narrow gauge engines were more or less monstrosities and only one each of the various designs was built—most of these soon to be much altered or to disappear—the Great Western design was so successful that, with only slight modification and enlargement, it remained the standard for express engines so long as the broad-gauge existed.

Meanwhile in America the four-coupled passenger engine with a leading bogie and outside cylinders had already been evolved, a design which with much enlargement and many improvements in detail was to remain the standard for the fastest express work till the end of the 19th century.

On the Continent of Europe where railway development lagged behind that in Great Britain and the United States very small engines were the rule. They were mostly six-wheel engines with single driving-wheels for passenger work and six-coupled wheels for goods trains. The stability of the latter when built, as they often were, with overhanging outside cylinders in front, and an overhanging firebox behind, was poor and they were suited only for very low speeds.

After the question of broad *v.* narrow gauge for Great

Britain had been settled nothing happened for a number of years to stimulate railways to any special effort in the way of locomotive building. Express trains continued to be worked by six-wheel engines with single driving wheels. They were mostly of the 2-2-2 type, some with inside and some with outside cylinders.

In Great Britain goods engines of many different types were originally used but from fairly early times the 0-6-0 engine with inside cylinders was slowly ousting all other types for the purposes of ordinary goods and mineral traffic.

In Great Britain in the '60s four-coupled engines began to be more and more used for express work particularly over lines with steep gradients. They were of the 2-4-0 type, the cylinders sometimes lying inside and sometimes outside.

The general characteristics of locomotive design had by now become fixed. Broadly speaking there were two classes of design —the European and the American. European locomotives had plate frames and were without bogies or equalizing levers. They were therefore wanting in flexibility and unsuited for working over indifferent permanent way, but they were light and compact and the design of all the different parts had been worked out with some care. American engines on the other hand, while often of rough workmanship, had all the devices for securing flexibility which the European engines lacked—bar frames, equalizing levers, bogies for passenger engines, and for goods engines a small pair of leading-wheels with a radial movement.

It was not till some time in the middle '70s that 4-4-0 engines with inside cylinders began to be turned out by various British railway companies. This type, which was gradually adopted by every big railway in Great Britain, was for a long time much the nearest approach to a standard British express engine that has ever existed, and from the point of view of economy, simplicity and general utility possesses advantages of a very high order, Ever since its first appearance it has been continuously developed, and, though at the present time the weight of the latest specimens has about reached the limit that the permanent way is expected to endure, the dimensions of the loading-gauge still make

0–6–0 GOODS ENGINE, MIDLAND RAILWAY

possible some increase in size, which will no doubt be utilized when the permissible weight-limit is increased.

From this time onwards therefore the single-driver locomotive was definitely pitted against the coupled locomotive.

Till the end of the 19th century express trains weighing (without engine and tender) more than 200 tons were uncommon, so except for railways with long stretches of main line steeper than about 1 in 120 there was little against the singles in the matter of adhesion. For many years the contest between the two types continued, and, though the singles were never within sight of victory, it was not till a general increase in the weight of the trains took place that the coupled engines finally got the better of it.

In very early days the important question of balancing the moving parts of the engine seems to have been neglected, but the unsteadiness of unbalanced engines and the damage which they did to the road soon caused attention to be directed to this matter. There is little difficulty in balancing revolving weights as this can be done by means of other revolving weights ; but the balancing of the reciprocating parts is more difficult. In two-cylinder engines no attempt is made to balance reciprocating weights in the only way in which they can be properly balanced, that is by means of other reciprocating weights. Instead they are partially balanced by means of revolving balance-weights. The revolving weights used for this purpose balance part of the backwards-and-forwards disturbances set up by the reciprocating weights, but themselves introduce fresh disturbances in a vertical direction which impose upon the rail once in each revolution of the driving-wheel stresses alternately greater and smaller than it supports when the engine is standing still. This action is known as the "hammer blow."

As the disturbances set up by the reciprocating parts are more serious the further these parts are from the centre-line of the engine, the disturbances arising with outside-cylinder engines are more serious than those arising with inside-cylinder engines. As, too, the balance-weights may be divided between all the coupled wheels, the greater the number of coupled wheels the smaller are the disturbances set up by each wheel, and from this point of view four-coupled engines are superior to singles and six-coupled engines to four-coupled engines.

During the last two decades of the 19th century many experiments were made with compound engines the principal result of which was the wide adoption in France of the 4-cylinder de Glehn type of engine.

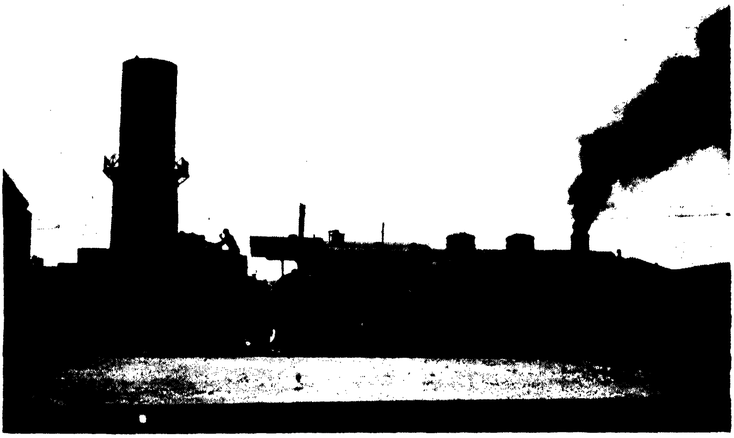
In a four-cylinder compound engine of this type (as also in four-cylinder simple engines) the balancing can be carried out far more effectively than in a two-cylinder engine. The cranks are usually arranged so that the high-pressure and low-pressure pistons on the same side of the engine are always moving in opposite directions. The high-pressure reciprocating parts, which are outside the frames, are smaller and lighter than the reciprocating parts of a simple engine of the same power would be and give rise to disturbances approximately equal to those due to the low-pressure reciprocating parts inside the frames. The forces set up by the movement of the two sets of reciprocating parts are thus so nearly equal and opposite that only a small adjustment, involving a very light hammer-blow, produces an almost complete balance of the backwards-and-forwards and side-to-side disturbances.

The precise details of the balancing arrangements of course vary a little in accordance with the dimensions of the engines and the views of individual designers. One may prefer entirely to eliminate the hammer-blow, another to reduce the other disturbances to the lowest possible point. But in all cases the balance is immensely superior to that of a two-cylinder engine.

The principal reason why satisfactorily-designed compound engines usually perform very well when they are given hard work to do is, I believe, that they are run with the regulator wide open. With two-cylinder simple engines this is hardly ever done, apparently because the drivers are afraid that the big-ends will run hot. With simple engines indeed the drivers' whole existence appears to be overshadowed by terror of this calamity.

With all compound engines the dimensions of the cylinders

4–8–2 4-CYLINDER COMPOUND EXPRESS ENGINE, CHEMIN DE FER DE L'EST



4–6–2 4 CYLINDER COMPOUND EXPRESS ENGINE, CHEMIN DE FER DU NORD

are such that the admission of steam into both high-pressure and low-pressure cylinders continues for a much greater proportion of the stroke of the pistons than is the case with simple engines, with the result that the turning effort is much more even in compound engines than it is in simple engines. It follows that, if the power developed is the same with each type of engine, the pressure upon the big-ends of the compound, being much better maintained throughout the stroke of the piston, is less at the beginning of each stroke, so that the maximum pressure which the big-ends have to support is smaller.

With four-cylinder compounds, where the effort which each big-end transmits is much smaller than with two-cylinder compounds, the conditions under which the big-ends work are yet more favourable and no difficulty is experienced in running the engines with the regulator wide open for any period of time that may be required.

The result is that satisfactorily designed four-cylinder compound engines when developing their maximum effort are able to use the steam at a much higher pressure than two-cylinder simple engines usually do, and so make use of a great deal of heat which could not otherwise be utilized. Many four-cylinder compounds work with a boiler pressure of 225 lb. per square inch. Simple engines hardly ever have a boiler pressure higher than 180 lb. per square inch and even so the pressure is reduced at the regulator.

In the process of making steam heat is required first to heat the feed-water from the temperature of the atmosphere to that of the steam in the boiler and then to evaporate this water. The steam can be made to do useful work only so long as it is between the temperature of the boiler and that of the exhaust —a small range in comparison with that through which it passes in the process of being produced from water at atmospheric temperature. If we assume that the pressure of the steam at the moment the valve opens to the exhaust is the same in all locomotives working at the same piston speed it is obvious that the higher the pressure during the period of admission, and the greater in consequence the range of temperature through which the steam falls while doing useful work, the greater is the proportion of the total heat contained in the steam which can be converted into useful work.

The almost universal practice with simple engines of reducing the pressure of the steam by running with the regulator only partly open is—economically—thoroughly bad. The effect of it is almost to waste all the heat used to raise the pressure of the steam above that to which it is reduced at the regulator, the only compensation being a slight drying of the steam with a correspondingly slight increase in its volume. There is, however, a considerable practical advantage in having in the boiler a large reserve of power that can be drawn upon whenever the engine is in difficulties.

Apart from compounding much attention has lately been paid to increasing the efficiency of locomotives. From the time the water is put into the tender till the moment when it enters the cylinders as steam, heat may be added to it at various stages with advantageous results, particularly if the heat employed would otherwise have gone to waste. There have, for instance, been built in America some very large engines, which, besides possessing boilers of enormous power, are fitted with arrangements for heating the water before it is sent into the boiler, then for superheating the steam on its way from the boiler to the high-pressure cylinders, and lastly for adding yet more heat to the steam as it passes between the high-pressure and low-pressure cylinders. If the feed-water can be heated up with exhaust steam, the result is pure gain, as the heat would otherwise have been dissipated in the atmosphere. One difficulty in the way of heating the feed-water lies in the fact that that marvellous appliance, the injector, will not work with very hot feed-water, and, in some cases, pumps have to be used instead, which are far more complicated than, and (if driven off the motion) not nearly so convenient as, injectors, which will work equally well whether the engine is standing or running. But superheating the steam is now the way in which increased economy is most generally sought, and thoroughly satisfactory results have been achieved.

The most widely-held view is that, for superheating to be really effective, quite a large amount of the heat of the fire must be diverted from the water in the boiler and applied to the steam in the superheater, so that the temperature of the steam is raised far above that at which no particle of moisture remains in it. A great deal of heat is taken from the steam on its way through the cylinders. The exhaust steam, which escapes during the return stroke of the piston, is comparatively cool, and reduces the temperature of the cylinder, which has to be heated up again by the next supply of incoming steam. In performing work, also, the steam loses an amount of heat proportional to the work done. When superheated steam is employed, there should, in theory at least, be so much heat in it that the loss of all that which is abstracted in the cylinders is not sufficient to reduce the temperature to the point where drops of water begin to form; otherwise the steam is no longer superheated, and the useful characteristics of superheated steam are lost. The principal ones are its greater volume (a given amount of heat will produce a greater volume of superheated, than of saturated, steam at a given pressure), its greater liveliness, which makes it far more rapid in its movements than wet steam, and its low conductivity of heat, which (perhaps) causes it to give up comparatively little of the heat, which it contains, to the metal surfaces with which it comes into contact. If the steam remained superheated till after the exhaust had taken place, this extra liveliness should enable locomotives using it to attain much higher speeds than is now possible. The best designed express locomotives working with ordinary wet steam would probably be unable, in any circumstances, to reach a speed of more than about 100 miles an hour on the level, on account of their inability to get rid of their exhaust steam, which could not escape rapidly enough through the exhaust passages. But superheated steam is many times more nimble in its movements than wet steam, and with it no difficulties of this kind should be encountered in reaching speeds which are to-day unheard of. Unfortunately however, by the time the exhaust takes place, the steam, even though highly superheated to begin with, is nearly certain to be more or less wet, though it is much less wet than in an engine using saturated steam.

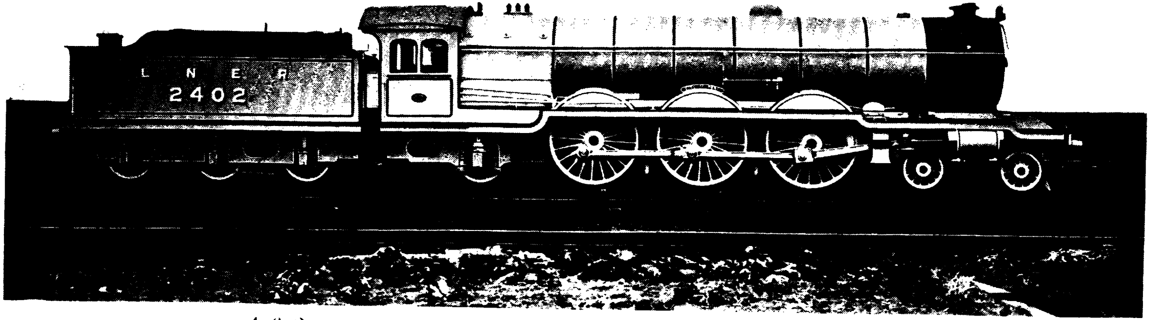
In the present century a large and rapid increase has been made in the size and power of locomotives all over the world. For passenger work the 4-4-0 gave way first to the 4-4-2; then followed the adoption of the 4-6-0 and after that of the 4-6-2 and the 4-8-2.

Goods engines received one or more additional pairs of coupled wheels and on the Continent of Europe and in America engines with two groups of driving-wheels were introduced.

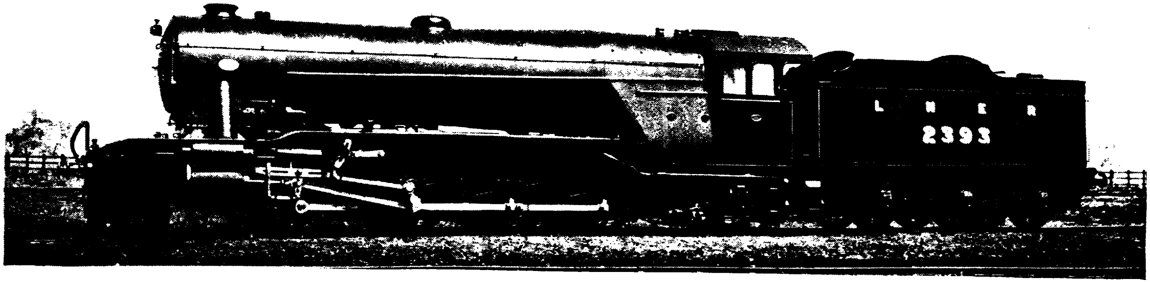
Some of these bigger engines even when not of the compound type were given four cylinders, and lately a movement towards the introduction of three-cylinder simple engines has made much headway.

With the introduction of engines with more than two coupled axles in front of the fire-box the length of the boiler barrel becomes considerable. As extremely long tubes are not desirable they are sometimes shortened at the front end by continuing the smoke-box into the barrel of the boiler and thus providing a smoke-box of increased capacity suitable for housing the superheater-headers and giving increased space for the reception of ashes drawn through the tubes. At the back end in the same way the fire-box may be continued forward into the barrel of the boiler thus providing increased space for the combustion of the furnace gases before they are swept into the tubes.

One of the objections to the introduction of very big engines is that when the grate reaches a certain size it is more than one man can do to supply it with coal when the engine is working hard. Automatic stokers are largely used in the United States, but in this country grates have hardly yet reached these dimensions. The comparatively good coal which British engines burn often enables them to do the same amount of work as engines in other countries do which have grates 50 to 100 per cent bigger. But the question of reducing the work demanded of the fireman is bound to come more and more to the front. If oil were not so expensive, the problem could be solved completely and easily by the use of liquid fuel, but unfortunately this is not now possible, except in those parts of the world where oil is produced in



4–6–2 EXPRESS ENGINE, LONDON AND NORTH EASTERN RAILWAY



bulk. No greater contrast could be imagined than there is between the continuous and exacting work of a fireman on a big coal-burning engine and the almost complete leisure of the same functionary on an oil-burner. The former, in extreme cases, has hardly time to mop the perspiration from his brow after throwing one charge upon the fire before it is time for him to begin putting on the next, while the latter regulates the production of steam from nothing at all to the greatest effort of which the largest engine is capable by turning a handle which is conveniently arranged in front of him as he sits at his ease. The problem of automatically supplying the furnace with solid fuel is, of course, one of much greater difficulty. Indeed, it seems doubtful whether it will ever be possible altogether to dispense with the fireman's shovel. In the first installations, at least, it is more probable that a certain proportion of the fuel will be introduced automatically into the fire-box, and the fireman left to complete the supply in the ordinary way.

The diameter of the blast-pipe orifice is one of the most important dimensions of a locomotive. In Great Britain blast-pipes are as a rule given orifices the sections of which cannot be varied. This means that the blast-pipe orifice must be small enough to produce a draught sufficient in all circumstances thereby frequently causing back-pressure in the cylinders greater than is necessary to produce the steam required. In some other countries, particularly France, variable blast-pipes are the rule and when used with care and skill appreciably increase the efficiency of the locomotive.

With moderate-sized engines and moderate pressures plain flat slide-valves did well enough. As pressures increased measures were sometimes taken to reduce the power required to move the valves by arranging for the steam to be excluded from part of the back of the valve. Later piston-valves were introduced and have been employed upon almost all engines working with superheated steam. They possess many advantages. Steam can be admitted to the cylinders round almost three-quarters of the circumference of the valves, which may be placed very close to the ends of the cylinders so that the steam-ports can be made short, straight and of large section. Then, as the valves need be pressed against the walls of the cylindrical chamber in which they work only just hard enough to keep them steam-tight, much less power is required to move them than is the case with flat slide-valves. (In Germany, indeed, an arrangement is employed which dispenses with any pressure between the piston-valves and the chambers which contain them. A sleeve fitted loosely on the valve-spindle is turned so as to fit the chamber accurately and no piston-rings are used on the piston-valves. The adjustment is, however, so delicate that the drivers are instructed not to put the valves into full gear when steam is shut off for fear the increased travel should cause them to jam.) A further advantage of piston-valves is that steam may be admitted past the inner edges of the valves, and exhausted past the outer edges so that the exhaust from each end of the cylinder is kept separate and there is no possibility of the two streams interfering with one another.

The steam locomotive is a very compact and handy machine and, in a strictly limited sense, highly developed. That is to say that since the steam locomotive was first employed to haul trains along railways a hundred years ago the design and workmanship of practically every detail have been enormously improved while the increases in size and power that have taken place are so great as to put the modern engine and her ancient prototype into the relative positions of the largest horse and the most diminutive donkey. Nevertheless, except for the almost universal adoption of superheating in the present century, and for the spasmodic employment of compounding, such improvements as have taken place from the earliest days up to the present time have hardly been more than such as must in any case have imposed themselves as matters of ordinary routine. Railway managers and engineers, sheltered as they are and always have been from any competition except that under the control of a few professional colleagues just as anxious as themselves to avoid it, have shown little interest in, or appreciation of the importance of, far-reaching and radical improvements in the design of locomotives. The failure to achieve progress is most noticeable when the effort measured in horse-power is considered which modern locomotives can develop. An engine is doing quite ordinarily well if she is developing fifteen horse-power for every ton of her own weight. Twenty horse-power per ton is work far above the average, and the absolute maximum that a locomotive has ever achieved seems to be somewhere in the region of thirty horse-power per ton.

The greatest long-sustained effort I have myself ever witnessed was that of a 4-6-2 four-cylinder compound on the Nord described in another chapter, which kept up an average of 23 horse-power per ton all the way up the Survilliers bank (12 miles), the effort rising to 26 horse-power per ton at the top of the bank. The engine was doing approximately her best, but there were minor defects in her design which may have slightly reduced her efficiency. In England a Midland three-cylinder compound fitted with a superheater once under my observation got up to 23 horse-power per ton-weight of engine. (In both these cases the horse-power was calculated from a formula but the results were probably fairly accurate.) When the enormous horse-powers developed by very light internal-combustion engines are remembered, and the revolutionary progress in their design in the last thirty years is compared with the development of the locomotive in the last century the slowness of progress in locomotive design is painfully apparent.

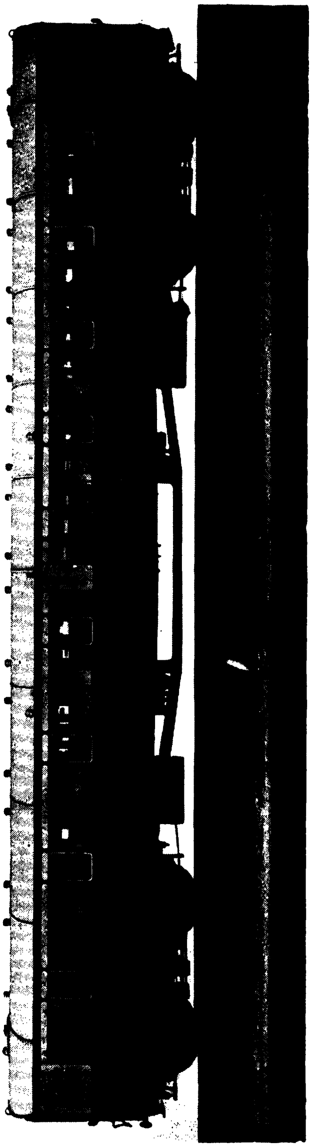
The biggest South Western and Caledonian engines long ago had bogie tenders because, owing to the absence of water-troughs on these lines, a large load of water had to be carried, and a few other bogie tenders have from time to time been built for various other lines, but in Great Britain the great majority of tenders run on six wheels. Now that most of the railways have put down water-troughs, the weight of the tenders need not exceed what can be carried on three axles and as the shortness of the wheel-base of a tender allows it to round curves quite easily, without being carried on bogies, there is no particular object in using bogies—the six wheel arrangement has indeed some advantages, as it enables the lateral stability of the tender to be secured more easily and this is a matter of some importance in a vehicle carrying a big load of water, which may, in certain circumstances, surge from side to side.

A difficulty arises with tenders owing to the great difference between the weight of a tender full and of the same tender empty. Taking the spring-borne part of the tender only, the difference in weight may easily be as much as three to one. At the same time the maximum difference in the level of the floor of the tender must not exceed a very few inches on account of the necessity for keeping the couplings at or very near the normal distance from rail-level. This means that springs strong enough to carry the tender when full have so little play that when the tender is empty there is a possibility that some inequality in the road may relieve one of the springs of all weight and even cause it to lift its wheel off the rail.

To obviate this danger (which it must be admitted does not seem to have been responsible for many accidents) the Chemin de fer de l'Est has devised an arrangement of double springs in which the weight of the tender is normally carried by springs of the ordinary kind, but when the weight of the tender has been seriously reduced a much more flexible set of supplementary springs comes into operation.

Where it is possible to make frequent stops for water, the use of tank-engines makes it unnecessary to have tenders at all, and, as it is just on services of this nature that the engines most often change their direction, tank-engines, which run equally well in either direction, possess great advantages. Lately, on certain lines like the Great Western, the use of tank-engines has been extended, and some big engines of this type have been built, which are capable of performing fairly long runs with express trains. Where water-troughs exist at sufficiently frequent intervals there is little to prevent a tank-engine from performing runs as long as are performed by engines with tenders, but the troughs are not as a rule close enough together to enable tank-engines to undertake very long runs. The height from the rail of the spring-borne portion of the engine must not vary more than a very little, as the machinery has to be arranged to work at one height and any considerable deviation therefrom would have very serious ill-effects. As any difference in weight, such as there would be between an engine with her tanks and bunker empty and the same engine with her tanks and bunker full, has the effect of raising and lowering the height of the spring-borne portion, this difference must be confined within narrow limits, and so the tanks must not be too big ; moreover, the engines which work the principal expresses are already about as heavy as is desirable, so, if they had also to carry 15 or 20 tons of coal and water, it would be necessary to provide them with at least one more pair of wheels which would greatly increase their cost and the difficulty of designing them. It is, therefore, not all likely that tank-engines will ever be much used for working express trains, though the performances of the big Brighton tank-engines on the " Southern Belle " have shown that, in certain circumstances, they are capable of doing so.

The principal reason for the increased power of modern engines is the increased weight per passenger of modern carriages. The art of building carriages has proceeded quite as fast as has the art of building engines to haul them, and while British designers have not refused to learn from the designers of other countries, they have also done a great deal of original thinking with satisfactory results. Various lines have at different times introduced Pullman cars, which once were considered to afford the acme of luxury in railway travelling. The Brighton Railway was the only railway which consistently ran large numbers of these vehicles before the war, but since the war their use has been much extended. At all times the influence which they have exerted upon the design of railway carriages has been out of all proportion to their numbers, and, if at the present time British passenger vehicles are at least equal to any in the world, this is largely due to the fact that the Pullmans showed the British designers that their designs were susceptible of great improvements, and suggested lines of advance, which have since been thought out and acted upon with success. Striking indeed is the difference between the shanties on four wheels, which not so very long ago were the standard British railway carriages, and the strongly-built, roomy, and smooth-running vehicles, of which all British main-line trains, and not a few of the suburban trains too, are now composed. In this conservative country the carriages were at first built closely to resemble the stage coaches which they replaced, and only step by step did the stage coach idea disappear, till at the present time the tendency is to make the different kinds of passenger vehicles as much as possible like the rooms of an ordinary house. Owing to the nature and extent of the American territory, the desirability of this course became apparent in the United States long before it did in Europe, but, once the European designers had thrown over their original prejudices, it was discovered that European, and even British insular, conditions afforded ample room for the development of what may be called the dwelling-house theory in the construction of railway vehicles. British designers have not by any means slavishly followed in the steps of their American confrères, and whatever may be the advantages of the American types of vehicle, which commend them to Americans, there is no doubt that British carriages are far better adapted to the views of British travellers than carriages of the American design would be. This is particularly the case in the matter of privacy. In America the carriages, including the sleeping carriages, are, as a rule, without partitions. In Great Britain almost all the carriages except the dining-cars are divided into small compartments (though a regrettable attempt to introduce open carriages into this country has lately been made by the London and North Eastern Railway). Americans appear to like to be together as much as possible, but an Englishman, after a very short experience of the misery which one baby endowed with lusty lungs can inflict upon perhaps the sixty or seventy occupants of an American carriage, comes to the conclusion that compartment carriages, where a refuge from such inflictions can almost always be found, possess decisive advantages. British corridor carriages with vestibules for passing from one carriage to another, enabling the passengers to move about freely in and out of the dining cars and smoking compartments, render stops entirely unnecessary except for setting down and taking up



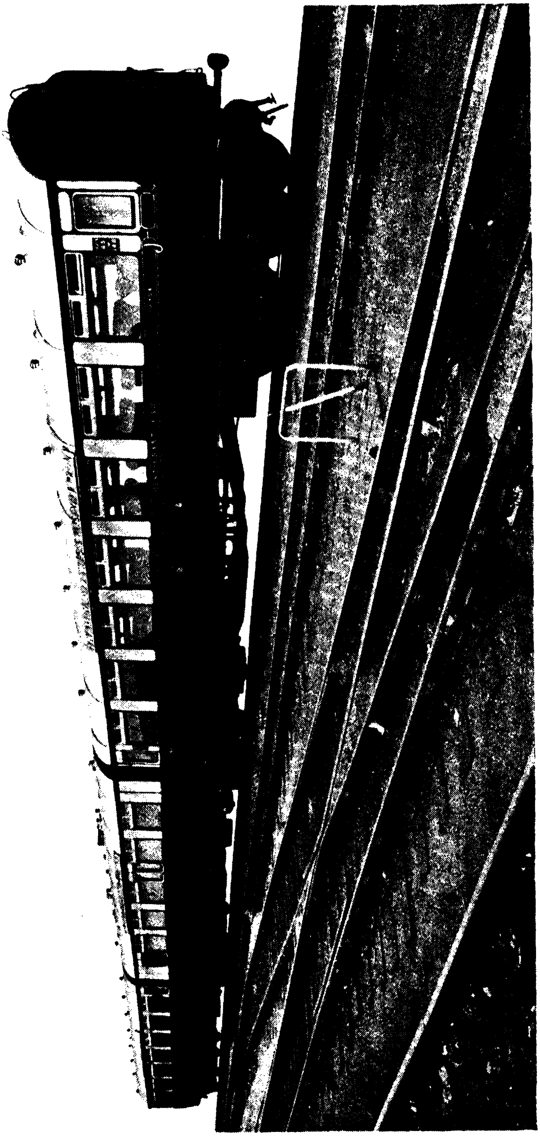
passengers and for locomotive purposes. No development of recent years has been more striking than the increased distances which the principal trains run without stopping. So far as the passengers are concerned, these longer runs are chiefly due to the introduction of corridor carriages and dining cars, while, as regards the engines, their requirements have been met by the installation of water-troughs on nearly all the principal English long-distance lines, and by more perfect lubricating arrangements, which enable the bearings to run for longer periods without attention. Corridor carriages naturally cannot seat so many people as carriages of the closed compartment type (unless indeed the space allowed for each passenger is severely reduced, as is unfortunately done on some British railways), and what with the introduction of dining cars, and the much more solid build of vehicles generally, the weight of the trains has much increased of late years, and there is no doubt at all that passengers, in main-line trains at least, get more for their money than they used to get. One extremely desirable, though expensive, reform that has been carried out is not perhaps so generally appreciated as it ought to be, and that is the much greater strength of modern carriages, which gives far increased security in case of accident. Time was when, if an accident took place, it was a constant occurrence for the carriages to telescope, that is, to be crushed together lengthwise, with the most disastrous consequences for their occupants. Present-day carriages are built so strongly that when an accident takes place telescoping does not as a rule occur—though, unfortunately, there are exceptions to this rule—and in some accidents it is remarkable how small, for this reason, the loss of life and the injuries have been. So, if these carriages have been expensive to build, there has been some corresponding economy. In another direction, too, the economy must to some extent balance the extra expense. For far too long British designers built their carriages without bogies, but modern carriages almost invariably run on bogies, which, though they involve some increased expense, by their greater flexibility much increase the smoothness of the motion and diminish the wear and tear of wheels, springs, and rails.

The carriages are thereby made easier for the engine to haul, and the expenses of the upkeep of both carriages and permanent way are reduced.

The much greater smoothness of motion of carriages supported on bogies than of those with 4 or 6 wheels is readily understood when the mechanism of the bogie is laid open. Besides the swivelling arrangements, an appliance known as a bolster is suspended from the bogie across the middle of the frame, with liberty to move a little from side to side. The bolster is a kind of oblong box containing springs which give a certain amount of elasticity between the bottom and the cover of the box, and it is upon the cover of the box that the weight of the carriage rests, and to it that the bogie pin is secured. The bogie being attached to the carriage it supports by the central pin only, it is an easy matter to complete the attachment, and the bogie can be erected complete, before it need be brought to the carriage to be secured to it. To avoid the necessity of lifting the carriage to receive the bogie, a very neat arrangement is in use in some railway shops. While the carriage is standing upon supports above one line of rails, a complete bogie is wheeled up upon the adjoining line on to a table worked by hydraulic power. The table, with the bogie on it, is then lowered into a pit, run sideways under the flooring until it is underneath the carriage, and then raised into position and secured.

A good deal of attention has lately been paid in this country to the improvement of the coupling arrangements between passenger vehicles. So as to secure the greatest possible measure of stability in running it is desirable that there should not be any sideways movement between adjacent vehicles. Ordinary buffers and screw-couplings do not offer any direct impediment to such movements though they tend to prevent them from attaining any great amplitude.

One method tried to eliminate sideways movements is to couple adjacent vehicles by means of very powerful and rigid automatic couplers, and at the same time to keep the gangways between the two vehicles firmly pressed against one another by means of powerful springs—the gangways in this manner



acting as much-more-than-usually efficient buffers. A more radical method is that which has been in use for some years on the Great Northern line, where large heavy eyes attached to the frames of adjacent vehicles both embrace the pivot of a single bogie, which supports one end of both vehicles. As many vehicles as required can be joined together in this manner. Adjacent vehicles cannot of course be separated from one another except in the shops, and a small mishap, like one hot axle, may make it necessary to lay by a whole set of articulated carriages.

Till the time when corridor and sleeping carriages and dining-cars were introduced, the British loading-gauge afforded plenty of room, and passenger vehicles were not built up to the full limits of height and width permissible. Since then, however, every available inch of space has been requisitioned. As regards height, the first step taken to provide more light and air was the introduction of clerestories which at one time had a considerable vogue, but the latest practice is to utilize all the space available above, as well as at the sides, and to give the carriages high elliptical roofs.

Perhaps the present-day sleeping carriages, in which each passenger has a compartment to himself, are the most striking examples of the luxury which railways can supply, though even with carriages built as wide as the loading-gauge will allow, a very tall man has in some cases barely enough room to lie full length. Although there is no reason to doubt that sleeping-carriages, even of the most luxurious type, bring in an adequate profit to the railway when they are reasonably full, it is certainly in these vehicles that the ordinary railway traveller gets the greatest amount of accommodation for his money. When it is remembered that the space occupied by each compartment is certainly more than double that which would be occupied by a first-class passenger in a day train, the extra fare charged of twenty shillings for a 400 or 500 mile journey certainly does not seem excessive. And it is only since sleeping carriages became so luxurious that the extra fare has been twenty shillings; not so long ago it was but five shillings for any journey. How great a contrast these charges are with those which have to be paid upon the Continent is taught by a very short experience of those of the International Sleeping Car Company. But British railways have never tried to make money directly out of the sleeping carriage supplements, being, perhaps, of opinion that the principal function of these vehicles was to attract to the first-class people who, if there were no sleeping carriages, would have travelled third-class, and to induce people to travel who only have time to do so by night, and who, unless they could travel in a really comfortable manner, would prefer not to travel at all.

A sleeping compartment, containing one person only, fitted with a three-speed electric fan and a lamp which will give either a bright light or a dull glow, certainly offers very reasonable possibilities of passing a comfortable night. Comfortable as it is however, and perhaps approaching the limit of what is commercially possible on a large scale, the accommodation which it supplies is far surpassed by that offered in carriages of special construction, particularly in countries where very long journeys are made. In America I once passed the night in a private railway carriage in which I was given to myself a room about 12 ft. by 10 ft., with a balcony outside. But for the ordinary mortal, on ordinary occasions, anything of this sort is, of course, out of the question.

A good deal is heard from time to time about the desirability of providing sleeping accommodation for third-class passengers. So far the railway companies have utterly refused to move in the matter and have furnished a conspicuous example of how the absence of any real competition between them enables them to ignore any question which they consider awkward. It is, nevertheless, rather surprising that they should adopt this attitude in a case of the kind. They are offered in this matter an opportunity of securing a reputation for liberality and progressiveness at very small cost to themselves. The only lines on which any real demand for third-class sleeping accommodation exists, are the East and West Coast and Midland routes to Scotland. If third class sleeping carriages were attached to six or seven trains between London and

ARTICULATED SLEEPING CARRIAGE, LONDON AND NORTH EASTERN RAILWAY

Scotland each way every night, it is probable that any existing demand would be fairly well satisfied. And the expense should be quite small. It is certainly possible to design third-class sleeping carriages to contain three beds a side in the same space as is now allotted to an ordinary third-class compartment, which in a corridor carriage holds eight people, so that the extra space required would amount to very little, particularly as sleeping carriages can be better filled than ordinary carriages, because berths have to be ordered beforehand, and the number required is accurately known. The accommodation offered would be by no means luxurious, but the opportunity would be given the third-class traveller of avoiding, by the payment of a supplement, the utter misery which he now endures on a long night journey unless he can secure the whole of one side of a carriage for himself. The Red Cross trains running in France during the war were composed of what were in effect third-class sleeping carriages.

Since wood, as a rule, enters largely into the composition of railway carriages, the possibility always exists of their catching fire. So small a thing as a hot axle, or even a spark from the engine, might start a fire, and, when an accident takes place, an escape of the compressed gas carried for lighting or for cooking purposes, or a live coal from the furnace of the engine, may produce the most serious consequences. Indeed, the risk of fire is, perhaps, the chief thing to fear when an accident happens. For these reasons it is important to construct the carriages of uninflammable materials and it is possible that in a few years' time it will be the ordinary practice to make the sides and roofs and as many of the other parts as possible out of steel; this material, besides being uninflammable, makes very stiff and strong carriage bodies, which offer great resistance to telescoping. In America, where fires are much more common than in Europe, and where the railway carriages are often so difficult to escape from as to be perfect death traps, the use of steel bodies has made more progress than here, but several accidents which have taken place in the course of the last twenty years in which people were burnt to cinders, have drawn attention sharply to the importance of making British railway carriages as little as possible liable to catch fire. At the same time it must not be forgotten that, even when the bodies of passenger vehicles are constructed entirely of steel, it is practically impossible to exclude all inflammable materials from the inside fittings, and even the clothes and hand-luggage of the passengers might, in certain circumstances, produce smoke, which would asphyxiate persons who were trapped in a carriage. In such circumstances the fact that the carriages were constructed of steel, which is much more difficult to break through than wood, might quite possibly make the results of an accident worse rather than better. The whole question, indeed, of providing an easy means of escape from railway carriages after an accident has taken place is of great importance. On main line journeys, when stops are infrequent and of some duration, doors at either end of corridor carriages are sufficient for normal requirements, but may be quite insufficient in case of an accident, and must be supplemented by other means of exit. In this country, therefore, corridor carriages are generally given the same number of doors as ordinary compartment carriages. An objection to doors as emergency exits is that when an accident takes place it may easily happen that they become jammed, so that it is impossible to open them. Some twenty-five years ago the question was carefully gone into by the Prussian State Railways, in consequence of a serious accident which had taken place on one of their lines, and it was decided that the safest plan was to retain the arrangement of doors at the ends only, but to make the windows very large and easy to open, and to provide suitable hand-holds and foot-holds so as to enable the passengers, if necessary, to escape by the windows.

In suburban trains, besides the question of safety, that of filling and emptying the carriages in the shortest time is of importance. If the passengers could be prevailed upon always to enter the carriage at one end and to leave it at the other, and if a central passage could always be kept clear, doors at either end would, no doubt, be a good and sufficient arrangement. As, however, these conditions appear to be unattainable, it is not surprising to find that the ordinary arrangement of side doors is usually retained for suburban trains.

Accidents have been known to occur through a wheel working loose upon its axle. A wheel is secured upon its axle by having its centre bored out to a diameter very slightly less than that of the axle, which is then forced in by hydraulic pressure. This pressure should amount to something like eighty tons. If the axle is a little too small, or the hole in the wheel a little too big, the pressure required to force the axle into the wheel is not great enough, and the wheel may possibly work loose in service. In some carriage shops, therefore, a machine is used which automatically records the pressure exerted, and this makes it almost impossible for an insecurely fastened wheel to be put into service.

Another most important machine in the carriage shops, tending this time to ensure the comfort of the passenger, is one in which the carriage wheels are revolved to ascertain whether they are properly balanced. If they are found to be in any way defective, a metal plate of the required weight to effect the proper balance is fastened onto the inside of the wheel. Quite a small departure from the proper balance has a very bad effect upon the running of a wheel, causing it to tend to swing backwards and forwards in the axle-box guides.

The cleaning of the carriages, which is a serious business, is, in large centres, often done by means of a vacuum cleaner. There is a large central installation where the vacuum is maintained, and from here led by pipes wherever a vacuum is required for cleaning purposes. If there are building or repairing shops near by, the same vacuum can often be made use of in them for a variety of other purposes.

The lighting of railway carriages has always been rather a difficult problem. For a long time no serious attempt was made to provide more light than was enough to differentiate light from darkness. Anything like reading by the exiguous rays of the candles originally provided was, of course, out of the question, and the dirty oil-lamps, which lasted for so long, were almost equally devoid of any real utility. These were the dark days of railway travelling. Since then, although the difficulty in the way of giving each passenger light enough to read by, and at the same time providing general illumination for a whole compartment has not yet been quite satisfactorily overcome, really serious attempts to solve the lighting problem have been made. For some time now the competition has been between gas and electricity. First gas got the start, then electricity made greater progress, then improved incandescent mantles gave a fresh impetus to gas, while more perfect electrical appliances were being evolved by the electricians; it now seems probable that electricity will gain the victory. Where electric light is used as few heavy accumulators as possible have to be carried, so, while they are indispensable for providing electricity as long as the train is standing still, the current required is procured from a dynamo as soon as possible after the train starts. The dynamo is driven from one of the carriage axles by means of a belt. Whatever may be the pace of the train, the current required for the lamps is the same, and so a good deal of ingenuity is necessary to arrange for regulating devices, which will ensure that the proper supply shall always reach the lamps, and this without wasting more energy than is absolutely necessary, for all the power has to come from the engine, and, if it is wastefully used, there is unnecessary expense. A drawback of electricity is that, in case of fog, when the trains may have to crawl along for hours together, the accumulators may give out, and there is then no opportunity of re-charging them from the dynamo, so that the light may fail altogether. Gas possesses an advantage over electricity in that a supply is taken in before the train starts, and it has not to be made *en route*. It is generally manufactured by the railway company at a special gasworks, and is stored in cylindrical holders underneath the carriages, which, as it is compressed to a high pressure, can hold a large supply. From the cylindrical holders it is led at a reduced pressure to the burners, where the now generally used inverted incandescent mantles enable a very small amount of gas to give forth an extremely bright light, and one which, unlike electricity, has no need of being nicely regulated to counteract variations in the speed of the train.

Where a number of carriages are always coupled together, the electric lighting arrangements may be simplified by generating and storing the electricity on one carriage only, but any carriage, which is liable to be detached from the others, must have sufficient storage capacity to last at least till it can receive a fresh supply. In connection with carriage lighting the ever-present danger of fire has to be carefully considered; in this respect, electricity, though certainly not entirely safe, possesses advantages over gas, an escape of which, when an accident takes place, is too frequently the cause of a fire. Something can, however, be done to minimise the danger from gas by fixing the gas cylinders as closely as possible under the frames, where they get the greatest amount of protection, and by arranging valves, which automatically cut off the supply of gas when the pipes get broken.

In working the goods traffic a compromise is necessary between the interests of the railways and of their customers. The railways like full train-loads of fully loaded vehicles, their customers like their consignments to be delivered with as little delay as possible. These two aims are often incompatible with one another. It may take a long time to collect enough goods to load a vehicle fully, and a still longer time before there are enough fully loaded vehicles to make up a train for any given destination.

The 4-wheel wagons, which are almost exclusively used for goods traffic in this country, cannot carry a very large weight of goods in comparison either with their own dead weight or with the space which they occupy in the sidings and goods stations. It is possible to construct vehicles much more economical in both these respects. But in Great Britain the consignees insist upon so much of the goods traffic being delivered without delay that it is found more convenient to transport all sorts of general merchandise in vehicles of small capacity. No doubt there are many cases where full loads could be secured regularly for vehicles of much larger size than those in actual use, but, although employment might be found for a certain number of such vehicles, so many cases would still arise, where the small 4-wheel wagons were big enough, that these would have to be used in conjunction with the bigger wagons, while, at the same time, so much expense would be incurred in adapting the goods stations for the reception of the big wagons that it is quite doubtful whether any economy would result from their use. For general merchandise, indeed, it very often happens that the 4-wheel wagons, far from being too small, are much too big, and one loaded up to its full capacity is, in some places, rather a rare object. But, though the 4-wheel wagon is nearly always amply big enough for general goods traffic the case is different where heavy mineral traffic is concerned. Here there is some scope for the introduction of the big wagon, with its attendant advantages of greater paying weight per train, and greater economy of space at the loading and unloading stations. Up to about the end of last century the small 4-wheel wagon reigned supreme for mineral as well as general goods traffic, but the comparatively evil days, on which the railways then fell, directed attention to the economies which might be effected in the working of the goods and mineral traffic. It was then that stricter attention began to be paid to the loading of the goods trains, with the result that hundreds of thousands of miles of goods mileage per annum were saved, and the possibility of using larger and more economical vehicles for suitable classes of traffic was seriously taken into consideration. Since then this latter reform, though it has not been lost sight of, has, it must be confessed, proceeded rather slowly. But still some progress has been made, and a number of vehicles of increased capacity are now in use.

All sorts of unexpected difficulties constantly crop up when a new departure of this sort is tried. I was once shown a steel wagon of large capacity used for carrying coal, and built only ten or twelve years previously, the floor of which had wasted away to the thickness of half-a-crown, so that it was no longer safe and was about to receive a wooden floor covering. It appears that when it rains the rain water, percolating down through the coal, absorbs some of the sulphur which the coal contains and so becomes like very dilute sulphuric acid and attacks the steel floors of the wagons with serious results.

The question of the employment of bigger wagons is a large one, as there are several hundred thousand mineral wagons in Great Britain, and, if it were only a matter of gradually replacing such of these as are engaged on traffic for which the wagons of large capacity would be more economical, it must take some years to solve, particularly as most of the mineral wagons do not belong to the railways at all, but to private owners. But, besides the actual replacing of one kind of wagon by another, at all the places throughout the country where the wagons are loaded, unloaded, or manœuvred, modifications must also be introduced for the accommodation of the bigger vehicles, and these modifications would not be the easier to carry through from the fact that, like the wagons, many of the places where these modifications would be necessary do not belong to the railways, but to private owners.

There are so many objections to the use of private owners' wagons, and so few advantages, that it is difficult to understand how the British system of allowing private owners to use their own vehicles has been permitted to go on. A private owner's wagon can obviously not be utilized to the same extent as a wagon belonging to a railway company, which can be sent anywhere, where there may happen to be a demand for it, the moment it is empty, and although the railways no doubt take great care to ensure that the wagons, which they accept to run over their lines, are of proper design and suitable strength, they can hardly exercise the same degree of supervision over them as over vehicles belonging to themselves. Then questions connected with the rights of private owners to run their own vehicles over a railway may, and sometimes do, cause litigation, and other questions, such as allegations of undue preference shown in moving vehicles belonging to the railway before vehicles belonging to private owners, can hardly fail to arise from time to time.

The working of railways can never be a perfectly safe pursuit, and one of the most obvious dangers is that of being either run over or crushed by moving vehicles, a danger to which those men who are engaged in shunting and marshalling operations are naturally the most exposed. The carelessness bred of familiarity is sure always to claim a certain number of victims, whatever safeguards are employed, but when it is unnecessary for the men to go in between the vehicles, the risks which they run are very greatly diminished, and the death-roll due to shunting accidents has caused special attention to be directed to this point. The desired result may be effected in various ways. In Great Britain the use of shunting poles enables the shunters to couple the wagons while they are themselves standing in positions of safety, where no moving vehicle can strike them. It is possible to go further than this, and, by means of automatic couplers, to arrange that two vehicles, when brought together, shall couple of themselves without the intervention of any outside agency. This system, universally used in the United States for vehicles of every kind, is not employed to any appreciable extent in Great Britain. Automatic couplers, of which there are numerous kinds, consist essentially of a large, strong hook, movable round a pivot, which, engaging with a corresponding hook on another vehicle, is then locked in position by a special mechanism which the shock of coupling puts into action. One objection to the use of automatic couplers lies in the difficulty of designing a coupler which will stand the tremendous shocks to which it is frequently subjected in coupling operations. An automatic coupler is necessarily a somewhat complicated piece of mechanism anyhow, and, to be really effective, there must also be an arrangement to enable the shunters to unloose it, without going between the vehicles, which makes it more complicated still. In point of fact, automatic couplers are very liable to get out of order, and require constant attention to keep them in a proper state of repair.

Besides the coupling and uncoupling, which goes on during shunting operations, the brakes have frequently to be put on or released, and, unless the shunters are continually to be running into danger by crossing the rails, it must be possible to apply or release the brake from either side of a wagon. Obviously it is a difficult matter to provide mechanism which will permit of the brake's being applied from either side, and then, if necessary, released from the side opposite to that from which it has been applied. The Government, having for many years, at more or less long intervals, urged upon the companies the desirability of using all their endeavours to evolve or discover such a brake, has now decided to be satisfied if brake levers are fitted on both sides, without any arrangement for releasing the brake from the side opposite to that from which it was applied. This is, of course, a great simplification, though it is not a complete solution, as it is often necessary to release the brake while the vehicle is in motion. The Great Western has, however, gone further than this, and has several thousand wagons fitted with an apparatus which allows the brake to be applied or released from either side indifferently. In the Great Western either-side-brake the brake levers on either side of the wagon work onto the same shaft. The brake is applied by depressing one of the brake-levers, and is held by a catch, which engages in one of a series of teeth—in much the same way, in principle, as with an ordinary wagon brake, though the details are different. The brake-levers are connected to the brake rigging by a loose joint, which enables the levers to be raised without any corresponding movement of the rigging. This upward movement of the lever is utilized to work a trigger, and the brake is released by the trigger mechanism knocking up the catch by which the brake is held on.

For calculating the power that a locomotive will be required to develop, or for appraising the power that a locomotive has developed, it is important to possess a formula which will indicate as nearly as possible the amount of the resistances to be expected in all the different conditions in which a locomotive works. These resistances may at once be divided into two: (1) the exactly calculable resistances due to gravity and acceleration, and (2) all the other resistances, such as those due to the displacement of the air, to the slight compression of the road under the train, to the play of the springs and to the friction which arises in the bearings and from contact between wheels and rails. While the resistance due to gravity is always exactly proportional to the gradient on which the train is running and that due to acceleration can always be determined with precision, the other resistances vary considerably according to circumstances, and with regard to them no formula can be depended upon to give perfectly accurate results. The most that can be hoped for is one giving reasonably close results for some particular set of conditions. From a practical point of view the set of conditions attending the running of express passenger trains along first-class main lines is by the far most important, for it is usually under these conditions alone that the locomotive is called on to exert for any length of time something approaching the maximum power which the boiler is capable of supplying. The maximum effort which the goods engines can exert is far more dependent upon adhesion than upon boiler power, and stopping passenger trains make very little demand upon the boiler.

The formula principally required is then one from which can be deduced the resistances, other than those due to gravity, and acceleration, which will have to be overcome in working a train composed of heavy bogie rolling-stock over strong, well-maintained permanent way free from sharp curves, in average weather conditions. A number of investigators have carried out experiments with a view to discovering such a formula, and considering the variableness of the conditions which are found even between those attending one express train and those attending another, the results which they have reached show considerable uniformity. The Deeley formula which places the resistance of the whole train in lbs. per ton at $3+\frac{V^2}{290}$ (V being the speed in miles per hour) is about the simplest and is probably as accurate as any other.

There is however a very important reservation to be made. The resistance per ton of the locomotive is, for a variety of reasons, much greater than that of the rest of the train, including the tender. For one thing the locomotive at the head of the train encounters a much greater air-resistance than the other vehicles. There is also the very considerable frictional resistance arising in the numerous bearings and steam-tight packings of the locomotive which do not exist in the other vehicles. The locomotive, moreover, performs practically the whole of the work of compressing the road. In these circumstances the resistance of a four- or six-coupled locomotive at high speeds appears to be about four times as great per ton as that of the tender and other vehicles composing the train, so that for the Deeley formula to give accurate results it is necessary for the weights of locomotive and train to be in fixed proportion to one another. This proportion seems to be about 1 to 4, in which circumstances the resistance of the locomotive seems to be about equal to that of the whole of the rest of the train. If, then, the train (including the tender) weighs more than four times as much as the locomotive alone, the resistance of that part of the train which is in excess of four times the weight of the locomotive should give rise to a resistance per ton about five-eighths as great as that which is indicated by the formula. In the same way, if the train weighs less than four times as much as the locomotive, the resistance per ton should in corresponding proportion be greater than that indicated by the formula. In addition to all this, it seems probable that the Deeley formula is applicable to trains composed of vehicles of medium weight, say, not more than 30 tons apiece, running over good, but not the very best, permanent way, but that the resistance of trains composed of very large vehicles weighing, say, 45 tons apiece, running over the very best permanent way, may be 20 per cent. lower than that indicated by the formula.

CHAPTER V

So far as I know the most remarkable high-speed locomotive work that has ever been performed was done in Germany round about the year 1905. From about 1900 experiments with high-speed electric cars were proceeding on the Berlin-Zossen railway, and in 1903 these experiments culminated in the attainment of speeds of about 130 miles an hour. These achievements seem to have put the various German railway administrations on their mettle, with the result that experiments were carried out during the next year or two to test the capabilities of steam locomotives, and, though the speed of the electric vehicles was not approached, the performances recorded were superior to anything that has ever been done before or since by steam locomotives. These events attracted hardly any attention in this country, and I never came across any full report of them. The highest start-to-stop speed achieved seems to have exceeded 80 miles an hour. This was done by an engine running light.

Reports of very high speeds on United States railways were common in the last dozen years of the nineteenth century, but the details furnished were usually so vague that it was impossible to take most of them seriously. In 1895, however, the Race to Aberdeen induced the New York Central and Lake Shore Companies to arrange special high-speed runs on their main-lines. Except for the final run on the Lake Shore route the results obtained were similar to those obtained in Great Britain. On this final run the train, consisting of a 4–6–0 engine with 5 ft. 6 in. driving-wheels and three cars weighing 130 tons, is said to have started from Erie and passed a point just outside Buffalo, 86 miles from the start, in 70 min. 46 sec., the speed thus averaging 72.9 miles an hour. A great deal of controversy was aroused over this run; full details were however published in the *Engineer*, and although the figures were startling, there does not seem to be any reason to suppose that they were inaccurate.

In 1897 the Philadelphia & Reading Company began to run between Camden (Philadelphia) and Atlantic City (55½ miles) in 50 minutes start to stop, and shortly afterwards the Pennsylvania began to cover its 58¼ miles between the same points in 52 minutes. For some fifteen summers these timings were repeated, and during that period many very remarkable runs seem to have been made, with start-to-stop speeds occasionally exceeding 75 miles an hour. A number of runs exceeding 70 miles an hour seem also to have been performed with the 18-hour New York-Chicago expresses on the New York Central route when time was being made up. But, as was also the case with the German records, very few details of these performances reached this country, and the few bare figures supplied were not very illuminating.

The fastest long-distance run that has ever been made seems to have been one on the Pennsylvania line from Chicago to Pittsburgh performed on 8 June, 1905. I am indebted for information as to the details of this run to the Chief of Motive Power of the Pennsylvania Railroad, who has kindly supplied me with particulars. The train, consisting of a 4-4-2 engine with 6 ft. 8 in. driving wheels, and three coaches weighing 140 tons, left Chicago at 7.25 and arrived at Pittsburgh at 2.45. The distance is just under 468 miles, so the run, inclusive of all stops and delays, had occupied 440 minutes, and the average speed from end to end was 63.9 miles an hour. A booked stop was made at Fort Wayne (148.4 miles) where engines were changed, and stops were also made at Lima (207.8 miles) to examine a hot axle-box, near Crestline (279.8 miles) to drop a coach (the train from here onwards consisting of two coaches weighing 100 tons), near Smithville (340.8 miles) to replace a burst air hose, and at Alliance (384.6 miles) where water was taken. There is no mention of changing engines after Fort Wayne. In respect of the five stops the train was standing still for 28 minutes, so that the total running time was 412 minutes and the average running-speed 68.2 miles an hour. Speed restrictions at the start made it necessary to spend 29 minutes in running the first 22.4 miles, and more speed restrictions at the finish caused the last 4.7 miles to occupy 7 minutes. If these sections, and also the time spent in standing still, are left out of account, 441.5 miles were run in 376 minutes (70½ m.p.h.). There appear to be no steep gradients, no considerable lengths of rising or falling gradient, and few, if any, sharp curves except perhaps in, or quite close to, Chicago and Pittsburgh. The absence of any long falling gradients no doubt accounts for the fact that the top speed is said to have been only 90 miles an hour. The fastest start-to-stop run appears to have been that from Lima to Crestline. Crestline Station (72 miles) was passed 59 minutes after the start from Lima, and the train was stopped about 1,000 feet beyond, so the run must have been performed at an average start-to-stop speed of not less than 72 miles an hour.

There is, fortunately, no doubt about the British record. On 9 May, 1904, the Great Western Railway ran a special train from Plymouth to Paddington which was throughout timed in detail by the late Mr. Charles Rous-Marten. This train, composed of a 4-4-0 engine and five vehicles weighing 148 tons, ran from Plymouth to Bristol, 128 miles 10 chains, in 123 min. 19 sec., the last 75¼ miles from passing Exeter at reduced speed occupying 64 min. 17 sec. From Bristol to Paddington, 118 miles 33 chains, occupied 99 min. 46 sec. On this section the train was composed of four vehicles weighing 120 tons and the engine was a 4-2-2. The speed from Exeter to Bristol was thus just over 70 miles an hour and from Bristol to Paddington 71.2 miles an hour. It was on this occasion that a top-speed of 102.3 miles an hour was attained on the steep falling gradients between Whiteball Tunnel and Taunton, and east of Swindon the average speed for 73 miles was 80 miles an hour.

In France almost all the best locomotive work has been performed on the Nord. Here, as elsewhere, a number of the finest runs do not appear to have been timed in detail. I understand that on one occasion one of the 4-4-2 express engines ran from Paris to Chantilly (25½ miles) in about

23 minutes start to stop, the Survilliers bank—12 miles, averaging 1 in 230 up—being included in this section. I have also heard on what seemed quite good authority, though my informant was not present, that one of the 4-6-2 engines of the 3.1151 class once ran from St. Quentin to Jeumont, 52¾ miles, in 42 minutes start-to-stop with a train weighing probably 250 tons. With no details available it is unfortunately impossible to examine these performances. On the Nord I have, however, myself at various times been fortunate enough to witness performances of outstanding merit, some of which may be set forth in detail.

On 15 April, 1902, engine No. 2.645, a 4-4-2, with 171 tons behind the tender, ran from Paris to Amiens, about 81 miles, in 73 min. 33 sec. start-to-stop. Speed was gained very quickly from the start, kilometre 7 (rather more than 4¼ miles) being passed in 5 min. 29 sec. Here the speed was 73 m.p.h. Then follow 20 kilometres rising on an average at 1 in 230. For this stretch the speed averaged 68 m.p.h., and was 65.4 m.p.h. at the summit. Soon after this the line begins to fall and from post 32 seven kilometres were run at an average speed of 80 m.p.h., the speed for kilometres 37–39 being 81 m.p.h. Soon after this there was a service slack for facing points which cost about 15 seconds, and then a few miles further on another very severe service slack through Creil Station, costing about 1 min. 25 sec. After speed had been regained 29 kilometres of gradients rising on an average at about 1 in 350 were run at 69 m.p.h. speed at the summit, where the gradient is 1 in 310, rising to 70 m.p.h. Thence 40 kilometres, almost all down hill, occupied 19 min. 37 sec. (76 m.p.h.), the 103rd kilometre occupying $27^2/_5$ seconds (81½ m.p.h.). Longueau, 126 kilometres from the start, was passed in 68 min. 6 sec. Between Longueau and Amiens there was a severe slack on account of repairs to the permanent way which were proceeding ; this slack cost about 2 min. 10 sec., and but for it the time to Amiens should have been 71 min. 23 sec., and the average speed 68 m.p.h. start to stop. From about kilometre 7 somewhat more than 71 miles were run in an hour in spite of the two service slacks. The detailed timing of this run was as follows:

	H.	M.	S.
Paris, depart.	0	0	0
Kilometre 4 pass	0	3	53 2/5
" 5 "	0	4	25 2/5
" 7 "	0	5	29 1/5
" 8 "	0	5	59 4/5
" 27 "	0	16	26 1/5
" 32 "	0	18	59 1/5
" 37 "	0	21	18 3/5
" 39 "	0	22	13 4/5
" 48 "	0	26	44 2/5
" 52 "	0	29	37 1/5
" 57 "	0	32	54
" 67 "	0	38	13 4/5
" 86 "	0	48	29
" 87 "	0	49	0 2/5
" 99 "	0	54	45 2/5
" 102 "	0	56	9 2/5
" 103 "	0	56	36 4/5
" 110 "	1	0	1 4/5
" 126 "	1	8	6
Amiens, arrive	1	13	33

On 9 June, 1913, the 4-6-2 Nord engine No. 3.1156, with a load of 292 tons behind the tender, in the course of a run from Paris to Amiens was driven up the Survilliers and Gannes banks as hard as she would go. As already remarked, the Survilliers bank begins about 7 kilometres from the Gare du Nord and continues thence for 20 kilometres, the average rate of ascent being 1 in 230. Owing to a service slack for facing points the speed, which for the 6th kilometre had exceeded 66 m.p.h., was slightly under 64 for the 8th. Here the cut-off in the high-pressure cylinders was 55 per cent, and the regulator was wide open. Gradually, as we ascended the bank, the cut-off was increased to 62 per cent. In these circumstances the speed rose till the 25th kilometre was run in exactly 33 seconds (67¾ m.p.h.), and for the

27th kilometre, run in 33 3/5 seconds, it was 66½ m.p.h. The engine steamed well all the time. The temperature of the superheated steam was about 645° F., and the variable blast-pipe was set to give an orifice with an area equal to that of a circle something over 6½ inches in diameter, except as we were approaching the summit, when the opening was yet further increased.

The Gannes bank really begins about kilometre 48 before Creil Station, but the hardest part of it is between kilometre 66 and the summit at kilometre 86. For the first two-thirds of this distance the ascent averages about 1 in 265, and for the rest about 1 in 310, which is the actual rate of ascent for the last two or three kilometres. We began this ascent at about 64 m.p.h.; again with the regulator wide open, the cut-off was gradually increased as we proceeded, and we finished up by running each of the last three kilometres in 32 2/5 seconds (69 m.p.h.), while the average speed for the twenty was 65.8 m.p.h. The times were:

	H.	*M.*	*S.*
Paris, depart.	0	0	0
Kilometre 7 pass	0	5	55 4/5
,, 12 ,, ...	0	8	52 1/5
,, 17 ,, ...	0	11	52
,, 22 ,, ...	0	14	46
,, 24 ,, ...	0	15	52 4/5
,, 25 ,, ...	0	16	25 4/5
,, 26 ,, ...	0	16	59 4/5
,, 27 ,, ...	0	17	33 2/5
,, 28 ,, ...	0	18	7
,, 66 ,, ...	0	43	17 3/5
,, 71 ,, ...	0	46	14 4/5
,, 76 ,, ...	0	49	6 1/5
,, 81 ,, ...	0	51	53 4/5
,, 83 ,, ...	0	52	59 4/5
,, 86 ,, ...	0	54	37

The best work that I have ever seen in the way of weight-pulling combined with high speed, was performed quite recently by the new 4-6-2 express engines of the Chemin de fer du Nord on a journey from Paris to Calais and back.

The road is one of at least average difficulty. After a downhill start from Paris there are, as already described, twenty kilometres from post 7 rising on an average at 1 in 230. There are then twenty kilometres descent from post 28 at about 1 in 220. From kilometre 51, just beyond Creil, there is an ascent to post 63 of about 1 in 500, and then, after a dip to post 66, the ascent continues more steeply (about 1 in 280) to post 86. Hence to post 127 there is an almost, but not quite, continuous fall, mostly at about 1 in 300. Gentle undulations in the neighbourhood of Amiens, are succeeded by a long stretch of nearly level line to Abbeville, which in turn is followed by fifty kilometres of level to near Etaples. There are then 8 kilometres rising at about 1 in 500, five kilometres rising at about 1 in 135, and six kilometres falling at about 1 in 140 after which the line is nearly level to Boulogne. After Boulogne there are sharp undulations at 1 in 125 leading to the Caffiers banks—ten kilometres of 1 in 125 up, followed by eleven kilometres of 1 in 125 down. The remainder of the distance to Calais Pier is nearly level. (A kilometre is about five-eighths of a mile.)

From Paris the train was the 10 a.m., the weight of which was 531 tons behind the tender. The engine was one of those which have lately been fitted with a feed-heating apparatus and pump. Exhaust steam, the amount of which is regulated by an automatic device, is led from the blast-pipe to one of two drums which are placed on either side of the boiler near the chimney. In this drum it is passed through a separator, which extracts most of the oil which it contains, and it is then mixed up with cold feed-water, which is delivered from one of the cylinders of the pump. The hot water so produced is passed, under the slight pressure due to the exhaust steam, to the second drum, which is under atmospheric pressure only, and contains partitions over which the water falls. This action tends to throw out any air or carbonic acid gas which the water may contain. Some of the water falls into the force-pump which sends it on into the boiler, and the rest continues to circulate till it rejoins the feed-pipe from the tender. The water is heated to nearly 100°C, and the economy in fuel due to the apparatus is said to amount to 15 per cent.

We started with steam pressure at the blowing-off point of sixteen kilogrammes per square centimetre (227 lb. per sq. in.). Sixty miles an hour was reached about two and a half miles from the start, and the speed at kilometre 7 was about 66 m.p.h.; it did not fall below 60 m.p.h. before kilometre 12, after which it gradually diminished till the 19th kilometre took 41 $^1/_5$ sec. (54¼ m.p.h.). The cut-off in the high-pressure cylinders was soon after this increased to 55 per cent. of the stroke with the result that speed recovered, and the last three kilometres to post 27 were run in 38 sec., 39$^1/_5$ sec. and 38$^3/_5$ sec. respectively, this last being equal to a shade under 58 m.p.h. Before post 27 the h.p. cut-off was further increased to 60 per cent., but not soon enough to have any great influence on the speed. The twenty kilometres from post 7 were run in 12 min. 47 sec. (58¼ m.p.h.), and post 28 (the kilometre post next after the summit and about 17¼ miles from Paris) was passed in 19 min. 43 sec. from the start.

Downhill speed soon reached 74 m.p.h., but owing to recent relaying, had to be moderated before Chantilly, and was then reduced to about 50 m.p.h. for traversing the junction at Creil. On gradients rising at about 1 in 500 it had recovered to 61 m.p.h. by the time kilometre 63 was passed, and the subsequent dip brought it up to quite 68 m.p.h. It then fell slowly till at about post 80 the h.p. cut-off was increased to 55 per cent., but for almost the only time during the run, steam pressure had fallen by about 20 lb., and speed up 1 in 310 to the Gannes summit at kilometre 86, was the same as it had been up the 1 in 200 to the Survilliers summit at kilometre 27.

We were now well before time, so on the falling gradients towards Amiens no attempt was made to run fast, and a particularly careful slack was made at Amiens. So slowly did we go, indeed, that the piece between posts 86 and 142 took

4 min. 20 sec., more than it had taken when last I had made the same journey. We then began to run harder, and traversed 6 kilometres from post 142 in 3 min. 7 sec. (71½ m.p.h.), but soon after this were stopped by signal at Hangest (151.6 kilometres or 94¼ miles from Paris) 95 min. 53 sec. from the start, a message having been received from one of the stations we had passed to stop and examine the train. The examination revealing nothing amiss, we proceeded and covered the remaining 14¾ miles to Abbeville in 17 min. 4 sec. with a top speed at 72½ m.p.h.

After a stop of less than two minutes, we were off again, and took 1 min. 32 sec. to pass kilometre 176 (about 700 yards). Sixty miles an hour was reached about post 182, passed in 6 min. 47 sec., and from post 188 forty kilometres were run in 21 min. 18 sec. (70 m.p.h.). Steam was cut off at 40 per cent. in the h.p. cylinders, and at 65 per cent. in the l.p. cylinders, and the temperature of the steam was 310°C. On the rising gradients beyond Etaples speed did not get below 60 m.p.h. before post 235, and the 238th kilometre took 43¹/₅ sec. (51¾ m.p.h.). A fairly rapid run down the other side of the bank ensued, and Boulogne (Tintelleries), 49 miles from Abbeville, was passed in 46 min. 50 sec. On the ups and downs at 1 in 125 beyond Boulogne, speed was almost everywhere more than 60 m.p.h., but there was a very severe slack for a long way up the Caffiers bank, where the line had just been relaid, so that the ten kilometres from post 268 took 11 min. 52 sec. In these circumstances the loss of time amounted to fully 5 min. Downhill 74½ m.p.h. was reached about post 285 and post 292 was passed in 75 min. 11 sec. from Abbeville (72 miles), but a slow stop caused the last 3¼ miles to take 6 min. 9 sec., and we finally stopped at Calais in 81 min. 20 sec. from Abbeville, and 2¼ minutes late The actual running time had thus amounted to 194¼ min. as against a booked running time of 192 min., but ten minutes had been lost by the slacks near Chantilly, and on the Caffiers bank, and by stopping and starting again at Hangest. In addition to this the speed had been purposely reduced for a long way before

Amiens, when the train was before time. Thirty-two tons of water had been used on the whole run.

The return journey was made on another engine of the same type (also equipped with a feed-water heater and pump) with a train weighing 581 tons behind the tender.

We were due to start at 2.50 p.m., but did not get off till 3.12 p.m. The first six kilometres ($3\frac{3}{4}$ miles) to post 291 took 7 min. 39 sec., and the next kilometre, which is level, 45 sec. (49.7 m.p.h.). From post 290 the eleven kilometres ascent at 1 in 125 occupied 9 min. 23 sec. (43.6 m.p.h.) and the speed at the summit was only the smallest shade under 40 m.p.h. All the time the regulator was wide open and steam pressure in the boiler at blowing-off point, while the h.p. and l.p. cut-offs which were 60 and 65 per cent. at the beginning of the incline were gradually increased to 70 and 70 at the end. In these circumstances pressure in the l.p. valve-chests rose to four kilogrammes per square centimetre (56 lb. per sq. in.). On the subsequent descent speed soon reached the authorized limit of 120 kilometres ($74\frac{1}{2}$ miles) an hour, and over the ups and downs to Boulogne and for some distance beyond, I did not get any timing under 60 m.p.h. On the ascent of 1 in 140 to kilometre 238 speed only just fell under 50 m.p.h., and we had reached 66 m.p.h. on the subsequent descent when an adverse signal at Dannes-Camiers caused speed to be reduced to 10 m.p.h., and lost us two minutes. Etaples, $43\frac{1}{2}$ miles from Calais, was passed in 50 min. After this, 47 kilometres of level line from post 225 were run in 25 min. 23 sec. (69 m.p.h.). Steam was cut off at 40 and 65 per cent., and the boiler steamed perfectly. We drew up at Abbeville ($75\frac{1}{4}$ miles) in 78 min. 30 sec. from the start at Calais.

After stopping $3\frac{1}{2}$ min. at Abbeville we made a very slow and difficult start, and took 11 min. 1 sec. to pass post 164 (seven miles) where we reached 60 m.p.h. The line rises so slightly as to be practically level. Speed continued slowly to increase till eleven kilometres from post 153 were run in 5 min. 54 sec. ($69\frac{1}{2}$ m.p.h.). The next nine kilometres, in which there are two and a half rising at 1 in 200 took 5 min.

(1 sec. very nearly 67 m.p.h.), and we passed through Amiens (28 miles) in 30 min. 20 sec. from the Abbeville start. At post 120 speed was about 63 m.p.h. and then 26 kilometres, mostly uphill at about 1 in 300, to post 94 occupied 16 min. (60½ m.p.h.). From near post 94 there was a long slack over a piece of line that had recently been relaid, which lost us about 3¾ min. On the descent to Creil 20 kilometres from post 76 were run in exactly ten minutes (74½ m.p.h.).

Up the bank beyond Creil speed was allowed to die down to 44 m.p.h. to traverse another stretch of line which had recently been relaid, but after that slowly rose till kilometre 29-28 was run in 43³/₅ sec. (51.3 m.p.h.), and downhill towards Paris 74½ m.p.h. was again maintained for some distance. A very slow and cautious stop eventually landed us in the Gare du Nord 115 min. 24 sec., after leaving Abbeville (109 miles), about 5 min. of which were due to the various delays we had suffered.

The fastest start-to-stop run in which I have ever taken part was one on the Pennsylvania lines between Camden (Philadelphia) and Atlantic City. The 58¼ miles took 52 min. 5 sec. start to stop (67.1 m.p.h.). The time allowed the particular train with which I travelled was 54 minutes, but as later in the year—my journey took place early in June—all the best trains were given 52 minutes, the run may be regarded as an ordinary one. The line, with a good many ups and downs, reaches a summit 15 miles out of Camden, the last four miles to the summit rising at 1 in 196; from mile-post 15 it undulates with a falling tendency the rest of the way to Atlantic City. The engine was a 4-4-2 weighing 81 tons, the 8-wheel tender weighed (full) 59 tons, and the train behind the tender weighed 229 tons. For the first couple of miles speed had to be kept low, but then it gradually rose till the 11th mile was run at 72 m.p.h. The four miles' ascent at 1 in 196 to post 15 brought the speed down to 65½ m.p.h. Then the next 40 miles were run in 29 min. 46 sec. (80.6 m.p.h.), and post 55 was passed 47 min. 11³/₅ sec. from the start. After this speed had to be severely restricted for the last mile or so where the railway passed on the level through the streets of Atlantic City. The work was quite easily done and the motion of the engine was strikingly smooth. The following were the times:

	H.	*M.*	*S.*
Camden, depart.	0	0	0
Post 2 pass	0	5	14 2/5
" 10 "	0	13	1 1/5
" 11 "	0	13	51
" 15 "	0	17	26 2/5
" 20 "	0	21	29 1/5
" 25 "	0	25	7 4/5
" 30 "	0	28	53 1/5
" 36 "	0	33	14 3/5
" 40 "	0	36	9 4/5
" 46 "	0	40	35 2/5
" 50 "	0	43	29 2/5
" 55 "	0	47	11 3/5
Atlantic City, arrive	0	52	5

In Great Britain I have never seen anything even remotely comparable with the best work I have seen in France and America. The best long-distance run in which I have taken part was one from Exeter to Paddington, on which a 4-6-0 four-cylinder engine, with about 320 tons behind the tender, ran the 173½ miles in 172 minutes in spite of three slacks costing about 2 minutes in all. Before 1924 my best sustained burst of high speed was as long ago as 1897, when one of the smaller Midland singles with a train of about 120 tons ran 10 miles downhill between Leagrave and Bedford in 7 min. 40 sec.—78¼ m.p.h. In 1924, however, a Great Western four-cylinder 4-6-0 with a train of thirteen 8-wheel vehicles (mostly of the 70-ft. type), weighing approximately 440 tons, gave me by far the best downhill run that I have ever had in Great Britain. From post 73¾ on the direct main-line to Exeter 21 miles were covered at an average speed of 75 m.p.h., 10 of these from post 82 occupying 7 min. 34 sec. (79¼ m.p.h.) and 8 from post 83 occupying 5 min. 58 2/5 sec. (80.3 m.p.h.). The 4 miles from post 85 were run in 2 min. 54 3/5 sec. (82.3 m.p.h.), and the fastest mile—from post 87¼—occupied 43 1/5 sec. (83.3 m.p.h.).

On another occasion another four-cylinder 4-6-0 with a train weighing about 300 tons ran 6 miles from post $83\frac{3}{4}$ in 4 min. 29 sec. (80.2 m.p.h.), the mile from post $87\frac{1}{4}$ in this case also taking $43^1/_5$ sec.

Quite recently, however, a Great Western 4-6-0 engine of the latest type with a train of thirteen heavily loaded 8-wheel vehicles weighing at least 460 tons behind the tender ran down the bank from Whiteball tunnel past Taunton in a way which out-distanced the two performances just described. For thirteen miles the speed averaged 80 m.p.h.; ten miles from post 171 occupied 7 min. $17^4/_5$ sec. (82.1 m.p.h.); one complete mile was run in $42^3/_5$ sec. (84.5 m.p.h.) and several quarter-miles in $10^3/_5$ sec. each (84.9 m.p.h.).

A Midland three-cylinder compound with 270 tons ran a mile down the St. Alban's bank (1 in 176) in 44 sec. (81.8 m.p.h.) and $2\frac{1}{2}$ miles in 1 min. $52^2/_5$ sec. (80 m.p.h.), and a very heavy North-Western train ran $2\frac{1}{2}$ miles down Shap in 1 min. $52^1/_5$ sec.

When I am timing a train carefully, I use two watches—a stop-watch and an ordinary watch. The stop-watch is one of the kind with four dials. These are those containing:

(1) The centre-second split hand; and

(2) The minute-recorder which works with it,

both these hands being started and stopped by the same knob, while the centre-second hand is split by another knob;

(3) The ordinary minute- and hour-hands; and

(4) The ordinary second-hand,

these working precisely as in an ordinary watch.

I start the centre-second hand as the train starts and stop it as the train comes to a stand at the end of its run, the combined readings of the minute-recorder and centre-second hand thus giving the time occupied by the whole run. I check these readings by noting and writing down both at the beginning and end of the run the time as shown by the hour- and minute-hands of the stop-watch and by those of the watch of ordinary construction. There is thus a three-fold check upon the accuracy of the over-all timing. For intermediate timings—miles, quarter-miles, kilometres, or passing-points of any kind—I split the centre-second hand and write down the reading in minutes (which are taken from the minute-recorder), seconds and fifths-of-seconds. This gives the time, reckoned from the start, at which the point in question is passed. If a large number of points are timed, as should always be done when the run is of particular interest, these timings act as a very complete check upon one another. When, for instance, at high speed, every quarter- or half-mile or every kilometre is timed, any unexpected variation in the timings of successive lengths will at once throw doubt upon the accuracy of these timings and cause them to be investigated and rejected if no satisfactory explanation is apparent.

Beyond this I test the stop-watch frequently by running the centre-hand (with the split part of it stopped so as to make the strain upon the mechanism as great as possible) for considerable periods, and seeing that it keeps pace exactly with the ordinary second-hand; at the same time I see that the minute-recorder keeps pace with the minute-hand. In my experience the minute recorder is the most troublesome part of the watch and the one most likely to go wrong. Fortunately any error in its working is quite easy to detect. A good precaution to take, when the watch returns from the repairer, is to see that the two parts of the centre-second hand will not catch in one another when the hand is split.

It is by no means an easy matter to secure a reliable stop-watch. I had untold trouble in finding one. Some, priced at £10 or more, which I tried were quite worthless, the centre-second hand not keeping pace with the ordinary second-hand which, of course, showed that the mechanism was radically defective; almost every other possible kind of defect, too, had to be guarded against. I had no idea that watches could go wrong in so many ways as the first stop-watches which I tried showed themselves capable of doing.

CHAPTER VI

The London, Midland & Scottish Railway, the biggest of the groups formed under the Railways Act, comprises two very big Companies, the North Western and the Midland; two smaller but still very important companies, the Caledonian and the Lancashire & Yorkshire; and also the Glasgow & South Western, Highland, North Staffordshire and Furness Companies.

This great group, which has a capital of about £400,000,000 and a mileage of about 7,500, runs its own trains to the north coast of Scotland, to the south coast of England, and to many points both on the east and west coasts of both countries. It also possesses railways in Ireland.

The lines which eventually formed the North Western Railway were for the most part those which were the earliest to be built and so had first choice of ground. The consequence was that the principal North Western lines were more direct and had easier gradients than any lines between the same places which were subsequently built by other companies, and between the more important centres of population served by alternative routes the North Western usually got most of the traffic. North of Lancaster towards Scotland and north-east of Manchester towards Leeds, indeed, the country traversed is so broken and hilly that heavy gradients were unavoidable; but even so, the North Western secured routes more favourable than those of any rival line.

The North Western was for a long time so well satisfied with its important long-distance traffic out of London that it did little to develop such suburban traffic as it possessed. About twenty years ago, however, it came to the conclusion that the time had arrived for a change of policy, and it gradually put in hand a scheme for opening up the suburban district, through which its main-line runs. The original intention was that a new line should start from a deep level station underneath Euston, and run underground for several miles, where it is practically impossible to secure land above ground for widening purposes, and then, when it emerged from the town, should continue on the surface. The above-ground part of this scheme was begun without delay, but the construction of the elaborate and costly underground line and the deep level station was put off. On consideration, Euston did not appear to be the place at which the great body of suburban passengers would find it most convenient to arrive in London, and it seemed as though the considerable expense, which would be involved by the construction of the underground line, might (partly at least) be saved, while greater conveniences might at the same time be offered to the public if arrangements could be made for conveying passengers to a number of different points. The outcome of this was a completely new scheme, which gives passengers living along the North Western line between London and Watford unique facilities for reaching practically every part of the Metropolis. From the suburban stations new electrical services have been introduced to Broad Street, along the North London line, which passed under the control of the North Western company, to Euston itself along the existing surface lines, some of which have been arranged for electric traction, and to various other points in different directions, along existing lines which have also been electrified, while a direct connection has been made between the main line at Queen's Park and an extension of the Baker Street and Waterloo Tube, which has been built with capital provided by the North Western.

A notable exception to the general convenience of the lay-out of the North Western main-line is found in the position of Euston and its approaches. In order to carry the line over the canal at Camden it was necessary to have recourse to a gradient of 1 in 70 for the first half mile from the terminus, which makes a bad start and a worse finish.

Once clear of this ascent, the North Western main line gives very easy running as far as Crewe. There are one or two curves where a certain amount of caution is necessary, but otherwise the running conditions are extremely favourable, and the branches to Birmingham, Liverpool and Manchester present few difficulties. On the main line north of Crewe there are some miles of more difficult gradients before Preston, but it is only for the last 60 miles to Carlisle that the gradients are continuously severe. In the 31 miles between Carnforth and Shap summit the line rises some 900 ft., the steepest piece being the last 4½ miles from just beyond Tebay, which is 1 in 75. For a great many years there has been talk of constructing a tunnel, by which the trains would avoid the climb to Shap summit, but nothing has so far come of it, and the engines will probably continue to pant over this mountain road for a very long time to come.

Crewe was in a very special way the centre of the North Western line. Besides being the site of the great locomotive works, it was situated almost exactly at the half-way point of the principal main line, and it was on Crewe that all the principal branches converged. Though not reserved exclusively for North Western trains, the number of trains belonging to other companies that made their way there was not great, and it is probable that at no other junction in Great Britain was there exchanged so much traffic in which only a single company was concerned.

Though up to the middle '90s of last century the North Western was not in the forefront of the railways which performed long non-stop runs, it is owing to the Ramsbottom water troughs which this railway was the first to adopt that British railways at the present time stand in this respect pre-eminent among those of all the world.

The troughs can be laid down on any level piece of line 500 or 600 yards long, even if there is a gentle curve. They are some 18 inches wide, and are placed midway between the rails. Under the tender there is a scoop, which normally lies well clear of the sleepers, but which can be lowered, when necessary, by means of some pneumatic or other arrangement, so that its mouth descends some inches below the level of the water in the troughs. On reaching a trough the fireman lowers the scoop, and the water, impelled by the impetus of the train, rushes up the scoop, and thence up a vertical pipe (which is a continuation of the scoop), out of which it overflows into the tank of the tender. If the line were level at either end of the trough, the scoop must strike against it if not raised out of harm's way. For this reason the line is arranged to fall slightly for some distance as the train reaches the trough, and to rise again to the same extent at the end as it passes off it. The ballast, where troughs exist, is constantly being flooded, and must be laid and maintained in the most careful way.

To begin with a speciality of the North Western, the troughs were for many years used successfully by that line before their utility was recognized to any extent elsewhere. The North Western did not perform longer runs without a stop than other companies, and, though the troughs afforded certain conveniences for conducting the traffic, it was quite easy to get on without them, and they were generally neglected. One or two companies performed runs of over 120 miles without using troughs, and it does not seem to have occurred to anyone that longer runs than this were desirable. Some striking object-lesson was necessary to impress upon people's minds the advantages of the water troughs, and this object-lesson was supplied in 1895, when the railway race to Aberdeen, between the East and West Coast routes, took place. During that race the North Western, with much lighter tenders than any of the other companies concerned, regularly took the West Coast train to Carlisle (299¼ miles), with only one stop, while in the remaining 240½ miles to Aberdeen, the Caledonian normally stopped (at least) twice, and the East Coast stopped five times in covering its 523½ miles. The average length of run was, therefore, for the North Western, about 150 miles; for the Caledonian, 80 miles; and for the East Coast companies, 87 miles. The Caledonian, it is true, on the last night of the race, managed to cover the 150¾ miles from Carlisle to Perth without a stop, but the train was even lighter than usual, and the speed for this stage was a good deal lower than for any of the other stages of the journey, so that it looks as if water had to be economized. After the race to Aberdeen, one Company after another adopted the troughs, and soon all the English Companies, whose main lines were more than 100 miles long, except the South Western, had laid them down, though even now they are not employed in Scotland. Perhaps one of the reasons for the troughs not being laid down in Scotland is that, owing to the greater severity of the winter in the north, it is feared that they would comparatively often freeze, and so be rendered useless. This is not, of course, anything like a complete explanation, and a more powerful reason probably is that, owing to the hilly character of most of the Scottish main lines, it would be more difficult and expensive than usual to arrange for an adequate number of troughs in the places where they are wanted.

The most obvious use of the troughs is to enable long runs to be made, but they have a variety of other uses. One of the most economical steps that a railway can take is to supply the boilers of its engines with water which will not deposit hard and adhesive scale. As it does not matter much to ten miles or so where the troughs are situated, it is often possible to choose a spot where a natural supply of good water is to be had cheaply, and, even if good natural water is not available, a water-softening installation on a large and economical scale may be arranged to feed the troughs. The first cost, and the weight of the tenders also, can generally be made less on railways which use water troughs, and, owing to the elimination of stops, the line may perhaps be able to accommodate more trains in a given time.

The Midland, unlike almost all the other railways which had their termini in London, did not regard the Metropolis as its headquarters. Its London extension was only an afterthought, and, important as its traffic on that and other extensions became, the principal activities of the Midland were devoted to its interests in the centre of England. Its headquarters were at Derby, which was almost the geographical centre of the system, and it was upon the centre of England that all its chief lines converged. But, if the central part of its territory was its special care, there was no railway in England which showed so much enterprise in reaching out towards parts of the country remote from its centre. Outside the central area, the Midland had its own lines to London, Manchester, Bristol, Carlisle, and Heysham, and by means of joint railways or running powers could run its trains to Cromer and Yarmouth on the east coast, to Bournemouth on the south coast, to various points on the Bristol Channel, to Liverpool, and to Stranraer in Scotland. A few years before the War also the Midland bought the Belfast & Northern Counties Railway, so that it possessed several hundred miles of railway in Ireland, and a little later absorbed the London, Tilbury & Southend Railway.

The Midland first secured access to London over the North Western line to Euston and after that over the Great Northern line from Hitchin to King's Cross, but in the '60's of last century found itself obliged to build a new line from Bedford to London with a passenger terminus at St. Pancras, and large goods and coal depots in various parts of London.

Like all the principal railways north of the Thames the revenue of the Midland was principally derived from goods and mineral traffic, receipts from passengers amounting to less than a third of the whole. It is probable that a greater proportion of the Midland receipts came from coal traffic than was the case with any other big railway. A great part of this traffic was concentrated at Toton, a couple of miles north of Trent. Here are situated the marshalling sidings from which are distributed the enormous quantities of coal raised in the numerous neighbouring collieries. The sidings lie on either side of the main line to the north, those to the east dealing principally with full wagons coming from the collieries, and those to the west with the empty returning wagons, and in both cases the marshalling is performed by the help of gravity. In other parts of the country a special undulation, known as a "hump," has had to be built in order to make the force of gravity available, but at Toton the trains of wagons from both directions arrive at a level high above the sidings destined to receive them, and there is no necessity to push them laboriously up one side of a hill to make them run down the other side. Some idea of the volume of the traffic dealt with may be gathered when it is stated that there are 30 roads parallel to one another to the east of the main line and 18 to the west, and, even so, trains are despatched to many more destinations than there are roads on which to make them up. The system of working is that a train arrives on the high level, the train engine is detached, and then, when it is the turn of this particular train to be broken up, a shunting engine comes on behind and gradually pushes it over the brow of the hill; here at first, for a short distance, there is a steep descent, on which the wagon rapidly gains speed, and subsequently, right to the end of the siding, the descent continues, but much less steeply, so that a wagon which runs normally will, when properly started, continue in motion for any distance, but one which has been brought to a standstill will not start again of itself. The wagons are run down the hill either singly, or, if more than one for the same destination are already next one another, these are sent down together. The work is done very quickly, sometimes only 20 yards separating one shunt—as each wagon or number of wagons is called—from the next. The points are set for each shunt in accordance with marks placed upon it, and are controlled from a box near the divergence of the different roads. All wagons do not run equally well, some being better maintained than others; frost may harden the lubricating grease and make them run stiffly, and wind exercises an accelerating or retarding effect, in accordance with its direction; so the incline, on which the wagons acquire their momentum, must be made steep enough to give an unnecessarily great impetus to a wagon which runs freely, and its course may have to be retarded. At the bottom of the steep part of the incline, therefore, stand shunters, armed with brake-sticks, and, as each wagon passes them, they observe whether it is going too fast; if it is, one of the shunters manipulates the brake and runs beside the wagon till the speed has been sufficiently reduced. Sometimes, but very rarely, a wagon runs so badly that it has not enough momentum to carry it to its appointed position; in this case it is usually necessary

TOTON SIDINGS

for the pushing engine, when it is next disengaged, to descend the incline and take the wagon to its proper place.

In this way the different trains are made up, but before they can start on their journey a certain amount of subsequent shunting is generally necessary to get the wagons in the right order. This is done in the ordinary way by the awkward process of the trains being run backwards and forwards by an engine, and offers the greatest contrast to the simple and expeditious method of making up the trains by the help of gravity. When a train is arranged with the wagons in the proper order, a brake van is run down by gravity from a short siding, where a number of these vans are standing in readiness, and attached to the rear, and then everything is ready for the start. Some of the trains leaving Toton for the south are very heavily loaded. One, which starts in the afternoon, sometimes loads up to eighty full wagons, and is drawn by two engines. The day I was there, there were 71 loaded wagons, and, even so, the procession seemed endless. To relieve the main line there is, as far as beyond Trent, a loop by which most of the traffic to and from the south leaves and enters the Toton sidings, and this loop adds another to the very large number of lines which cross and connect with one another round about Trent.

Having examined the working of the coal traffic we may now turn to the ordinary goods traffic. One of the means adopted of late years to secure more economical working has been the system of transferring goods from one vehicle to another at certain large centres, instead of despatching them straight to their destinations in the first instance. In this way parcels of goods travel for a part of their journey in wagons which also contain consignments for other destinations, and more can, therefore, be loaded into one wagon than would otherwise be possible. Among other large centres where this system is practised, is Leeds, where the goods station is also interesting in other ways, being, as it is, large and of modern design.

The station is a rectangular building containing six lines of rails (numbered 1 to 6), arranged three and three, with a platform down the middle, and two more platforms beside the outside lines; at the two outside platforms the drays draw up and consignments for or from the town are loaded onto the drays, or unloaded from them. Traffic from the north is dealt with at one side of the station and from the south at the other.

At Leeds, too, besides handling goods in transit, the railway carries on a warehousing business. Above about half of the station there is a large warehouse in two floors, reached by a lift. A great part of this is let by the year to firms who find it a convenient spot to store their goods.

The day is divided into two unequal parts, the time from 4 p.m. to midnight being utilized for despatching goods, and the rest of the day for receiving goods for Leeds, and for transferring from one vehicle to another goods which have arrived for destinations beyond Leeds. As the trains arrive, as many wagons as there is room for are backed into the platform lines, and, as they are unloaded, each consignment is identified by the checker, and, if destined for delivery in the town, wheeled away by a porter to that part of the platform at which is drawn up the dray which will serve the district in which the address is situated. If, on the other hand, the consignment is to be sent on by rail, the porter wheels it straight to one of a number of wagons marked for various destinations, which stand near at hand all day at the end of the same, or of another, platform; and the consignment is straightway packed in the vehicle in which it will continue its journey, either to another transfer station or to its final destination. In this way small consignments of goods which reach Leeds from all directions are united to form considerable loads as they continue their journey.

The successful working of this system depends, of course, very largely upon an accurate knowledge of the geography of the line, the routes followed by the different trains, and other particulars, and is a system which is calculated to show better and better results the longer it goes on and the longer the men who work it have spent in mastering the rather complicated details. At Leeds, certainly, the system makes it possible normally to despatch a large proportion of wagons with full loads.

The moment a wagon has been fully loaded, it is drawn forward by a rope worked from a hydraulic capstan to a traversing table, which quickly carries it across to one of the centre lines of rails. Just as the traversing table is about to reach its proper position over this centre line of rails, a short stout pole is placed slantwise with one end on the ground and the other under the body of the wagon, so that the latter is slightly lifted, and at the right moment tumbles forward off the traversing table onto the rails, along which it is run out of the shed, to be sheeted and subsequently marshalled in the train, of which it will form part. The whole operation is very rapidly performed. When any movement of wagons is about to take place, one to six blasts on a horn are blown as a warning signal, the number of blasts corresponding to the number of the road on which the movement is to be made. As the supply of empty wagons becomes exhausted, more are brought into the shed along the centre lines of rails, and so work proceeds till, by 4 p.m., all the receiving and transferring for the day is over, and attention is turned to the purely outwards traffic.

In the central area between Leicester and Leeds the Midland had so many lines carrying a big traffic that although the line passing through Trent and Chesterfield and avoiding Derby and Sheffield on one side and Nottingham on the other was officially known as the main line, it did not differ appreciably in importance from several of the loops along which an almost equally large traffic was conducted. The central area is, moreover, so full of junctions that, although the gradients are not nearly so formidable as those on many of the lines on the fringes of the system, it is less well suited for fast running than are some of these latter, which were built later and more with a view to express through traffic. The lines which connect Derby and Sheffield with Manchester through the Pennines naturally have steep gradients, not infrequently as steep as 1 in 90; and between Leeds and Carlisle there are long stretches of 1 in 100, and the summit of the line is 1,167 ft, above the sea.

In its endeavours continually to strengthen its hold over its central area the Midland was before the war contemplating the construction of a new cut-off through Bradford, which would have enabled the Scottish trains to avoid Leeds altogether and would probably have saved them some miles in so doing. In the new conditions which have arisen under the Railways Act this project may be regarded as definitely abandoned.

Other companies serving very large towns for the most part arranged their best trains so as to serve some one particular locality. The Midland, with such towns as Birmingham, Leicester, Nottingham, Derby, Sheffield and Leeds situated at intermediate points on its system, was obliged to arrange many of its express trains so as to serve these places in addition to the terminal points. As, also, the Midland long-distance lines such as those from London to Glasgow, Edinburgh and Manchester were usually longer or harder than those of its rivals, it followed that a great part of the Midland main-line passenger traffic was traffic to and from intermediate places. When at a relatively late period the Midland built its own line to London and secured a good connection with its Scottish allies over its Settle and Carlisle line, it never made more than a half-hearted bid for the very-long-distance traffic.

Train-working methods on the Midland had for a good many years been different from those of other big lines. Up to the end of the nineteenth century Midland engines had differed little in size and power from those of other British railways, but in the present century when other railways began to build engines much bigger than those which they had before employed, the Midland still adhered to 4-4-0 engines for its expresses and 0-6-0 engines for its heaviest goods trains. Then, although Midland engines were, and always had been, weight for weight, at least as efficient as the average in this country, the weight of the trains which they were allowed to haul was limited to decidedly low figures, and very free use was made of pilot engines. In the northern and central parts of the system where there are hindrances from heavy gradients and service slacks the trains have not usually been very fast, and south of Leicester and Nottingham, though the best trains have been fully up to the standard of those run by other companies, the tasks set the Midland engines were usually not very formidable when the limited weight of the trains is remembered. But though the opportunities of performing exceptional work were restricted, the timing of some of the trains over the moderately hard gradients of the southern part of the system was sharp enough to make some of the work of the locomotives quite interesting.

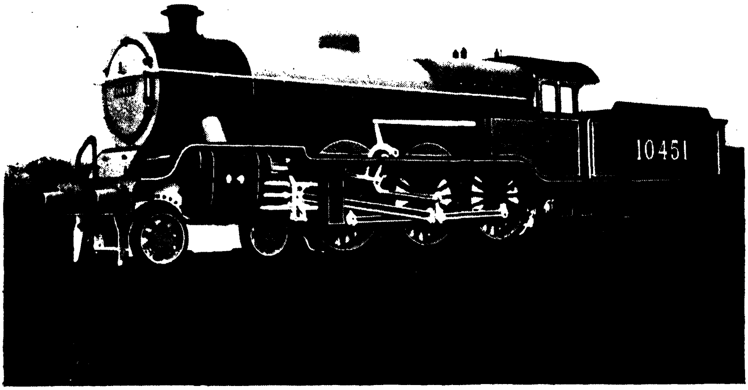
Owing to the limited weight of the trains, the Midland was able for many years to work the chief expresses into and out of St. Pancras with single-wheel engines. These engines, on account both of their graceful design and their handsome dark red colouring, were among the finest looking engines ever built. A good many batches of them were turned out at intervals over a period of about a dozen years, the latest built having driving-wheels no less than 7 ft. 9½ ins. in diameter. When the building of the single-wheelers ceased and four-coupled engines of much greater power were required than any which the Midland had up to that time possessed, the designers turned their attention to the construction of a compound type and produced the only compound express engines that have ever worked with complete success in this country.

These engines have four-coupled wheels 7 ft. in diameter and three cylinders, all driving the first coupled axle. One high-pressure cylinder, 19 in. by 26 in., lies on the centre line of the engine, and the two low-pressure cylinders, 21 in. by 26 in., are placed outside the frames. The pressure of the steam was originally 220 lb. per sq. in., but at a later period when superheaters were added, was reduced to 190 lb. per sq. in. The engine weighs in working order something over 60 tons and the tender (full) 46 tons.

A run on the footplate of one of these engines from St. Pancras to Derby produced some of the best uphill work I have seen.

The train was composed of seven bogie vehicles weighing 190 tons empty, and, with passengers and luggage, about 200 tons.

The start was not rapid, the first 5½ uphill miles occupying 9 min. 49 sec., after which there was a relaying slack involving the loss of 1½ minutes. Mile-post 10 was not passed till 16 min. 11 sec. had elapsed, but downhill beyond Elstree speed increased rapidly, and for the 17th mile was over 72 m.p.h. From post 17 to post 22½ is nearly all uphill—as far as post 21, the gradient averages 1 in 176. The 21st mile was run in $61\,^1/_5$ sec. (58.8 m.p.h.) and the next half-mile in 31 seconds (58 m.p.h.); here the speed was lowest. Eleven undulating miles, not easier than level, from post 23 occupied 9 min. 35 sec., and then, after 75 m.p.h. had been reached at post 36, there was another permanent way slack which cost about 2 min. 25 sec. From post 43 seven miles were run at an average speed of just under 77 m.p.h.; there was in this length a doubtful timing of 80 m.p.h. for one quarter-mile only. We thus entered on the generally rising gradients beyond Bedford at well over 75 m.p.h. and, never losing the impetus thus acquired, did a remarkable ascent of Sharnbrook bank, the last 3½ miles of which from mile-post 56 rise at 1 in 119. The regulator was wide open and the cut-off was gradually increased as we proceeded, till at the summit the reversing-gear was almost in full gear. In these circumstances the speed at the summit of the bank had not quite fallen to 55 m.p.h. There was plenty of steam all the time and it is noteworthy that at this speed, with almost the maximum possible amount of steam being passed through the cylinders, there was no sign of the engine running herself out of breath. The succeeding descent produced a top speed of 78½ m.p.h., but after this there was a very severe slack with almost a stop in Wellingboro' station. By the time we passed post 70 the slack had already caused a loss of 3 min. 20 sec., and this was not all, as speed did not exceed 56½ m.p.h. for the 71st mile, and this was a great handicap in climbing Desborough bank as compared with the high speed at which Sharnbrook bank had been begun. Desborough bank consists altogether of ten miles, averaging about 1 in 165, but steepening a good deal towards the summit. The engine was given nearly as much steam as she had had up Sharnbrook bank, and ran eight miles from post 70 at 54 m.p.h. and the last half-mile to the summit at post 78½ at over 53 m.p.h.



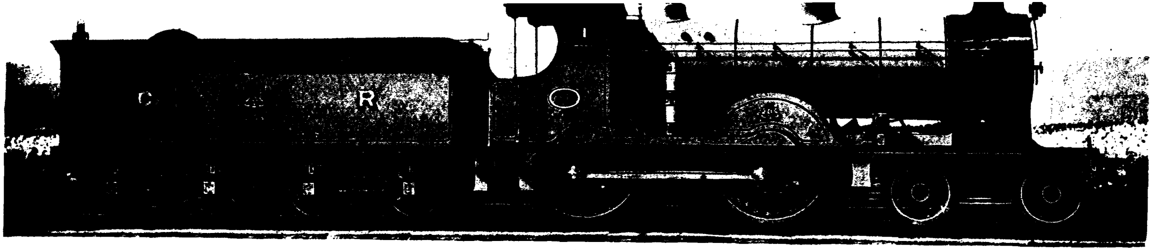
4–6–0, 4-CYLINDER EXPRESS ENGINE, LONDON MIDLAND & SCOTTISH RAILWAY

4–4–0, 3-CYLINDER COMPOUND EXPRESS ENGINE, LONDON MIDLAND & SCOTTISH RAILWAY

A careful slack was made over the curve at Market Harboro', and Leicester (99 miles) was reached in 105 min. 20 sec. from St. Pancras. At least seven minutes had been lost on account of the three permanent-way slacks, so the run was equivalent to one at slightly over 60 m.p.h. start to stop, in spite of the fact that the top speed had been barely 80 m.p.h. Continuing to Derby the character of the line changes completely. For twenty miles there is so slight a fall as to make it almost level. Seventy miles an hour was reached in nine miles, and then ten more miles occupied 8 min. 10 sec., the fastest piece being three miles from mile-post 110, which took 2 min. $22^2/_5$ sec. ($75\frac{3}{4}$ m.p.h.). Post 120, nearly 21 miles from the start was passed in 20 min. 30 sec., and after a very slow stop the train drew up in Derby station more than two minutes early.

Quite lately the London, Midland & Scottish group seems to have made up its mind definitely to adopt the 3-cylinder compound design for its standard 4-4-0 express engines, and large batches of these engines have lately been turned out and are working all over the system. A few slight modifications have been introduced into the design of the new engines—chiefly slightly smaller wheels and slightly increased steam pressure.

At various times towards the end of last century the engines of the Caledonian Railway were called upon to perform feats of so spectacular a nature that the successful accomplishment of these feats may be said to have opened new eras in the history of the locomotive. When considering the express train service of the Caledonian one is, therefore, inclined to think of this company as different from other companies, and to judge it according to a higher standard. The performances in 1888 of the single-wheel engine, No. 123, were the foundation of the Caledonian engines' great reputation, and the fame of No. 123 may be matched with that of the Great Northern 8 ft. singles, and the old broad-gauge singles of the Great Western. She had a leading bogie, driving-wheels 7 ft. in diameter, and a small pair of wheels under the foot-plate, and inside cylinders. She weighed 42 tons, of which 17 tons rested upon the driving-wheels. The grate area was 17 sq. ft. At the time she was constructed the building of new single engines had almost ceased, and no engines of precisely her type had ever yet been seen. In 1888, a year or two after she made her appearance, the race to Edinburgh took place, and she was chosen to work the West Coast train from Carlisle to Edinburgh. The train was a particularly light one—about 80 tons without engine and tender—but only 112 minutes were allowed for the 100¾ miles, and on the way the Beattock bank had to be ascended. Now, of all the obstacles which British engines are called upon to surmount, the Beattock bank—10 miles, averaging 1 in 80, the last 6 of which are 1 in 75—is the particular one, which in popular estimation is held to impose the greatest test upon the locomotive, so that to put a single engine, which most people regarded as an obsolescent type of machine, to haul over such a road a train, to which the attention of the whole country was directed, was to place her in a position of such prominence that her success, if achieved, must make the deepest possible impression. And No. 123 succeeded. Day after day she performed the journey well under booked time, and, what was more, her uphill work was better than her downhill work. Downhill she does not appear to have attained any remarkable speeds, in spite of the existence of long stretches of favourable line, where she certainly could, if put to it, have attained very high speeds indeed. But it was uphill principally that she proved her mettle—she made light work of the Beattock bank, and then all the world rubbed their eyes and began to see that the single engine had been, perhaps, overhastily abandoned. Looked at from this distance of time, and in the light of subsequent experience, the performances of No. 123, although certainly good, do not appear by any means so marvellous as they appeared in 1888. They were, in fact, just what might be expected from a properly designed engine of that sort, in the hands of a competent driver and a competent fireman. But, none the less, they made a profound impression, and, although curiously enough No. 123 was the only engine of her precise design ever built, she was the forerunner of a large number of single engines of the same general



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CALEDONIAN RAILWAY: (1) 4-4-0 EXPRESS ENGINE; (2) SINGLE ENGINE, NO. 123

type, which were built for a good many of the principal English lines in the course of the next dozen years.

The greatest landmark in the history of British locomotives was the appearance in the early part of 1896 of a new design of 4-4-0 express engine on the Caledonian Railway. The first engine of the class bore the name of "Dunalastair."

This class of engine was the first in Great Britain to be given a boiler with a barrel of diameter notably greater than the clear space between the wheels (about 4 ft. 5½ in.). In engines built up to the end of 1895 the centre of the boiler barrel often lay actually between the tops of the driving-wheels. Even when the centre lay above the tops of the driving-wheels, the largest external diameter of the barrel was hardly ever so much as 4 ft. 5 in. This limit was no doubt due in part to weight restrictions imposed by the permanent-way authorities. The North Western permanent-way engineers, for instance, up to quite a late period refused to allow the weight on any axle to exceed 15 tons. "Dunalastair" and her sisters were given boilers with barrels of a greatest external diameter of 4 ft. 9¼ in., and, to arrange for only the minimum clearance between these boilers and the flanges of the driving wheels, the centre-line of the boiler had to be put 7 ft. 9 in. above the rails. With so large a barrel there was room for 265 tubes 1¾ in. in diameter, together with adequate water space between the tubes; and the tubes, being only 10 ft. 7 in. long between the tube plates, were not long enough in proportion to their diameter unduly to retard the draught. When there is no obvious fault in the design of a boiler, such as insufficient water spaces, tubes too small in proportion to their length, too shallow a fire-box or too small a grate, the most satisfactory measure of the power of the boiler is probably the sum of the clear sections of the tubes. With a given draught this dimension determines the volume of hot gases that can come into contact with the heating surface in each unit of time. This practically means that, with fuel of the same quality, the power of different engines varies as the square of the diameter of the boiler-barrel. As the square of 4 ft. 9¼ in. is to the square of 4 ft. 5 in. about as seven is to six, the boilers of the "Dunalastairs" were probably a sixth more powerful than any that had previously been constructed. The grate area was 20.6 sq. ft., the heating surface of the fire-box 119 sq. ft., and the total heating surface 1403 sq. ft. The safety valves blew off at 160 lb. per sq. in. The barrel of the boiler was thus of unusually large diameter and, as short as possible compatibly with the provision of a connecting rod of adequate length. To economize length to the utmost conical pistons were employed. In this manner it was possible to keep down the total wheelbase and the length of the frames to the lowest point, and so produce an engine of great power in comparison with her weight. Except for the increased diameter of the boiler, the design of the engine was almost the same as that of previous express engines of the Caledonian. The driving and coupled wheels were, as before, 6 ft. 6 in. in diameter, but the diameter of the cylinders was increased from 18 in. to 18¼ in. The weight was 47 tons, instead of 45 tons, the greater part of the increase being due to the enlarged boiler. The tenders used with these engines weighed, when full, 40 tons.

The feats of these engines are dealt with in another chapter.

On the Caledonian, as on the Great Northern, a point was reached when the period of exceptional locomotive work came to a definite end. In the case of the Caledonian the period of greatness really terminated on 1 December, 1896, when the agreement between the East Coast and West Coast routes for slowing down the Anglo-Scottish services came into force. For some years after this, however, there were a few runs on the Caledonian which kept alive the remembrance of the railway's too-short period of brilliancy. Under my own observation, so lately as 1913 one of the 4-4-0 engines fitted with a superheater ran from Forfar to Perth (32½ miles) in a few seconds under 33 minutes with 335 tons behind the tender. But taking everything into consideration, the story of the decline of Caledonian locomotive speeds from the highest levels of 1895 and 1896 is as dismal a story as can be found in the annals of any British railway.

Scotland is a country where the distribution of the population would, in any case, make it very difficult sharply to divide the spheres of the different railways. There is a rather narrow industrial zone, stretching roughly across the middle, north-east to south-west, where the population is very thick, and hardly anywhere else any traffic of much value except the tourist traffic.

In many ways the Caledonian Railway lay in an advantageous position. What used to be the Caledonian main line from Carlisle to the north keeps very much to the centre of Scotland, and so makes it easy to serve the places on either side by means of branch lines, while the main line itself keeps quite clear of Edinburgh on the one hand and Glasgow on the other. From Carlisle to Edinburgh and Glasgow the Caledonian route follows the same line for nearly three-quarters of the way, and yet this route to each of these places is a distinctly better one than the direct North British line to Edinburgh, or the direct Glasgow and South Western line to Glasgow. But, if its central position gave the Caledonian numerous advantages, this position also had its drawbacks in that, except for a few outlying districts, the Caledonian had practically no part of Scotland to itself. Protected on the north and south by the estuaries of the Tay and Forth, the North British contrived to secure for itself the whole of the county of Fife, while a large part of Ayrshire was a Glasgow and South Western monopoly. But the Caledonian could not claim as its own preserve any considerable part of the central industrial zone. In the country lying to the east of Glasgow there was hardly a single place which was not quite close to some line or other of both Caledonian and North British, and there were few districts anywhere so closely intersected throughout by the lines of two independent companies. Further west to the south of the Clyde, where the North British did not penetrate, another part of the district served by the Caledonian was equally closely intersected by the lines of the Glasgow and South Western.

In this central district the coal traffic, both inland and for export, is of course very heavy, and the Caledonian had its full share. For the export trade much trouble was taken to arrange that the coal, when it had been brought down to the docks, should be loaded as quickly and cheaply as possible onto the steamers, with the result that some very elaborate and efficient machinery was brought into use. One of the best equipped docks in this respect is the Rothesay Dock at Clydebank, belonging to the Clyde Trust, which is provided with a number of coal hoists of the most modern description. These hoists, which consist of huge frameworks of steel, containing immense lifts, stand at intervals by the water's edge, and measure some 80 or 90 feet in height. They are worked by electricity, the machinery being arranged at the top of the hoists, and the different movements are controlled by a man sitting in a house just below the machinery, whence he has a good view of all that passes. The control is exercised by means of a single lever, which can be inserted into any one of several parallel slots ; the backwards or forwards motion of this lever in the appropriate slot produces the desired result.

The coal trains having been brought into the dock premises by the railway, the wagons are hauled by a rope wound round an electric capstan to the weighing machine, where each wagon is weighed. The wagon is then run forward a few yards to an electric turn-table, where it is turned through the necessary angle, and then one end of the turn-table is elevated a few inches and so runs it onto the hoist ; here it is locked in position by means of a bolt, which is shot out immediately behind the leading wheels, and so prevents them from running backwards. The hoist is then set in motion and the wagon raised to any point desired, and the coal is tipped into a shoot which extends outwards and downwards towards the hold of the vessel lying alongside. To carry out the tipping, a door at the outward end of the wagon is unfastened, and the landward end is raised through an angle of about 45 degrees, so that an avalanche of coal is discharged through the shoot, and in a few seconds the wagon is empty. It is then restored to a horizontal position, the door is closed, it is lowered to a railway line at a higher level than that on which it reached the hoist, the wheels are unlocked, and the wagon runs off the hoist by gravity onto a second weighing machine, where it is again weighed, and everything is ready for dealing with a fresh wagon. In this manner the hoist is capable of dealing with a wagon every minute, which, with wagons of the usual size, means that it can put on board ship 600 tons of coal an hour, but the difficulties of trimming the load make it impossible to maintain this speed for long together. The hoists are built for dealing with 30-ton wagons if necessary, but this is not often the case.

The electricity required is generated in a power-station belonging to the docks. Although the demand for the hoists and other electrical machinery varies greatly from minute to minute, it has been found possible in this power-station to dispense altogether with accumulators. This is achieved by the adoption of a patent system, the chief feature of which is an enormous fly-wheel turning at 375 revolutions a minute, in which a great reserve of energy is stored.

In recent years the work of the railways in dealing with coal has been much complicated owing to the great refinements which have been introduced into the preparation of coal for the market. Between the time that the coal is raised to the surface and that at which it leaves the colliery sidings a great deal of work is done upon it at the pit's mouth in the way of cleaning it and dividing it up into different qualities and sizes. At a colliery which I visited, the coal—which is lifted in the little trucks in which it has already travelled, perhaps a mile, underground, behind a pit pony or on a tramway worked by an endless rope—is first of all weighed by a clerk, and then slid down one of a number of shoots; the larger pieces, amounting to something over 50 per cent of the whole, are caught on the way down by suitable sieves, and, after being picked over by hand by a number of boys and girls, are ready for loading into the railway wagons. The pieces of less than two inches cubed, known as dross, continue their descent, and, falling into railway wagons, are carried a few yards to a building containing the washing plant; here the wagons are tipped, and the dross is sucked up a pipe to the top of the building, and on its subsequent descent is, first of all, divided by a machine into four sizes and undergoes a process of washing, by which it is freed from stones and other heavy incombustible matter; finally, yet a fifth quality of coal, consisting of the finest particles and containing a large admixture of fine earth and stone, is produced, which is principally used for working the winding engines of the colliery itself. What with the different qualities of coal coming from the different seams, or even from the same seam, and the different sizes into which the small coal is divided, one mine may produce coal which is sold under a dozen different descriptions; and as each description of coal has to be kept separate, and cannot therefore be transported in a wagon which contains any other size or quality, the difficulties which the railways experience in making up the coal trains and distributing the coal are very formidable.

Situated as Glasgow is, quite close to the beautiful shores of the Firth of Clyde, a very large part of the suburban traffic is conducted to and from the numerous little seaside towns on that estuary, and there is also in summer an enormous volume of tourist traffic to places beyond. In all of this traffic both the railways which serve Glasgow participate as fully as they can, and both have numerous steamers running in connection with their trains, which bring passengers from Glasgow down to various points of embarkation; from the various piers not the railway steamers only, but numerous others, ply in every direction across the more or less sheltered Firth and the land-locked waters which connect with it. A great part of this traffic starts from Glasgow Central Station, where there is, besides the high-level terminus, an underground station, through which run many local trains.

The Central Station, which was opened only in 1879, has since then been reconstructed twice; at its last reconstruction which took place about twenty-five years ago, it became so large as to rank as one of the very biggest stations in Great Britain, and the engineers were faced with all the problems which arise in connection with the working of traffic on a very large scale, and have to be solved, in each case, on the lines which the space available and the local conditions render expedient.

As the Central Station is situated immediately to the north of the River Clyde, the provision of an adequate number of approach-lines involved the building of a very broad new bridge across the river, a task that was rendered doubly difficult by the insecure nature of the ground in which the foundations had to be sunk. Then, beyond the provision of adequate approaches to a big station, a most important point is that there must be, somewhere close by, a sufficient number of conveniently arranged sidings for storing rolling-stock, from which the empty trains can be brought into the station as required, and to which they can be got out of the way directly they are no longer wanted, so as to be cleaned and prepared for their next journey. Space for these was found by utilizing the site of the old Bridge Street Station, just south of the river. In order to make the sidings as accessible as possible, they were arranged not all next to one another, but in convenient positions beside the different running lines, to which some of them are connected at both ends.

Increased space for the station proper was secured partly by taking in more ground on the west and partly by lengthening the existing station towards the south, with the result that the area was about doubled. The shape of the space at the disposal of the designers was peculiar, because the railway company's hotel already occupied one corner of the station and made it impossible for the platforms on the west side to be carried so far north as those on the east, and a sudden contraction in the width of ground available, due to the fact that sufficient space could not be secured on the east side, made it impossible to carry some of the platforms as far to the south as was desirable. The result is that the north end of each successive platform stops short of the point reached by the one to the east of it, and that the platforms in the middle of the station have been made much shorter than those at either side. In these circumstances, the general scheme of working is to use the platforms at either side for the long-distance trains, which are often comparatively long, and to devote the shorter platforms to the shorter local trains. In harmony with this arrangement the cab-rank is placed between two of the longer platforms on the west side of the station, at which most of the long-distance trains arrive. One of the principal features of the station is the concourse or large open space between the main booking-offices and the ends of the platforms, which gives standing room for many thousands of people. Among the numerous offices, bookstalls, and waiting-rooms, which surround the concourse, is the Left Parcels Office, an institution which is highly appreciated by people who come into Glasgow to shop; here, for a small payment, parcels may be sent from shops in the town, addressed to their purchasers, who call for them as they pass to their trains. A large indicator showing the platform from which each train will depart, is displayed high up on the side of one of the buildings flanking the concourse. It stands in such a manner as to be easily visible from the greater part of the concourse, where at times when the number of passengers is very great, large crowds can congregate under shelter, and, with the help of the indications given, hold themselves in readiness for passing, as soon as the gates are opened, to the trains in which they desire to travel.

At the northern entrance the station is on a level with the street, but, owing to the natural descent of the ground towards the river, and the fact that the interior of the station has an upward slope for some distance from this entrance, the greater part of the passenger station lies high above the street, and there is a great deal of accommodation on a lower level, which is devoted to a number of objects, one of the most important of which is the handling of parcels and of luggage unaccompanied by its owners. Large receiving and sorting offices are supplemented by a passage leading right across the station transversely and connected with different points on the surface and also with the low-level station by means of hydraulic hoists. In addition to the main entrance, access to the station is provided by means of stairways at a variety of convenient points, and a ramp for the entrance of empty cabs has been arranged below the dining-room and above the kitchen of the hotel. The cab-rank stretches the whole length of the main arrival platform; an extension of this platform, conveniently remote from the rest of the station, is used for

THE CONCOURSE, GLASGOW CENTRAL STATION

dealing with fish, fruit and milk, and road vehicles have easy access to it along the cab-rank.

The signalling of the trains into and out of such a station as the Central is a matter of great complication, and, as a train, entering by any one of the approach lines, can be turned into any platform, the number of different indications that it must be possible to give the drivers is considerable. In these circumstances, the extreme simplicity of the signals is very remarkable. At the entrance to the station there are only two signals (one below the other) for each approach line, and, if it were not for the fact that some of the platforms are long enough to take two trains, one behind the other, only one signal for each line would be necessary. If the platform, at which the train is to draw up, is free, the top signal is lowered; if a train is already standing at the north end of it, leaving the south end free, the bottom signal is lowered. The number of the platform for which the points are set is made known to the driver by means of large figures (illuminated by night) which are displayed below the signal which allows him to proceed. The signals and indicating figures are interlocked with circuit-breakers, which are arranged at intervals along the rails; and these circuit-breakers, by the fact that they are depressed by the flanges of the wheels of any train standing upon them, bear continuous witness to the presence of that train. The single box, from which the signals and the 130 odd sets of points are worked, stands upon the side of the new bridge. An electro-pneumatic system of moving the signals and points is in use; the movement of any lever in the signal box actuates by means of electricity a valve situated close to the points or the signal which it is desired to move; and the movements of the valve in turn admit compressed air to, or release it from, a cylinder from which the actual movement of the points or the signal is effected. By the use of this system all the usual point-rods and signal-wires are dispensed with; much space is saved, particularly on the bridge, where space is extremely valuable, while, inside the signal box, it has been found possible to install some 350 levers in a frame little more than 80 feet long.

Big as the station is, the Company, from its experience of the remarkable development of traffic which has taken place in the past, is fully aware that at no distant date it may be necessary to make it yet bigger. The station has, therefore, been so built that, when the time arrives, it will be possible to carry out a further enlargment on the west side, where there is space available for several more platforms to be added to the existing ones. This will be done in such a manner that the further extension will harmonize completely with the present building. The bridge over the Clyde was constructed with this eventuality in view, and will want no alteration when it is decided to proceed with the new work.

The Lancashire and Yorkshire was a line which lent itself to comparison with the Great Central. Very close neighbours, both extended from east to west across England, and each had an important eastern and an important western district, which were joined together by a single pass through the Pennine Hills. The Lancashire & Yorkshire, however, was much the more compact system, and less exposed to possible competition, and the density of its traffic was far greater. With a much shorter mileage, the Lancashire & Yorkshire had a considerably greater paid-up capital than the Great Central, and earned more than proportionally large profits. Indeed, the Lancashire & Yorkshire, with its network of lines closely embracing its numerous Yorkshire, and yet more numerous Lancashire, centres, was in a thoroughly comfortable position, and had not felt impelled to any such ambitious scheme as urged its southern neighbour to London.

On a railway such as this, with important towns situated within a few miles of one another over practically its whole area, the heavy traffic with frequent stops produced conditions specially favourable for electric working, and the Lancashire & Yorkshire was the first company to electrify a length of standard railway which had before been worked by steam locomotives. The Liverpool to Southport line has now been worked by electricity for a long time, and various other sections of the line in Lancashire have been successively electrified.

A very important part of the Lancashire & Yorkshire Railway's

activities was its steamboat service from Goole and Hull to many of the principal Continental ports from Denmark to northern France. On the west coast of Great Britain the cross-Channel and a great part of the coasting services naturally fell to the railway companies, which, by the ease with which they could arrange suitable connections with their own vessels, were in a position to control the course of traffic that originated on their lines. The east coast Continental traffic being by its extent and variety much less amenable to control is more difficult to monopolize, but the Lancashire & Yorkshire, by running services to so large a number of Continental ports, was able to control quite a large proportion of the Continental traffic originating at or destined for its own stations. The Company at the same time ran in conjunction with the North Western a service between Fleetwood and Belfast, and contributed its full share to the very large marine traffic now in the hands of the London, Midland & Scottish group.

The Glasgow & South Western Railway was more closely connected with the Midland Railway than any other Scottish line with any other English one, and formed the continuation of the Midland's route to Glasgow. The Glasgow & South Western route from Carlisle to Glasgow shared the characteristics of the Midland route from London to Carlisle in that it was longer than the rival West Coast route, but passed more important places on the way.

In early days when it was considered unlikely that more than one line between Glasgow and Carlisle would be required there was great rivalry between the Annandale route, eventually secured by the Caledonian Railway, and the Nithsdale route, along which the Glasgow & South Western was built. At that remote period the terrors of the ascent now known as Beattock bank were so great that it was considered probable that it would be worth while to choose the longer Nithsdale route for the principal main-line so as to make use of a summit four hundred feet lower than Beattock summit. As so frequently happened when in early days there was rivalry between two routes, both finished by being built, and, though there can to-day be no two opinions about the superiority of the Annandale route for the principal main-line, there is equally no question but that the Nithsdale route is also indispensable.

Beyond the Glasgow-Carlisle main-line the Glasgow & South Western Railway consisted for the most part of a thick network of local and coast lines to the west and south-west of Glasgow, all of them carrying a heavy traffic, and many of them having steamboat connections. The system was completed by various lines (some of them joint lines) through the rather remote districts of the extreme south-west of Scotland, over which the most important service was that to Stranraer in connection with the Larne-Stranraer steamboat service.

The London, Midland & Scottish group reaches the furthest north over the lines of the Highland Railway. The Highland main-line stretched for 279 miles through country which is to all intents devoid of industries, and is to a great extent devoid also of agriculture.

Though the populous parts of Scotland are well supplied with railways, directly they are left behind the traveller reaches districts where railways are not looked upon as a matter of course. Here, rather, he has to be thankful that railways exist at all, and any company which has built a railway must be looked on as a public benefactor. Prolonged shunting operations at every second station are quite normal incidents of the journey, and, if necessary, half-a-dozen trucks of coal are attached to the rear of a passenger train, whose occupants are expected to overlook the bumping, which they consequently receive every time the train stops. If no member of the station staff is unoccupied, one of the ladies of the stationmaster's family is turned on to examine the tickets, and a free and easy feeling characterizes all the proceedings. In these remote places, no doubt, the traffic is, owing to the paucity of the population, of strictly limited extent, and to make the railway pay, or, indeed, not lose heavily, the adoption of every species of economy is of importance. A large capital expenditure is out of the question, so the line is single and tunnels are almost completely avoided, the line closely follows the surface of the country, and the steep hills which have to be surmounted are overcome by taking a winding course. All this vastly increases the difficulties of working, and the chances of unpunctuality, with its attendant evils; but, when these evils are forced upon the attention, it is only fair to compare things with what they would be if the railway did not exist at all. The most conspicuous instance in Great Britain of a line built through the wilderness was the Highland Railway. No doubt its construction was primarily due to the great landlords, who wanted a means of access to their estates, and it would hardly have been undertaken at all if the summer attractions of the Highlands had not promised to produce a considerable pleasure traffic which would partially offset the exceeding barrenness of the country traversed. A railway of this kind cannot be looked on as a strictly commercial undertaking, and its founders no doubt regarded it as a convenience, for which they were in the last resort, ready to pay, without hoping for much direct return on their capital.

The Highland Railway, unlike its neighbour the Great North, was almost entirely composed of main-line, with one or two long branches. The main-line, traversing as it did country of great natural difficulties, to overcome which there was, as already remarked, available only a limited amount of capital, was naturally of a very roundabout character—the distance, indeed, from Perth to Wick by the main-line of the Highland Railway was almost exactly twice the distance between these two points as the crow flies, and this, too, was after the construction of the Aviemore-Inverness cut-off, which saves 26 miles as compared with the route followed before the cut-off was made. On at least two occasions since this cut-off was completed, it has had to be closed for long periods and the traffic diverted to the old line on account of cloudbursts so severe and concentrated as to destroy viaducts and wash away sections of the line.

CHAPTER VII

THE constituent companies forming the London & North Eastern group were seven in number. Four of them—the Great Northern, Great Eastern, Great Central and North British—were of about the same size and importance; the North Eastern was much bigger than any of these four, and the Hull & Barnsley and Great North of Scotland much smaller.

The North Eastern always occupied a position rather different from that of any other British railway company. It was very largely self-contained, occupying as it did a considerable area of country from which all other big companies were excluded, but which was at the same time thickly populated, full of industrial activity and an area which provided very heavy railway traffic. While the North Eastern was thus to a great extent independent of the good will of its neighbours, its geographical position, lying as it did right athwart the lines of communication between England and Scotland everywhere except near the west coast, made it an indispensable link in the East Coast route to Scotland. So, as regards its partners in this route the Great Northern and the North British, these lines were far more dependent upon the North Eastern than the North Eastern was on them, and not improbably on this account there does not at any time seem to have been the same feeling of community of interest between the three partners in the East Coast route as there was between the two partners in the West Coast route. It is no doubt, in any case, more difficult for three partners to work together smoothly than it is for two, and, in addition to this, the East Coast route was much less cleanly divided than was the case with the West Coast route.

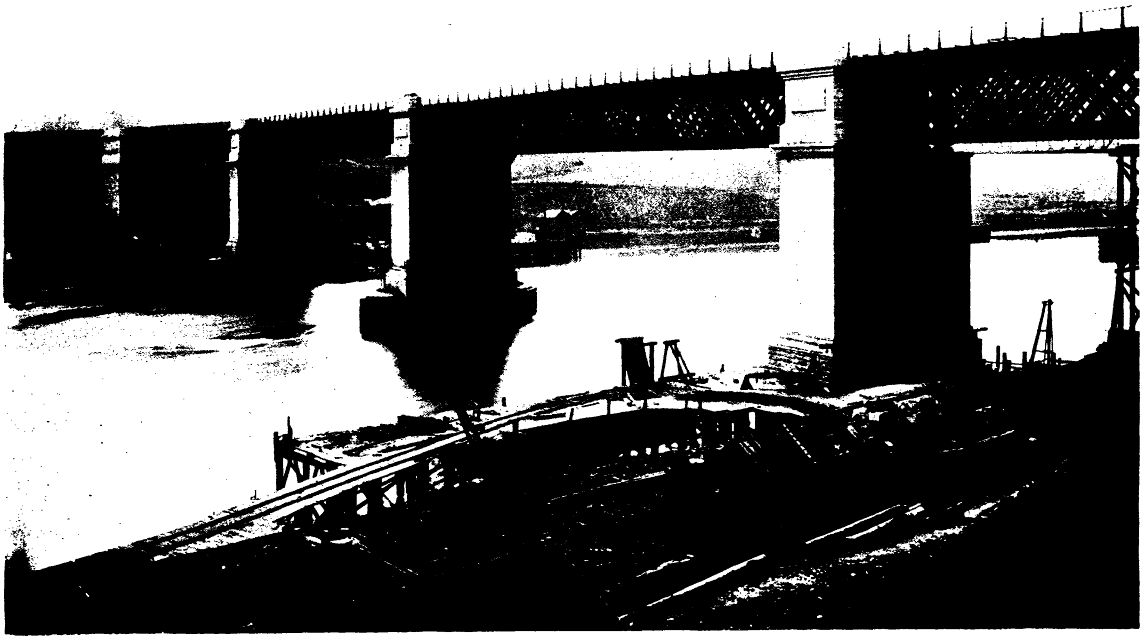
The latter was sharply divided at Carlisle, and the North Western and Caledonian Companies each worked all the traffic over the whole of its own road, but on the East Coast route the division of lines and the working arrangements were of some complication. For 160 miles out of London the line belonged to the Great Northern Railway; but it was not found convenient to stop all the trains at a point near where the Great Northern Railway ended and the North Eastern Railway began, so most of the expresses were hauled as far as York—188 miles—by Great Northern engines. On to Berwick (335½ miles from London) the line belonged to the North Eastern, and the remaining 57½ miles to Edinburgh belonged to the North British. But instead of handing the trains on to North British engines at Berwick, the North Eastern engines worked the whole way through to Edinburgh. In the 130½ miles hence to Aberdeen, where the traffic was worked by North British engines, the Forth Bridge, which was the joint property of four railway companies, was traversed; further on a section of the line belonged to the North British and Caledonian Railways jointly, and the last 38¼ miles from Kinnaber Junction were run over the line of the Caledonian.

There does not on the face of it seem to have been much reason why North Eastern engines should have run the East Coast trains, including those which stopped at Berwick, over the North British Railway between Edinburgh and Berwick, but the North Eastern appeared to like sending its engines to Edinburgh, and at one time even had considerable litigation with the North British in order to endeavour to secure the right to continue doing so, which the latter company had refused any longer to recognize. During this period the usually slow-running North British engines were suddenly called upon to bestir themselves in a way almost unknown upon that railway where on the other sections the natural obstacles were so numerous and so great. The North British found itself obliged, in order to keep time with one or two trains which otherwise would not have stopped at Berwick, to cover the 57½ miles thence to Edinburgh in about an hour. The road is an easy one; for most of the first 16 miles, it is true, the line rises at about 1 in 200, but after this there are no difficulties worth mentioning. The North British Railway, being in a sort of way bound in honour to lose no time on this run, generally, if not always, used two engines, and had no difficulty in keeping time under all conditions. I travelled one night by the 11.30 from King's Cross while this system of working was in force. The North Eastern saved several minutes on the run from Newcastle to Berwick, where we stayed 7 minutes; then, starting off again from Berwick behind two North British 6 ft. 6 in. bogie engines, we reached Edinburgh in 59 minutes —well before time. The whole run from Newcastle, Berwick stop and all, took 9 minutes less than the fastest non-stop run between the two points takes to-day. And this was in 1897.

This was, however, merely an interlude, and before very long the North Eastern engines again ran through to Edinburgh and continued to do so till the North Eastern company lost its separate identity.

In other directions, too, the strength of the North Eastern Railway's position seems sometimes to have led to actual high-handedness on its part, or given rise to a fear of such high-handedness, and so caused a certain amount of friction. One result of this was the building of the Hull and Barnsley Railway, the promoters of which wished to put an end to the North Eastern's monopoly of the Hull traffic. The Hull and Barnsley having been built for this purpose, the Railways Act, which was regarded as re-imposing the monopoly of the North Eastern, was by no means well received locally.

As elsewhere remarked, the existence of two or more railways serving the same districts having usually had the effect of limiting rather than increasing the facilities offered to the public, it is interesting to see what the effect of freedom from the presence of rival lines was on a rich and prosperous company like the North Eastern. While it must regretfully be admitted that this freedom from the burden of having to consider the effect upon any rival line of each new departure was certainly not sufficient to fire the North Eastern to any manifestation of unusual enterprise in the service of the public, its record with regard to experiments of different kinds and



KING EDWARD BRIDGE, NEWCASTLE

minor improvements is a decidedly good one. Its principal field of activity was in connection with the goods traffic. At an early stage in comparison with other British railways, it began a serious study of the possibilities of bringing about economies by the improved loading of goods wagons and goods trains. As accurate knowledge of the relevant facts lies at the root of all improvement, the first step was to ascertain the exact state of affairs which it was desired to improve, a step which involved the collection and tabulation of complete statistics. This was therefore taken in hand on a scale and with a completeness never before attempted in this country, and by making use of the knowledge thus acquired considerable economies were effected.

Then with regard to the rates charged on certain mineral traffic the North Eastern instituted a sliding scale of payments, the rates rising or falling according as the trade in the minerals in question was good or bad. In the matter of any increase in goods rates, the law made the position of the railways so difficult that any scheme of this kind could hardly have been carried out unless a thoroughly good understanding had existed between the traders and the company, and unless at the same time a single company had been in control of all the traffic of the districted affected.

The North Eastern early electrified its suburban lines round Newcastle, and later proceeded to electrify one of its purely mineral lines with results which were apparently satisfactory. Later still it was announced that it had been decided to electrify the main-line between York and Newcastle, and a large electric express engine was built which, it appears, gave highly satisfactory results on trial. (The trials presumably took place on the electrified mineral line just mentioned.) However this may be, when the North Eastern was amalgamated with the other lines now forming part of the London & North Eastern Railway, the project of electrifying the main-line was at once dropped.

In circumstances such as these it is extremely difficult for anyone not intimately connected with the railway to ascertain what really happened and whether electrification promised well or not. While there is little doubt that the electrification of suburban lines carrying a very large traffic is usually justifiable, the question of the electrification of main-lines is quite another matter. The only really certain thing about it is that it involves enormous capital expenditure. Beyond this, and particularly with regard to the economies to be anticipated, there seems to be nothing to rely upon more convincing than individual opinion. The electrical engineers are confident of brilliant success, the advocates of steam traction anticipate failure, and there is no doubt in this (as in most other controversies on this planet) a large middle party which is always in favour of a quiet life and of doing nothing. I have no knowledge of what took place behind the scenes, but should be much surprised to find that the vicissitudes of this affair were not more due to the waxing or waning influence of certain prominent individuals than to any other cause.

When motor vehicles first became a commercial success the North Eastern was one of the first railways to try them in the country districts.

As regards the passenger services, it is believed that for some time before the war the North Eastern, alone among the companies concerned in working the Anglo-Scottish traffic, realized the unsatisfactory nature of the agreement which, ever since it was concluded in 1896 between the companies concerned, had forbidden the acceleration of the Anglo-Scottish services and was inflicting upon the travelling public a large amount of perfectly unnecessary waste of time. Unfortunately the North Eastern's efforts stopped short at the realization of these facts and did not cause it to take any steps to remedy them, which, if it had been really in earnest about the matter, it was in a better position to do than any other company engaged in the Anglo-Scottish traffic, at any rate as far as Edinburgh was concerned. The distance from King's Cross to Edinburgh is 392½ miles, and, except for the first 160 miles out of London, which belonged to the Great Northern, the North Eastern owned the line as far as Berwick, and it exercised running powers over the remaining length as far as Edinburgh.

As regards the passenger services in its own district, some of them were among the best in the country. The run of 44¼ miles from Darlington to York, performed in 43 minutes, was for some years the fastest-timed run in Great Britain, and the best trains in summer between Leeds and Scarborough were far above the average of British expresses. But the volume of good services was small, and they seem to have been put on more as an advertisement than with the genuine desire of benefiting the public.

Among the peculiarities of the North Eastern Railway were its relations with its servants. The period of regular railway strikes may be considered to have set in with the big strike of 1911, and we are now so much accustomed to incidents of this kind that we have almost forgotten the peaceful times before the great bulk of the railway servants were delivered over to the agitators. But long before 1911 there were several quite big strikes on the North Eastern. The North Eastern Board, too, pursued a policy towards trade-unions different from that of the other big railways. They gave official recognition to the trade-unions and negotiated with them as representing the railway servants long before Government control during the war imposed this policy upon the other railways.

The large area of country which the North Eastern had almost to itself was bounded on the south by a district traversed in every direction by the interlacing lines of so many important companies that York Station, into which these companies had running powers, had to accommodate the trains of at least six different railways.

The three railways running into London which have now become part of the London & North Eastern group—the Great Northern, Great Eastern and Great Central—had already before the war endeavoured to amalgamate with one another, but had been unable to secure Parliamentary sanction for this course. They had, however, concluded a joint working agreement for reducing certain overlapping services. This was the result of a situation which developed quite recently and does not appear to have been foreseen for any considerable length of time. Originally, indeed, the three lines had little in common.

The Great Northern Railway was not very early in the field, and came into existence in the teeth of the most strenuous opposition as a short cut between London and various big towns in the North which were already connected with London by a more roundabout route from Euston. There are thus no big industrial centres on the Great Northern main-line anywhere south of Yorkshire, and alike for this reason and on account of the easy gradients and general freedom from sharp curves which the main-line enjoys, it is specially suited for high-speed, non-stop, long-distance traffic. Beyond the territory served directly by the company lay in one direction the continuation of the East Coast route to Scotland and in another the Sheffield and Manchester district of what used to be the Manchester, Sheffield & Lincolnshire Railway.

The services between London and both of these areas were conducted over the Great Northern, and for a long time the facilities which the Great Northern main-line affords for fast running were utilized for making these trains the fastest batch of trains in the country. This was particularly necessary in the case of the London-Manchester expresses, as the Great Northern and Manchester, Sheffield & Lincolnshire route was considerably longer than the routes of the North Western and Midland Railways, and the gradients on the line between Sheffield and Manchester are so severe and the curves so sharp that there high speed is out of the question.

In these circumstances the Great Northern ran so well between King's Cross and Grantham that the best times between London and Manchester were the same as by the shorter and much easier North Western route. The fastest timing in this service was 117 minutes for the 105½ miles from Grantham to King's Cross. This in the '80s of last century was a really fine performance.

Naturally the engines used for working the principal Great Northern expresses were the object of a great deal of attention on account of the unique nature of their performances. Neither was their appearance in any way less well calculated to attract attention than were their performances. Two types of engine, each with a single pair of driving wheels, were employed. The more numerous type, and the one with the more striking appearance, had a leading bogie, driving wheels 8 feet in diameter driven through outside cylinders, and a small pair of trailing wheels under the footplate. The domeless boiler was pitched so low that the top of it lay only slightly higher than the covers of the driving wheels. The design was thus one of the utmost neatness and simplicity, and one calculated to bring out to the utmost the great size of the driving wheels.

The other type of engine employed to work the express trains had driving wheels 7 ft. 6 in. in diameter and inside cylinders. Owing to the better balancing due to the position of the cylinders inside the frames it was not thought necessary to employ a leading bogie, so there was only one pair of leading wheels; these were placed unusually far forward so as to secure steady running. Examples of both these types of engines were built over a long period of years, and there were many minor differences between different engines of each type. In both types the boiler, lying as it did between the driving wheels, was limited in diameter to the space there available, and the area of the grate was about 18 sq. ft. The eight-wheel engine weighed about 45 tons, and the six-wheeler about 40 tons. In practice one type seems to have been about as good as the other.

Single engines have always appealed to the imagination. Their appearance is often very striking, with their great driving wheels which give an impression of immense capacity for speed. For a long time practically all express engines were singles, and, even after coupled engines had been introduced, the singles were often more powerful than the coupled engines, and worked the principal trains, so that, till comparatively recent times, most of the more famous British engines were of the single type. At a time when few express trains weighed so much as 150 tons and troubles from want of adhesion did not arise, the single engine was naturally used, as she fulfilled all requirements, was simple to design and keep in repair, and ran freely. Whether in point of fact single engines as a whole are capable of faster or better work than coupled engines can hardly be decided for want of really comparative trials. Big driving wheels and the absence of coupling rods undoubtedly tend to smoothness of running, and a single is obviously rather cheaper to build and to keep in repair than a coupled engine; but these advantages are by no means overwhelming, and the extremely high place which the singles won in popular esteem seems to have been due as much to the absence of real competition and to sentiment as to the actual work which they did. In particular, the ability to reach exceptionally high speeds, which the big driving wheels suggest, appears to be more a matter of the design of the steam passages than of the size of the driving wheels, and there is no reason to suppose that singles are capable of higher speeds than equally well designed coupled engines.

The single engines of course worked the racing trains over the Great Northern line in the race to Edinburgh in 1888 and in the race to Aberdeen in 1895. It does not appear that they were ever worked at their full power, but they nevertheless did very well. They also worked the accelerated Scottish services of 1896. Mr. Stirling, the designer of the singles, died in 1895. After his death, four-coupled express engines were introduced, and although his singles survived for many years and a few more singles were built subsequently, all the harder work was gradually transferred to coupled engines.

In 1896 occurred the Preston accident in which the North Western's accelerated train for Aberdeen ran off the rails in consequence of excessive speed on a sharp curve. This accident, referred to at length elsewhere, sounded the death-knell of a movement towards a general acceleration of British express trains which was then in progress, and on no line during the next few years was the general retrogression of passenger services so marked as on the Great Northern. A circumstance which conduced largely to this result was that in 1899 the Great Central Railway which had just opened its London extension, refused any longer to co-operate with the Great Northern in working the

King's Cross—Manchester service already described, which therefore came to an end.

With regards to the Leeds traffic the Great Northern, having a shorter line and better gradients than its only possible rival, the Midland had no difficulty in keeping a little in front without running particularly fast. There was, of course, no reason why the Great Northern should not very greatly have accelerated its Leeds services, and so have preserved its reputation for speed and at the same time have conferred a benefit on the travelling public, without troubling itself to consider what the Midland was doing. Possibly, if a similar situation had arisen ten or fifteen years earlier it might have done something of this kind. At various exceptional periods there have been progressive influences at work on British railways, which have endeavoured to improve the services because they have seen that improvements were in themselves desirable. The Great Northern enjoyed such a period in the '80s, the Caledonian in the early '90s, and the Great Western in the first years of the present century, while, as already remarked, there seem to have been certain abortive stirrings in the same direction on the North Eastern a few years before the war. But, as it was, the Great Northern at the end of last century was no longer under progressive influences, and had relapsed into the attitude usual among railways of assuming that if it could so arrange matters with its rivals as not to be outdone by them it made very little difference what sort of facilities were offered to the public, at any rate as far as speed was concerned. So the years which closed the nineteenth century closed also the tale of the supremacy in speed of the Great Northern, and no serious attempt was ever subsequently made to regain the abandoned position.

In saying this I do not mean that the Great Northern's best trains were bad as British trains went. Round about the year 1904, indeed, a decided advance in the speed of express trains was made on several of the principal British railways, the Great Northern among others, and the time from Leeds to King's Cross was reduced to three and a half hours. (The distance is 185½ miles.) But a performance such as this, while approximately as good as the best to be found elsewhere in Great Britain, was far from restoring to the Great Northern its former superiority, as might easily have been done if a bolder policy had been adopted.

Though the Great Northern engines have long lost the prominent position which the relatively high speed of Great Northern expresses secured for them in former times, the Great Northern has continued well to the front in the matter of the design of express engines. It was on this line that the 4-4-2 type of engine was first introduced, and though the Great Western was first with one engine of the 4-6-2 type, it was the Great Northern that first built a considerable batch of 4-6-2 engines. These engines have three cylinders—an arrangement the advantages of which are not very clear. When more than two cylinders are required the four-cylinder arrangement with its much better balancing and much simpler valve-gear would appear to be far superior to the three-cylinder arrangement.

The Great Northern some years before the war found it necessary to begin a new loop which, leaving the old main-line at Wood Green, takes in a new area of suburban country lying towards the east, and rejoins the main-line near Stevenage. This line will increase the suburban traffic, but the principal advantage which it brings is a new main-line route into London alternative to the old main-line, which, besides carrying a very heavy traffic, has the disadvantage of narrowing from four to two lines of rails over Welwyn viaduct and elsewhere.

As war broke out before the construction of this new loop had advanced very far, it was completed only in 1924. The principal engineering feature is the Ponsbourne tunnel. This tunnel, though more than a mile and a half long, does not lie very deep below the surface of the ground, and, as tunnels go, was probably not very difficult to construct. I went over it a few weeks before the war as far as it had then progressed. Work was carried on simultaneously at both ends and at a number of points between, which latter were reached from the surface of the ground by means of hoists. Descending into the workings by one of these hoists it was found that a length of about twenty yards had already been excavated and lined with bricks, while there were bricklayers at work on scaffoldings, continuing the work of lining the tunnel as excavation proceeded. The soil appeared to be clay, and was damp and muddy without being really wet. Though a mere trifle as compared with the difficulty of giving the right direction to a tunnel driven through, say, the Alps, the task of ensuring that the direction taken by each of the numerous headings should be exactly accurate was obviously one of considerable difficulty and responsibility, and we met a surveying party which was constantly occupied in checking the work as it proceeded.

Above ground were a number of contractor's engines working over the usual extremely unevenly laid lines of rails. It is most reassuring to observe how seldom these engines leave the rails in spite of the facilities for so doing. They were engaged in disposing of the soil excavated, and in distributing bricks that came from a brickworks which had been laid down near by specially for the purpose of manufacturing the bricks required.

The lines which subsequently became the main-lines of the Great Eastern Railway began their existence some ten years before the main-line of the Great Northern. The following extracts from the *Colchester Gazette*, of November 7, 1835 describe the situation at that time.

"THE ESSEX RAILWAY.—We last week ventured to give it as our opinion that the spirit and enterprise of the present day would inevitably bring about a Railway through this county. There will be however but two lines, the one along the great eastern road to Chelmsford, Colchester, and Ipswich,—this is called the Eastern Counties Railway ; and the other, through Stortford, is called the North-Eastern Road. The Grand Northern Railway, which was started by Mr. Gibbs, and was to have gone through Roothings, Dunmow; and Walden, is likely to come to nothing. The inhabitants of Essex are, therefore, left in a comparatively easy position to make their choice. Mr. Walker's line, through Stortford, will merely skirt one corner of the county, while the Eastern Counties

Railway will run through its centre. The traffic upon the latter is so great and the number of travellers so large that success must attend this undertaking. We therefore look upon it as a most advantageous investment for the capitalist. One of the most singular advantages of the eastern line is, that a vast and populous extent of country will be brought within its range at very little expense. Its whole course is so level that there will not be occasion for a single tunnel. Of course, the less an undertaking costs the less are its outgoings, and the greater the profits. We are quite aware it is regarded with jealousy by some of our agriculturists. Why, we are at a loss to divine. Let them recollect it is now morally certain that all the more remote parts of the kingdom will have the benefits of Railways. Will it not then be fatal to the interests of our Essex farmers should they not possess for their produce equal advantages. It must be recollected that the question is not whether Railways will, or will not, be beneficial to the country generally; but it is whether Essex can afford to do without what all the other counties will possess. It might or might not be right for them to have their corn and cattle thus conveyed to London, if there were no project on foot in favour of others; but as not only one but very many companies are in the course of formation, our readers will at once see why we would recommend their giving immediate sanction and support to the *Eastern Counties Company.—Colchester Gazette, 7th November.*

"The exact line of the Eastern Counties Railway, from Chelmsford to London, is now marked out, and may be seen by any one travelling the high road.—*Ibid.*"

In the year 1835 an attempt was made to found a company for the purpose of building a railway which was to be called the "Great Northern Railway." The idea was to build a line from London to York passing through or near Dunmow, whence a branch was to start for Norwich. The railway would in this way have covered a considerable part of the country now served by the main-line of the Great Northern and the two main-lines of the Great Eastern. It was stated that the distance from London to York would be 188¾ miles and to

Norwich 103 miles. Nothing, however, seems to have come of this project.

As it turned out, railway building in the Eastern counties was very far from being the profitable business so confidently anticipated, and it was not very long before the East Anglian railways were in financial trouble ; and different parts of what subsequently became the Great Eastern Railway were consequently built in a very piecemeal manner. In these circumstances they have fitted in with one another better than might have been expected. Whatever indeed, might have been the plan laid down for railway building in the Eastern counties, a line running from London to Yarmouth not far from the coast was clearly indispensable, and a line from London to Cambridge and King's Lynn was also desirable. There were, no doubt, many possible ways of covering the districts lying between these two lines, but the only obvious fault in the existing lay-out, and that is not a very serious one, is the roundabout nature of both routes between London and Norwich.

In sharp contrast with most of the outlying districts served by the Great Eastern, which were almost purely agricultural, the suburban district which it served produced the heaviest traffic that any British railway had to cope with.

Railways have almost all come to the conclusion that their short distance suburban passenger traffic is more trouble than it is worth. Such lines as they possess they must continue to work, and work to the best advantage they can, but only in very exceptional circumstances do the railways now seek to extend the field of their suburban operations. The Great Eastern, therefore, though making the best of a bad job, and bringing to bear much resource towards solving the different problems which were constantly presenting themselves owing to the growth of the suburbs which it served, probably did not regard its suburban traffic with any enthusiasm. But, enthusiastic or not, it had to provide transport for the densely packed masses of people which populate the urban and suburban districts through which its lines passed and made the total of passengers travelling by the Great Eastern each year greater than the numbers transported by any other company. The quickest possible succession of trains as long as the platforms will take, composed of carriages seating six a side, is at some times of the day barely sufficient for the crowds of people who use these lines. But when all is said and done, the Great Eastern would probably have been quite as well off if it had never carried a single suburban passenger.

Liverpool Street, although conveniently situated for City passengers, is disadvantageously placed for the purposes of most other people. It is a long way from the chief residential districts, and it is often very difficult of access, both on account of the congestion of the narrow streets of the City, and of the small space available for vehicles in the yard of the station itself. The Underground Railway, too, reaches it by a route which is very circuitous. In these circumstances it is not surprising that the Great Eastern gave the Central London Tube every encouragement to carry on its line to Liverpool Street. The extension of this tube to Liverpool Street has provided a rapid and easy means of access from the best part of London, and, by making it easy for people to reach Liverpool Street below ground, has encouraged them to send their luggage on ahead, and avoid suffering from, and adding to, the congestion of the streets, which, in early August and at other busy times of the year, makes the approach to Liverpool Street in any kind of road vehicle an experience from which the hardiest are inclined to shrink.

The most profitable part of the Great Eastern's passenger traffic was the summer traffic to and from the numerous seaside places on the system. To realize the importance attaching to Cromer and Yarmouth at this time of the year, it is only necessary to compare the summer train service to these places with that provided during the rest of the year. In normal years Cromer and Yarmouth are both of them served by trains run specially for the summer visitors, and performing the journey in half an hour less time than the best winter trains, the Yarmouth train not stopping at all *en route*, and the Cromer train stopping only at North Walsham. It was apparently for these summer trains alone that the Great Eastern laid down its water troughs, for during the rest of the year there was no train that ran more than about 70 miles without stopping. Though Cromer and Yarmouth are the most important of the seaside places on the East Coast, there must be nearly a score of others, all of which are given carefully planned connections with London, and contribute very sensibly to the receipts of the railway.

The Continental service from Liverpool Street, in so far as it competes with that of the Southern Railway, is handicapped, as regards London passengers, by the fact that Victoria is for most people a much more accessible station. But, though great pains are taken to attract passengers to and from London, more reliance is probably placed upon those from the north of England and the Midlands, for whom through carriages to Harwich are run from many of the most important towns.

The Great Eastern Railway, though in the happy position of having its own district largely to itself, had certain disadvantages to cope with, which made it a difficult line to work satisfactorily. It had a large suburban traffic into London in the morning and out of London at night, almost all of which, in either direction, had to be accommodated within a short space of time, it served no provincial towns of first-rate importance, and there was a complicated network of cross-country lines with small traffic, to be provided for; the suburban traffic was conducted at extremely low fares, though its existence necessitated a large expenditure of money to provide the requisite accommodation, both as regards running lines and terminal facilities; owing to the absence of any very large centre of population besides London, the Company had nowhere a steady flow of really profitable traffic—passengers or goods—to make up for the low receipts of the numerous single lines across country, and in consequence of the railway's running through the East End of London and the works being situated there, the Great Eastern suffered severely from the exactions of the local authorities where the rates reached the highest level.

The question of electrifying the Great Eastern suburban lines comes up at intervals, but the great capital expense involved seems to have deterred the Great Eastern, which was always a poor company, from doing anything, and now that the Great Eastern has been merged in the London & North Eastern group, the group authorities do not seem at all anxious to tackle the question. Meanwhile everything possible has been done in the way of increasing the capacity of the lines for steam traction in the way of re-arranging the signals, shortening the block sections and making arrangements for getting engines onto their trains with as little delay as possible.

Before the war the possibility of instituting train-ferries between England and the Continent had aroused a certain amount of discussion, and various schemes had been considered, particularly one for a ferry between Newhaven and Dieppe. But the idea had made little headway. As the war proceeded and ever greater quantities of supplies and rolling-stock had to be sent over to France, military exigencies very quickly brought about the materialization of the idea and ferries were arranged from both Southampton and Richborough. Though indispensable in war-time, the Channel ferries do not seem to have impressed the commercial world very deeply, and for some time after the work of removing Government property from France had been completed they had ceased to be employed. Quite recently, however, a private company working in close connection with the London & North Eastern group has re-established one of the ferries, and ferry-boats now ply between Harwich and Zeebrugge, and so supplement the Continental service which the Great Eastern Railway was at so much pains to develop.

Train-ferries are, of course, no new idea. For many decades they have been in use in various parts of the world, but usually on inland waters like the Great Lakes of America or land-locked seas where the range of the tides is small like the Baltic. Though there is no reason why they should not be of great use for goods traffic between England and the Continent, it is hardly likely that any serious attempt will be made to use them for passenger traffic. The difficulty and delay involved in getting the trains onto and off the ferry-boats where the sea passage is shortest and the range of the tides is consequently very great (as is the case in the narrower parts of the Channel) and the difficulty of driving a broad-beamed vessel like a ferry-boat at any great speed are all against the use of ferries. They are also quite unsuited for use in rough weather, as it would be exceedingly unpleasant to continue a journey on land in a train that had been full of sea-sick passengers.

The Manchester, Sheffield & Lincolnshire Railway changed its title to " Great Central Railway " when its London extension was opened for traffic towards the end of last century. Originally designed to connect Sheffield with Manchester, it had by that time acquired a very thick network of lines across Central England from sea to sea, and hardly any part of the system (which comprised many joint lines and the sphere of action of which was enlarged by running powers over the lines of many other companies) was more than a few miles away from the lines of some other railway.

Besides working its own trains, the Great Central provided engines to work the trains of the Cheshire Lines Committee in those parts of Lancashire and Cheshire where the Midland, Great Northern, and Great Central had pooled their interests in the common undertaking, known as the Cheshire Lines. All the three companies had large interests in both Liverpool and Manchester, and had to be able to run direct between the two cities, so, instead of each possessing its own line, or having running powers over another line, the three companies united to finance and work this undertaking, which comprised, besides the main line between Liverpool and Manchester, some hundred miles of railway in the adjoining district. Such of the trains which ran over these lines, therefore, as did not belong to one or other of the owning companies, were the property of the Committee which consisted of nine members—three of the directors of each of the three companies—and the working was mostly entrusted to Great Central engines.

In the west the importance of the old line depended absolutely upon the Woodhead tunnels, and even now these tunnels are of first-rate importance. Sheffield lies at the foot of the eastern slope of the Pennine Chain, and Manchester is similarly situated to the west. There is in this neighbourhood no pass through these hills low enough to be suitable for a main-line of railway, so the Company's engineers had to do the best they could to find a suitable location for a tunnel. The Manchester, Sheffield & Lincolnshire being the first railway in the field, their engineers had a free choice as to the location of the tunnel ; but, even so, they were obliged to recommend the construction of a tunnel no less than three miles long, which, with the primitive engineering appliances available in the '40s of last century, was an undertaking of the most formidable kind. It was, however, successfully carried out. First one single-line tunnel was constructed and then a second single-line tunnel ; and so the tunnels are to-day. The only new work of a heavy character that has been done upon them since they were constructed has been in endeavouring to improve the ventilation. This is a matter of some importance in the uphill tunnel, where the fires of big modern engines working heavy trains up a gradient of 1 in 201 consume a great deal of oxygen ; and no less was it a matter of some difficulty to arrange where air-shafts several hundred feet deep had to be constructed.

The eastern end of the tunnels is more than 1,000 ft. above the sea, and there are ascents of nearly 800 ft. to this point both from Sheffield and from Manchester. The ascent from Sheffield is slightly the steeper, and in both cases the curves are numerous and sharp. For a long time this line was the only direct line between Manchester and Sheffield, but some thirty years ago the Midland, by building a new length of line through the hill country, secured for itself by a southerly course a direct route between the two cities. This route is approximately as hard as the Woodhead tunnel route, it involved much more tunnelling and is some miles longer.

In the east the company's principal source of revenue was the great commercial and fishing port of Grimsby, which grew up with the railway and, as time went on, underwent a continuous process of development. When no further development of Grimsby was possible and trade still continued to grow an enormous new series of docks was put in hand at Immingham near by, and came into use a few years before the war.

The Manchester, Sheffield & Lincolnshire Railway was never in a really comfortable position. Almost everywhere it was harassed by the close proximity of other railways to which, in a great number of cases, it was obliged to hand on for despatch to the consuming centres in the south the goods which it had collected and carried for only short distances. Particularly was this the case with the coal traffic, of which a great deal originates in the districts served by the company. In these circumstances it began to cast longing eyes on the Metropolis.

It is now nearly sixty years since the Midland, which before was dependent first on the North Western and then on the Great Northern for its entrance into London, found itself obliged to make a way for itself over the (from a railway point of view) comparatively desert stretch of country which separates Bedford from the Metropolis. For a considerable time no-one thought that another of the northern companies would ever be inclined to face the great cost that an extension to London would involve; but in the early '90s the Manchester, Sheffield & Lincolnshire Railway, dissatisfied with its position, which made it hardly more than the gathering ground for traffic, particularly coal traffic, from which other companies, to whom this traffic had to be handed over, secured the chief profit, received the authorization of Parliament to extend its line to London. In 1898 the London Extension was complete, and the name of the railway was changed to "Great Central." It had not been necessary to construct a new line the whole way south of the old Manchester, Sheffield & Lincolnshire's district, as running powers were secured over nearly 40 miles of the Metropolitan Railway immediately outside the London area. Subsequently, however, with the help of the Great Western, a new loop was constructed to the west of the Metropolitan line, which gave the Great Central another route into London. (This loop increases the distance between London and the north by some 4¼ miles.) So the Great Central became one of the established main routes from the north to London.

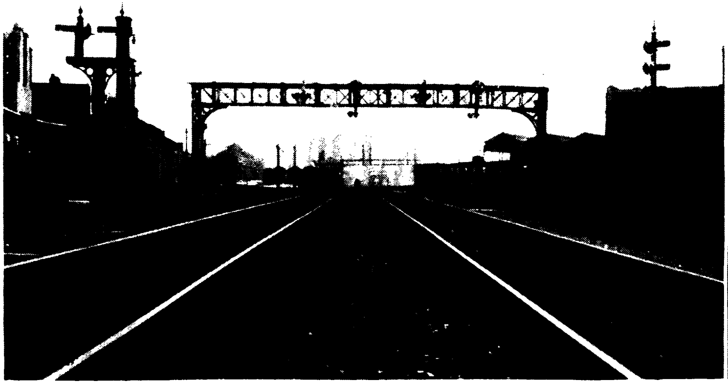
When the Manchester, Sheffield & Lincolnshire eventually got its Bill through Parliament and set to work to build the London extension, it naturally happened that the gradients of the new line were less favourable than those of the existing railways which had had first choice of the ground. There is a summit about half-way between Sheffield and Nottingham which is approached from the north over a good many miles of 1 in 100, and from the south by an almost, but not quite, continuous ten-mile bank of 1 in 131. This section, too, is by no means straight. South of Nottingham as far as the point where the Metropolitan Railway is reached at Quainton Road Junction, 44¼ miles out of London, there is nothing worse than 1 in 176. But a great part of the line is built with this gradient, and in two places going south (one a little way out of Leicester, and the other up to and through Catesby tunnel) there are continuous ascents between six and seven miles long at 1 in 176. On the Metropolitan section the gradients again become steeper and include 5½ miles' continuous ascent at 1 in 117 from Aylesbury and six miles' almost continuous fall at 1 in 105 from Amersham.

It is over this route from Marylebone that there has for long been run the train that seems best to deserve the title of the fastest train in England. It now starts at 2.32 a.m. and carries the London newspapers and such passengers as may feel impelled to begin their journey at that hour of the morning.

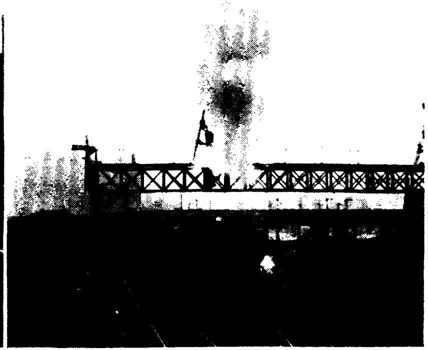
Not long ago I joined the engine of this train at Marylebone. She was one of the large 4-4-0 engines. The train, mostly composed of newspaper vans, weighed about 170 tons behind the tender.

The first run of 59¼ miles to Brackley is timed slower than the remaining stages, and nothing of note occurred except that 6½ miles between Rickmansworth and Amersham were run in 8 minutes 45 seconds. There is a pretty severe service slack at Rickmansworth, and the line rises at 1 in 105 nearly all the way. We had started from Marylebone one minute late, but reached Brackley punctually (59¼ miles in 65 minutes 37 seconds).

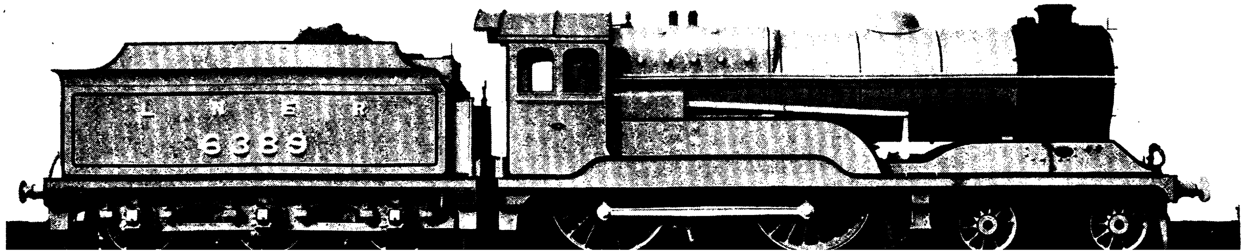
Hence the train is timed much faster. It was by this time



THE APPROACH TO MARYLEBONE STATION.
(PRINCIPAL SIGNALS ARE OF COLOUR-LIGHT TYPE)



EXPRESS TRAIN LEAVING
MARYLEBONE STATION



light enough to see the mile-posts. The distance of 24 miles (all but 4 chains) to Rugby is timed to be run in 24 minutes. For the first 2½ miles the line ascends at 176 and by the time the summit was passed we were doing about 50 m.p.h. The succeeding 10 miles, where the line undulates mostly at 1 in 176, with a rising tendency, were run in 9 min. 15 sec., and post 134 (12¾ miles from Brackley) was passed in 14 min. 15 sec. Next there is a seven-mile fall, also at 1 in 176, beginning in Catesby tunnel, on which speed gradually rose. Timing was difficult because the engine was working so gently that the draught was insufficient to carry the exhaust steam overhead and many of the mile-posts were obscured. I secured, however, a timing of 2¼ miles in 101 1/5 seconds, which is 80 m.p.h. Rugby was reached in 1 1/5 seconds over the booked time.

From Rugby to Leicester the even shorter run of 20 miles (less 11 chains) is timed to be completed in 20 minutes. The start is downhill, and the first 2 miles took little more than 3 minutes. Next, up 3½ miles of 1 in 176, the speed continued to rise slightly, and at the summit was over 59 m.p.h. A speed of about 75 m.p.h. was reached at post 113 (the posts are numbered from Manchester) and 5 miles from post 111 were run in 3 minutes 50 seconds (78¼ m.p.h.). A quick stop at Leicester landed us there 19 minutes 11 seconds from the start at Rugby (62 m.p.h.). So easy was the work that though the engine blows off at 180 lbs. per sq. in. steam had been allowed to drop to 150 lb. at Rugby and continued to fall slowly for the rest of the way.

At Leicester the 4-4-0 engine went off and some vans were dropped; the weight of the train was thus reduced to about 150 tons behind the tender.

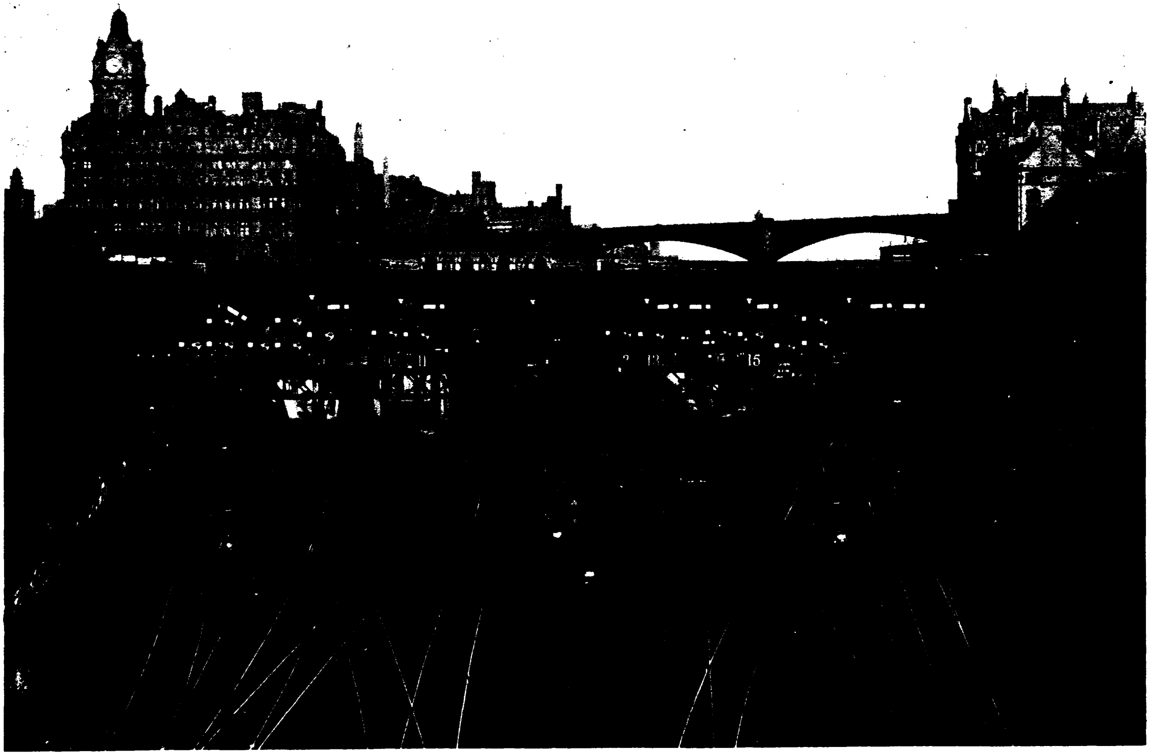
The new engine was a three-cylinder compound without a superheater. For the 22 miles 44 chains to Nottingham (Arkwright Street) 22 minutes are allowed. The start is uphill. Nearly a mile to post 102 occupied 2¼ minutes, and the next 2 miles were run in 86 seconds and 77 seconds respectively. Here the line begins to fall and a speed of 60 m.p.h. was reached in less than 5 miles from the start.

Loughborough (9 miles 71 chains) was passed in 11 minutes 7 seconds at over 79 m.p.h., and the lowest speed on the subsequent ascent was 64 m.p.h. Hence speed gradually rose till 1 mile (86½–85½) at the bottom of the descent of 1 in 176 was run in exactly 45 seconds (80 m.p.h.). Ruddington (19 miles 4 chains) was passed in 18 minutes 33 seconds, and we drew up at Arkwright Street 11 seconds late, reckoning from the start at Leicester, having averaged 61 m.p.h. start-to-stop. We reached Nottingham half a minute before time.

It would appear possible that if the traffic by the Great Central route increases beyond a certain point, the bottle-neck which begins at Neasden and continues almost into Marylebone terminus may in future give rise to trouble if the terminus is enlarged. At the present time Marylebone has only four platforms, for the service of which, and of the adjacent goods station, the double line from Neasden is no doubt amply sufficient. But Marylebone has been built in such a manner as to make a very large extension of the station possible, and there is, practically speaking, no way of widening the line. The situation is, however, eased by the fact that there are no stations on the bottle-neck, and so all trains run over it at very much the same speed.

As regards the geographical features of the territory which it served, the North British was the most awkwardly placed railway in Great Britain. Except on the main-line from Berwick through Edinburgh to the outskirts of Glasgow the gradients throughout this territory are almost everywhere of much more than average steepness, and sharp curves abound, while a great part of the country served is so deeply indented with arms of the sea, particularly the estuaries of the Tay and the Forth, that the difficulties of communication between many important places quite close to one another were overcome only at a relatively late date and at very heavy cost.

These difficulties of communication due to the presence of arms of the sea were, indeed, not an unmixed disadvantage to the North British, as owing to them the Company contrived to secure for itself several districts, particularly the County of Fife, which, if they had been more accessible, must almost



WAVERLEY STATION, EDINBURGH

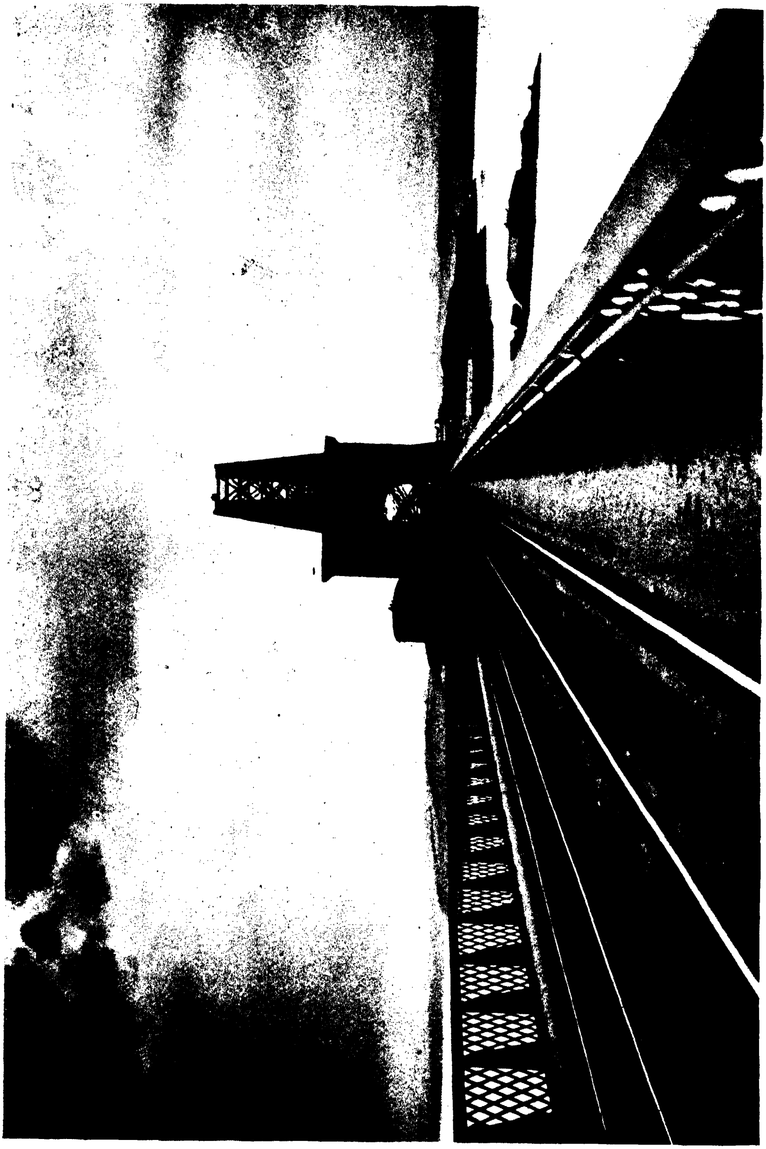
[Facing page

necessarily have been shared with other railways. For Scotland is a country in which, largely owing to the restricted area of the districts which furnish an intense traffic, there was in former times more than usually severe competition for the country which each railway desired to serve.

So before the Forth and Tay Bridges, and particularly the latter, were built, the North British was a rather scattered railway; but, as soon as these bridges gave direct access to Perth and Aberdeen, the system radiated most conveniently from its centre in Edinburgh, when two long arms stretched north and south to Aberdeen and Carlisle, and two shorter arms east and west to Berwick and Glasgow. With the extra traffic brought by the Forth Bridge the already conspicuously inadequate accommodation in Edinburgh became more glaringly insufficient. Waverley Station in a press of traffic had for years, according to everyone who has ever written on the subject, been the place of all others where the nearest approach could be found to complete pandemonium. My own acquaintance with the old station was of the slightest, but the hideous inconvenience of the place could not fail to strike the most casual observer. This state of affairs at the very heart and centre of the system made the North British trains a by-word for unpunctuality, and it became necessary to remedy matters, however great the cost. Anyone going to Waverley now, and having in mind what things used to be like, will give the North British all the praise it deserves for the admirable manner in which, with all the difficulties to face, which are inseparable from rebuilding operations on a very large scale, in the centre of a busy city, it evolved order out of chaos, and constructed a station really worthy of the importance of its position. Even now, however, at really busy times it is not always quite so easy as is desirable to ascertain at which platform some particular train may be found.

The Glasgow terminus of the North British at Queen Street (High Level) was in size and convenience a very long way behind both the Central and St. Enoch's. The main line from Glasgow starts northwards, where the ground rises very steeply, and, consequently, immediately on leaving the terminus, a longish ascent at 1 in 45 is encountered, a good part of which is in tunnel. For many years the trains were worked in and out of Queen Street by means of a stationary engine and a rope, but this has now been given up in favour of ordinary locomotives, and the trains are helped up the incline by powerful tank engines. If the traffic in and out of Queen Street (High Level) were anything like that dealt with at the Central, this very awkward approach would be a serious handicap; as is the case at the Central, a great part of the Queen Street passenger traffic does not use the high-level station at all, but traverses Glasgow from east to west by means of an underground line, which passes through Queen Street station at right angles to the high level line.

The opening of the Forth and Tay Bridges and the rebuilding of Waverley Station were steps which could not fail to produce immediately satisfactory effects. The other great enterprise of the North British Railway—the construction, technically not by the North British itself, but by a company in close alliance with it, of the West Highland Railway—was of a much more speculative character. The construction of the West Highland line seems to have been prompted by a desire to enter country which had, up to that time, been regarded more or less as a preserve of the Caledonian, if such a term can be applied to country so sparsely populated. The Caledonian had its Callander and Oban line connecting the West Coast with the populous central district of Scotland. It is improbable that the Callander and Oban has ever been a very profitable line. To push another railway into this inhospitable, if beautiful, district was a bold undertaking indeed. As there are no big works and no particular trouble seems to have been taken to avoid heavy gradients and sharp curves, the line cannot have been expensive to build, it is true, but a survey of the country, either on the map or from the carriage windows, inspires questionings as to how enough traffic is provided to make these 140 odd miles of line from Craigendoran to Mallaig pay their way. The questionings become more insistent when it is remembered that for nine months of the year there are, beyond Arrochar and Tarbet Station—*i.e.*, over more than



120 miles of the line—only two passenger trains a day. Up to this point, which the railway appears to regard as the limit of what may be called the suburban district, the trains are comparatively frequent. But a pretty close acquaintance with the traffic dealt with at Arrochar and Tarbet during the height of the tourist season leads me to suppose that even this favoured spot, which serves the two villages, and also secures such of the passing Loch Lomond and Loch Long excursionists as do not travel all the way by steamer, can hardly be a gold-mine for the railway. The opening of the West Highland Railway to Fort William led to quite an outburst of railway building in the West Highlands, the Caledonian seeking to consolidate its position by pushing north to Ballachulish, the West Highland itself being carried later to Mallaig, and the Invergarry and Fort Augustus Railway being built to connect the West Highland with Loch Ness. This was during the era when that species of competition was rife which led railways to seek to invade the districts of other railways, but it is likely to be many a long day before any more railways are built in the West Highlands. The Invergarry and Fort Augustus Railway indeed, having proved unable to pay its working expenses, was for a time abandoned altogether. There is, however, one short connecting link that is badly wanted to join the West Highland Railway to the Highland Railway. The two railways at one point lie fairly close to one another, and, if a line were built from somewhere about Tulloch on the West Highland to somewhere about Newtonmore on the Highland, the very serious difficulties, which now attend a progress across the Highlands east and west, would be greatly diminished.

The inclusion of the Great North of Scotland Railway in the London & North Eastern group brings that group as far north as the shores of the Moray Firth, which from the dividend-earning point of view is as far north as any British railway is likely to desire to go. With headquarters at Aberdeen, where it had large interests and was part-owner of the Central passenger station, which was greatly enlarged a few years before the war, the Great North consisted of a number of shortish lines, one very much the same as another in importance. For the most part it traversed country containing a fairly large population spread over a great many villages and small towns devoted chiefly to agriculture—as thriving as British agriculture could reasonably be expected to be—and to fishing. It had its district to itself with the exception of a certain small amount of overlapping with the Highland Railway in the north-west, and was in a fairly comfortable position. There was a kind of main-line between Aberdeen and Elgin over which were run trains quite creditable both as to speed and as to the rolling stock of which they were composed.

CHAPTER VIII

In the grouping scheme under the Railways Act the Great Western, alone among the most important of the old companies, has been left very much as it was. The other constituent companies of the Great Western group—the Cambrian and various lines serving the South Wales coalfields—were short railways, the importance of which was chiefly local, and they were all of them very small in comparison with the Great Western.

The *Railway Magazine*, in its first number published on 1 May, 1835, remarks as follows :

" The Great Western Railway was first contemplated at the commencement of the year 1833, and the support of the merchants of Bristol had been confidently relied upon ; but they preferred waiting the issue of the investigation of the merits of the London and Birmingham Railways then before Parliament. The result was favourable to the projectors ; the investigation removed every doubt that had been entertained, and the merchants of Bristol became convinced of the advantages of a Railway between Bristol and London."

It also prints :

" *An Account of the Proceedings of the Great Western Railway Company, with Extracts from Evidence given in support of the Bill, before the Committee of the House of Commons, in the Session of* 1834."

and comments thereon as follows :

" A PERUSAL of this Pamphlet, written avowedly as an explanation of the case of the promoters of the Great Western Railway, not only carries full conviction with it as to the course pursued by them, but strongly illustrates the value and importance of the general system of Railways.

" The unhappy fate of the first attempt in Parliament to carry that measure, has in many respects led to a manifest improvement in the designs, and has quite ensured the success of their present application for legislative sanction to the Bill. It seems to us impossible, after the extraordinary success in raising a Capital for the whole Line, notwithstanding the natural difficulties aggravated by the loss of their Bill last year, that the House of Lords should again reject a measure fraught with such important benefits to the West of England. The excellence of the Line is unquestionable,—having for 113 miles no inclination which exceeds 11 feet per mile. The greater portion is indeed under 6 feet per mile. A judicious step has been taken in making a short ascent near Bath, not exceeding 2½ miles in length at an inclination of 1 in 107, upon which locomotive engines can work, as on the Liverpool and Manchester Railway, by which arrangement a longer ascent, for nearly nine miles at 16 feet per mile, has been avoided.

"One most important fact must not be omitted, as regards the present aspect of this Company in carrying their Bill through Parliament. The Land Owners on the Line have assented or are neutral for 90 miles, and the only dissents are upon 25 miles of the Road. In fact it is ardently desired by almost all who are not interested either in Canal Shares or Property similarly circumstanced. This ought and will have due weight with the Legislature, in looking to the merits of the measure.

"Nor does this Railway seem to us to concern the City of Bristol *alone*. It is planned upon a far more comprehensive scheme, and the interest which attaches to it generally in the West of England, arises from the power and design of the Company to extend the Railway through the Towns of Gloucestershire, as well as into Devonshire, through Bradford, Trowbridge, and Frome.

"The traffic must be very extensive, and we really do regard this undertaking as one of those most surely calculated to uphold the importance, and to exemplify the advantage and profit, to be derived from well-designed Railways."

The Great Western early suffered a blow which changed the whole course of its subsequent history. Beginning its existence under the control of men who were able to foresee, and endeavoured to provide for, the great developments which were to come, it adopted the broad gauge of 7 feet, while other companies remained faithful to the narrow (or as it is now called, "standard") gauge of 4 ft. 8½ inches introduced by Stephenson. Before long the difficulties brought about by the break of gauge became so serious that a Government enquiry into the merits of the two gauges was set on foot, with the result that it was decided that the narrow gauge was thenceforward to be standard in Great Britain.

This decision was at once recognized by the Great Western to mean that sooner or later the broad gauge lines would have to be altered to standard gauge, and had the effect of inducing in the officers and directors of that line a state of mind amounting to almost complete apathy towards progress. This apathy was by no means confined to the broad gauge lines and rolling stock; it seemed to pervade every department of the railway and lasted for something like forty years till, indeed, it was time to prepare for the final conversion of the last broad gauge lines.

With one main-line running to Birkenhead and another to Penzance, the area of country covered by the Great Western was greater than that covered by any other company, and the total length of line was much greater than that owned by any other company, reaching, as it eventually did, a total of 3,000 miles. An unusually large proportion of single line was, however, included in this total, with the result that receipts were on a lower scale than those of many other companies.

Owing to the geographical formation of the West Country, and to other causes, the lines forming the Great Western system were formerly exceptionally scattered, and a large number of extremely expensive new railways were necessary in order to link up the different districts, in which these lines lay. Some forty years ago the Great Western, which had the greatest mileage of any company in Great Britain, had hardly a single really direct route from London to any town of first-rate importance, and, where there were two routes, the Great Western one was invariably the longer. The North

Western route to Birmingham, and the South Western route to Exeter and to Plymouth were 15 to 20 miles shorter than those of the Great Western, the important South Wales district was cut off from direct communication with Bristol and London by the estuary of the Severn, and had no really good connection with Birmingham, and, even between London and Bristol, where there was a direct line, the trains took some quarter of an hour longer than necessary because of an old contract, whereby the railway company had bound itself to the owner of the Swindon refreshment rooms to stop all the trains there for ten minutes. In addition to all this some of the lines were broad gauge, and, though over a good many of them a third rail had been laid down to accommodate standard gauge rolling stock, the existence of two gauges greatly increased the difficulty of working the line. Such, then, was the position which the management had to change in order to make the Great Western the compact and easily worked system which it now is and, step by step, all the old obstacles were removed till to-day the line is among the leading railways of the world. The first work of magnitude that was undertaken was the construction of the Severn Tunnel, linking up the two banks of the estuary of that river. Next, in 1892, the last of the broad gauge lines were converted to narrow gauge, and the use of broad gauge rolling stock ceased for ever. The next step was the purchase, in 1895, of the remainder of the lease of the Swindon refreshment rooms, and from that date many of the express trains began to run through Swindon, saving much time thereby. The price paid was £100,000. Beyond this, four important short-cuts were taken in hand. Firstly, a line was built leaving the main line some miles beyond Swindon and running direct to the Severn Tunnel, shortening the distance to South Wales by about 11 miles, and also giving an alternative route for part of the way between London and Bristol slightly shorter than the original main line through the Box Tunnel. Secondly, by building two new lengths of line and bringing up to the requirements of main line traffic other lengths of existing line, a new route was made to Exeter and the west. This route leaves the old main line at Reading and rejoins it near Taunton. It saves rather more than 20 miles, and makes the Great Western route to Plymouth shorter than that of the Southern Railway. Thirdly, by short lengths of new line, a greatly improved route was provided between Birmingham and South Wales and Bristol; and, fourthly, two lengths of new line between Acton and a point north of Oxford have given a new route from Paddington to Birmingham, two or three miles shorter than that of the North Western. The opening of the new route to Ireland, by way of Fishguard, has also to be credited to the enterprise of the Great Western during the same period.

This enterprise was stimulated by a determined attempt early in the present century on the part of a group of financiers to get through Parliament a Bill to authorize a new line to Bristol, which it was proposed to link up with London by means of the main-line of the South Western Railway.

The original main-line of the Great Western from London to Swindon was built as regards both curves and gradients in such a manner as to provide the most favourable possible conditions for express trains; and on to Bristol, except for short descents at 1 in 100 a few miles beyond Swindon and through the Box Tunnel and for the curve at Bath, the lay-out of the line is equally favourable. As far as the nature of the country traversed made it possible, the allied companies (Bristol & Exeter, etc.) which built the continuation of the line to the far West, worked on the same principles; and though a fairly sharp ascent from Taunton to Whiteball Tunnel and a somewhat easier but still very noticeable descent thence to Exeter, together with a good many sharp curves where the line follows the South Devon coast, were unavoidable, the line from Paddington as far as Newton Abbot is, on the whole, a remarkably easy one. From Newton Abbot (214 miles *via* this route) right on to Penzance (325¼ miles) the character of the country traversed is completely different, and a long succession of natural obstacles in the form of steep hills, deep gorges, and inlets of the sea, make the line both in the matter of very sharp curves and extremely severe and fairly long gradients, one of excessive severity.

The worst bit of all is from Newton Abbot to Plymouth. This stretch of line seems to have been intended to be worked on the "atmospheric system." In this system a tube of large diameter was laid between the rails and a piston, attached to a vehicle of special construction which hauled the train, lay in the tube. Pumping engines were installed at intervals along the railway, and these engines were intended to maintain a vacuum in the tube in front of the piston, while the pressure of the atmosphere in the tube behind the piston was to provide pressure enough on the piston to drive the train forward.

The connection between the piston and the vehicle of special construction to which it was attached made it necessary to arrange a slit in the tube. This slit was provided with a flexible cord which was intended to fit so tightly as to exclude the air, but it is not surprising to learn that the arrangement was a complete failure. So the working of the South Devon line had to be taken over by steam locomotives. It was, and is, by far the hardest piece of main-line to be found in Great Britain. Among other very steep bits there is about a mile on either side of Dainton Tunnel averaging 1 in 45, with a few hundred yards at 1 in 36 on the east side of the tunnel, and at 1 in 37 on the west side. Beyond Totnes there are further bits of 1 in 50 up, and between Hemerdon and Plympton rather more than two miles averaging 1 in 42 down. Hemerdon bank is nearly straight, but almost everywhere else the curves are numerous and sharp. Attempts were naturally made to find an easier route across this corner of Devonshire, particularly at the time when a large amount of reconstruction was proceeding after the abolition of the broad gauge. But though a new and in many ways improved line lying to the north of the existing route was surveyed, it seems to have been found impossible to circumvent the Hemerdon bank, and the route of the old line was retained with only slight modifications mostly due to the necessity of constructing new viaducts.

Although the Great Western main-line in Cornwall has severe gradients and sharp curves, it is not quite so severe a road as the South Devon line. Here also when the gauge was changed a great deal of reconstruction took place, the old timber viaducts being replaced by stone structures and the line being doubled. The doubling of the line the whole way to Penzance is now nearly complete except for Saltash Bridge. Here presumably the existing single line will have to suffice.

The Westbury cut-off, which, as already stated, reduces the distance from Paddington to Taunton and beyond by about 20 miles, is somewhat steeper than the Bristol main-line, but except for a few miles in the neighbourhood of Bruton has no really severe gradients.

Although the line to the extreme West is served by the best trains and is best known to the general public, it is probable that the line to South Wales *via* the Severn Tunnel is more productive of revenue for the railway. Indeed, from the time the Severn Tunnel was made the Great Western seems to have devoted more money and energy to the South Wales area than to any other part of its territory. With the amalgamation of the South Wales railways into the Western group the importance of this district did not cease to grow, with the result that the Severn Tunnel is becoming insufficient for the growing traffic, and it has been announced that the tunnel is to be supplemented by a new bridge.

Additional interest to this promised development is lent by the fact that it has been proposed to substitute for a bridge a barrage which will impound the tidal waters of the Severn estuary and contain turbines, by means of which it will be possible to generate electricity on a large scale by the force of the tide. The bridge being definitely required by the railway for a definite object is likely to materialize, but it is impossible to regard the carrying out of the scheme for the production of electrical energy, or its revenue-earning prospects if carried out, otherwise than as problematical.

Except for the heavy gradients unavoidably introduced in the neighbourhood of the Severn Tunnel, the South Wales line is easy as far as Cardiff in the same way as the main-line to the West is easy as far as Newton Abbot. Although the character of the country does not change at Cardiff quite so abruptly as at Newton Abbot, the gradients west of Cardiff become notably more severe and in several places attain the unusual figure of 1 in 50.

With all the recent developments, the Great Western traffic to and from London has naturally not ceased to grow, and corresponding improvements and extensions have had to be taken in hand in the London district. The old engine-shed at Westbourne Park was removed, and the engines now find more extensive accommodation in the new sheds at Old Oak Common; and the remodelling and extension of Paddington Station, and the railway approaches thereto, have been completed. Except for the platforms being some distance below the level of the street, there is little fault to be found with the arrangements at Paddington. The station is compact, yet fairly spacious, and it is one of the few where there are adequate means of passing from one platform to another.

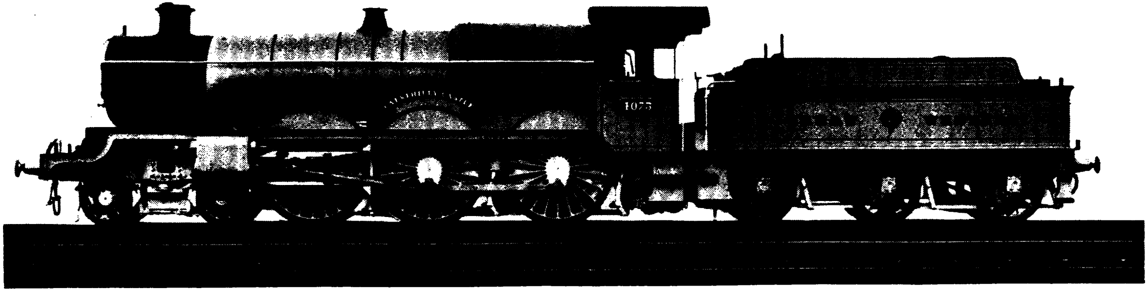
The existence for many decades of broad gauge lines on the Great Western long kept alive in this country a discussion as to what constituted, theoretically, the best railway gauge from the points of view of both safety and economy.

As regards safety, the standard gauge has turned out to be sufficiently wide to take engines and carriages having the highest centres of gravity. In early days, when the engines were very small, their centre of gravity was naturally low. It is obvious that the lower the centre of gravity the less chance there is of the engines' overturning, and for this reason a low centre of gravity was held to be conducive to safety. As more and more powerful engines were required, necessitating bigger boilers, and, in some cases, bigger wheels, the centre line of the boiler had to be raised more and more, either to clear the axles or cranks, or on account of the boiler's own greater diameter, which eventually reached a point when it was impossible any longer to get it in between the wheels, so that it had to be raised above them. Each step involved a higher centre of gravity for the whole engine, and the progress which has been realized in the power of engines, has been made possible only by recognition of the fact that such increased height is not dangerous. In a locomotive a great deal of the weight is placed very low down—the frames, cylinders and wheels are all very heavy—and the boiler is much lighter than its appearance would suggest, so that in engines with quite high-pitched boilers the centre of gravity and the rails still make approximately an equilateral triangle. On a line which is straight it does not matter much what the height of the centre of gravity is, but on curves, within the limits attainable, the higher it is the better. When passing round a curve the engine exerts a certain strain upon the outer rail, tending to push it outwards. The direction whence the push comes is from the centre of gravity of the engine, and therefore the higher this point is, the more does the strain come upon the rail from above and the less likely is it to burst the road. In electric locomotives the centre of gravity can be, and generally is, placed very low indeed, and, in America, at least one serious accident has occurred through the road's being burst by engines of this type. So much is this danger to be feared that in some recent electric engines considerable complications have been introduced with the object of raising the centre of gravity to the same height as in steam locomotives.

As regards economy, the standard gauge of British railways had, from the nature of the case, to be fixed before anything could be accurately known of future requirements, and was therefore a step in the dark. If railways could be begun again, there is little doubt that a wider gauge would be chosen, but, owing to the fact that it has been found not merely possible, but also advantageous, to build railway vehicles much higher and wider than would at one time have been considered safe, the distance between the rails (4 ft. 8½ in.) has been found sufficient. What, indeed, has limited the full development of British railway vehicles is the comparatively small dimensions of the tunnels and the little space left by the platforms and bridges. In most other countries the gauge of the rails is the same, but more, sometimes much more, space has been left at the sides and above, and vehicles much higher and wider than would pass the British loading-gauge are successfully run. As the loading-gauge is, so is it likely to remain, for it is almost inconceivable that any radical reconstruction of British railways could take place so as to admit of the use of much higher and wider vehicles ; and, although some scheming is required, everything that is really necessary can be done with the existing loading-gauge. But, that the existing gauge of the rails has turned out to be fairly adequate, is due more to good luck than to foresight. If the dimensions of existing railway vehicles had been foreseen, it is certain that in early days a wider gauge would have been thought necessary to carry them. As it is, the 4 ft. 8½ in. gauge is, and probably will continue to be, just sufficient, though not by any means ample, for the requirements of locomotive and carriage designing, while that it is adequate as regards the speed and weight of the trains, is evident from the fact that the limit in neither of these particulars has, in this country, so far been nearly reached in every-day work. But, if railways could be begun over again in the light of modern experience, it is almost certain that not only a wider gauge of the rails, but also a bigger loading-gauge, would be chosen. Increased economy has been made possible in ocean transport by the construction of larger and larger vessels, and the larger the vessel the greater the economy appears to be. Up to the present time, the standard gauge and the headroom available have been sufficient to render somewhat analogous economies possible in railway transport, but bigger dimensions would have made progress easier, and, therefore, almost certainly faster than it has been. In the United States, indeed, where many of the trains are as long and heavy as possible, so great an authority as Mr. Harriman appears to have thought that a wider gauge with still more headroom might have to be adopted sooner or later. But the railways of Great Britain, where trains of all kinds are comparatively light and fast, would have less to gain than those of other countries from being able to run extremely heavy trains, so, though it is certainly to be regretted that there is not a little more headroom for engines and passenger vehicles like corridor carriages and sleeping carriages, there is not very much fault to be found with the 4 ft. 8½ in. gauge of the rails.

For more than forty years the broad gauge expresses were worked by engines with single driving-wheels, 8 ft. in diameter —on account of their long service, one of the most celebrated classes of engine that has ever existed. As the broad gauge allowed ample room in every direction the task of the designers was much facilitated and the engines were simple, compact, and powerful, and suffered in no way from any of their parts being cramped. They ran on eight wheels, there being two pairs of carrying wheels in front of, and one behind, the driving wheels. The total wheel-base was only 18 ft.—equivalent to one of 12 ft. on the standard gauge—and, as there was thus no difficulty in the matter of rounding curves, no special arrangements were necessary to give flexibility, and so all the axle-boxes were fitted direct to the main frames. With inside cylinders only 18 in. by 24 in., a gauge of 7 ft., and a comparatively slow movement of the reciprocating parts owing to the large diameter of the driving-wheels, these engines possessed also great stability, and at that early period, when they were first introduced, were little less than works of genius. They were modified slightly as time went on, but there was little real difference between the first engines of the class and those which were working in the last days of the broad gauge.

Engines of this type hauling very light trains over a line so level and well laid as that of the Great Western were, of course, admirably fitted for running at very high speeds, and when they first came out seem to have performed some runs at average start-to-stop speeds which are to-day rarely attempted, though there is apparently no record of the attainment by any of them of a maximum speed so high as 80 miles an hour. It has been officially stated by the Great Western Railway that on one occasion one of these engines ran from London to Didcot in 47 minutes. The distance at that time was rather less than the present 53 miles from Paddington, and the average speed must have been about 67 miles an hour start to stop. Much as we may admire the ability of the designers of the first engines, it is a sorry commentary on the enterprise of the Great Western that the trains had improved so little in the intervening years as to leave the engines which worked them in the '40's still good enough to work them in the '90's. Since the abolition of the broad gauge, the locomotive designing of the Great Western has, like almost everything else connected with that railway, made great strides, as may be seen by an inspection of one of the engines used for working those expresses, which now make the Great Western famous throughout the world. Big and imposing she is, though not perhaps so pleasing in outline as British engines generally are. Of her efficiency there can be no doubt. Consider how every detail has been thought out and how many well-attested improvements have been applied. Some railways do not like employing a steam pressure in the boiler higher than 175 lbs. per square inch, but for this engine and her sisters the Great Western boiler-makers have to make boilers which will keep tight with 225 lbs.; and this makes the engines both more powerful and more elastic—if they are called upon to make a special effort they may use steam faster than they can make it till the pressure is reduced to 175 lbs., and still be as well off for steam as engines whose safety-valves blow off at that point. Her six-coupled wheels, of the same diameter as are given to four-coupled express engines, allow her to reach the highest speeds without the indefinable effort of movement, which is noticed in engines with small wheels, and, as there is at the same time more than fifty tons' weight on the coupled wheels, she is able to gain, or regain, speed very rapidly, and to climb hills well. (I once had a very good opportunity of comparing the powers of a four-coupled and a six-coupled engine, of almost precisely the same weights, of getting rapidly into speed with heavy trains, when both engines were doing approximately their best. The six-coupled engine with a train of 310 tons took 120 seconds to cover the first half-mile. The next day the four-coupled engine, working the same train with 300 tons, under substantially similar conditions, took 147 seconds for the same distance. This was not on the Great Western.) On the important West of England trains the qualities both of rapid acceleration and of hill climbing are of great use, as there are some half-dozen stations between Paddington and Plymouth through which the trains have to slow down, and on the South Devon section



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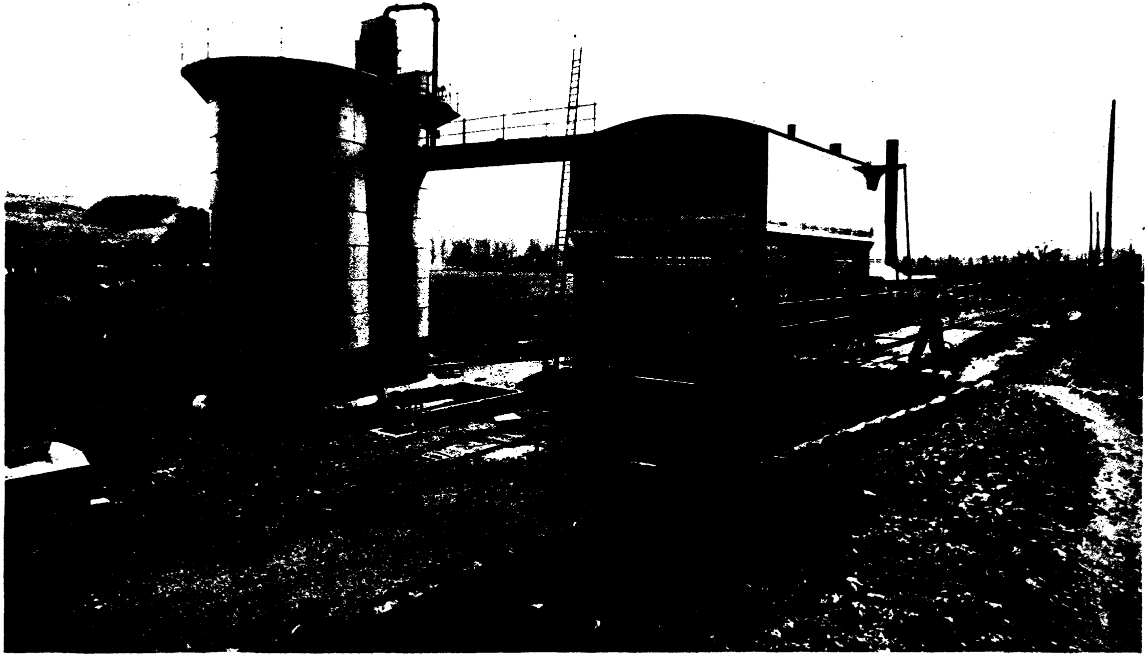
of the line between Newton Abbot and Plymouth, the gradients in some places are so steep that the heavier trains are sometimes actually more than a four-coupled engine could undertake at all with any certainty of not coming to a stand. Worst of all is the Hemerdon bank already referred to, which the up-trains from Plymouth encounter at the very beginning of their journey. This ascent is nearly twice as steep as the Beattock bank on the Caledonian, and is certainly the most formidable obstacle met with on any of the more important British main lines. Taking the maximum pull that the pistons can exert, without skidding the wheels, as one-fifth of the adhesion weight, we find that engines of this kind can exert a pull of about 10 tons, and can therefore just struggle up 1 in 42 with 250 tons behind the tender. If only four of the wheels were coupled, the train load would, under the same conditions, have to be reduced to about 125 tons.

The efficiency of the boiler is increased by the employment of a superheater of the Swindon type, which, though it does not raise the temperature of the steam to nearly the same extent as does the Schmidt design, has nevertheless proved of value.

As these engines are often obliged to exert a high power for long periods together, the strain on the machinery is considerable. In order to reduce this strain, the ordinary arrangement of two cylinders is, in some cases, replaced by an arrangement involving the use of four much smaller cylinders two inside the frames, driving the first coupled axle, and two outside, driving the second coupled axle. The driving stresses are in this way much diminished. Beyond this, a yet more important advantage is secured in that the cranks are so arranged that the pistons of the inside and the outside cylinders on either side of the engine are made always to move in opposite directions and so approximately to balance one another. This makes it unnecessary to put into the driving-wheels balance weights of the kind that are used in 2-cylinder engines, which, much to the detriment of the permanent way, once in every revolution of the wheels increase the weight which the rail has to support. Another device tending to spare the permanent way is the connecting together by means of equalizing levers of the springs of all the coupled wheels, which prevents any one pair of wheels from ever supporting more than its allotted share of the weight of the engine.

Before the present standard designs of express engines were evolved, the Great Western took the unusual step of importing several engines from France. In 1900, the Chemin de fer du Nord had brought out a 4-cylinder compound engine with the 4-4-2 arrangement of wheels, the performances of which were so remarkable that they attracted the widest attention in many other countries besides France. The Nord soon multiplied the type, and other French railways adopted it, always with the most satisfactory results, so after a time the Great Western, which was rapidly improving its trains, and was feeling the need for more and more powerful engines, imported from France an engine precisely like the Nord engines, and then, a year or two later, two similar, but slightly bigger, engines of the same pattern as some built for the French Paris-Orleans line. Though this experiment did not result in the full adoption of the French design, the employment in one of the now standard types of Great Western express engines of various prominent features of the French engines—four cylinders with balanced reciprocating parts, Walschaert's valve-gear, and the high boiler pressure of 225 lbs. per square inch—is no doubt, in part at least, due to these importations.

The Great Western, possibly owing to the high pressures employed in a good many of the boilers, has gone in largely for softening the water chemically before it is supplied to the engines. One big installation is situated near Goring on the main-line to Bristol for filling the water-troughs, which are there laid down on all four lines. The plant consists of an engine-house, in which is an engine for pumping the water, and two steel towers about fifty feet high, in which the softening process takes place. The principal impurity found in the Goring water is carbonate of lime, and, for precipitating this, quick-lime dissolved in water is employed. A mixture in the right proportions, ascertained by periodical chemical tests, is made



GREAT WESTERN RAILWAY, WATER-SOFTENING PLANT

at the top of one of the towers, and once in twelve hours the charge is passed down to the bottom of the tower and up again through pipes, in which it gets thoroughly mixed with more water, till a liquid is produced the colour of milk (known as milk of lime). This is added gradually to the hard water, which is being continually pumped up to the top of the first tower. The water is then directed down a pipe in the middle of the adjoining tower, from the bottom of which it rises again through a number of pipes in which are placed spiral plates which offer a very large surface for the deposit of the impurities which the chemical action of the milk of lime has precipitated. The softened water, after passing out from the tops of these pipes, through which it has slowly ascended, rises through a filter, which collects any solid matter that may not have been precipitated onto the spiral plates, and thence runs away from the top of the second tower into the reservoir, whence it is drawn upon as required. Nearly half a million gallons of soft water—that is, well over 2,000 tons—are required on a normal day. All this water does not, however, find its way into the tenders, as a great deal is spilled during the the process of picking up water at speed—so much, indeed, that it has been found worth while to collect as much of the of the overflow as possible, and lead it back by a special pipe to the well from which the hard water is drawn.

The Great Western, ever since it got rid of the Swindon stop, has been noted for the number of long runs which its engines perform. Directly the stop at Swindon was cut out some of the trains began to run through to Bristol (118¼ miles *via* Bath); soon afterwards runs to Exeter (194 miles) were introduced; and for a year or two before the opening of the line to the West, via Westbury, the 245¾ miles between Paddington and Plymouth, *via* Bristol, used to be run without a stop. The distance to Plymouth has now been reduced to 225¾ miles, but this still gives the Great Western the longest non-stop run in the world, though the London, Midland & Scottish, which in summer has runs of over 200 miles, is not far behind. The runs performed on the Plymouth line are longer than those found on the other main-lines of the Great

Western, but along all its principal lines there are a considerable number of trains running distances of well over 100 miles without a stop. All over England, indeed, such runs are much more numerous than are to be found in any other country. Considering the relatively small area of England, this is, at first sight, rather a remarkable fact. Looked at a little closer, it is less surprising. The circumstances which create a demand for long non-stop runs are the existence of very large towns, which can provide train-loads of people all of whom wish to perform one particular journey ; and England, with her large urban populations widely distributed at considerable distances from the Metropolis, but at the same time close enough to make the time necessary to complete the journey not a serious deterrent, offers conditions which are very favourable to the development of long-distance non-stop runs. In America and on the Continent of Europe, where the conditions are different, the number of such runs is much smaller.

As the length of run performed without a stop increases, so also do the difficulties of serving intermediate stations, at which the express trains do not call. When the number of long runs performed on the Great Western is considered, it is not surprising to find that this line is the one on which the practice of slipping carriages at speed has reached its greatest development. Particularly is this the case with the West of England expresses, from which Westbury, Taunton, and Exeter all receive slips. Many people living at intermediate places along this line have to deplore the impossibility of attaching carriages at speed in the same way as they are detached, for they find the up journey a much longer and more tiresome business than the down journey.

A serious attempt was made during the years before the war to increase local traffic by running rail-motors, or short trains so arranged that they could be driven from either end without any change in the position of the locomotive, which was sometimes placed at one end and sometimes in between two carriages. The Great Western was particularly active in introducing rail-motors. They are very easy and convenient to handle, and quite cheap to build and keep in repair. Beyond

GREAT WESTERN RAILWAY, GORING WATER TROUGHS

this the principal advantage which they offer is that the passengers can be taken up or set down at places where it would not pay to build a regular station. A short, cheap wooden platform, with no booking office and no station staff, is all that is required, and in some cases even this can be dispensed with and the passengers taken up or set down at a level crossing or other convenient point, in a manner which would be impossible, or at least highly undesirable, with an ordinary train. In this manner it is possible to give facilities for short-distance journeys, which would otherwise either not be made at all, or be made by some means other than by rail. A considerable part, therefore, of the traffic conducted in motor vehicles must be regarded as entirely new traffic, which, so far as the railways are concerned, would otherwise not have existed at all. The distances covered being short, and the passengers, from the nature of the case, few, the conditions are simplified as much as possible in every way, and one class has to suffice. Motor vehicles are, indeed, less part of the ordinary train service than glorified omnibuses, which are introduced to give extra facilities in certain places where there happens to be a sphere of usefulness for them.

CHAPTER IX

THE importance to London of the Southern Railway group, consisting of the former London & South Western, London, Brighton & South Coast and South Eastern Companies, may be realized from the fact that the accommodation provided by the termini belonging to this group is approximately equal to that of the London termini of the other three groups combined.

The South Western alone among the big railways serving the Metropolis refrained from building a terminus north of the Thames and thus avoided the necessity of making a big bridge across the river. The difficulty of access to Waterloo has, indeed, always been something of a drawback, and though since the construction of the Baker Street and Waterloo Tube the position has been considerably improved, the question of providing easy access for road vehicles still remains acute. Up to quite recent times, too, Waterloo was a thoroughly unsatisfactory station. With its narrow platforms, steep, inconvenient approaches and cramped buildings, it was more in keeping with its dingy surroundings than worthy of its importance as the terminus of a great railway. It was, indeed, nothing but a provisional structure destined to endure only until convenient opportunities should arise for its gradual reconstruction. This reconstruction was begun a few years before the war and formally completed in 1922, and Waterloo now, besides being the biggest railway terminus in Great Britain, is, so far as its interior arrangements are concerned, one of the best arranged and most convenient. With approaches leading through conveniently placed booking offices to a broad concourse which gives access to the twenty-one platforms, and provided with efficient indicators to direct passengers to their trains, its principal features are in accordance with the best modern ideas.

Waterloo Station was something of an after-thought, and, from the original terminus at Nine Elms, an elaborate and costly viaduct has been necessary, and the greatest economy of space has naturally been practised. But at Nine Elms the Southern Railway has its operations much facilitated by the possession of a considerable area of ground, so much, indeed, that till shortly before the war the locomotive works were situated there. Now that they have been removed much valuable space has been set free for other purposes. The most important business of the Southern Railway at Nine Elms is the conduct of the goods traffic. At Nine Elms is a big goods station where work goes on for practically the whole of the twenty-four hours, but it is during the night, from about 7.30 p.m. to 5 or 6 the following morning, that the greatest activity prevails. Though the railway is always glad to receive goods as early as possible, it is not till about 7 p.m. that the steady stream of railway drays and vans, supplemented by those of public carriers and of private persons, begins to pour in at the gates and range itself along the platform, onto which the contents of these vehicles are unloaded preparatory to being loaded again into the trains, which leave at intervals throughout the night.

To anyone walking about the great despatching shed at Nine Elms, the extraordinarily retail character of the trade of the country is brought home when the smallness of the average consignment is seen. In most cases what the local tradesman or distributor seems to do is to forward to London a list of his requirements, and, by return, receive all the things he wants, subdivided and marked in a such a manner that he has very little left to do but to hand them straight on to his customers. In these circumstances the work of keeping correct lists of all the different consignments and of seeing that they get sent to their proper destinations—work on which the efficient conduct of the traffic is entirely dependent—becomes a matter of great complication and, of course, adds immensely to the expense incurred by the railway. The greater part of this work is done, as the packages are unloaded from the drays, by men standing at desks ranged along the platform, who receive, check and weigh the consigments delivered, and pass them on, to be wheeled by porters to the wagons in which they are to be packed and sent off; or, if no wagon for the right destination is at once available, to some place where they can easily be got at when wanted. Hydraulic cranes are installed at intervals to facilitate the handling of the bulkier objects; but the cranes are not much used, as few of the packages received are big enough to make this necessary. When the packages reach the wagons in which they are to travel further checking is necessary, and the invoices are drawn up, while the packers proceed with the work of firmly, yet tenderly, wedging the different packages together, so as to make the best use of the space at their disposal, and, at the same time, make it practically impossible for any package to break loose or fall onto the line. This result is further ensured by the tarpaulin sheet with which the wagon is covered before it starts off. That the weight-carrying capacity, at least, of the wagons is not fully utilized, is shown by the fact that at Nine Elms it is calculated that the average wagon-load is three tons, instead of the ten tons which each wagon is constructed to hold. But three tons a wagon is in reality a very good result, and much superior to the results shown in many other places.

The various lines of rails in the shed will accommodate something over 150 wagons at a time. These wagons, at three tons each, will hold a very respectable quantity of merchandise, but they are far from sufficient to receive all that offers at Nine Elms on a normal evening, and, as the night wears on, the old-fashioned shunting engines, which ply up and down in the yard outside, have a good deal of work to do in hauling out the strings of wagons which are already loaded, replacing them with empty ones, and carrying out such marshalling operations as are necessary to complete the different trains, and get the wagons for the different destinations in order, so that those which are to be dropped at any particular station shall always be in the right position next the engine. In the course of the night three wagons, generally speaking, come in empty to each berth and go away again full.

In another shed, next to the one just described, are drawn up wagons ready to receive such large consignments as come in.

This shed is arranged so as to enable the drays to draw up on one side of a platform, at the most convenient spot for their contents to be loaded straight into a railway wagon, which is standing on the other side. In this way the goods require the least possible amount of handling, and are, of course, much easier to deal with than the miscellaneous collection of things for many different destinations, which are disposed of in the bigger shed, where, moreover, owing to the fact that there are several railway platforms, but only one roadway, it is in most cases necessary to move them some distance between the time they are unloaded from the drays and the time they are loaded again on to the railway wagons. Further on, again, where goods for Southampton Docks and for the steamers serving the Channel Islands are sent off, some large consignments are handled.

The different trains are sent off as far as possible in such order as will cause them to reach their destinations at convenient times in the morning. The Plymouth train, for instance, starts at 10.30 p.m., and, running probably as far as Exeter before it drops any wagons, reaches Plymouth at 6.30 a.m., while trains which are to run only short distances do not leave till perhaps 6 a.m.

All the traffic dealt with in the evening is outwards traffic, but, as the night passes, and the trains are sent off, space is gradually made for the incoming trains, which will begin to arrive early in the morning with supplies to be distributed throughout London before a great part of the world is awake. Owing to the careful order in which all these things will arrive, their reception will involve much less labour than the despatch of the outwards goods necessitates.

At Clapham Junction, four miles from Waterloo, the main line is relieved of some of the suburban traffic, which branches off along the Windsor line. The volume of suburban traffic which the main line has to accommodate still remains considerable for some distance, but the existence of four lines of rail and of several flying junctions, helps to prevent delays, and otherwise the line is admirably laid out in a series of long gentle inclines all the way to Salisbury.

There are four lines of rail from London to the point where the Southampton line leaves the main line to the West, a few miles beyond Basingstoke. The capacity of a railway with four lines is, in ordinary circumstances, much more than twice as great as that of a double line, because the pace of the trains varies a great deal, and, on a double line, it is impossible to arrange for a regular succession of trains at very short intervals of time. To get the greatest value out of a railway, the greatest possible tonnage must be passed over it in a given time, and to do this the ideal conditions are that each train should be as heavy as possible and should occupy as short a section as possible of the running lines for as short a space of time as possible, and that all the trains should be run at the same speed. The weight of a train is generally limited from considerations other than those for securing the greatest possible economy, but by increasing the number of block sections up to the manageable limit, the capacity of the lines may be proportionately increased. On underground and tube railways, where all the trains run at exactly the same speed, and the block sections are also very short, the capacity of each line becomes very great. To make the capacity of an ordinary double line as great as possible, the trains have to be arranged so that those of approximately the same speed follow one another—the expresses run at certain times and the goods trains at other times—but to draw up a really satisfactory scheme of working is of course very difficult. Where the traffic is very great, and two sets of double lines are laid, the working is much facilitated, as one pair of lines is used for the faster, and the other for the slower, traffic, with the result that all the trains running on either line are much more nearly of a pace than they would otherwise be. But on main lines, even when there are four lines of rails, it is not possible to do more than arrange that trains using the same lines shall run at approximately the same speed, and, in order to achieve this, goods trains are frequently run faster than would otherwise be necessary.

Where trains are frequent one of the arrangements for obviating delays and increasing the safety of working, is the use of flying junctions. There are, as before remarked, several of these on the main-line of the Southern Railway. In the case of a main line where a branch line deviates to the right, for instance, a down train, running onto the branch line, has, at ordinary junctions, to cross over the up main line, which it blocks for up main-line trains. If a flying junction is used, the branch-line leaves the main line on the far side, and then gradually rises or falls till it can be led over or under the main-lines, thereby rendering any suspension of traffic on the up main-line unnecessary, and making collisions impossible. There are, too, other advantages afforded by flying-junctions. Where-ever a line diverges from another which is straight, it is advantageous to make the curve which it describes as flat as possible, and to give the outer rail an adequate amount of super-elevation, so as to necessitate as small a reduction of speed as possible. In the case of ordinary double line junctions, with ordinary crossings, very strict limits are set to the maximum radius of the curve described by the line, which diverges from the straight, and then crosses the second straight line at an angle which must not be sharper than 1 in 8; and, to make matters worse, it is only beyond the crossing that any super-elevation at all is possible. Both of these difficulties are avoided in flying junctions.

Salisbury station was the scene of one of the most remarkable accidents that has ever taken place. On 30 June, 1906, the *New York* called at Plymouth and landed forty-three passengers for London, who started off late the same night in a special train. This train ran without a stop to Templecombe, which was reached punctually. Here engines were changed, No. 421 came on, and the train started off again at 1.26 a.m., being timed to cover the remaining 112¼ miles to Waterloo in 115 minutes. A few minutes were lost on the steep gradients at the start, and partially regained on the favourable stretch of line descending towards Salisbury, where the speed seems to have risen to about 70 miles an hour—quite a normal speed with one of the most powerful express engines and a train which weighed only about 120 tons behind the tender. But just beyond Salisbury Station the line bends sharply to the left, and it had been most explicitly laid down in the instructions issued by the railway company to the engine drivers that speed must be greatly reduced to pass over this curve in safety. Whether the driver—a thoroughly experienced man—forgot for a moment where he was, or whether he was suddenly taken ill, will never now be known ; steam had been shut off and the whistle sounded, but the brake was not applied ; the train dashed through Salisbury Station at a speed which those who witnessed it recognized as fraught with disaster. At a point just beyond, where the line is on a curve with a radius of only 8 chains, the impetus was so tremendous that the left-hand side of the engine rose into the air, and the engine turned over on to her right side, crashing, as she fell, into a milk train, which happened to be passing on the adjoining line. The first four out of the five carriages, of which the express was composed, were almost completely destroyed, and 24 of the passengers and the driver and fireman were killed, and also two other railway servants. Both the engine-men having lost their lives it was impossible to do more than theorize as to how it happened that the train was allowed to rush to destruction in this manner. The speed at the point where the accident took place ought to have been not more than 30 miles an hour, and calculations which were afterwards made showed that a speed of about 67 miles an hour was necessary to overturn the engine in the way in which she was overturned. The accident was in every way noteworthy—when one takes place owing to a curve, it generally occurs through one of the wheels coming off the line, and it is doubtful whether more than quite a few other genuine cases of the actual overturning of an engine by centrifugal force have ever been known. The fact that no derailment, in the proper sense of the word took place at all bears witness to the extraordinary way in which an engine with a flexible wheel-base—No. 421 is an 8-wheel four-coupled engine, with a leading bogie—running over a well-laid line, with a check-rail, will keep the rails on a very sharp curve at high speeds.

The Salisbury-Exeter section of the Southern Railway is one of the most difficult lines in England. Leaving Salisbury the first 17 miles are an almost continuous ascent ; in the next

17 miles are three descents and two ascents, all steep, and in some places as much as 1 in 80; next, a few miles of comparative level brings the train to Yeovil Junction, 39 miles from Salisbury. After this there are three principal banks—4 miles at 1 in 150 immediately after leaving Yeovil Junction; 3 miles at 1 in 80 to a summit at post 133¼; and, worst of all, 7 miles from post 146½ to the Honiton Tunnel, of which the 4½ miles from Seaton Junction are at 1 in 80, and the rest not much easier.

When the Great Western's main line to the West, *via* Westbury, had been opened, the distance to Exeter became almost the same by either route—the South Western had only about two miles the better of it. If a race were to take place the two companies should be very evenly matched, for, though the Southern gradients are the harder, there are on the Great Western route a greater number of curves which have to be traversed slowly. Exeter, however, in comparison with Plymouth, is a small place, and Plymouth is the objective of both lines. As the crow flies, Plymouth is less than 40 miles from Exeter, but exactly in between is the high-lying and practically uninhabited region of Dartmoor, which could not be crossed and had to be avoided on one side or the other. The Southern line, striking first of all north-west from Exeter, and then due west, keeps to the western edge of the moor when at length it turns south. No amount of engineering skill could prevent a line through such country from being an exceptionally difficult one. A great deal of it is at 1 in 80, or a little worse, and, though the rising gradients are not absolutely continuous, the line climbs so steeply that a summit of 950 feet is reached near the great Meldon Viaduct, which spans the gorge descending from the foot of Yes Tor—the highest point in the West Country. From this summit there is a correspondingly steep descent to Plymouth, which is not reached till the train has travelled 59 miles from Exeter (Queen Street)—about half as far again as if the line thence were straight. The Great Western line, on its southerly course, does not make quite so wide a *détour*, and running along the coast for the first 20 miles, does not reach the hilly country till after Newton Abbot. But, owing to the extreme severity of the Great Western route from here onward, it is not impossible that, if the hypothetical race between the two lines were continued from Exeter to Plymouth, the Great Western's 52 miles from St. David's would take nearly as long as the Southern's 59 from Queen Street.

The express engines used by the Southern Railway for its best trains between Waterloo and Exeter are 4-6-0 machines with outside cylinders and a boiler pressure of 200 lbs. per sq. in., known as the "King Arthur" class.

I was lately permitted to make a very interesting journey from Waterloo to Salisbury and back upon these engines. On the outward journey with the 3 p.m. train, No. 780 had nine vehicles weighing, with passengers and luggage, about 280 tons behind the tender. After a punctual start the four rather awkward miles to Clapham Junction occupied seven minutes, and it took some time longer to attain 60 m.p.h., but the gentle fall past Surbiton brought speed well over this point and post 20 was passed at about 68 m.p.h. From here there is a continuous ascent for 11 miles averaging about 1 in 330, which was covered in 10½ minutes, speed at the summit not falling below 57 m.p.h. A mile or two of slight fall or level soon brought it again over 60 m.p.h., but after this a long stretch of line was encountered where recent relaying operations made it necessary to restrict speed, and it was not for some ten miles that full speed could be resumed, so that over this section the loss of time amounted to fully 4½ minutes. From post 46 there is a 5 miles' ascent, almost all at 1 in 249, and it was only when half this climb had been accomplished that speed again fell below 60 m.p.h. After the summit at mile-post 51 was passed speed rose and the 10½ miles between Overton and Andover Junction were run in 8 min. 40 sec. The succeeding ascent to Grateley, the last 3 miles of which are at 1 in 165, brought us down to just under 53 m.p.h., and then an easy run downhill to Salisbury landed us at that station 87 min. 55 sec. after we had left Waterloo. As the distance is over 83½ miles, and we had lost at least 4½ minutes owing to temporary speed restrictions, this run was fully

4–6–0 EXPRESS ENGINE, SOUTHERN RAILWAY

equivalent to an unhindered run at 60 m.p.h. start-to-stop. Steam had been cut off at 22 per cent of the stroke almost all the way, and on the uphill and level sections the regulator was usually wide open, with boiler pressure at or near the blowing-off point of 200 lb. per sq. in.

For the return journey with the 4.34 p.m. train the engine was No. 453, " King Arthur," and the train consisted of seven vehicles weighing about 220 tons. An uphill start over the sharpest curves does not favour the rapid attainment of speed, and we did not do badly to run the first mile in something under 3 minutes and to pass post 82 in 3 min. 51 sec. For the next mile the speed was 46 m.p.h., and we had entered on the steep 4 miles to near post 77½ (the first two-thirds of which are at 1 in 169 and the rest at 1 in 140). All the way up this ascent speed was between 48 and 50 m.p.h., but when the gradient eased to 1 in 245 speed immediately rose to over 51 m.p.h. for mile 77–76. Here an adverse signal brought about a loss of 1¾ minutes, and it was not for a mile after the summit at post 73½ had been passed that 60 m.p.h. was reached. This increased to a maximum of 77 m.p.h. on the descent towards Andover Junction. Hence there is a 3-mile ascent at 1 in 178, which brought speed down to 61 m.p.h., but after the summit was passed it rapidly rose to over 65 and so continued till a further signal check—slight this time, and costing only about a quarter of a minute—was encountered near the junction with the Southampton main-line. Basingstoke, 36 miles from Salisbury, was passed in 38 minutes (two of which were due to signal delays), and after this speed remained high for a long way. Post 27 (56¾ miles from the start at Salisbury) was passed in 54 min. 51 sec.; here the last 45 miles had been run in 38 min. 6 sec. (70½ m.p.h.), and the 11 miles from post 38 had been covered at an average speed of 75 m.p.h.

From here onwards long stretches of road had to be traversed at reduced speed owing to recent relaying, so the run was of little further interest. Even so, when we were stopped by signal between Vauxhall and Waterloo we had run 83 miles in 91 min. 22 sec. With a continuation as far as Clapham Junction of running similar to that before post 27 and with a normal approach to Waterloo, an unhindered run from Salisbury should in similar conditions be completed in about 78 minutes. The engine was, moreover, working quite easily all the way and, so far as could be judged, could without difficulty have done 25 per cent harder work.

Probably the most important step which the South Western ever took was the purchase, some thirty years ago, of Southampton Docks. From that time onward the Company has continuously developed the docks and at the present time the Southern Railway is putting in hand further large extensions. The present area of the docks is roughly a triangle, with a base to landward of some half to three-quarters of a mile, and projecting about a mile into the estuary, the western shore of which will be used for the extensions. Southampton is one of the places where Nature has been really kind. The first branch of the tidal wave reaches Southampton *via* one side of the Isle of Wight, and is followed exactly two hours later by a second branch round the other side, with the result that there are two successive high-tides at two-hour intervals—practically one continuous high-tide for this period. The range of the tides is not very great, and the place, though land-locked and complete sheltered, is approached by a deep water channel. With all these advantages Southampton was a tempting place to develop, and certainly the railway has stinted neither money nor energy. Since the Company took over the docks there has been a prodigious and rapid increase in the size of the biggest steamships, but Southampton, with all its natural advantages, has kept, and is keeping, well abreast of the requirements of these vessels. The *Olympic* herself lies easily in the deep-water dock, and the Trafalgar dry dock was altered to take her in. At the time of my visit she was lying comfortably alongside in the deep-water dock, where there are never less than 40 feet of water—a contrast indeed to the *Majestic*, which lay beside her, and had not so long ago been one of the biggest ships in the Atlantic trade. The reconstruction of the Trafalgar Dock, a work of some magnitude, included replacing the original gates, which opened outwards, and so could withstand pressure from the outside only, by a single sliding gate, which will withstand pressure from either side, and so makes it possible to have a higher level of water inside the dock than there is in the sea outside. The pumping engines, used for pumping the water out of this dock, are powerful enough to complete their work, if necessary, within two hours, but in practice the pumps do not work at their full power, as it is more convenient that the level of the water should sink gradually to enable the hulls of the ships to be got at for cleaning at leisure. Close by are some shops, erected by Messrs. Harland & Wolff, conveniently situated for carrying out heavy repairs on the ships lying in the docks.

The most important part of the traffic dealt with at Southampton is the passenger and troop traffic, and, for the purposes of this traffic, the trains can be run into the various sheds, which extend along the waterside, and so get quite close to the berths at which the ships lie. These sheds are supplemented in some cases by covered gangways between shed and ship, so that the passengers are completely protected from the weather.

The greater part of the many acres of covered-in space is composed of transit-sheds, used for housing merchandise provisionally till such time as it can be loaded onto the ships or into the trains in case it cannot be transferred direct from one to the other.

Southampton is chiefly concerned with high-class goods—manufactured articles of considerable value—and does not trouble itself much with such things as raw materials in bulk. There are, nevertheless, large storage warehouses for grain, chilled meat and various other things, which arrive in large quantities, and are warehoused till opportunities arise for their distribution.

The fifty-one berths and six dry-docks at Southampton are not by any means exclusively used by great ocean liners. Private yachts from all parts frequently visit the docks. When I was there a beautiful yacht, belonging to an American millionaire had just been taken into one of the smaller dry docks. His Majesty's ships are by no means strangers to the place, and here also is the starting-point of the Southern Railway's cross-Channel service to Havre. This service, which runs at night, offers in its own way great conveniences, which are perhaps not so widely appreciated as they ought to be. The steamers leave either Southampton or Havre at midnight, and give the passenger an uninterrupted seven or eight hours, which, if he happens to be a good sailor, or if the sea happens to be smooth, offers possibilities of an adequate night's rest. Those who have experienced the miseries involved in crossing by night from Calais to Dover will appreciate the advantages which the longer crossing gives.

London Bridge, though it has the disadvantage of being situated south of the Thames, is in a fairly convenient position for people going to the City, and the rebuilt Victoria is certainly the most spaciously built and conveniently placed station in London. The reconstruction of Victoria was part only of a very ambitious scheme of widenings, which was to embrace the whole of the main line to Brighton, and is not yet complete. As time passed this main line had become more and more crowded with traffic, and the difficulties of working it had increased correspondingly. This was particularly felt on the section between Croydon and Redhill, where one pair of lines had to suffice not only for the Brighton trains to and from Victoria and London Bridge, but also for a large number of stopping trains belonging to the South Eastern, to which railway a section of the line actually belonged. Here relief had first of all to be provided, and in 1900 a new double line was opened by the Brighton Company. As far as Stoat's Nest, some three or four miles, it runs beside the old line, then diverges to the west, crosses over the old line a little before Merstham Tunnel and rejoins it just before Earlswood. I got some idea of the enormous advantage conferred by this line on the Brighton Company when, shortly after it was opened, an express train, in which I was travelling, ran past, and got in front of, no less than three trains which were running along the old line. After this widening was finished other sections of the main line were successively taken in hand, and four lines now extend all the way from Victoria to the north end of Balcombe Tunnel, about 32 miles. Meanwhile, the reconstruction of Victoria Station was begun, and, after it had been steadily proceeded with for some years, the present station was brought into existence. The works included the demolition of a long line of houses, the alteration of the level of several hundred yards of street, and the building of a large wing of the Grosvenor Hotel. The chief point that strikes the observer is its great length—the platforms are something like a quarter of a mile long. This arrangement was necessary, as it was impossible to widen the station towards the south where the South Eastern terminus already stood, and only quite a narrow strip of land was available on the north towards Buckingham Palace Road. The platforms are, therefore, arranged in such a manner that two trains can be drawn up, one behind the other, at each. Specially convenient features of the new station are the large circulating area round the booking offices and waiting rooms, and the wide platforms, which give a feeling of spaciousness, unfortunately too often lacking in London termini. When it is remembered that the old station was bit by bit swept away, and the new one, in which no trace of the old one can be detected, put in its place, without a day's suspension of the traffic, it must be recognized that the engineers performed a very considerable feat.

In Brighton the Southern Railway possesses in some respects the most favourably situated sea-side town in the world. The main line runs in practically a straight line from London to Brighton. It is well suited for fast running—it is admirably laid, it has fairly easy gradients, and, except in the London area, there are no curves where speed has to be seriously reduced. The possibilities of traffic between London and Brighton are, therefore, immense. But, owing probably to the crowded state of the line and the great consideration which has to be given to the valuable suburban and semi-suburban traffic conducted along it, which make it a matter of some difficulty to fit in trains running very much faster than the average, no attempt has ever been made to develop the London-Brighton traffic to anything like the point which the very favourable position of Brighton renders possible. There is no disguising the fact that for a very long time the trains between London and Brighton were slow. Not so very long ago the best up train took 70 minutes and the best down train 65 minutes (except on Sundays, when there was a train in either direction in an hour). Later one-hour trains in each direction began to run on week-days, and have now been multiplied till there are a fair number of them each way, but better things are required. If the Southern Railway intends to make full use of Brighton it will have to put on a frequent service of really fast trains in both directions, which, now that the line to Brighton has been quadrupled to the very edge of the suburban area, should present no insuperable difficulties.

The London-Brighton service has been compared by many writers with the celebrated service in the United States between Philadelphia and Atlantic City, and the comparison is instructive. I do not know what the present timings of these American trains are, but for many summers the Pennsylvania Railway used to cover the 58¼ miles from its Camden station to Atlantic City in 52 minutes, start-to-stop, and the rival Philadelphia and Reading trains were allowed 50 minutes for their 55½ miles, also start-to-stop. I am not acquainted with the line of the latter company, but on the Pennsylvania line the best trains lost at least a minute at either end of the run owing to speed restrictions. The Brighton line is not, on the whole, more difficult than the Pennsylvania, so it is certainly possible to run between London and Brighton in 45 minutes, and, if it paid the American railways to run these trains for the benefit of Philadelphia, how much more should it pay the British company to run equally fast trains for the benefit of London, which has four times the population of Philadelphia. At present people coming up to London from Brighton for the day, or going down to Brighton from London, cannot do the double journey in less than two hours. This is probably just long enough to deter them from travelling very frequently. If the double journey could be done in an hour and a-half, a new set of conditions would arise, and Brighton, from being a provincial town, would become practically a suburb of London.

If the Brighton Railway possessed a district very rich in passengers, it did not secure this district for nothing. There are few lines where the natural obstacles are so continuous. In the 51 miles between Victoria and Brighton, the ridges and depressions all lie across the path of the line, and the works include the bridge over the Thames at Grosvenor Road, a considerable viaduct, and some half-dozen tunnels—two of them more than a mile long. The great expense is probably the chief reason why this line was not earlier widened, and, even now, the widenings have only proceeded as far as the point after which the natural obstacles become the most severe and continuous.

With the widening of the main line and the rebuilding of Victoria Station, the Brighton Railway's reforming energies were not exhausted. For many years the railway companies had been complaining that the short-distance traffic was being filched from them by tramways, which, passing people's doors at short intervals of time, offered attractions with which railways could not compete, and in many cases, being subsidized by the rates, demanded excessively low fares. For very short-distance traffic it is improbable that the railways will ever be able to recover the ground which they have lost to the tramways ; but the tramcars, running as they do through the streets, can never attain any very great speed, and, though this is a matter of minor importance for very short-distance traffic, the Brighton Company thought that for distances over about a couple of miles it might be possible, by introducing electric working, to provide a service so much superior to that of the tramcars in point of speed that there would be a very good chance of competing with the tramways successfully. The Brighton Company possessed a line, nine miles long, beginning at Victoria, running through South London, and finishing up at London Bridge, which was peculiarly exposed to tramway competition, and a beginning was made by the electrification of this line. When it was worked by steam locomotives, the nine miles, in which there are the same number of intermediate stations, took some 35 minutes to cover. Owing to the much greater rapidity with which the electric trains can get away from the stations, the journey now takes only about two-thirds of the time which it used to take.

Since then a good many suburban lines have been electrified, and the Southern group, with its large suburban traffic, is the group which has so far gone furthest in this direction.

The use of electricity as the motive power for railway trains is a subject on which a very large amount of misconception exists in the minds of people without technical knowledge—misconception which is unfortunately encouraged by the unguarded language used and the extravagant claims put forward for electricity by people who ought to know better, including many prominent electrical engineers. Just as it would be ridiculous to deny the advantages which electricity offers for moving certain classes of traffic, it is absurd to suggest that electricity has yet proved itself equal to steam for each and every kind of tractive work upon railways. It may do so in the future, or it may not.

The advantages which electricity has so far shown itself to possess are primarily those fitting it to work trains upon underground and tube railways or through long tunnels. Beyond its unquestionable utility in tunnels, electricity has one considerable advantage for working trains which stop frequently and so must frequently be started from rest—that is to say, practically all urban and suburban passenger traffic. With electricity it is possible to make as many of the axles of the train as desired—all if necessary—driving axles, and so utilize as much of the weight of the train as desired for purposes of adhesion ; this enables the train to gain speed very rapidly from rest, and so makes possible both higher average speed and a more rapid succession of trains.

Large claims, too, are made for electricity in respect of more rapid working in terminal stations. It is asserted that the time required for detaching an engine from one end of the train and attaching another at the other end, together with the time lost in getting the detached engine out of the way, is saved. Considering the great rapidity with which these operations with steam locomotives can be carried out and the fact that a certain amount of time is in any case necessary for getting the arriving passengers out of the train and the departing passengers into it, it is probable that any advantage which there may be on the side of electricity in these respects is not worth much in practice. A further small advantage with electricity is that the space required for refuge sidings for steam locomotives is saved.

Electricity, on the other hand, is by no means free from special technical disadvantages as compared with steam, the principal one being that, whereas with steam the breakdown of one locomotive, or even of several locomotives, usually causes only a certain amount of local delay, any interruption in the continuous supply of current from the power-station may paralyze the traffic of a whole district. So serious is this disadvantage that for this reason alone the German military authorities before the war refused to sanction the electrification of any railway near the frontiers of the German Empire. The insulation too of electric currents required for signalling or other purposes must obviously be a more difficult matter on electrified lines. Then, also, though with electricity the disturbances due to the unbalanced reciprocating masses of a steam engine are absent, it is often necessary to introduce into the design of an electric motor complications with a view to raising the centre of gravity to a height comparable with that of a steam locomotive, so as to avoid the tendency of motors with a very low centre of gravity to burst the rails on curves.

Electrification, moreover, presents certain objectionable features as regards the maintenance or the safety of the line. With the third-rail system, the platelayers find it much more difficult to get at the sleepers for the purpose of packing them than is the case on an ordinary steam-worked line. The obstruction caused by the third-rail is also a serious matter, particularly in goods yards, where shunters have constantly to be crossing the rails. With the overhead equipment the driver's view ahead is to a certain extent impeded, and there is always the possibility that some part of this equipment may fall upon the line and cause an accident.

When due weight has been given to these various points, the only thing left to consider in deciding between the advantages of steam and of electric traction is the relative cost of the two systems. Here electricity starts heavily handicapped, as the building of a central power-station and the installation of the conducting wires or rails involves enormous capital expenditure over and above that necessary with a steam railway.

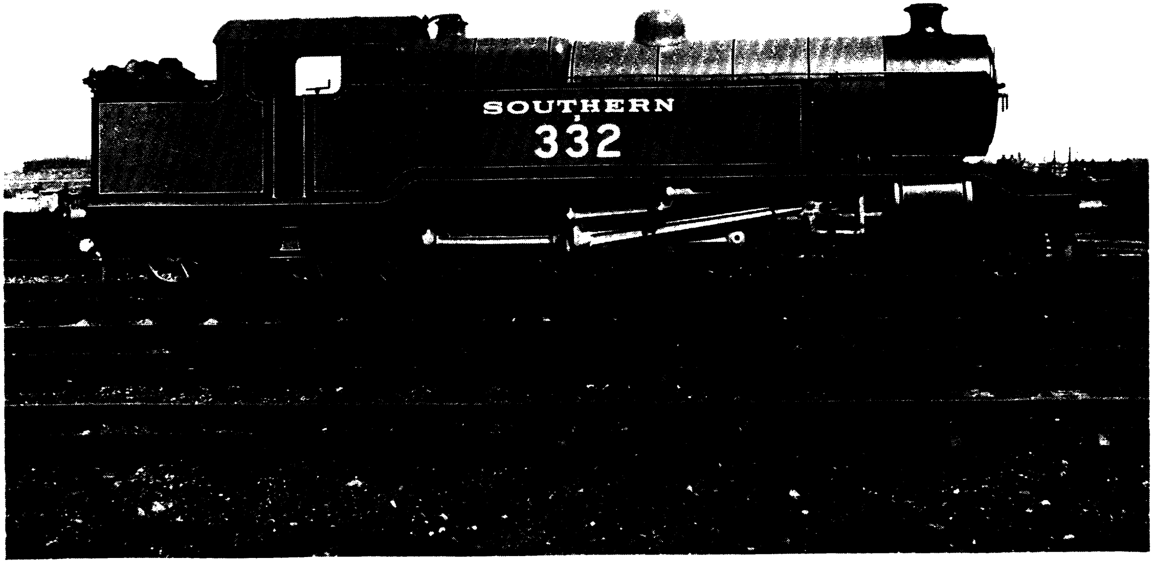
In countries where a great deal of water power is available current can no doubt be generated so cheaply that sufficient saving is usually effected to pay interest on the cost of the electrical installation and produce a substantial profit in comparison with steam working. But in flat districts like the greater part of Great Britain, where the electricity has to be produced by steam engines, the matter is quite different. The most economical type of stationary engine appears to be able to produce at the power-station about twice as much power for each ton of coal consumed as the most economical type of steam locomotive can produce. Against this economy must be set the cost of the current lost in the process of transmission from the power-station to the driving wheels, together with interest on the capital cost of the fixed electrical installation and the cost of maintaining it. As regards the motors themselves, the cost of an electric locomotive seems to be much higher than that of a steam locomotive of equal power, but the electric locomotive is capable of working almost continuously, while a very large proportion of a steam locomotive's time must be spent in the running shed. Electric locomotives also are likely to be cheaper to maintain than are steam locomotives.

At the present time a very serious practical objection to the immediate electrification of railways exists in the fact that there is no sort of general agreement as to the best system of electrification to adopt. A very complete example of the difficulties arising from this state of things is found in the matter of the electrification of the three railways which have been amalgamated to form the Southern group. Of these the Brighton Railway was the first to adopt electricity as a motive power and the Brighton section of the Southern Railway now possesses a large mileage of electrified lines, and, moreover, elaborate plans for further electrification have been made. Some years later the South Western also went in for electrification on a fairly large scale, but introduced a system completely different from that adopted by the Brighton line. Finally, the South Eastern came to the conclusion that it also must electrify a large part of its lines, but found that neither of the systems of electrification adopted by its neighbours was suitable for its own requirements, and therefore at first proposed to introduce yet a third system. The complication with regard to the South Eastern section of the Southern Railway has now been got out of the way, but the difficulty with regard to the other two systems remains.

It is fair to remark that when and if the steam locomotive is superseded by other modes of traction there can hardly be a doubt that railways will appeal much less than is now the case to the non-technical public. Probably the steam locomotive has at least as strong a hold upon the imagination of at least as large a proportion of the population as had the horse before the advent of railways. There is so much about the steam locomotive which suggests life. Fire, steam, smoke, the deep rhythmical beat of the exhaust, all help enormously in making that powerful appeal to the imagination which the steam locomotive addresses to so many people. The mere fact that the steam locomotive is not covered in has been an enormous advantage in stimulating general interest. Every part can be studied almost as easily as the points of a horse, and the gradual growth and development of the locomotive can readily be discerned and their causes understood by people who have had no technical training. The internal combustion engine, or the electric locomotive, can never be much more to look at than boxes on wheels, and, although probably not less interesting than the steam locomotive to engineers, who understand all about them, must be hopelessly left behind as regards the strength of the appeal which they make to popular imagination ; and though it is neither possible to estimate the pecuniary value of sentiment, nor desirable to attempt to do so, the railways could hardly fail to be heavy losers if the appeal to sentiment which they make were to be greatly weakened. For myself, I must confess that I am one of that large company of people who find in the steam locomotive an object to which attaches a very high degree of romance. I know few more thrilling sensations than to stand on the footplate of an express engine which is rushing along at seventy miles an hour through the sleeping country, with the dawn just beginning to appear, while the dusky forms of the driver and fireman and the great cloud of white steam, as it rolls away overhead, are lit up from time to time by the glare from the furnace when the door is opened for a fresh charge of fuel.

One of the greatest names among the designers of locomotives is that of William Stroudley, for many years locomotive superintendent of the Brighton Railway. His fame does not rest upon any particularly startling achievements of his engines. Little opportunity was ever given them to distinguish themselves by such means. Nor were any very important new inventions made by Mr. Stroudley, but the striking originality of his designs, their great every-day efficiency, the masterly way in which all the details were worked out, and his firm grasp of the importance of reducing the number of types of engines employed, and of making as many as possible of the parts of the different types the same, made a deep impression upon the subsequent development of locomotive practice.

The outstanding feature of interest in Mr. Stroudley's designs was his wholesale adoption of the four-wheels-coupled-in-front arrangement. This arrangement possesses almost every possible advantage, if it is desired to construct an engine of moderate weight, of great power in comparison with her weight, and a smooth runner. Front-coupled tank engines are, of course, used now to a considerable extent, but for express passenger trains other designers have always held that the leading pair (if not two pairs) of wheels have quite enough to do to lead, and no designer has ever before or since ventured to use leading coupled wheels for express engines, being apparently afraid that, even if they did not leave the rails,



4–6–4 EXPRESS TANK ENGINE, SOUTHERN RAILWAY

they would do some damage to the permanent way. But Mr. Stroudley had no fears on the score of the front-coupled wheels, and it is by his express engines of the "Gladstone" class—6-wheel engines with four-coupled leading wheels, 6 ft. 6 in. in diameter, and a small pair of carrying wheels under the footplate—that he will be remembered more than by any others; if confidence has ever been justified his has been by the record of these admirable locomotives, which, more than thirty years after the appearance of the type, were capable of dealing with the best trains on the Brighton Raiway, and have never yet been the cause of an accident. The virtues of the design lie in its great compactness. The two pairs of front coupled wheels can be put as close together as necessary, and there are no large wheels behind to set limits to the size and disposition of the fire-box or the internal width of the cab; the small trailing wheels are conveniently placed under the fire-box, not too far from the driving wheels, and run more smoothly than coupled wheels would run. In consequence of this arrangement, these engines are remarkably little fatiguing to travel upon. With the addition of a leading bogie, this type of engine becomes the 4-4-2 type, which is now one of the favourite kinds of modern express engine. Though no very spectacular feats are generally credited to the "Gladstones," there is a legend, for the truth of which I do not vouch, that one of them on one occasion, many years ago, when working a light special train, passed Redhill from Brighton—nearly 30 miles—in 26 minutes from the start. More recently I timed one of these engines to cover 22 miles, more uphill than down, in 21 minutes 13 seconds with a load of 150 tons behind the tender.

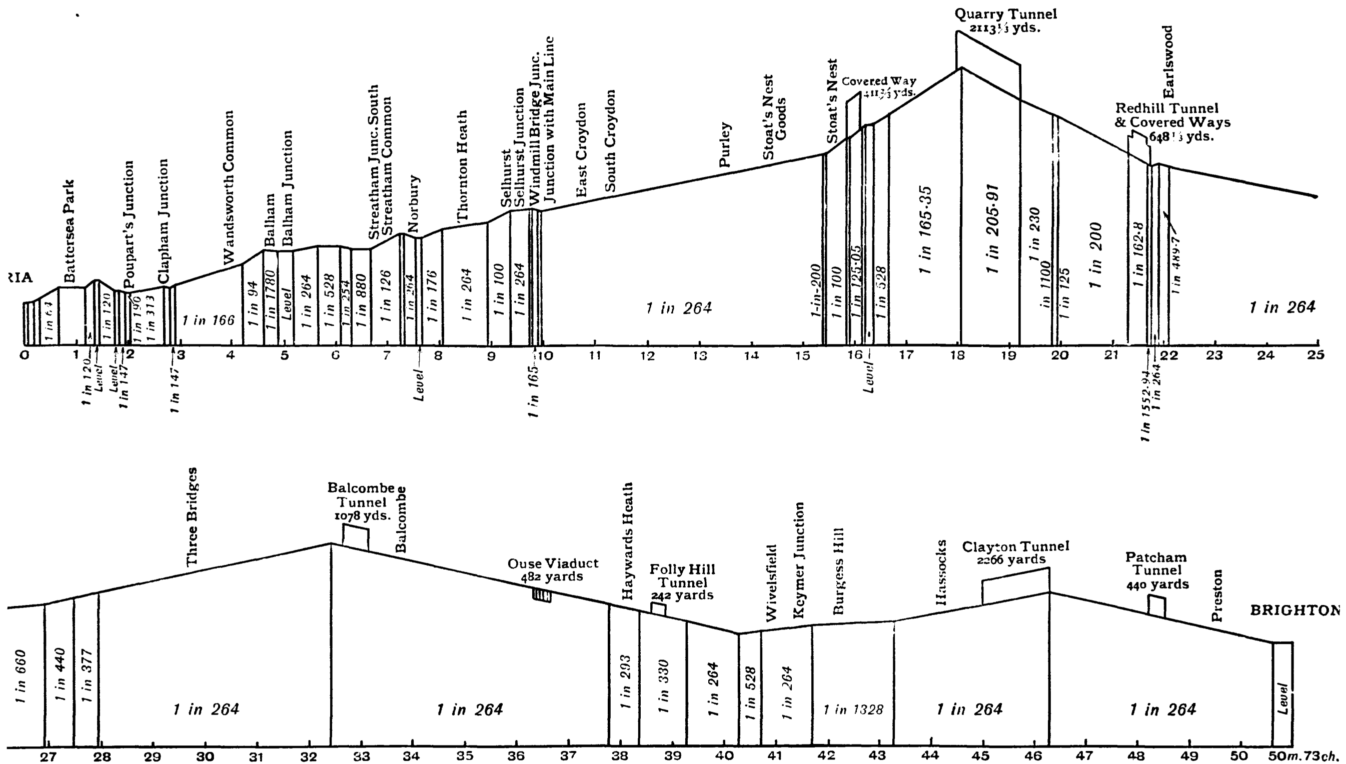
After Mr. Stroudley's death the Brighton Company abandoned the front-coupled arrangement for express engines, and for some time all the new express engines built were of the orthodox 4-4-0 type. Later, however, the practice of this line again departed somewhat from the ordinary in the extensive use made of tank-engines for working the fastest express trains. The use of tank engines has, of course, lately been extended on other lines besides, and the increase in the size and power of such engines on many lines has been as noticeable as has been the case with express and goods engines with tenders. But for tank-engines to take their turn regularly with tender engines of the most powerful type in working express trains timed at over 50 miles an hour is a condition of affairs found only on the Brighton section of the Southern Railway. The tank-engines, which perform this work, are naturally large and powerful machines with big driving wheels. They are of several types, the latest of which has outside cylinders (22 in. by 28 in.), driving wheels 6 ft. 9 in. in diameter and a bogie at either end (4-6-4). The weight in full working order, with 2,700 gallons of water and 3½ tons of coal, is 98½ tons. Steam blows off at 170 lbs. per sq. in.

I spent a day on one of these machines, the most interesting part of which was a journey with the 1.20 p.m. train from Brighton to Victoria. There were frequent snowstorms with a strongish east wind, and the North and South Downs were thickly covered with snow.

The train (exclusive of engine) weighed 271½ tons empty, and probably about 290 tons with passengers and luggage.

The start was punctual. The first mile to post 49½ took exactly 3 minutes, and post 46, about a quarter of a mile short of Clayton Tunnel, was passed in 7 min. 49 sec. Seventy miles an hour was touched at the bottom of the succeeding descent near post 40, and then the rising gradients had reduced speed to about 63 m.p.h. by the time we passed Hayward's Heath. Hence to post 32, just beyond Balcombe Tunnel, the line rises all the way at 1 in 264. It was not possible to see post 32 on account of the heavy clouds of steam hanging near the mouth of the tunnel, but from post 38 to post 31¾, just past the summit, the time occupied was 6 min. 8 sec. (61.3 m.p.h.), and speed fell only just below 60 m.p.h. in the tunnel where, to avoid skidding, the drivers always reduce the steam supply. (Post 33¼ to post 31¼ in 90²/₅ sec.).

Downhill towards Horley speed just failed to touch 77 m.p.h., and then four miles up 1 in 264 did not bring it down quite to 60. Here the Redhill tunnels and slightly more severe gradients are encountered, but the train entered Quarry Tunnel



PROFILE OF THE LINE BETWEEN VICTORIA AND BRIGHTON

at 56 m.p.h., and passed post 17, beyond the tunnel, in 35 min. 20 sec. from Brighton (33½ miles). Here we had run the last 30 miles in 28¾ min. and had ascended not less than 200 ft. in the process. After this the line falls all the way to Victoria. No further attempt was made to run fast, and Victoria was easily reached in 57 min. 9 sec. from Brighton.

At the time when the South Eastern and London, Chatham & Dover Railways were separate concerns, there was no county where there were greater opportunities for railway competition than in Kent. There was hardly a place of the least importance except Folkestone which could not be reached by way of either of these railways, and both had secured for themselves quite exceptional facilities for reaching the very heart of London. As the district served is rich in high-class passenger traffic, and the lines are unusually free from goods trains, there was some reason for expecting that the two railways would vie with one another in maintaining an exceptionally convenient and ample passenger service. The most enthusiastic admirer of the Kentish lines could hardly assert that these expectations were fulfilled. A capital expenditure, large even in comparison with the inflated amount that all British railways have been obliged to spend, left both companies hard up for money, and unable to find so much as was desirable for maintaining their road and rolling stock at that pitch of efficiency to which we are accustomed on most of the leading British lines, while the difficulties of working lines so complicated tended to make the trains both slow and unpunctual. The mere fact that each railway had two termini in London added immensely to the complication of working the London traffic. The peculiar difficulties to which the configuration of the South Eastern line into Cannon Street and Charing Cross gave rise, can hardly be over-estimated, and, if the London, Chatham & Dover was rather better off, the necessity of dividing or joining up a great many trains at Herne Hill was a fruitful source of delay. In this matter of their London termini the enterprise of the South Eastern and London, Chatham & Dover Railways has probably received less than justice at the hands of the travelling public. We all of us notice and complain about the delays which sometimes occur in getting into these stations, and are apt to forget the other aspect of the question, which is that the railways confer a considerable benefit upon us by taking us across the river and setting us down in one or other of these peculiarly well situated termini, instead of landing us, as they might reasonably do, somewhere in the wilds of South London, and leaving us to find our own way thence. Besides the difficulty of working in and about London there were so many places on both lines, too important to pass by and not big enough to be served by trains run exclusively for their benefit, that the number of stops, which had to be made, prevented most of the trains from attaining any great speed. Hampered, therefore, as the two railways were by difficulties of working on the one hand and by poverty on the other, the train-service provided neither by the one nor the other met with much approbation from the public, nor did the financial results satisfy the shareholders. In these circumstances it was decided to strike out a new line and, as separate working had proved a failure, to see what joint working would effect. In 1899, therefore, the two railways were amalgamated for all purposes of working, the agreement which they then entered into being the first of the agreements under which, before the war, by the conclusion of alliances between two or more companies, the country was partitioned afresh and all competition between the members of each alliance was being frankly and explicitly eliminated. To say that the amalgamation of the South Eastern and London, Chatham & Dover Railways was an unqualified success would be impossible. One of the first measures which the managing committee of the newly-christened "South Eastern & Chatham Railway" had to take was to raise a great deal of capital to be laid out on very necessary widenings and improvements, and this expenditure, coming at a time when all railways were experiencing some diminution in their prosperity, caused the financial results of the amalgamated lines to be worse than when the two were worked separately. Neither was the pace of the trains appreciably mended, though their punctuality was probably improved, and great convenience was caused by the construction of junctions between the two main-lines, where the South Eastern crossed the London, Chatham & Dover, near Chislehurst, so that trains for either of these lines could start from any of the termini of the amalgamated companies. The advantage of this became very apparent when, on 5 December, 1905, a most unfortunate and expensive accident occurred, which for some time made it impossible for Charing Cross Station to be used at all. On the afternoon of that day part of the roof of that station fell in. The roof was undergoing periodical repairs and painting, and, for this purpose, a staging had been erected, which added considerably to the weight which it had to bear. Suddenly one of the iron rods which braced the roof snapped, thereby subjecting the walls, which supported the roof, to a thrust so powerful that, before many minutes had elapsed, one of the walls collapsed and brought down a large part of the roof with it. The cause of the accident was a faulty weld in the rod which snapped, a flaw which it was impossible to discover and which had not prevented the rod from holding the roof securely for more than forty years. The station had to be closed for several months while a new roof was erected, and during this time the South Eastern must have fully realized the advantage which its amalgamation with the London, Chatham & Dover gave it in enabling it to fall back upon Victoria. The new roof, of the ridge and furrow type, gives the station quite a new and, most people think, improved appearance, though, even now, it is difficult not to regard the whole station and the bridge leading to it as a blot upon what might be one of the finest views in London. The question, which was raised in connection with the King Edward Memorial, of removing Charing Cross Station to the south side of the river, and building a new road-bridge in place of the existing bridge, is full of attraction. Over a bridge of really adequate width a station south of the river would be as easy of access as the present station; much more space could probably be found for the station, which would become practically part of the terminus at Waterloo, and this would enable far more useful connections than at present to be made.

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Besides the collapse of the roof of Charing Cross station, the South Eastern Railway suffered several subsequent mishaps of a rather serious kind, though fortunately they were unattended by loss of life. One day it was suddenly discovered that the lining of Sevenoaks Tunnel might be expected at any moment to fall in, and the whole of the main-line traffic had to be diverted without notice and despatched by alternative routes till the very serious business of relining the tunnel was completed. Then in the second year of the War a landslip between Folkestone and Dover swept a considerable section of the main-line bodily some fifty yards seawards. A very serious accident was narrowly averted, as a train which was just entering this section, though it escaped serious damage, was marooned by the landslip and could only be withdrawn some time later. Direct railway communication between Folkestone and Dover was thus interrupted throughout the rest of the War.

The slowness of the Continental trains to and from Dover and Folkestone is perhaps the least creditable part of the service of the Southern Railway. These trains are very important, with fares probably the highest in the world, and the Tonbridge line, over which most of them run, though fairly difficult for the first 30 miles out of London, does not present any very formidable hindrances to high speed. The 4.30 p.m. put on in July, 1913, was timed to perform the run of 76½ miles from Charing Cross to Dover Pier in 90 minutes, which is a respectable, though not a brilliant, timing, but since the war this timing has not been re-introduced and all the trains are slower, often considerably slower, than this. The impression created by these mediocre performances is the more unfortunate for the fact that the trains on the French side of the Channel, which run in connection with those of the Southern, leave less to be desired than any trains in the world. The stock of which they are made up is at least as good as that of which the British trains are composed, the speed at which they are timed is some ten miles an hour higher, and they often make up time as well, while the fares are much lower than on the Southern.

If the Southern's Continental trains are not entirely satisfactory, matters are better with regard to the cross-Channel steamers. There is no branch of engineering which is more thoroughly understood in Great Britain than the construction of swift and seaworthy steamers for channel crossings and short-distance voyages of all kinds, and the Southern, by its prompt appreciation of the advantages and possibilities of the steam turbine, did its best to provide vessels worthy of the importance of the service which it carries on. No steamers could, of course, perform with absolute regularity so difficult a voyage as that across the Channel, but, when the conditions are favourable, it is seldom indeed that any delay can be laid to the charge of the turbines.

Dover, being situated at the very corner of England at the nearest point to the Continent, has in some respects great natural advantages as a naval and shipping centre and a point of embarkation. But Nature has provided little shelter, and the very narrowness of the Channel increases the difficulties of navigation due to the tides and winds. In order fully to utilize Dover it was necessary to provide artificial shelter on a large scale. For many years the principal shelter was that given by the Admiralty Pier, and this was quite inadequate to make Dover a place of any great importance for shipping. But, fortunately for the South Eastern, the Admiralty realized the advantages which the position affords, and, after many years' arduous work, the enormous harbour of refuge was completed, which, enclosing as it does about a square mile of sea, provides adequate shelter for a fleet of any size. Arrangements were at the same time made to enable large liners to come alongside, and Dover now possesses all the necessary qualifications for a first-class naval and shipping centre.

Now that pits have actually been sunk and operations started on a large scale in the Kent coalfields, it may take very few years to effect a great change in the character of the extreme south-east corner of England, but the present is too early to found any confident hopes upon what the results of the working of Kent coal are likely to be.

Whether in years to come Dover will acquire added fame as the starting-point of a Channel tunnel cannot be foreseen. If it is decided to construct a tunnel between England and France, it is almost certain that the English end of it will be quite close to Dover. This question of a tunnel is remarkably alluring to many minds, and at intervals during the last hundred years more or less elaborately thought out proposals have been brought forward for joining the two countries by this means. The geological formation of the bed of the Channel is believed to be fairly well known, and it is not thought that any very great engineering difficulties would be met with in constructing a tunnel. The enormous progress which has been made in recent years in the practical application of electricity would, of course, greatly facilitate both the construction of a tunnel and its working when constructed, and if, before electricity was available, engineers were confident of their ability to make and work a tunnel, there would now appear to be no doubt on that score, in spite of the fact that nothing of the kind on a scale in the least approaching such magnitude has ever yet been attempted. Besides the various projects for a tunnel, the construction of different kinds of bridges has been suggested; the difficulties connected with all these projects have, however, appeared on examination to be greater than those involved in the construction of a tunnel.

CHAPTER X

A FEW minutes after midnight of the 12–13 July, 1896, the Aberdeen express which had left Euston at 8 p.m. on the 12th ran off the rails at a point a little north of Preston station. The train was made up of two 2-4-0 engines (the leading engine having 6 ft. coupled wheels and the second engine 6 ft. 6 in. coupled wheels), and seven bogie vehicles weighing (empty) 157 tons. The line where the accident occurred was on a reverse curve, which at one place had a radius of only seven chains. It was laid down in the railway company's regulations that this curve should not be traversed at a speed higher than 10 miles an hour. At the Board of Trade enquiry it appeared that the speed of the train when it left the rails was almost certainly at least 40 miles an hour.

As regards loss of life the accident was not a specially serious one. Indeed, as the train was completely wrecked and yet only one passenger was killed, the casualties were on a scale much lower than might have been expected. But with regard to its moral effect and the deterioration of British passenger services which it brought about, this accident, coming at the exact moment it did, was by far the most disastrous that has ever occurred in this country, and inflicted incalculable damage upon the interests of the travelling public, damage which to the present time is far from having been made good.

In order properly to understand how this came about it is necessary first of all to go back to the events of the previous year (1895).

The year 1895 brought with it demonstrations of the capabilities of express engines in the way of high speed that marked a far greater step forward than has ever been made before or since. The attitude taken up by railway managers in the matter of the speed of express trains is and always has been of the most curious kind. Side by side with the determined resolve to avoid as far as possible any increase in speed, there has always existed in their minds the clearest possible recognition of the fact that speed is what the public wants, so much so that any attempt on the part of one railway company to steal a march on its rival, even to the extent of five minutes in a journey of several hundred miles, is almost sure to provoke counter-measures. Then as, owing to their normal policy of "go-slow," both sides have an enormous margin of speed in hand, very marked accelerations may take place till the rivals have had time to settle their differences.

Something of this kind occurred in 1895. The Forth Bridge had lately been completed, and the East Coast, instead of having further than the West Coast to go to reach Perth and Aberdeen from London had ten miles less to Perth and 16½ miles less to Aberdeen. The West Coast was apparently unwilling to offer the East Coast concessions in the matter of time such as the latter was willing to accept, and so both sides drifted into a speed competition which was excellent for the public and not at all bad for the railway companies. The racing began in the middle of July and lasted in all for something over a month, the trains concerned being those leaving Euston and King's Cross at 8 p.m. for Aberdeen.

Till the heavy Scottish tourist traffic was over the West Coast had things very much its own way. The pace throughout was not in these circumstances very high, the best run being one in which the West Coast covered its 540 miles in 10 hours. But quite early in the proceedings the Caledonian on one occasion ran from Perth to Forfar—32½ miles—in 32½ minutes start-to-stop. The train at this period probably weighed 120 tons behind the tender. I travelled by it one night from Euston to Perth and found it to be composed of five bogie vehicles, which would come to about that weight.

When the heavy tourist traffic was over the East Coast began to take the race more seriously; but, even so, some days elapsed before it was able to inflict a decisive defeat upon the

West Coast. This, however, was at last achieved by a run in which the 523½ miles from King's Cross to Aberdeen were covered in 8 hrs. 40 min. Thereupon the East Coast ceased to compete. The West Coast, not to be outdone, ran its train for one more night, reaching Aberdeen in 8 hrs. 32 min., and then also stopped.

Even when the throughout speed had reached these high levels great differences were still to be observed between the work performed by different engines on the different stages of either route—as was also the case in the race to Edinburgh seven years before.

To take the West Coast first, it is found that on the final occasion the journey was performed in four stages, stops being made at Crewe, Carlisle and Perth to change engines. The train consisted of three bogie vehicles weighing about 70 tons. The runs from Euston to Crewe and from Carlisle to Perth, performed respectively at 64 and 60½ miles an hour, were much inferior to the other two. The run of 141 miles from Crewe to Carlisle seems to have been performed by a 2-4-0 engine with 6 ft. 6 in. driving wheels, and weighing only 32 tons, in 126 minutes, which gives an average speed of slightly over 67 miles an hour.

Neither on the West Coast nor on the East Coast do the final runs appear to have been timed in detail by anyone; but for each complete stage the figures in the guard's journals are no doubt accurate enough. I note also that the figures for the Crewe-Carlisle run were explicitly accepted by the last Chief Mechanical Engineer of the North Western Railway.

The final stage of 89¾ miles from Perth to Aberdeen seems to have been covered by the Caledonian on the last morning of the race, and also upon one other occasion in slightly less than 81 minutes. This gives an average speed of about 66¾ miles an hour, which, in view of the greater proportion of time lost in starting and stopping on the shorter run, may be held to bring the speed of this run exactly into equality with that of the Crewe-Carlisle run of the North Western. The engine, however, was a considerably bigger one—a 4-4-0 weighing 45 tons.

As regards service slacks, the North Western train must certainly have slowed down greatly to pass through Preston, and presumably did not run at full speed past Penrith. Over the other curves, where big modern engines with long wheel-base usually slacken speed a little, it was probably found unnecessary to slow down an engine with so short a wheel-base as the little 2-4-0 that worked the racing train. The Caledonian must have slacked at Forfar and Guthrie, if not elsewhere.

As regard gradients, the North Western had indeed to cross Shap, but, as the last 5½ miles of this tremendous incline are said to have occupied only 6 minutes, it is difficult to regard even an ascent of this kind as a very serious hindrance for so light a train. The Caledonian road between Perth and Aberdeen, though it involves no very long ascent, undulates sharply for two-thirds of the distance.

On the East Coast the final journey was made in six stages, engines being changed at Grantham, York, Newcastle, Edinburgh and Dundee. The train weighed about 100 tons as far as Edinburgh, where it was reduced to about 90 tons. The first two runs were performed by Great Northern 8 ft. singles at about 62½ and 65 miles an hour respectively. For the first stage to Grantham over a decidedly easy road with only one service slack—at Peterborough—it is clear that the engine was not pressed, and over the yet more level stretch to York, 65 miles an hour cannot be regarded as the utmost of which an 8-ft. single was capable. The North Eastern does not appear to have managed to perform the run from York to Newcastle at much more than 60 miles an hour. The next stage of 124½ miles to Edinburgh was, however, run at an average speed of somewhere round about 66 miles an hour. The official record puts the time at 112 minutes, but it seems likely that the real time was one or two minutes more than this. There were at least two pretty severe service slacks—at Morpeth and Berwick. The train was worked by a 4-4-0 simple engine with driving and coupled wheels 7 ft. 1 in. in diameter.

From Edinburgh to Dundee a North British 4-4-0 engine with 6 ft. 6 in. driving and coupled wheels seems to have covered the 59½ miles in just about the same number of minutes. In view of the shortness of the run and the large number of curves and junctions where cautious running was necessary, this was a notable performance. On the last stage to Aberdeen part of the line is single, and the delays encountered on this section brought down the start-to-stop speed to a good deal less than 60 miles an hour.

It seems probable that it was only on the Newcastle-Edinburgh and Edinburgh-Dundee stages that the engines were working at or near the limit of their power. The circumstances of these two runs differed so widely that it is impossible to decide which was the finer performance. The former lends itself the more easily to comparison with the Crewe-Carlisle run, which must be considered the finest effort of the West Coast companies. Setting these two runs against one another, we find that with train-loads almost exactly in proportion to the weights of the respective engines, and with about the same amount of hindrance from service slacks, the North Western ran over a more difficult road at a slightly higher speed.

In Great Britain just at this period there was undoubtedly stirring a spirit among the railway directors and officers more enterprising than has ever been the case before or since.

The summer timings for 1896 of the Scottish expresses on both East and West Coast routes were fully in keeping with the demonstrations of unexampled speed that were expected to take place. The Caledonian was booked to run twice a day from Perth to Forfar, 32½ miles, in 32 minutes start-to-stop, and on several really difficult stages of the West Coast route between Wigan and Perth one or more trains were timed at over 56 miles an hour. The improvement in speed over the time-tables of 1 July, 1895, was on the same scale as if at the present time the London, Midland & Scottish group were to take to running from St. Pancras to Leicester in 95 minutes, or the Southern from Waterloo to Salisbury in 80.

It is pretty evident that all this did not take place without the most determined opposition from the party normally in power on British railways, whose propensities have already been alluded to. On this solitary occasion sufficient enterprise was forthcoming from some quarter or other to make possible the introduction of regular trains timed at speeds approaching the limit of what could be done without really serious effort with fairly light loads. (These trains were not, as in the races to Edinburgh and Aberdeen, trains which ran for an uncertain number of days to an emergency time-table, and then ceased running at short notice or no notice at all.)

From whatever quarter the enterprise did come it can only have been as the result of a bitter struggle that it temporarily overbore the prejudice so strongly entrenched behind many decades of inertia; and in achieving the introduction of this accelerated service it seems to have exhausted itself, for at the first subsequent breath of misfortune in the form of the Preston accident it collapsed.

Seldom can a piece of carelessness have had more unhappy results. That a railway of the immensely high standing of the North Western should have fallen headlong into so obvious a trap, and failed to take measures to protect its most important train from a peril so elementary was an unpardonable blunder, explicable only on the ground that it was one of those lapses of the human brain that seem to defy analysis. I am not speaking of the failure of the drivers to reduce speed sufficiently, but of the failure of the responsible officer to impress upon the drivers the necessity for respecting speed-limits on sharp curves, and of his failure to take steps to ensure that his orders should be carried out. So far as I know, this failure was never brought home to anybody.

After this accident had taken place the temporarily dispossessed party apparently resumed control, and before many days had passed had eliminated from the North Western service all trace of the promise of better things contained in the original July timings. North of Carlisle the Caledonian remained for the time unmoved and continued up to the end of November to run to, and often to improve upon, its original booked times. But the mischief had been done, the people antagonistic to speed had finally gained the upper hand, and in December the trains on both the East and West Coast routes were slowed down to a point from which up to the present they have never again been accelerated. Seldom has enterprise been more triumphantly crushed out of existence.

And what of the public? The actual running of the "Dunalastairs" in the summer and autumn of 1896 showed that with trains of moderate weight, speeds of 60 miles an hour start-to-stop could be attained over any part of the hardest but one of the great main-lines in Great Britain. (The one exception is the main-line of the North British Railway.) This being so there is no reason why, if speeds such as these had once been permanently adopted on one important route, they should not in due course have been introduced on all the express routes in the country. In 1896 the average speed of express trains was certainly rather under than over 50 miles an hour between stops. An average reduction in the proportion of one hour in every six could therefore have been effected in the time occupied on every journey of every express train. As time spent in travelling is generally useless for any other purpose, and for third-class passengers not only useless but tiring, there is good reason for supposing that all this time which the railways might have saved for their customers was simply wasted. I will not attempt to do the sum, but there can be little doubt that the amount of time (which is in effect human life) lost in this manner must have been great enough perceptibly to impair the national efficiency.

Coming to the actual achievements of the "Dunalastairs" in 1896, it is found that the 8 p.m. from Euston was timed to cover the three stages—Carlisle-Stirling (117¾ miles), Stirling-Perth (33 miles), and Perth-Forfar (32½ miles)—in 125, 35 and 32 minutes, while each of the two latter stages was covered in the same times by another train also. I never travelled in either of these trains myself, but the published experiences of the late Mr. Charles Rous-Marten and of other observers leave no doubt that time was usually gained between Carlisle and Stirling and at least kept on the other sections. Between Carlisle and Stirling, with the excessively severe road as far as Beattock summit, and the numerous speed restrictions encountered in the last 45 miles, it seems to have been usual to achieve start-to-stop times of about 60 miles an hour. The driver, who worked the train on the last night on which it ran, told me that on that occasion he reached Stirling in 118 minutes from Carlisle, and the duration of the runs of which particulars have been published was more often under this time than in excess of it. The weight of the train varied, but it appears generally not to have been less than 150 tons (exclusive of engine and tender).

With regard to the general question of speed it is clear that, from the point of view of the travelling public, there is no limit to the speed desirable. There are, indeed, certain trifling exceptions to this rule, such as that travellers do not usually desire to start a journey later than midnight nor to reach their destinations before 7 a.m. But apart from exceptions of this sort the ideal must always be to get the journey over as soon as possible.

For purposes of business, pleasure, development or repose, time spent in a railway train is generally useless, and always much less useful than time spent out of a railway train. The highest possible speed that can be attained without sacrifice of safety or comfort is therefore desirable.

The question of any necessary connection between high speed and danger or discomfort may at once be disposed of by a recital of the following facts.

(1) A gentleman who travelled in a high-speed electric car on the Berlin-Zossen railway in 1903 told me that at a speed of 130 miles an hour the motion was very remarkably smooth and easy, and that there was a complete absence of vibration. This line was laid with the ordinary type of permanent way employed by the Prussian State Railways.

(2) In a letter from the late Mr. Charles Rous-Marten to the General Manager of the Great Western Railway, published in the *Great Western Railway Magazine*, the following passage occurs:

". . . . thenceforward our velocity rapidly and steadily increased, the quarter-mile times diminishing from 11 sec. at the [Whiteball] tunnel entrance to 10.6 sec., 10.2 sec., 10 sec., 9.8 sec., 9.4 sec., 9.2 sec., and finally to 8.8 sec., this last being equivalent to a rate of 102.3 miles an hour. At this time the travelling was so curiously smooth that, but for the sound, it was difficult to believe we were moving at all. . . ."

These speeds were run over ordinary Great Western permanent way.

But, although there is obviously no objection to very high speeds when the conditions are favourable, it is by faster running uphill and on the level that acceleration can best be effected. As much time is saved by running a mile uphill at 60 m.p.h. instead of 50 m.p.h. as is saved by running a mile downhill at 100 m.p.h. instead of 75 m.p.h., and it is immensely easier to do the former than it is to do the latter. In fact so small a portion of most railway lines consists of downhill stretches where very high speeds are attainable, that the attainment of such speeds helps very little towards bringing about large accelerations. On the Chemin de fer du Nord, which is by far the fastest railway in Europe, speeds higher than 120 kilometres (74½ miles) an hour are forbidden.

In these circumstances it is obvious that existing rolling-stock and existing permanent way when in good condition are adequate for very great accelerations, and no one is likely to dispute that the same is the case with existing signals and existing brakes. That is to say that by far the larger part of the expense involved has already been incurred, leaving hardly anything to be met except that necessitated by the provision of more power. Without going deeply into the cost of this extra power, approximate figures may be indicated in a few words. A big modern engine working a train of 300 tons at 60 miles an hour over a line of average difficulty would probably burn 45 lb. of coal a mile. If the speed were raised to 70 miles an hour the coal consumption would be increased to 60 lb. a mile. That is to say, 15 lbs. more coal (costing about 1¾d.) would be burned each mile. Boiler repairs might at the same time be increased by 2d. a mile ; and that is about all. So a very small increase in the number of persons travelling would pay for a big acceleration.

Apart from the intrinsic importance of the acceleration of long-distance passenger trains it is interesting to examine closely the failure of the railway companies to effect reasonable periodical improvements in this direction on account of the light thereby thrown on the attitude of officialism in general when dealing with matters concerning the welfare of the public which have been committed into its hands.

The situation is shortly this : Railways from their first introduction right down to the present time have provided a means for transporting large masses of people from place to place at speeds which other means of transport cannot approach. For many decades there was nothing whatever that could hope to compete with the railways in speed, and even now road-motors, though easily able in favourable circumstances to attain the speeds of railway trains, are in fact prevented from competing owing to the absence of suitable roads, while the small dimensions of traffic by air have made aeroplane competition a negligible quantity. As regards long-distance traffic, the railways now, as formerly, feel themselves completely immune from all competition except the competition of other railways. The elimination of this latter form of competition has always been the object of railway managements, and so well have they succeeded that, except for a few periods, usually lasting a few weeks or a few days, no serious competition in speed between different railways has taken place in the century or so since railways came into existence. The managements having thus secured themselves from competition of every kind are furthermore secure from the pressure which might be exerted by public opinion because only a negligible minority of people know anything at all about railway speeds. The average member of the travelling public usually has not the slightest notion either of the speeds at which trains do travel or of those at which they ought to travel.

The Chief Mechanical Engineer of the London & North Eastern Railway recently, when reading a paper before the Institute of Mechanical Engineers on the subject of 3-cylinder locomotives, is reported to have said : "The *Newcastle Chronicle* of 7 May, 1847, describes a run from London to

Birmingham. . . . One of these 3-cylinder engines . . . worked the train from Wolverton to Birmingham and ran the first 41 miles in 42 minutes. It is very remarkable that the first 3-cylinder locomotive, built nearly eighty years ago, ran a train at a speed only equalled by the fastest trains which are running to-day."

I should put it another way and say that it is very remarkable that the fastest trains which are running to-day, in spite of every facility for greatly exceeding the speed attained by this ancient and crude engine of nearly eighty years ago, are only allowed to run at the same speed as she attained. It is one more proof of the most convincing kind that railway managers have consistently and deliberately run their trains at speeds far below those at which they ought to have been run.

On the part of the railways there is no apparent appreciation of the fact that the time of their passengers may be valuable and should, as far as possible, be economized both for the benefit of the passengers themselves (to serve whom the nation has permitted railways to come into existence) and also on account of the greater profit which the railways may expect to earn from an improved service. On the contrary, although speed is clearly recognized to be a matter of the first importance in any service where competition in speed is allowed to exist, every effort is made systematically to suppress such competition ; and when as is almost always the case the possibility of competition in speed has been successfully got out of the way by agreement, the railways invariably treat the question of making any serious attempt to economize their customers' time as one that may be ignored.

So the managements, untroubled by competition and sheltered by the utter ignorance of the general public from any inconvenient manifestation of public opinion, have in the matter of the speed of long-distance trains almost attained to that Nirvana to which officialism aspires, where the soul may sink itself in the contemplation of that perfection which consists in leaving things for evermore to run themselves without alteration, and where nobody ever need trouble himself to do anything whatever.

In writing thus I do not wish it to appear that I am attributing to this particular question a degree of public importance greater than that possessed by many other defects in our civilization, nor to officialism as found on railways qualities which are not shared to the full by officialism in other spheres. This failure to run express trains at reasonably adequate speeds is, indeed, probably the worst blot that disfigures the conduct of British Railways, but in other spheres there are, of course, scores of ways in which blind officialism wastes time to an equal or to a greater extent. I have myself, for instance, for years together been one of those slaves whose lives are passed in a Government Office, grinding out routine work, which for all the good it does anybody when done might just as well never be done at all. I have examined this particular question in some detail partly because it is germane to the subject of this volume and partly because the workings of officialism in general are here exhibited with exceptional clearness. There is no attempt to consider on its merits the question of introducing reasonable periodical accelerations. The matter is disposed of by the simple and effective method of boycott.

On 22 May, 1915, the most serious accident, so far as loss of life and personal injuries are concerned, that has ever taken place on a British Railway, occurred at Quintinshill, near Gretna on the Caledonian Railway. It is estimated that 224 persons were killed; the injured numbered 246.

The 11.45 p.m. and 12 midnight trains from Euston were timed to leave Carlisle at 5.50 a.m. and 6.5 a.m., and a local train from Carlisle was timed to leave at 6.10 a.m. On 22 May both the trains from London were behind time, so the local train was despatched from Carlisle in front of them. The local train reached Quintinshill at 6.30 a.m. and was shunted from the down to the up main-line to allow the two trains from London to get in front of it.

At Quintinshill there is a signal-box, but no station; there are passing loops on the outside of both up and down main-lines. When the local train reached Quintinshill the loop outside the down line was already occupied by a goods train, and the loop outside the up line was required for an empty wagon train which a few minutes later drew into it. Thus neither loop was available for the local train, which consequently had to be shunted onto the up main-line, where it remained till the accident occurred.

The night signalman at Quintinshill should have been relieved at 6 a.m., but his relief, who lived at Gretna, travelled thence by the local train and so did not arrive till 6.30 a.m. This was an unauthorized arrangement and was attended by a number of other irregularities which had the effect of so occupying the new signalman's attention that he entirely forgot that the train by which he himself had travelled was standing on the up main-line sixty yards from the signal-box, while at the same time the mechanical precautions which should have been taken to protect the local train were omitted.

In these circumstances the 5.50 a.m. from Carlisle passed Quintinshill safely at 6.38 a.m., but at 6.42 a.m. the signalman at Quintinshill accepted from Kirkpatrick, the next signal-box to the north, a troop train consisting of an engine and twenty-one other vehicles, and conveying a large number of officers and men of the 1/7th Royal Scots, which, travelling at high speed (the line falls at 1 in 200 for 4 miles before Quintinshill) at 6.50 a.m. collided with the stationary local train. The impact was so violent that the engine and fifteen coaches of the troop train, which measured 213 yards when running, were crushed into a space only 67 yards long, and much of the wreckage was thrown onto the down-line. Meanwhile the 6.5 train from Carlisle, composed of two engines and thirteen other vehicles, was rapidly approaching from the south. There was no time to put the signals to danger (at any rate they were not put to danger) and, though several railway servants at once realized the situation and ran to warn the drivers of the approaching train, they were not able to get far enough to do more than cause the brakes to be applied about three hundred yards from the obstruction and the momentum of the train to be slightly checked before it ran into the wreckage, with the result that the two engines and several vehicles next to the engines were added to the existing heap. Fire broke out at once, spread to the goods train and the empty wagon train in the two loops, and continued to burn for more than twenty-four hours, in spite of the fact that the Carlisle Fire Brigade were playing three jets of water upon the flames from 10 a.m. till midnight and then intermittently during the rest of the night.

Though the immediate cause of the accident is clear enough, it is noteworthy that the obvious lessons of the accident appear to have been entirely missed alike by the railway companies and by the Board of Trade inspector. The immediate cause was, of course, the irregularities committed by the signalmen, but the predisposing cause was that, owing to the lateness of the trains from London, the local train was despatched from Carlisle out of its proper place as arranged for in the time-table. If this had not been done the accident could not have happened. To put it in another way, the predisposing cause of the accident, without which the irregularities which the signalmen committed must have been powerless to bring about the accident, was the lateness at Carlisle of the trains from London and if these trains had made up the time they had lost, the accident could not have happened because there would have been no need to shunt the local train on to the up-line.

In these circumstances it was a matter of the highest interest to ascertain why the trains from London lost time, what the railway company's rules were on the subject of making up lost time, and what efforts, if any, were in fact made to recover the time lost. When, in the face of all this, we find that the Board of Trade inspector merely remarks "As the 11.45 p.m. and 12.0 midnight sleeping-car express trains *ex* Euston were running late, the 6.10 a.m. local train *ex* Carlisle was sent on ahead of them . . ." and utterly ignores all these points, it is not overstating the case if we describe these omissions as deplorable. The fact of the matter is that this question of the making up of lost time has always been abhorrent to officialism in this country.

In France and Germany the importance of making up lost time and of giving the drivers definite instructions on this subject was early recognized and printed regulations are issued to the drivers laying down exactly what they are expected to do. In Great Britain I have never been able to discover that the drivers get any printed instructions at all on this subject, though I suppose there must usually be some sort of tacit understanding about it. In these circumstances it appears that engine drivers in this country lack the definite and unequivocal guidance which they clearly ought to receive from their superiors, with the result that this question has always been most unsatisfactorily handled. Exceptionally energetic drivers have sometimes made up lost time, but as a general rule drivers have preferred not to do so with the result that the time of the travelling public has been wasted and their convenience ignored while, as the Quintinshill accident shows all too clearly, a very decided element of danger has been perfectly unnecessarily introduced.

In a highly complicated organization like that of a railway where each train has its few allotted minutes to traverse each section of the line, and where the lateness of one train affects the punctuality of those following it, those connecting with it and those crossing its path, it is obviously a matter of the first importance that each train should always be as nearly as possible in its proper place. When a train is once behind time the only possible way of getting it back into its proper place is to make up the time lost, due care of course being taken not to exceed the safe speed limits at any places where such limits exist, particularly on sharp curves. These facts were perfectly well known and attention had often been called to them long before the Quintinshill accident.

Quite apart from the question of the danger inherent in unpunctuality, punctuality has very important effects, which directly benefit the railway company, altogether apart from the sentiments of the passengers. Most important railway lines are more or less crowded with traffic, and very elaborate schemes have to be drawn up for getting the trains along. Each train has just its few allotted minutes for travelling over each section of the line, and, when they have elapsed, it is the next train's turn, and so on. If the proper train is not there at the proper time the scheme of working can no longer be carried out, and a greater or less degree of confusion results It wants comparatively little unpunctuality to bring about a considerable degree of confusion, for, if only one train is out of place its lateness may affect the working of scores of others—those following it, those crossing its path, those connecting with it, and those whose running is affected by the lateness of those delayed by it. And unpunctuality is not economical. So small a thing as an extra signal stop is an appreciable expense—so much energy is dissipated and has to be generated afresh by the engine, and there is so much extra wear and tear of the brake blocks and tires. Then, if there is unpunctuality, the work of the whole staff of the railway, which has to deal with the trains affected, is delayed, and has to be done at a time different from that at which it ought to be done, and perhaps the additional cost is incurred of paying men for working overtime.

It is most extraordinary that up to the present time the railways should have abstained from issuing a complete set of regulations on the subject of making up lost time and that the Government should have acquiesced in this abstention.

THE END

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