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THE FIRST PRINCIPLES OF RAILWAY SIGNALLING

BY C. B. BYLES

SIGNAL ENGINEER, LANCASHIRE & YORKSHIRE RAILWAY

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THE FIRST PRINCIPLES OF RAILWAY SIGNALLING

INCLUDING AN ACCOUNT OF THE LEGISLATION IN THE UNITED KINGDOM AFFECTING THE WORKING OF RAILWAYS AND THE PROVISION OF SIGNALLING AND SAFETY APPLIANCES

BY

C. B. BYLES,

SIGNAL ENGINEER, LANCASHIRE AND YORKSHIRE RAILWAY

SPECIAL LECTURER IN RAILWAY ECONOMICS IN THE UNIVERSITY OF MANCHESTER

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CONTENTS.

CHAPTER I.

Introduction and Historical Retrospect.

CHAPTER II.

The Growth of the Signalling System.

CHAPTER III.

The Theory of the Signalling System.

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CHAPTER IV.

The Outdoor Fixed Signals.

CHAPTER V.

The Block Telegraph System.

CHAPTER VI.

THE WORKING OF SINGLE LINES.

CHAPTER VII.

GOVERNMENT CONTROL—LEGISLATION 1839–1878.

CHAPTER VIII.

GOVERNMENT CONTROL—LATER LEGISLATION.

CHAPTER IX.

APPARATUS.

CHAPTER X.

The Problem of the Distant Signal.

CHAPTER XI.

Power and Automatic Signalling.

CHAPTER XII.

The Elimination of the Human Element.

APPENDIX I.

APPENDIX II.

INDEX.

LIST OF ILLUSTRATIONS AND DIAGRAMS.

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INTRODUCTION.

BY A. T. BLACKALL,

Signal Engineer, Great Western Railway.

This book is designed to be an exposition of the application of a settled theory to British Railway Signalling, and in this respect may be taken as a distinct and commendable advance on publications dealing with the subject as mere statements of fact in regard to methods adopted to meet given requirements, rather than from the standpoint of general principles.

There are, and inevitably must be, in the theory of railway signalling, some debatable points which lead to divergencies of practice of more or less importance on different railways, but the book, on the whole, may be regarded as setting forth fairly the generally accepted theory of British Railway Signalling, although, of course, finality in railway signalling cannot by any means be regarded as having been attained, excellent and efficient as are the various installations in use in this country.

The extensive and increasing utilisation of electrical appliances in connection with signalling work points to the necessity for the co-ordination of the block signalling and outdoor signalling on our railways, and is doubtless a determining factor in the growing tendency of railway companies to place the supervision of both under one control. Future developments will undoubtedly be assisted by this arrangement.

I can confidently recommend the following pages on this most interesting branch of railway work as well worthy of careful perusal.

A. T. BLACKALL.

CHAPTER I.

INTRODUCTION AND HISTORICAL RETROSPECT.

THE SIGNALLING SYSTEM AS A FACTOR IN THE RAILWAY TRANSPORTATION PROBLEM.

A recent authority has made clear the undeniable fact that railways exist for the purpose of selling transportation. Transportation on railways is afforded by the movement of trains, and the greater the amount of traffic which can be handled on any given section of the railway the greater its earning capacity. As a corrollary to this axiom it follows that the less the risk of accident to the traffic the smaller will be the loss due to damage and delay. The possibility of dealing with a maximum amount of traffic with the minimum of risk, or in other words, of striking an equilibrium between the factors of expedition and volume on one hand, and of safety on the other, is dependent to a very large extent on the signalling system of a railway. Thus it is merely stating a truism to say that the operation of a railway as a commercial undertaking under the conditions existing in this country to-day would be absolutely impossible without a signalling system. And in the expression "signalling system" is included the whole of the means and methods whereby the movements of trains are controlled. The importance of the signalling system as a factor in the railway transportation problem varies with the volume and speed of the traffic to be dealt with, the tendency being for its importance and necessity to become greater. Yet, unlike the works or the track, the signalling system of a railway is not a generic feature and, as its necessity was not contemplated in the early days of railways, so it is conceivable that, with the growth of other methods, and particularly with the adoption of other means of traction, the system as we now know it may be entirely superseded. Looked at in proper perspective as a small part of a great organisation, the signalling system of to-day may thus be considered merely as a temporary expedient for meeting a particular combination of conditions. It is very important at the outset clearly to appreciate this aspect of the subject, or otherwise there may be a tendency to confuse cause and effect.

Why a Signalling System may be Necessary on a Railway.

It may be of advantage, in order to clear the ground, to consider, in the first place, what are the conditions peculiar to the working of railways which involve the necessity for a signalling system. No other form of locomotion is dependent for safe working on means in any way to be compared with the signalling system of a railway. Vessels at sea, with a speed approximating to that of railway trains and with greater momentum and less power of retardation, are dependent for safety on a good look-out and must avoid collisions by altering their course. So, too, in the case of road traffic, where the density and variety of traffic are greater than on railways and the speed, unfortunately, often almost as great, collisions may be avoided in the same way by altering the direction or by pulling up.

But in the case of a railway, the fact of the vehicles being confined rigidly to a track allows the driver no option in regard to his course ; he can avoid collision only by stopping. Further, where there is a choice of tracks the choice does not rest with the driver, but with an independent agent. This inherent distinction is, of course, the determining factor in the case, but the other conditions, applying more or less to other forms of locomotion, are present in the case of railways to a greater or less extent. The weight and speed of the traffic make sudden stoppage impossible. Various kinds of traffic, such as fast and slow trains, goods and passenger trains, have to be run on the same track, and if the road is to be utilised to its fullest extent, the discrepancies arising from the varying speeds have to be balanced. The traffic is not only of various kinds, but may be of considerable volume, added to which complications arise from the presence of converging and diverging routes. Finally the traffic has to be conducted under varying conditions, such as by day and night, and during fog and snow. It is the combination of these various conditions and the necessity, notwithstanding them, for the traffic to be worked with regularity and safety that render a system of signalling essential. Yet it should be borne in mind that, notwithstanding their limitation to a track, railways may be less dependent on a signalling system as any of the other conditions are absent or lessened in degree, so that the risk arising from them is negligible. Thus there might be high speed but few trains, and, the times of the trains being known and the staff along the line being prepared, the necessary precautions would be taken and the risk of mishaps reduced to a minimum, notwithstanding the absence of signalling. These were actually the conditions in the early days of express trains, when for instance the Great Western Railway Flying Dutchman commenced running in 1864, and the express trains on the Great Northern Railway about the same time. So, too, on the other hand, there might be a dense traffic and great complication of routes, as on an ordinary tramway system, the factor of safety being obtained by low speed and stoppage at all critical points. On many foreign lines and in certain parts of the United States the determining conditions mentioned are found in a much smaller degree than in this country, and the risk of conducting the traffic with a less elaborate signalling system or with none at all becomes negligible. Extreme examples of this are the pioneer lines of undeveloped countries such as the Uganda Railway.

The Functions of Signalling.

Consideration may now be given to the functions which have to be fulfilled by a signalling system. It was pointed out above that a railway train is necessarily confined rigidly to a track, that where there are divergent routes the choice does not rest with the driver and that, in addition to this limitation, sudden stoppage for the purpose of avoiding collision is impossible. These conditions, combined with a dense traffic, conducted at varying speeds, are incompatible with safety without the introduction of some means of control. In other words, the driver of a train cannot be wholly responsible for safety as can the driver in other forms of locomotion. Hence an outside factor has to be introduced who can do what the driver is unable to do, and with whom the responsibility for the safety of the train may thus be shared.

This outside factor is the signalman, and to him is delegated the responsibility of seeing that the track is clear of obstruction, and (at diverging points) that the correct route is given. The function of a signalling system is to provide the means whereby, firstly, the signalman can fulfil this responsibility in respect of the track and the route, and whereby, secondly, he can communicate the necessary directions to the driver. Briefly expressed, signalling may thus be said to establish harmony between the train and the track. In an ideally perfect signalling system this harmony would be established with mechanical certainty; in other words it would be made actually impossible for a train movement to take place unless the condition of the track were such that that movement would be a safe one. In signalling systems as ordinarily arranged at the present day there are, as we shall see later, certain human links in the chain of operations whereby the mechanical certainty is broken. Broadly speaking a present-day signalling system should ensure that by regulations and apparatus the directions given by the signalman are in accordance with the actually prevailing condition of the track, and that the directions are so given that drivers may have the fullest opportunity of obeying them in the necessary time available.

The present tendency is gradually, by means of apparatus, to fill up the gaps which involve the responsibility of the signalman, but very little has been done to render compulsory the actual control of the train through the driver.

Here another warning must be given against the risk of considering the signalling system of to-day (even in its theoretically perfect form) as a standard method for all time. If for instance, under altered conditions, the driver could be put in direct touch with track conditions he might again (as in early railway days) assume the whole responsibility for his own safety. Or it might be found possible to control the train operation entirely from outside from a common centre. Under any such conditions the whole aspect of the case would be changed and the whole of the problems to be solved would be entirely new ones.

Early Railway Working Methods.

In order to trace the growth of traffic working methods and the corresponding development of the signalling system it is useful to obtain some idea of the conditions prevailing in early railway days. The early conception of a railway was simply of an improved highway, of a road on which rails should take the place of macadam and on which the coaches should be drawn by engines instead of by horses. The earlier railway Acts, indeed, contemplated the provision of the road alone by the railway company, the vehicles being supposed to be the property of the users of the railway exactly as coaches and wagons belonging to the public were run on the high roads. It was, of course, soon found necessary for the railway company to provide the vehicles and work the traffic, but nevertheless early railway ways and methods were in other respects simply coaching ways and methods adapted.

In coaching days the arrival of the coaches would form the important events of the day. The horn would be heard in the distance, the toll-gate man would open his gate, country carts would draw to one side and preparations would be made to clear a way in the inn yard. In early railway days the procedure was very much the same. The trains were few in number, the speed low, and frequent stoppage was made. At the appointed hours the trains would be expected and preparations made for their reception by clearing the way exactly as was done in the case of coach traffic. The time table would be arranged with a view to keeping the trains apart, and at first there would be very little liability of trains overtaking one another. At the few junctions and crossings, trains would wait their regular turn, or, as an alternative, every train would come to a stand before reaching the junction. An example of the former method is recorded of the crossing of the West London Railway over the Great Western Railway at West London Junction. Here the West London train was kept waiting in all cases until the Great Western train, due about the same time, had passed, however late the latter might be. There was, of course, no telegraph to announce the whereabouts of the Great Western train, and as the driver would be unable to stop if on his approach he found the West London train crossing, it would have been unsafe to allow it to do so until the Great Western train was safely past. The method of stopping trains from both directions at a junction would be adopted at places where the converging routes were of equal importance. An example of this kind was the junction of the Sheffield line and the Crewe line at Ardwick, near Manchester. Here the trains, after first coming to a stand, proceeded through the junction as they arrived, the necessary safety being obtained by the compulsory stoppage of every train first. The general idea, in short, in early railway working, was that the trains should run at fixed times, and that the driver would expect to find the way clear for him at the appointed time. On the other hand, the staff along the line were expected to prepare for the trains as the time for them arrived, and this was particularly necessary at places where the expected train was one which ran through without stopping.

These methods were no doubt adequate for dealing with the comparatively small amount of traffic, running at low speed, of those days ; and such methods are adopted in sparsely populated countries, where similar conditions prevail, even at the present time. The method of working known as the "dead reckoning" system, still in use on railways in some of the western states of America, is based on the same principles. It was very soon found impracticable, however, in this country as the amount of traffic and the speed of trains increased. In order to afford guidance to drivers it then became the practice to station men known as policemen at certain places where conditions might arise making it necessary for the trains to stop. These men, the ancestors of the modern signalman, were arrayed in top hats and swallow-tail coats, and had a somewhat military bearing. They were stationed at junctions and stations and were expected to signal to drivers to stop if in consequence of any unusual occurrence, such as the taking place of shunting operations, it was necessary for them to do so. The idea was still that, under ordinary circumstances, the line would be clear as a matter of course when the train became due, and if the policeman was not to be seen the driver would assume that such was the case.

It was soon found impossible for the policeman at a given station to give the necessary hand signals in all cases. Even the most energetic official could not be in two places at once, and the necessity for giving a danger signal for one train might arise when he was occupied elsewhere possibly in attending to another train. Thus was brought about the provision of the first fixed signals by means of which the policemen could exhibit a danger signal and leave it exhibited when he himself was not present. The fixed signal was, however, at first regarded merely as a substitute for the policeman, and one which need not be provided if the presence of the policeman could always be relied on.

Thus the points to be emphasised in recalling the ideas underlying the early methods of railway working are these. The trainmen were responsible for looking after the safety of their train, just as are those in charge of road vehicles. They had to look out for obstructions on the line, and to see that they kept clear of more important trains. At certain places where obstruction might be expected to arise, guidance was given by stationing policemen or, in their place, by fixed signals. But ordinarily, except in specified cases, the driver would, unless he received a signal to the contrary, be justified in proceeding. He would, in fact, expect that, his movement being a scheduled one, the road would be clear for him.

CHAPTER II.

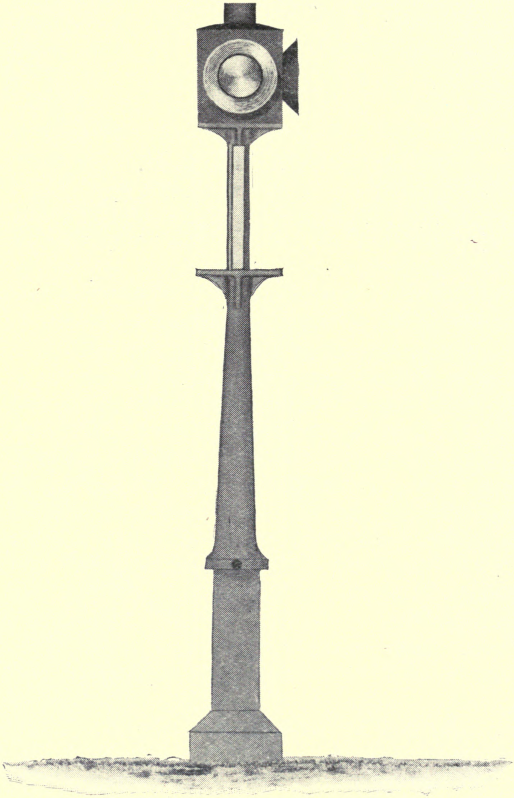
THE GROWTH OF THE SIGNALLING SYSTEM.

The Development of Traffic Working Conditions.

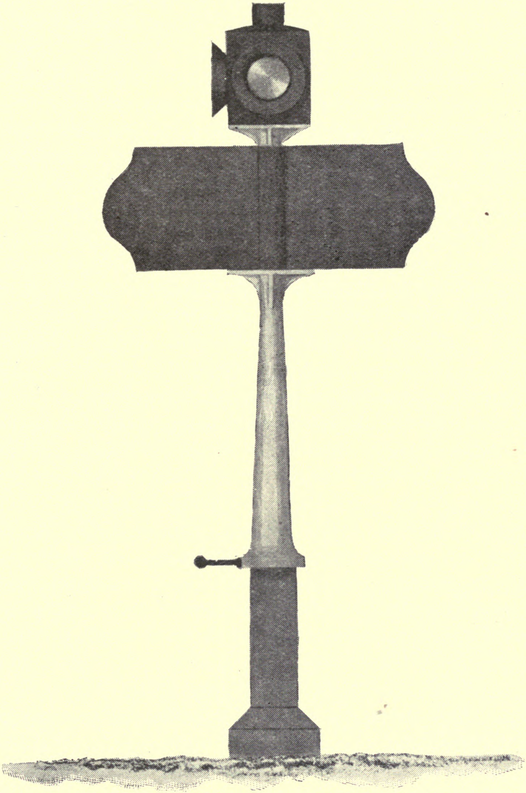
The development of traffic conditions leading to the evolution of the signalling system of to-day may be divided roughly into four stages. These stages do not, of course, mark any actual periods of transition, but are useful merely as indicating the sequence in which the development took place. We shall deal with general principles now, leaving the description of the apparatus employed and the methods of operation until later.

We have already seen that at certain places it was found necessary to provide fixed signals to take the place of the hand signals exhibited by policemen. At first such signals were provided at special places only, where, for instance, the station yard was a long one, or when the conditions made it difficult for a flag signal to be seen. Then gradually it became the practice to provide a signal for the protection of junctions and stations generally, or, in short, at any points where the presence of an obstruction might make it necessary to signal to drivers to stop. Thus the first stage in the traffic requirements was the necessity for providing a means whereby a signal to stop might be given.

As the speed and weight of the trains increased it became more difficult to stop them at short notice, while, on the other hand, the increase in the number of trains and of traffic movements generally, made it a matter of greater urgency that a train should be stopped without fail when necessary. The station signals which were first provided could not always be seen by drivers in sufficient time to enable them to stop, and thus in certain cases additional signals were provided in the rear for the purpose of giving the



Signal on the Liverpool & Manchester Railway, 1834;
in All-Right Position.



Signal on the Liverpool & Manchester Railway, 1834; in Danger Position.

necessary warning. These were known as auxiliary or distance signals, and their use was at first restricted to places where the presence of cuttings or tunnels, or other local conditions, rendered it difficult for the driver to see the station signal in time, or where the gradient made it difficult to stop quickly. The provision of these signals, the forerunners of the distant signals of to-day, marks the second stage of development.

With a further increase in the number of trains and particularly in the varying speeds at which they were run, it was found that a time table reckoning was not sufficient to regulate the traffic. Trains would get out of course through delay or mishap and, whereas formerly it was necessary to afford protection within station limits, a further necessity now arose for protecting trains while between stations or, in other words, of preventing them from overtaking one another while travelling. This need marks the third stage of development. To meet it was devised what was known as the time-interval system of working. In this system an attempt was made to prevent trains overtaking, by maintaining an interval of time between them. The policemen at the various signalling stations would exhibit their danger signal immediately a train passed them. The danger signal would continue to be shown for a given time, say for five minutes, and until the elapse of that time a following train would be brought to a stand and kept waiting. For a further period, varying with the class of train which had last passed and other circumstances, a caution signal would be shown, or the driver of a following train would be stopped and told what train was in front, and how long it had passed, and having received this warning he would be allowed to proceed. At the expiration of a further period the all-right signal would be shown, and following trains would be allowed to pass unchecked.

The time-interval system was no doubt better than none at all, and may be practicable as a means of regulating a comparatively light traffic. It is, however, obviously elusive as a positive safeguard, and under its working reliance must ultimately be placed on the protection afforded by the trainmen themselves, in the case of a stoppage between signalling stations. And although an economical system, as compared with the block system, it was cumbersome in that, in order to make provision for contingencies, a longer time interval had to be maintained than was, under ordinary conditions, necessary to enable the train in front to get sufficiently far ahead.

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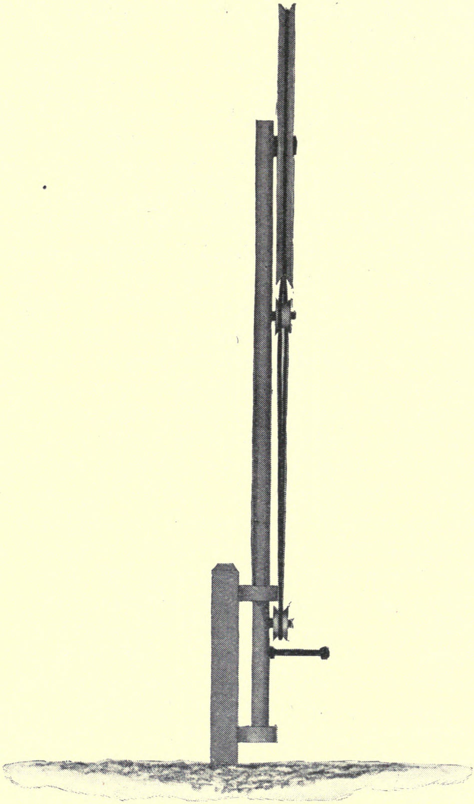
The time-interval system proved ineffective in avoiding collisions, and it became apparent that perfect security could be secured only by providing a definite space interval between following trains. The development of electric telegraphy provided a means whereby a system of working, having this object in view, became possible.

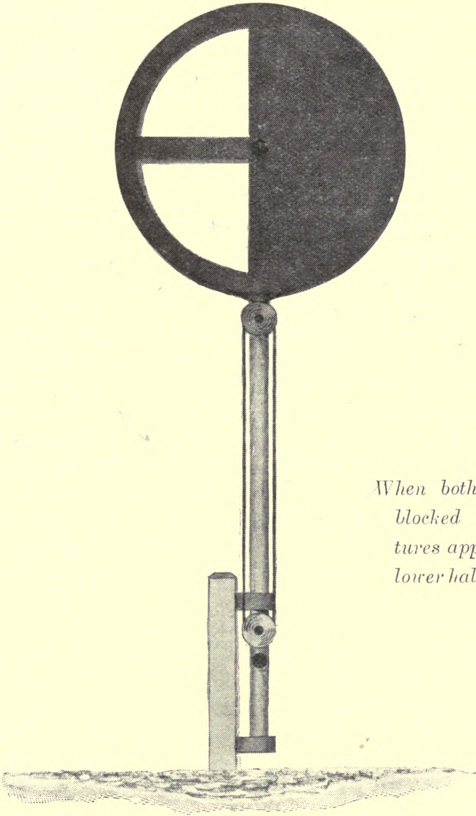
The idea of a space-interval system worked by means of electrical apparatus, originated about the year 1850, and became known as the block system. The use of such a system was gradually extended and the methods of working were improved, and about 1870 the block system had become established on the main lines of the leading railways. It was not, however, until after the passing of the Railway Regulation Act of 1889 that the whole of the passenger lines in Great Britain and Ireland were worked throughout on the block system.

Block working has become such a recognised feature of railway signalling, and its necessity is now assumed as such a matter of course, that it is difficult for us to realise the misgivings in regard to it which once beset the minds of railway officials. It was said that it would impede the traffic, that it would diminish the sense of responsibility in drivers, and that it would introduce new dangers. Much of the difficulty of early block working arose from a disinclination to follow out the space-interval principle to its logical conclusion. It was thought impossible to restrict the use of one section to one train and a species of hybrid block system, half space and half time-interval, was adopted, with the result of inevitable mishap for which the block system was blamed. When the signalling sections extended from station to station the length of time required for the passage of each block section was liable to cause delay to trains, but, as the practice arose of dividing up the lengths of line by intermediate block signalling stations, according to the amount of traffic to be accommodated, it was realised that the block system, so far from causing delay, actually increased the carrying capacity of the line.

Without anticipating the description of block signalling methods which will form the subject of another chapter, it is sufficient now to define the block system as a means of working whereby a definite interval of space is maintained between the tail of one train and the head of a following train. In the earlier days of block working the old conception that the line was normally clear was maintained and consequently the danger signal was exhibited only when a train was actually within the section concerned. Later practice has



Signal on the London & South-Western Railway, 1840;
Showing Up and Down Lines Clear.



When both lines were blocked both apertures appeared in the lower half of the disc.

Signal on the London & South-Western Railway, 1840; Showing one Line Clear and the other Blocked.

reversed this arrangement and the line is now considered blocked until it is required to be signalled as clear for the passage of a train. In the earliest railway days, as has been pointed out, the driver of a train was to all intents and purposes alone responsible for his own safety. To aid him were introduced successively the policeman, the fixed signals, the time-interval system and finally the block system. The introduction of the block system thus marks the final stage in the transference of responsibility (in respect of track conditions) from the driver to the signalman and the adoption of the space-interval principle marks the fourth of our stages in traffic working conditions. The exhibition of an all-right signal is now a definite indication that the line has been ascertained to be clear for the particular train and forms both an assurance of safety and an invitation to proceed.

The Development of Appliances.

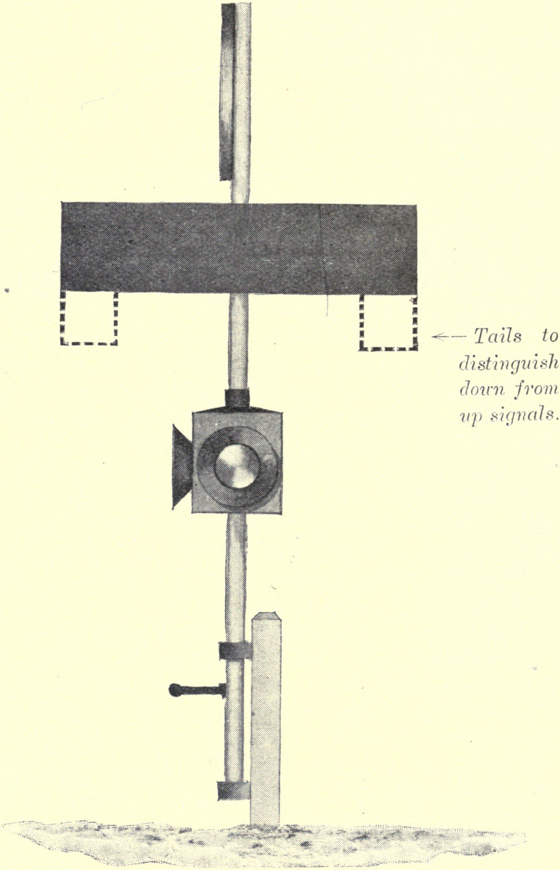
The gradual development of the traffic requirements which culminated in the adoption of the block system was accompanied by a corresponding evolution in the signals and appliances employed in the working of the signalling system generally. As was only natural, the earlier signalling arrangements were characterised by an entire absence of uniformity. As a need arose for some means of giving a signal to drivers at a given place or under given circumstances, the most readily adopted device was made use of, irrespective of the practice at other places or on other lines. Consequently the early signalling arrangements appear to us as a chaos of arbitrary signs, devoid of method and often contradictory in their meaning. For instance, on the Manchester & Liverpool Railway, a green light at Newton Junction indicated that the points were set for the Warrington direction, and the same information was given by day, by means of a gilt arrow. At the same place red and white posts were used to indicate that a passenger train was immediately ahead. Flags hoisted on poles were sometimes used with the inevitable drawback of being almost invisible in calm weather, while in some cases coloured lamps only were employed, there being apparently no day signal. On the Eastern Counties Railway baskets on poles were used as signals, and an interesting survival of the basket signal was in use on the Great Western Railway at Windsor as recently as the year 1889.

The traditional first railway signal is a candle, said to have been placed in a stationmaster's window on the Stockton &

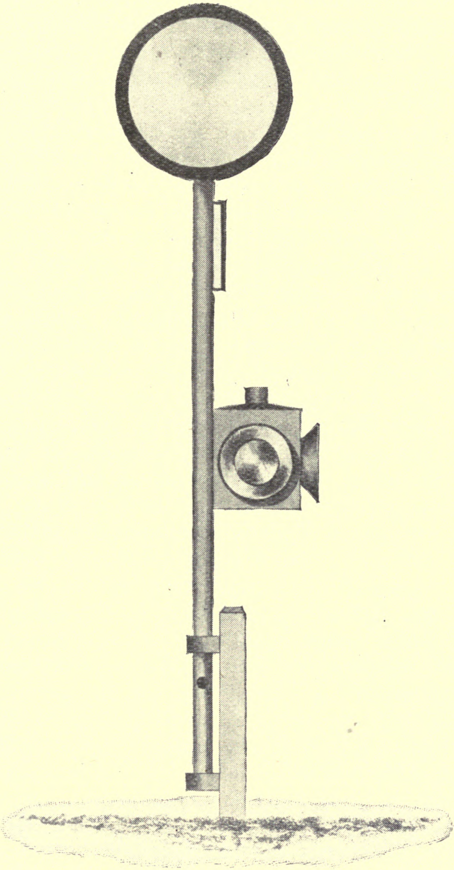
Darlington Railway as an indication to trains to stop. This tradition, like those universal legends which are found in slightly varying form among all the peoples of mankind, must, however, be regarded as typical rather than actual; and that station-master's house (if, indeed, it still exists) cannot rightfully claim pre-eminence as the cradle of the signalling art.

The erratic forms of signals mentioned gave way in time to signals in which some uniformity was attempted, at any rate so far as individual railways were concerned. Some of these early signals are given in the accompanying illustrations. It will be seen that they consisted of some form of board mounted on a post, and capable of being turned round. A lamp, turned at the same time, gave a night signal by means of coloured lenses. The all-right indication was in most cases given by turning the board edge-wise to the line, thus making it practically invisible. The Great Western and London & South-Western signals, however, gave positive all-right signals, the former by means of a separate disc (in place of the oblong cross-bar which stood for danger), and the latter by altering the positions of apertures in a disc. The disc form of signal, which stood for all right on the Great Western Railway, meant danger on many other lines, and this is an instance of the contradictory indications which were to be met with. The Great Western Railway signal had the advantage not only of giving definite signals for danger and all-right, but also of giving separate indications for the up and the down lines and for main and branch lines. The former object was effected by fixing projecting pieces on the ends of the cross-bars and the latter by duplicating both the discs and the cross-bars. The Great Western was, indeed, in signalling matters as in other respects, far ahead of its contemporaries. A point of interest in regard to these early board signals is that in their use was the origin of the expressions "on" and "off" which are still applied to the positions of signals. "Take the boards off" meant "Turn round the signal boards so that they may not be visible against the train."

Before the invention of the electric telegraph there had been in use, chiefly for naval and military purposes, a system of telegraphs worked by means of movable arms on posts. They were fixed on adjacent hill-tops and by combinations of movements messages were sent from hill to hill over long distances. These were known as semaphore telegraphs, the word "semaphore" meaning "that which bears a sign." About the year 1841, this idea was adapted to railway signalling, and this form of signal



Disc and Cross-bar Signal on the Great Western Railway, 1838-1892; in Danger Position.



Disc and Cross-Bar Signal on Great Western Railway, 1838-1892; in All-Right Position.

has ever since been known, somewhat tautologically, as the "semaphore signal." Its obvious advantages for railway purposes led to its rapid adoption, and by the year 1867, it was in very general use on railways in this country with the important exceptions of the Great Western and South-Western Railways. The disc and cross-bar signal survived for many years longer on the former line, but now the semaphore is employed universally throughout the British Isles.

It will be remembered that signals were at first provided at various points where they were required, and they were usually worked by means of a handle on the post. The policeman in charge had thus to run from signal to signal in order to operate them, with the result that their working was often overlooked or neglected or left until too late to avoid a collision. It is said that a policeman, employed at Watford about 1846, desirous of saving his legs, conceived the idea of attaching a weight to the signal and working it by means of a wire which he carried to the neighbourhood of his hut. The idea was adopted and thus originated the practice of concentrating the levers working the signals at a convenient spot. The points themselves, however, still continued to be worked by levers fixed close to them and there was generally no connection between the points and signals except, in some cases, a primitive form of wire locking on the ground.

This arrangement of partial concentration introduced a fresh element of risk. To save time the policeman would perhaps first turn off the signal intending afterwards to attend to a necessary set of points. But the points might in the end get overlooked and the all-right signal would then lead the train to disaster. To meet this possibility, the next improvement was made by concentrating the working of both the points and signals at one place and interlocking the levers with one another so that no contradictory movements could be made. The first locking frame erected, in fulfilment of this idea, was at Bricklayers Arms Junction, in the year 1856, and this was followed by one at Stratford in 1861. The forms of the apparatus employed underwent constant improvement and the installation of interlocking plants became general. The year 1870, which it will be remembered marks a general adoption of the block system on main lines, marks also a similar advance in concentration and interlocking, but as with the former, so with the latter, its universal use in Great Britain and Ireland did not come about until after 1889.

We have thus seen that the stages in the evolution of signalling appliances, which accompanied the development of traffic requirements, may be summarised as, firstly, isolated signals, then concentration of signal levers, and finally the concentration and interlocking of point and signal levers. Later developments, of which details have still to be given, have been in the direction of the elaboration and addition of appliances connected with interlocking plant by means of which the various operations are checked and safeguarded.

CHAPTER III.

THE THEORY OF THE SIGNALLING SYSTEM.

The Contingencies Provided for.

We have seen that the function of a railway signalling system is to establish harmony of action between, on the one hand, the signalman, who alone is able to see that the road is clear and that the correct route is given, and on the other hand the driver, by whom alone the movement of the train can be controlled. We have now to consider, in the first place, what are the contingencies in respect of which a signalling system is intended to afford security, and subsequently how security is afforded in actual practice. Broadly speaking signalling must provide for (*a*) the protection of obstruction, and (*b*) the indication of direction. The "obstruction" contemplated, in the working out of the system, is what may be termed authorised obstruction, or such obstruction as occurs under ordinary working conditions, including, to a partial extent, conditions which may arise by reason of mishaps to trains. It is, however, no part of the function of a signalling system, as such, to provide against obstruction from other accidental causes, such as the failure of the permanent way, the collapse of works, or the presence of foreign objects on the track. In the event of danger arising from any such causes, the signalling system might indeed be utilised, as a means of stopping trains, but this would be an exceptional use, and the possibility of making such use of it would, of course, depend on circumstances. It is, indeed, obvious that a system laid out for the control of traffic is not applicable to erratic occurrences resulting from extraneous circumstances. No signalling arrangements, for example, could have prevented the accident which took place on the

Midland Railway at Wellingboro, in the year 1898, when a luggage barrow fell from the platform in front of a Manchester express. It is true that signals are occasionally used for quite other purposes than those which they fulfil as part of the signalling system. These are, however, simply instances in which a part of the apparatus is employed in other work. Those who have travelled over the magnificent section of the Caledonian Railway from Callander to Oban may remember that along the length of line that passes under the flank of Ben Cruachan there is a series of signals at short intervals. The wires working these signals are so arranged that, should boulders come rolling down the mountain side on to the railway, the signals would be placed to danger by the breakage of the wires. The possible security to be looked for in this arrangement depends entirely on the position of the train when the boulders fall, and on whether or not they happen to jump the wires or roll against them. So, too, devices have been adopted for stopping traffic over viaducts in the case of subsidence taking place or in the event of the wind pressure becoming too high. All such arrangements are, however, quite outside the regular scope of the signalling system. Nor, again, is it a function of the signalling system to give warning of the need for speed reduction such as on curves, or to indicate stoppages necessary for traffic purposes.

The Protection of Obstruction.

The obstructions requiring protection which are contemplated in arranging a signalling system are those which occur in regular daily working. Points and crossings in the line of route form the most numerous and important, and include crossover-roads, siding and junction points, and crossings of other tracks. Points and crossings form obstruction in all cases as postulating the movement of vehicles from another track, and facing points, as forming in addition, a source of danger in themselves if they are not lying in the proper position for the passage of the train. Protection must be given for level crossings of public roadways, both for the safety of the public using the crossing and for the safety of the trains against heavy vehicular traffic. Draw-bridges and swing-bridges form obstruction, but happily are rarely found on English railways. Turntables in running lines are now almost obsolete, although they are still mentioned in the standard rule book. Protection has also, as a rule, to be provided for a passenger platform, although there may be no points or crossings, and the special reason for this will be explained later.

Finally, obstruction is formed by a train travelling on the same line, and this must be protected from the possibility of a rear collision. Definite means must be provided whereby the obstructions coming under each of these various heads shall be protected.

The Indication of Direction.

But, as has been stated, signalling must provide, not only for the protection of obstruction, but for the indication of direction. Hence at points of divergence must be provided signals which, by their form and grouping, shall indicate the direction in which the route has been given and (to some extent) the nature of the route.

Thus for the protection of obstruction and for the indication of direction definite signals are provided, and the lowering of the signals must not only indicate that the obstruction has been provided against and the correct route has been given, but must also give assurance that this condition of things is maintained so long as the signals remain in the all-right position. It should also be made clear that while a signal must be provided for the protection of each of the features mentioned, one such signal may combine in itself several functions either of protection or direction or both combined.

Definition of Terms.

It may be useful at this point, for the sake of the non-railway student, to define some of the terms which will hereafter be employed. Facing points (already alluded to) are those approached in the direction in which the movement of the points will turn the train to one track or another. All points, of course, become facing in one direction, but the expression is used for points in running lines which are facing to the direction in which the traffic usually passes. All the points in a single line are thus facing points. Points which are approached by the traffic in the opposite direction are known as trailing points. A fouling point is the position at the convergence of two tracks, at which a vehicle approaching on one track would commence to form an obstruction on the other track. A fouling point is usually considered as commencing at the last point at which there is an interval of 6 ft. between the inside rails of the converging tracks. A block signal box, or more conveniently a "section post," is a signalling location controlled by the block system. Usually, but not invariably, a section post comprises a signal box manned by a signalman. A block section is the length of line between adjacent section posts. The block section is usually referred to as the portion of line outside the actual area under the immediate operation of a signal box. The area of line which includes the points worked from a signal box and is within the limits of the stop signals for that box may be conveniently alluded to as the "yard," although the expression is not used in exactly this sense in railway regulations.

The Section Post the Unit of the Signalling System.

It has been seen that the responsibility for keeping clear of obstructions which formerly rested largely with the trainmen has with the development of the signalling system gradually been transferred to the signalman, and that, whereas formerly the road was regarded as normally clear, it is now considered as normally blocked, and that therefore a signal to proceed conveys both an invitation and an assurance. Bearing these two axioms in mind we have now to consider how the signalman ascertains that the line is clear or whether there is a train or other obstruction to be protected ; how, having ascertained that the line is clear, he maintains it free from obstruction and how, lastly, he conveys the necessary directions to drivers.

The section post is the unit of the signalling system. In ordinary cases the signalman is the operating agency, and his action is always positive and not merely prohibitive. For, as the line is normally blocked, so positive action and direct permission, on the part of the signalman, are necessary before the line may be considered clear and the movement of a train permitted. For the novice this is an important point to note ; the signalman is always master of the situation, and only as the result of action taken by him can a train approach him.

It need hardly be said that the idea on which melodramatic episodes are sometimes founded, of a signalman pulling a vital lever whereby a train is saved from destruction, immediately before he succumbs to faintness, is nothing more than a popular myth. As a matter of fact, under modern conditions, a signalman may sleep or faint at his post without causing any risk to the traffic. Whether such a proceeding would involve risk to himself is another matter. The risk to the traffic occurs if, on regaining consciousness, he takes some action, without first assuring himself as to what has taken place while he has been insensible. Accidents have occurred under such circumstances, although, happily, it is a very rare event for a signalman to sleep while on duty.

The Means by which the Space Interval is Provided for.

In ascertaining the state of the track (that is whether it is or is not clear of obstruction) the signalman is guided (*a*) by the block telegraph, and (*b*) by his own vision. Certain apparatus which may take the place of actual vision will be described in a subsequent chapter. But, as the employment of such apparatus does not affect the general principles involved, we shall for the present speak of actual vision, it being understood that this may under certain circumstances be replaced by apparatus.

Taking first the block telegraph system and leaving for subsequent description the actual methods of block working, we shall now consider the circumstances under which block section posts must be provided and the purposes which they fulfil.

On a length of plain line the only contingency to be guarded against, by the block system, is that of trains overtaking one another while travelling on the same track. Hence, on a line free from junctions, sidings or crossover connections or other complications, it is necessary merely to divide up the line into block sections with a block signal box (or other form of section post) at the end of each section. The sections would have to be of the length necessary to permit the proper movement of the traffic passing over the line, having regard to its density and average speed. Thus a line with few trains running at high speed could be signalled with long block sections. But if a dense traffic is to be accommodated, and especially if many of the trains travel at low speed, the block sections must be relatively short ones.

But continuous lengths of plain road are rarely met with—at any rate, in this country—and not only has the risk of trains overtaking to be provided against, but also the risk of the route being suddenly blocked by trains moving on to it at converging or crossing points. This may happen at junctions with other running lines, at crossings from the opposite main line and at connections leading from sidings. At all such places the space interval on the main route may be instantly destroyed by a converging or crossing movement. The block system must thus, as it were, provide for a lateral space interval as well as for a longitudinal space interval. Therefore, in order to maintain the principle of the space interval, section posts must be established at all points where there is a junction, crossover-road, siding connection or crossing. An exception is sometimes made in the case of an isolated siding connection with one main line, where, if trains are never shunted inside the siding, there is practically no risk of the main line being fouled from inside the siding. Section posts must also be established at swing-bridges, not primarily to maintain the space interval but in order that when the continuity of the main line is broken, trains may be held back on either side sufficiently far back to avoid the risk of their running into the gap. As junctions, crossings, and sidings occur generally at such frequent intervals in this country the section posts necessarily established at such places are usually sufficiently near together to keep the traffic going on the straight route. Signal boxes which are section posts only (and from which no points are worked) are relatively few in number. They are found necessary chiefly in country districts on important main lines where the stations and junctions are far between. It is on this account that wholly automatic section posts are unlikely to be introduced to any great extent in this country.

The section post must therefore, as a rule, fulfil the dual function of spacing following trains on the same line, and of affording protection from converging or crossing movements. And the signalman in charge of a section post is responsible for the sections on either side of his post (two on double lines, more in the cases of widened lines and junctions) and shares that responsibility with the man in charge of the post at the other end of each section. No train may approach a signalman in charge of a section post unless permission has been given by means of the block telegraph. No train may leave him unless he has obtained permission by the same means. Thus, the block telegraph furnishes the means whereby the signalman ascertains the condition of the track for a train proceeding on its journey.

Before permitting a train to approach him the signalman must not only satisfy himself by reference to the block instrument that the previous train on the same line has arrived, but he must ascertain that the line within the area of his immediate jurisdiction (referred to hereafter as his yard) is clear. This he must do by observation, either of the actual track, or of the apparatus taking the place of vision of the track, which has been referred to. Under ordinary circumstances, at the present time, the signalman must however, be able to see the track, and therefore the view from the signal box is an important matter. The signal box must be so placed that from it there may be a view of the whole of the running lines comprised in his yard. He must see these uninterruptedly from the point at which a train waiting at the first stop signal (on every running line) would come to a stand, up to the signal for departing into the next section. Similarly he must see the whole of the track in bay lines and platform lines or other subsidiary roads, not forming part of block sections, but on to which trains may have to be turned. Thus he will be able to keep a constant view of trains waiting at the entrance to his yard and of those within yard limits, including those waiting to depart into a section in advance. In other words, a train while on a running line must always be under the eye of a signalman except when actually travelling through a block section.

Further, the signalman must be able to see all the points worked from his box, both in order that he may see when vehicles are clear of the points and that he may not move them while vehicles are passing over them. In practice this includes all points in and those leading to running lines, as it is not usually necessary to work from the signal box points forming connections inside sidings. Fouling points of converging tracks must be seen or apparatus, to show whether vehicles are clear, must be provided.

In selecting a site for a signal box all these requirements must be considered, as being necessary in order that the signalman may ascertain the condition of these portions of the track by vision. There are other requirements in respect of the position of the signal box which may be conveniently referred to at this stage. The box must be within the distances, laid down by the Board of Trade, as the limit at which points may be worked. These are 250 yards distance for facing points and 300 yards for points which are not worked over in the facing direction by passenger trains. In the laying out of many modern yards these distances practically fix the position of the signal box longitudinally as, in order to give the utmost possible room in the sidings, the extreme points are often laid in at the full distance permissible.

The signal box should be kept as near the running lines as possible, so that the signalman may have the best opportunity of observing passing trains, and particularly of seeing the tail lamps. It is desirable also, when possible, to avoid placing a box where a siding on which vehicles are constantly passing or standing, would be between the box and the main line.

If the gates of a level crossing are to be worked from the signal box it is necessary to place the box in close proximity to the crossing. This is on account, not only of the difficulty which would be experienced in working gates from a distance, but also of the risk to the traffic on the public road which would arise unless the signalman were near enough to see exactly what was taking place at the crossing.

The height of the signal box must be determined with reference to the necessity of obtaining a good all-round view over the whole extent of the yard controlled from it. When a siding on which vehicles are liable to stand intervenes between the box and the main line the height will have to be such that a view may be obtained over the vehicles. As a rule a box controlling a large area should be higher than one whose connections are comparatively near at hand. On the other hand the box should not be too high to enable a view to be obtained under adjacent bridges and verandahs. Very high boxes are objectionable in foggy weather and also on the score of expense. The height of ordinary signal boxes usually averages from 8 to 10 ft. from rail to floor level. In pre-block days it was the custom to build very high boxes, apparently in order to get a view of the line as far as possible in either direction. This is now no longer necessary and the continued erection of abnormally high boxes on some railways is probably due to traditional usage.

The Means by which the Space Interval is Maintained.

Having thus seen how the signalman is enabled to ascertain whether the track is clear, we have next to consider how he maintains it in a clear condition for the passage of a train.

At junctions between goods lines (*i.e.*, all lines not passed by the Board of Trade as passenger lines) and passenger lines catch points or dead-end sidings are provided for the protection of the passenger lines. Similar protection is provided also in the case of connections leading from sidings and goods yards. The points of these catch-points or dead-end sidings are worked from the box, and thus nothing can approach the main line through them unless the signalman permits this by moving the points. The same thing applies to a crossover between main lines, where the points in each main line form protection against the fouling of the other main line through the crossing.

Catch-points are provided sometimes also at the outlet of passenger bay lines, but, if not, protection for the main line is afforded by the bay-line signal alone. The Board of Trade does not allow facing catch-points to be provided in passenger lines (other than bay lines), and as this protection therefore cannot be provided at the junction of passenger lines, as is done at goods line junctions, the signalman maintains the lateral space interval at such junctions by withholding permission for a train to approach from the converging direction. This is possible, as the branch line being a passenger line is necessarily worked on the block system.

Thus, it will be seen, it is impossible for anything to foul the main line or to approach on a converging passenger route except by the signalman's permission, and so by these means he is able, having once ascertained that the track is clear, to maintain it in that condition as long as circumstances render it necessary.

CHAPTER IV.

THE OUT-DOOR FIXED SIGNALS.

General Principles.

Having ascertained whether the track is clear or otherwise by means of the block telegraph and his own observation, in the manner described in the last chapter, the signalman is enabled by means of the fixed signals, worked from his box, to communicate the appropriate directions to drivers. In modern signalling the out-door signals convey two indications only, namely, "all right" and "danger," and, as has been already explained, the danger indication is always shown except when permission has to be given for a train movement to take place. Every signal must have a definite purpose. It should fulfil one of the functions of protection or direction previously described, but, of course, any one signal may, if necessary, fulfil more than one of these functions. In the earlier days of interlocking it frequently happened that signals were provided simply as complying with usage. This practice is still met with occasionally, but is a mischievous one, as leading to the unnecessary multiplication of signals. Unless the provision of a signal can be justified by reference to the principles of signalling, it is unnecessary, and should not be provided.

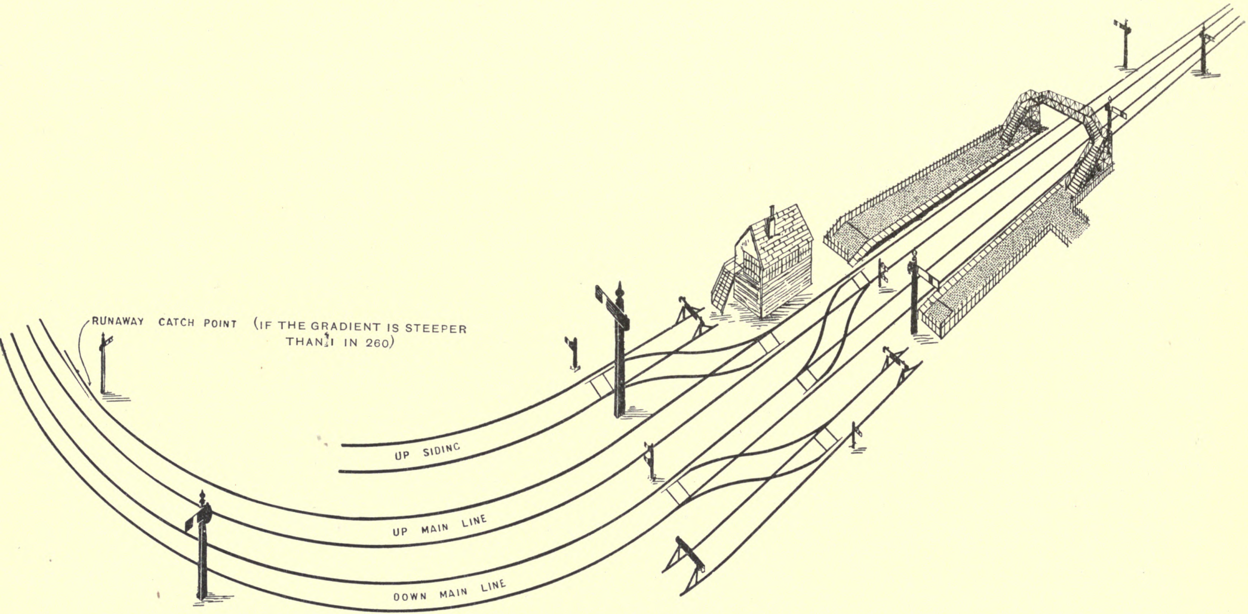
In protecting obstruction the out-door signals may act directly by being fixed at the immediate spot requiring protection or they may act indirectly, as forming the outdoor representation of the indication given by the block telegraph for the protection of obstruction at a distant point. The obstruction protected by the block telegraph may be either a train in motion in the section or a movement at the section post in advance. Thus, as will be seen more clearly later on, a movement within yard limits is protected not only by the signals belonging to that particular location, but also by the signals at the section post in the rear ; and the latter give their indication in obedience to the block telegraph. A train travelling through the section, on the other hand, is protected by the block telegraph alone, the outdoor indication being given, as in the former case, by means of the signals at the section post in the immediate rear of the train.

Theoretically, therefore, when block working is in operation, the only outdoor signal necessary is that protecting the entrance to a block section, as this signal protects also the connections and other obstructions occurring at the section post in advance. In practice, however, at least one signal protecting the latter is required on the spot in addition. This is partly on account of the strict space-interval principle being sometimes relaxed, especially in the case of trains which do not carry passengers, under which circumstances the train would be admitted into the section and would require to be stopped before actually entering the yard. Such a signal is required also, even when strict block working is maintained, to give assurance that the conditions within the yard remain unchanged after permission has been given for a train to approach and while it is passing through the section. It is possible by means of apparatus to cause the presence of a train in a given section automatically to secure in any desired position the points in the yard in advance of its movement. In practice, however, this is not done on ordinary railways, and reliance is placed on the signalman for maintaining the points under his control in the correct position after he has given permission for a train to approach. The signals immediately protecting the entrance to the yard give assurance that the signalman has fulfilled this condition.

The positions of the various signals about to be described may be seen on the accompanying sketches showing the signalling at a roadside station and at an ordinary simple junction.

Starting Signals.

The first signal which will be described is the one by which permission is given for a train to enter a block section. This signal is known as the starting or advanced starting signal, the name varying according to the number of signals in its rear, which are worked from the same signal box. The alternative nomenclature is unfortunate, as the distinguishing function of the signal is not defined by its relation to the signals which may happen to exist in the rear of it, but by its relation to the block section in advance. It would be far better to refer to any signal, whose



Signalling at a Roadside Station.

sole function is to give admission to a block section, as a starting signal, and signals provided for this purpose alone will be alluded to as starting signals in this book. A starting signal should, when possible, be far enough ahead of the farthest points worked from its signal box to give room for shunting operations to take place without the necessity for the engine to pass the signal. If it is not possible to give the necessary distance for this between the points and the starting signal it may be passed at danger for shunting purposes by verbal instruction from the signalman. Sometimes a small lower shunting arm is provided on the post to act in place of verbal instructions. It is not permissible, however, for a starting signal to be passed at danger, either by verbal permission or by the lowering of a shunt-arm, when the section ahead is so short that there would be any risk of the shunting train colliding with another train standing at the first stop signal for the box in advance. Shunt-ahead arms should therefore not be provided under starting signals under these circumstances. Starting signals at junctions should similarly, if possible, be placed far enough in advance of the junction points to give room for a train standing at the signal to be clear of the junction. This enables the junction to be left clear for a movement on another route, although a train may have to be held at a starting signal waiting for permission to enter the section ahead.

It is necessary, in order that a signalman may not overlook a train, of whatever length, while standing at a starting signal, that there should be an uninterrupted view of the line for the whole distance between the signal box and the starting signal. Similarly the signal should not be beyond the range of effective vision under average weather conditions. In practice a distance of 400 to 450 yards is quite far enough from the signal box for a starting signal. When track apparatus, taking the place of vision, is provided these conditions as to sight and distance do not apply. There should theoretically be a distance of at least 440 yards between a starting signal for one box, and the first stop signal for the box ahead, as otherwise the space interval may be reduced to a merely nominal amount in the case of a train proceeding to a starting signal while the section ahead is occupied. Where the sections are short, however, it is often found a great convenience to give not more distance between these signals than will suffice to hold a train of average length. The signalman must then use his discretion in allowing a train to proceed to the starting signal when the section ahead is blocked and the necessary security is obtained by first bringing the train practically to a stand at the signals in the rear of the starting signal. It sometimes happens, however, that there is not sufficient distance available to the signal for the box ahead to enable a starting signal to be provided in advance of the connections. In this case one of the signals, described below, protecting the connections will give admission to the section, in addition to protecting the points. Such signal should then not be passed, even for shunting purposes, unless the train is properly signalled to the box ahead by the block telegraph.

Home Signals.

It will be understood from what has been written that the various forms of obstruction defined in the third chapter are usually grouped together so that each group may be controlled from a signal box. It has further been seen that these obstructions must be protected on the immediate spot in addition to the protection which they enjoy by means of the block telegraph. Thus, the first occurring obstruction, whether it be siding or junction points, a cross-over, a highway level crossing, a passenger platform, or other form of obstruction, must be protected by a signal. This signal is known as the home signal and must be so placed as to cover the fouling point of the obstruction. It is usual to allow a slight margin between the home signal and the actual fouling point.

If the signal box is provided for block working purposes only and there are no connections or other forms of local obstruction to be protected, the home signal should be placed as near the box as possible, so as to enable the signalman to communicate with a driver who has been stopped, without drawing up the train and stopping it a second time at his box. It is sometimes found convenient to place the home signal in such cases a few yards ahead of the box. When there are no connections at a section post the home signal really falls within the definition of a starting signal, as its sole function is to give admission to the block section. There is, therefore, no actual necessity to provide another starting signal in such cases, but one is sometimes provided to enable a train waiting for permission to proceed to be brought within the protection of the home signal. If there is a passenger platform, a starting signal is always required in addition to the home signal, although there are no connections in order that should the section ahead be occupied, a following train may if necessary be drawn to the platform and the waiting time occupied in station duties.

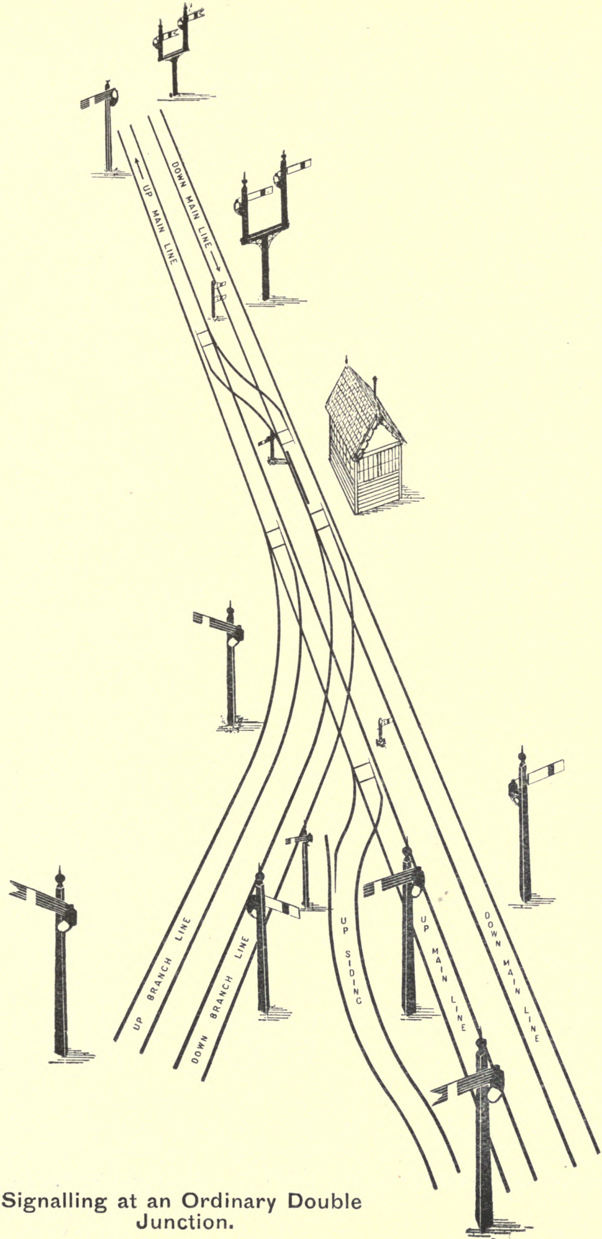
In every case it is essential that a train brought to a stand at a home signal should be well within view of the signal box or, failing this, that apparatus to indicate the presence of the train there should be provided. A train in this position is, of course, still within the block section, and is protected by the block system, but the fact of a train being detained involves a risk of its being forgotten by the signalman, and hence it is most important that under such circumstances it should be under his observation.

Junction Signals.

At junctions between converging lines a home signal must be provided from each direction. The positions will be determined by the first occurring fouling point, which may be the fouling point of the converging route or that of some connection or other form of obstruction short of the junction itself. In the diverging or facing direction the junction home signals must in like manner protect the first occurring obstruction. If the first point to be protected is the junction points themselves the home signal should be placed clear of the locking bar, so that a train standing at the signal may not stand on the bar. These signals must not only protect the points but they must in addition indicate the direction in which the points are set. For this purpose a separate arm must be provided for each direction, the arms being placed side by side in the order in which the respective routes diverge. It is usual to indicate the relative importance of the routes by making the arm for the more important direction a couple of feet higher than the other. This is known as "stepping" the arms, and a junction signal applying to several routes may have arms of three or four different heights. It tends to confusion, however, if the stepping of the arms is carried too far.

In the exceptional case of a main line junction leading in one direction to a siding or dead end, the arm for this direction should preferably be a smaller one than the others, and should show smaller lights by night. Signals protecting junctions in the facing direction are usually fixed on bracket posts, and hence are spoken of as bracket signals ; if there are more arms than can be accommodated on brackets, or if space is not available for a bracket post in the proper position, the arms are placed upon a bridge spanning as many roads as may be necessary.

In the early days of signalling and interlocking, junction signals instead of being placed at the actual point of obstruction, were placed immediately over the signal box, as shown in the illustration on page 37. A driver finding his signal at danger would



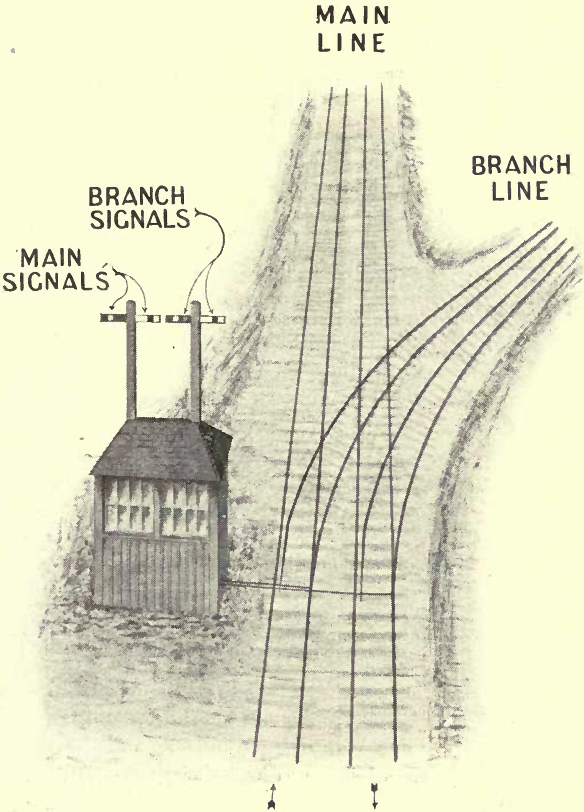
Signalling at an Ordinary Double Junction.

thus not be entitled to run up to the signal as he does to-day, but would have to be careful to stop clear of the junction itself. It is curious to find that the adoption of the modern method of arranging signals at junctions was at first objected to by the Board of Trade Inspectors.

Inner Home Signals.

We have disposed of the starting signal and the home signal, which are the main protecting signals for the block section and the yard respectively. In cases where the points worked from a signal box are numerous and are spread out over a considerable length of main line, it is necessary to provide one or more inner home signals ahead of the home signal itself. An inner home signal may be necessary, irrespective of whether or not there happens to be a starting signal ahead of the points. There are two contingencies to be provided for in these cases. When there are points a considerable distance ahead of a home signal, there is a risk, should the latter be placed to danger too soon after the passing of a train, (as the points would thereby become free), that they might be moved, with the possible result of obstructing the main line before the train had passed. This is particularly the case if the points are facing points. In the second place, it may become necessary in long yards to bring a train to a stand inside the home signal, and still in the rear of some of the points. After the train has come to a stand it may be necessary to alter the position of the points in advance, or to perform shunting operations, possibly with the train engine itself. Either of these contingencies should be met by providing one or more inner home signals at convenient fouling points in advance of the home signal. In the case of a train running through, the inner home signal will ensure that the points are not moved until the train has passed unless the signalman throws the signal to danger in front of a train, which is unlikely. In the case of a train brought to a stand inside the outer home signal, the inner home will hold it while any necessary movements are taking place in advance and will ensure that it is not re-started unless the circumstances are such that it should be allowed to do so.

The necessity for inner home signals is determined largely by local circumstances in any given case. But if there are facing points at about 200 yards or more from the outer home signal, an inner home should invariably be provided, and in such cases the inner and outer junction signals should be of the same form, so far as the arms leading through the junction are concerned. So, also, if there is a passenger platform there must always be an



Early Junction Signalling Arrangements.

inner home signal at the fouling point next in advance of the platform. The inner home should not be at the end of the platform itself unless that happens to be the fouling point, as the signal is required to protect the fouling point and not to mark the end of the platform, and such protection is best afforded by placing the signal close up to the fouling point to be covered.

Calling-on Arms.

The lowering of a signal (other than a distant signal) gives permission to proceed up to the next signal whether at that particular box or at the box in advance. It is sometimes necessary at large stations to bring a train past a signal while the line, between that signal and the next is occupied. This frequently happens at terminal stations and sometimes also at junctions where trains have to form connections. The driver must then be stopped at the signal box by flag and informed of the state of things ahead, or otherwise he cannot be expected to be prepared to stop clear of the obstruction. At busy places this mode of working is found inconvenient and is liable to lead to mistake. To avoid this, small lower arms are sometimes fixed under the home signals in such cases and the lowering of the small arm, or calling-on arm, conveys to the driver exactly the same information as would otherwise be given by the signalman verbally. In fact the calling-on arm bears to the home signal exactly the same relationship that the shunt-ahead arm bears to the starting signal, although the interpretations given are of course different. To ensure that the driver shall have his train well under control it is usual to insist that the train must come to a stand before a calling-on arm is lowered. These arms generally show no light when at danger and a small green light when lowered. Generally when the home signal itself is lowered, the calling-on arm remains at danger, but some companies lower both arms together except when the calling-on arm only is required. The former is decidedly the better practice as each arm conveys a distinct message and the giving of both messages simultaneously cannot be justified. A calling-on arm should never be employed unless it is desired to stop a train short of the next signal as if used otherwise the value of any signals in advance is thereby weakened. For instance it would not be proper to use a calling-on arm simply to indicate that the inner home signal was at danger as this would involve the inference that the lowering of the outer home itself would imply that the inner home also was lowered, which would be contrary to the fundamental principles of signalling.

Siding and Shunting Signals.

The extent to which these signals are employed varies considerably on the various railways. When a shunting movement on a main line or through points worked from a box is not governed by a fixed signal, a hand signal must be given by the signalman from the box. Hand signals are liable to be misunderstood, particularly if more than one engine happens to be in the neighbourhood, and if the shunting movements are frequent. On the other hand, at a roadside station where little shunting takes place, shunting operations can quite well be controlled by hand signals. The extent to which shunting and siding signals should be provided thus depends entirely on circumstances. It is usual in every case to provide a signal at the points leading from a siding to a main line and usually at the points of a cross-over road. Signals are frequently provided also for setting back from a main line to a siding. Some companies go further and provide a shunting signal for every possible shunting movement on main lines and also within sidings, so far as the movements are made over points worked from a box. This involves a large number of signals and heavy expense, but if the shunting operations are very frequent and the main lines are heavily worked, the outlay is no doubt justified. Whatever may be the practice of a line generally, signals should always be provided at large stations to control shunting movements which occur regularly, and particularly if complete trains are concerned, as in the case of backing out empty trains at terminal stations. The provision of shunting signals not only guards against misunderstanding, but saves time in making the movements. Backing signals must never be provided for a movement in the wrong direction on a running road unless means are taken to guard against the movement being continued along the wrong road into the block section. Hence, before a backing signal is lowered, some points must be set to turn the vehicles either into a siding or across to the proper road for the direction concerned. If no points are available for this purpose the backing signal should not be provided. An exception to this is sometimes made in the case of very short sections (as in station yards) where wrong-road working is permitted. A wrong-road backing signal may then be provided if controlled from the box at the opposite end of the section and the provision for diverting the movement away from the facing road would then be made at the distant box.

Siding and shunting signals take the form either of low semaphores with small arms and lights, dwarf semaphores standing two or three feet above rail level, or revolving lamps fitted with discs. These signals either protect obstruction or indicate direction on similar principles to running signals. In the case of siding or shunting signals for two or more directions, as it is not usual even when semaphores are used, to provide bracket signals, the arms are placed one above the other. The top arm then applies to the direction leading off to the left, the second arm to the next in order from the left, and so on. In the illustration of a roadside station on page 31, two two-arm dwarf signals are shown ; the top arm in each case is for backing through the cross-over road, and the lower arm for backing into the siding. In the junction illustration on page 35, the top arm of the dwarf signal at the cross-over road points leads through the cross-over to the down main line, and the lower arm through the cross-over to the down branch.

Distant Signals.

So far as through running is concerned, distant signals are, perhaps, the most important of the main-line signals, as they give the key to the situation in respect of each section post. Unlike all the signals already described, distant signals may be passed when in the danger position. They are, in fact, caution signals, and in American practice a distant signal in the normal position is spoken of as at "caution." A distant signal is distinguished by an arm with a notch cut in the end in place of the square end of the arm of a stop signal. By night no distinction is made in the light of a distant signal, and in this matter British practice is no doubt theoretically defective. A distant signal when at danger indicates that the home signal for the box concerned is at danger ; when at all right it indicates that, not only the home signal but, any other running signals for the same box, have been lowered also. In other words the lowering of a distant signal indicates that the road is clear up to the home signal for the block signal box next in advance of the box from which the distant signal is worked. As a distant signal affords the first intimation to a driver that he may have to stop at a home signal, it must be sufficiently far back from the home signal to enable him to do so if he finds the distant signal at danger. The necessary distance varies according to gradient and other circumstances, and may be from about 800 yards to 1,000 yards or 1,200 yards. In the case of very short block sections special arrangements have to be made in regard to the location and working of distant signals, and these are referred to in Chapter X. It will be sufficient now to state that when, in locating a distant signal, it is necessary to fix it near the signals belonging to the box in the rear, the distant signal is placed as a lower arm on the starting or other signal in the rear. It is then controlled by the upper arm so that the distant signal cannot be lowered unless the upper arm is lowered first. Distant signals should, as a rule, be of the same form as the home signals to which they apply. That is to say, if the home signal is a bracket signal (at a junction) the distant signal should be a bracket signal also. If for any reason, it is inexpedient to provide a distant signal for a diverging route at a junction, a distant signal must be provided for the main route only, and when the home signal for the diverging route is lowered the distant must not be lowered, but must be passed at danger by the branch train. It is an important rule that a distant signal at a junction must be lowered for one direction only. This is in order that a driver, on passing a distant signal at all-right, may know exactly where he is going.

CHAPTER V.

THE BLOCK TELEGRAPH SYSTEM.

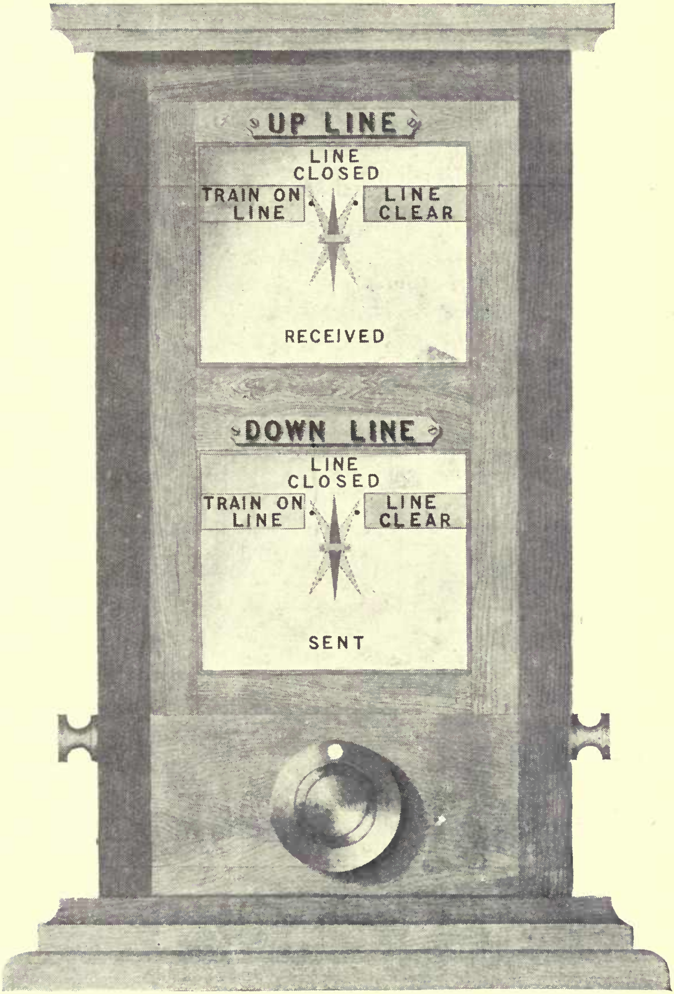
Definition.

We have already seen that the idea of utilising the electric telegraph for the purpose of maintaining an interval of space between following trains originated about the year 1850, but that it was not until about 20 years later that the block system of working was adopted to any great extent. We have seen also under what circumstances it is necessary to establish a block section post, and how the signalman in charge of a section post is enabled to provide for and maintain a clear road, in pursuance of the space-interval principle.

Any system of working by which it is sought to maintain an interval of space between following trains may properly be described as a block system. The Regulation of Railways Act, 1889, refers to the "Block System" without making any attempt to define the expression, or to suggest how the system is to be worked. The memorandum of the requirements of the Board of Trade (which is referred to in Chapter VII) contains a definition of a block system, but says nothing as to the form of the apparatus to be employed or the method of working, except that it is laid down that a separate instrument must be provided for signalling on each road. Apparently, the practice adopted largely in America of block signalling by means of a telegraph speaking instrument or a telephone only, would not be approved by the British Board of Trade.

Development of Methods and Codes.

The block telegraph regulations and codes in use on the majority of railways in the British Isles are known as the Railway Clearing House Regulations, as they have been drawn up from



Three-Position Block Instrument.

time to time by a Clearing House Committee of representatives of the companies. These regulations are now adopted by the companies who are parties to the Clearing House, with very few exceptions. Each company adopting the standard regulations makes what slight additions or alterations to them which it may find necessary to meet its special conditions. On the other hand the few companies who do not adopt the regulations (chiefly those south of the Thames) use many of the standard codes.

The standard regulations have been arrived at as the result of many years of effort. Originally the methods of block working varied greatly on different railways, and the codes were often contradictory. Consequently at one time the signalman at a junction between two railways might have two separate codes to remember. This lead to a serious accident at Canonbury in the year 1881, and as a result of that occurrence the first effort was made to arrive at some uniformity. The only immediate result was the general adoption of a bell signal of six beats to indicate danger. In the year 1884 codes were drawn up by the companies in which some of the more important signals were uniform, but it was not until the year 1904 that a standard Railway Clearing House code was adopted generally. The description of block working about to be given refers to this standard code. No attempt will be made to deal exhaustively either with the regulations or the code, the object being to set out the general principles on which these are based and the way in which they provide for the maintenance of the space interval.

Block Telegraph Instruments.

There is very slight variation in the forms of the instruments used for block signalling. They consist usually of some form of needle instrument, there being one needle for each main line in each direction, or four needles in all for an ordinary double-line block signal box. In the illustration of a three-position block instrument two needles are mounted in one case, a useful feature where space is a consideration, but as a rule there is a separate case for each needle. Some companies mount a red and white flag on the needle, and this flag appears through an aperture in the case in place of the needle itself, the flag being suitably lettered. This instrument is used on the Great Western Railway, and is known as Spagnoletti's disc block instrument. Block instruments in which the indication is given by a small semaphore are also used. Such instruments give two indications only, namely, "line clear" and "line blocked," whereas the needle instruments give a third indication, "train on line." The two descriptions of instruments are sometimes referred to as "two position" and "three position" block instruments, and also as "one wire" and "three wire" block instruments respectively, the latter designation referring to the number of line wires required to equip a section in each case. A bell is provided in each box for each double-line section; this is rung usually by a tapper key, but sometimes (as in the illustration) by a plunger passing through the commutator handle. The commutator handle operates switches by means of which the direction of the current which controls the block needle is brought into operation and given the polarity required to deflect the needle to the right or to the left. In the absence of current the needle will, of course, hang vertically, or (in the case of the disc block instrument) the flag will show half red and half white. This is known as the normal position of the indicators. The advantage of combining the bell plunger with the commutator handle, is that the signalman is able to ring the bell and turn the needle without removing his hand, and when the traffic is heavy the time thus saved is a consideration.

Block working by means of a three-position block instrument may be regarded as the standard British practice and the standard Railway Clearing House regulations are drawn up with the use of such instruments in view. There are certain disadvantages attendant on the use of two-position instruments, which will appear in the course of the subsequent description of the method of working. Their advantages consist in the smaller cost for erection and maintenance which they involve, as compared with three-position instruments. The tendency is for the use of two-position instruments to be discontinued, and where they are used by railways adopting the Railway Clearing House regulations, slight modifications in the wording of the regulations are introduced to render them applicable to the two-position instruments.

Method of Working and Equipment.

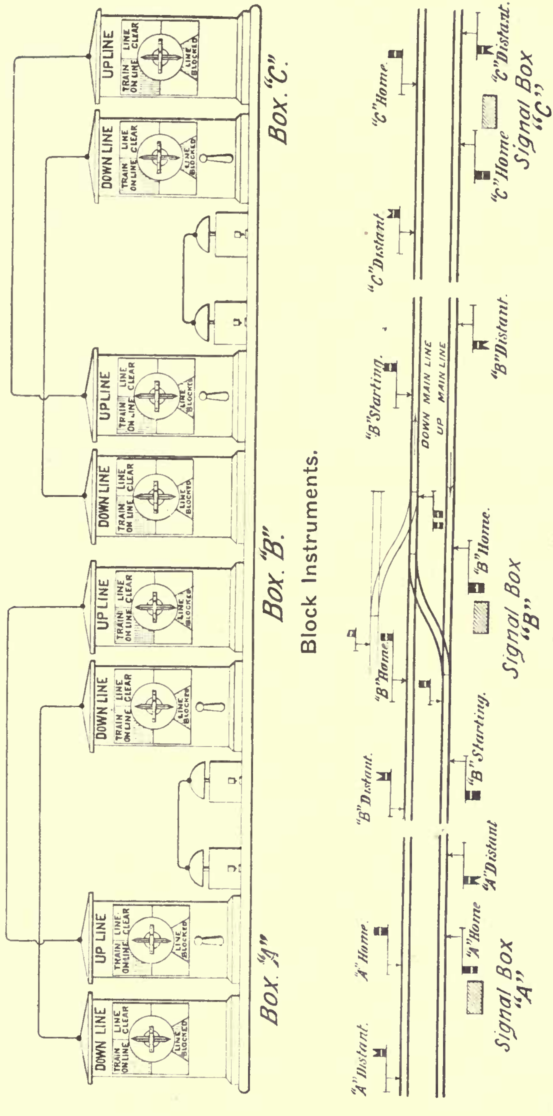
The principles on which any form of three-position block instruments are worked are not affected by the slight variations in the forms of the instruments or in the means by which the bell or dial signals are given. The equipment about to be described applies to the signal box B, shown on the diagram on page 47, and situated between boxes A and C on a double line of railway, and the arrangements are similar in any signal box equipped with three-position block instruments and controlling an ordinary double line of way.

Signal box B, it will be seen, has four block indicators, one for the up and one for the down line in the direction of A, and similar indicators for each line in the direction of C, and each of these moves simultaneously with the needle for the same line in the adjacent signal box. There are also two bells which are rung from A and C respectively, and B in turn has pushes or tappers by means of which he can ring to A and C. B can control the indicators for the lines on which trains approach his box, that is the needle for the down line from A and that for the up line from C. He has, however, no control over the needles for the lines on which trains leave him (the up line to A and the down line to C), and these needles are controlled by A and C respectively. In the case of a junction there would be an additional pair of indicators for each converging route (double line), and the method of controlling them would be exactly the same.

If no train is passing in either section, and if no permission for a train to pass has been given, all the indicators will be in the normal position, and the lines are considered blocked or closed. As the normal position is the position which is assumed by the needle in the absence of current, it follows that any failure in the wires or connections will result in the "line blocked" indication being given.

Asking Permission for a Train to Enter a Section.

Assuming now that A requires to pass a train in the direction of B he will first call B's attention by giving one beat on the bell. The call-attention signal is necessary to ensure B's presence at the bell when the code is given, and also that, in the event of B declining to accept the train (as will be seen later), A may be aware that the refusal is not the result of the call not having been heard. B will indicate that his attention has been gained by repeating the one ring to A, who will then give the code ring describing the class of train which he desires to send. The signification of this signal is "Is line clear for ——— train?" the blank referring to the class of train. The "Is line clear?" codes are made up of various combinations of three, four and five beats, and refer to all classes of trains from a stopping goods to an express passenger train, including light engines. There is an obvious necessity for thus describing at the outset the class of train for which permission to approach is required; firstly (as will be seen later), as the conditions under which trains may be



Block Instruments.

Out-Door Signals.

Diagrams Illustrating the Method of Block Signalling, showing the Block Instruments in three Adjacent Signal Boxes.

permitted to approach vary with the class of train, and secondly (even assuming the line to be clear), as there may be reasons which make it possible to dispose of one class of train but not another. To take an example, B might be asked to accept a goods train which it would be necessary for him to shunt for an express to pass. His refuge siding being, however, already occupied, and knowing that there would not be time for the goods train to get to C in front of the express, B would refuse the train, and A would then have to hold it back and shunt it at his own station.

If, however, B decides to allow the train to approach, he "accepts" it by repeating the number of beats given by A, and at the same time turns the indicator for the down line to "line clear." The indication of line clear will then be given on the corresponding instrument in A box. This indicator, as has been explained, can be moved by B only, and thus A has before him a visual indication of the permission which B has given to him for the train to enter the section A—B, while B has a similar reminder that such permission has been given by him to A. A having thus received permission, may lower his fixed signals as an indication to the driver that the block regulations have been complied with, and that the line is clear for the train to pass through the section.

Train Entering Section in Advance.

As soon as the train passes his box A will give two beats on the bell to B indicating "train entering section"; B will turn his indicator to "train on line," and both men will then have before them an indication that a train is actually occupying the section. While a train is in the section A is, of course, aware that no following train can be accepted upon the same line, and obviously, therefore, he must not offer any other train to B until B has intimated that the first one has arrived. When A has received the signal from B indicating that the train has arrived at the opposite end of the section, and has seen the block indicator restored to its normal or line blocked position, his responsibility in regard to that particular train has come to an end.

Before proceeding to describe the operations to be performed by B in respect of this train and the conditions to be complied with before B may give permission for it to approach him, let us assume that the train is still travelling from A to B, and consider what contingencies may arise while it is within the section, and how these are provided for in the block regulations.

Train Coming to a Stand in a Section.

In the first place, the train may come to a stand in the section. Experience has shown that there is a risk when trains are standing in a section, if not actually within the signalman's sight, that the signalman in advance may jump to the conclusion that the train has passed him. When once the block indicators are in consequence displaced from the train on line position the block protection for that train is destroyed. Hence it is necessary (unless means are provided whereby the train can itself control the block instruments or signals) for immediate protection, to be provided for the standing train, independently of the block telegraph. It does not very frequently happen that a stop within a block section is made for traffic purposes, as places at which stops are made regularly are usually block section posts. But if it happens that there is no block box at a regular stopping place, as, for example, at a passenger station, home and distant signals must be provided specially and these must be placed at danger for the protection of trains stopping at the station, being lowered again immediately the train has left the station.

But a stoppage within the section may result from engine failure or other mishap, and as no fixed signals are available to provide protection in such cases, the train-men are required to make immediate arrangements for one of their number, with detonators and hand signals, to go back a sufficient distance to enable them to stop a following train, should it find its way into the section by mistake. When the nature of the mishap is such that the opposite road is fouled, reliance must be placed on the promptitude of the train-men in going forward to stop a train approaching in the opposite direction, and many thrilling incidents are narrated of further accidents being narrowly averted by such action. The block regulations make partial provision for the latter emergency, for should the train not arrive at B box in about the usual time after passing A, the signalman at B is required to stop any train proceeding from B to A, and caution the driver to keep a sharp look out and to be prepared to stop if necessary in the section. If there happens to be a tunnel between A and B, there would be less possibility of the driver on the opposite line being able to stop before coming into contact with an obstruction, and therefore the signalman at B must in that case go further and detain the train in the opposite direction at his box, until he is satisfied that the delayed train has not blocked the opposite road.

Train Breaking Loose in a Section.

Another possible occurrence while the train is passing through the section is that it may break in two or more portions. To enable a signalman to know that the whole of a train has arrived at his box, the last vehicle of every train must carry a tail lamp both by day and by night, and unless the signalman can see the tail lamp he must assume that a portion of the train has been left behind in the section. The course to be followed when a train arrives with a tail lamp missing will be described when the procedure in signal box B is dealt with. So far as the train is concerned, however, one of two things will happen. If the train be a passenger train, the severance of the continuous brake connection will quickly bring both portions of the train to a stand, and the same conditions will apply as to the train brought to a stand in the section as described above. If, as more frequently happens, it is a goods train which breaks loose, the signalman in B box will know from the absence of the tail lamp, when the first portion passes him, that part of the train has been left behind, and will take steps accordingly. It will, however, still be incumbent on the guard to go back and protect the detached portion of his train.

Rear Portion of Train on a Rising Gradient Running Back.

But the break-away may occur on a rising gradient, and if the train be unbraked the rear portion will probably run back, and unless means are taken to prevent it, will destroy the space interval at the box in the rear by entering the section at the wrong end. To guard against this, points known as runaway catch-points are provided so as to throw off the line any vehicles which run back in the wrong direction. These points are usually held open by a spring or weight and are closed merely by the pressure of wheels passing in the proper direction, falling open again in readiness to intercept runaway vehicles immediately the last wheel of the train has passed through. The Board of Trade requires runaway catch-points to be provided on gradients of an inclination steeper than 1 in 260. The breaking-away of goods trains occurs most frequently when starting or when passing over a summit or change of gradient. Hence it is usual on inclines to provide catch-points a train's length below each home signal and below a summit and, if the incline be a long one, at intervals according to the circumstances, in addition. As a signalman is at liberty to send a train to stand at a starting signal while the section ahead is occupied, it is obvious that there should if possible be a runaway catch-point in any case in such a position that any runaway vehicles shall be intercepted before they can collide with a train standing at a starting signal. On the other hand, it is not desirable that shunting should take place over loose runaway catch-points, and thus, when the sections are short, and it is therefore necessary to place the catch-points further back than this, it becomes necessary to control the catch-points from a signal box. Under such circumstances a signalman would not be justified in permitting a following train to pass over the catch-points until the preceding train had cleared the section ahead. For, assuming that the controlled catch-points are the only ones in the section, he would otherwise have no assurance that a portion of the ascending train would not run back as far as the catch-points, thus colliding with any train which had been allowed to pass beyond them.

Giving Permission for a Train to Approach.

Consideration will now be given to the procedure to be followed by the signalman at B, towards whom the train is approaching, and to the conditions to be fulfilled by B before permission is given by him for the train to leave A. The average interval of space provided for in block signalling will, of course, vary in extent according to the length of the sections and other circumstances, but the standard block regulations contemplate a *minimum* space of a quarter of a mile between the tail of one train and the head of a following train. There are exceptions to this principle, but it will be seen that so far as strict block working is concerned, the maintenance of the quarter-mile space is the guiding idea of the regulations.

It will be remembered that in the example already given of the method of signalling, A, having gained the attention of B, gave a code ring by means of which he asked B whether the line was clear for the particular class of train he desired to send. Before B may accept the train by repeating the code and turning the indicator to line clear, he must satisfy himself that certain conditions are fulfilled. To begin with, he must be sure that the indicator is in its normal position, showing that there is no train actually in the section, in case the rule prohibiting a train being offered under such circumstances should perhaps have been disregarded by A.

The home signal for B is the first place at which B, when once he has accepted the train, will be able to stop it again, and therefore he must make sure that the line is clear for at least a quarter of a mile ahead of his home signal. If there is a facing junction at B it will be sufficient if there is a clear length of a quarter of a mile on any of the diverging routes, although not necessarily on the particular route on which the train is to run. The facing points must, however, be set for the direction in which the clearance is taken advantage of.

If it happens that the forward section is so short that it is less than a quarter of a mile from the home signal at B to the home signal for C, B must not accept the train unless he has received intimation from C that the previous train has cleared the section B–C. Similarly if, on account of fog or other circumstances, B cannot satisfy himself that there is the necessary clearance ahead of his home signal he should wait for the same intimation from C before accepting the train.

At junctions the train must not be accepted if permission has been given for a train to approach from any direction from which the route might be fouled by converging or crossing.

Having once given permission for the train to approach from A, signalman B must maintain all the conditions which were necessary before permission was given. All the points at B over which the train has to pass must be kept in such position that no movement on to the main line concerned can take place ; no permission must be given for a train to approach from a conflicting direction at a junction, and in short the space interval must be rigidly maintained until the train is safely past.

If, when B receives the "Is line clear ?" signal from A, any of the conditions enumerated are not fulfilled, he must refuse to allow the train to approach. This refusal is intimated to A by the bell code not being repeated by B and by the indicator, instead of being turned to line clear, being maintained in the normal position. A must then offer the train again at short intervals until such time as B is in a position to accept it.

Train Entering Section in the Rear.

Assuming that all the conditions referred to have been fulfilled, and that B has accepted the train, he will in due course receive two beats on the bell from A, indicating that the train has entered the section. B will then turn the indicator to train on line and will proceed to offer the train forward to C and the same procedure will be gone through again. It is sometimes necessary, when the sections are short, for the "Is line clear ?" signal to be sent to the box in advance before the train actually enters the section in the rear, in order that the signals may be lowered before they are seen by the driver of the approaching train.

Train out of Section.

In due course the train will arrive at or pass signal box B and when the signalman has satisfied himself by seeing the tail lamp that no portion of the train has been left behind in the section he will give three beats on the bell (two, pause, one) to A, indicating that the train has passed out of the section, at the same time restoring the block indicator to its normal position. The transactions between A and B in respect of that particular train are then complete. The train must not, however, be regarded as out of the section until the last vehicle has passed within the protection of the home signal.

Train an Unusually Long Time in Section.

If however the train does not reach B within reasonable time after entering the section at A, the signalman must assume that a mishap has taken place and must take steps to caution or stop any train going to the opposite direction, as already explained.

Train Passing Without Tail Lamp.

If, when the train arrives, it is found that the tail lamp is missing the signalman must assume that a portion of the train has been left behind in the section. He will probably not observe the absence of the tail lamp in time to stop the train himself, and therefore he must forward the prescribed bell signal "Train passed without tail lamp" to C who will take steps to stop the train. He must also give a similar signal to A, instead of giving "Train out of section" and must leave the block indicator in the train on line position. This will be an indication to A that the following train must be stopped and the driver advised of the circumstances, before being allowed to enter the section. As there would be a risk of the portion left behind having left the road and having possibly fouled the opposite main line, B must provide against this by stopping all trains proceeding towards A and cautioning the drivers. If it happens that there is a tunnel in the section or if there are runaway catch-points this risk would be increased, and B must in either of these cases stop trains from proceeding towards C until he has satisfied himself that the line is clear and A must prevent any following trains from leaving him in the direction of B.

The Blocking-Back Signal.

It has been explained that, under standard block working arrangements, the line is considered normally blocked and that no movement may take place without the direct permission of the signalman. Experience has shown, however, that there is a risk of signalmen overlooking vehicles standing on a main line and that they may in consequence, notwithstanding the presence of the obstruction, move the indicator from blocked to clear and so permit a train to approach. As a partial safeguard against this possibility, the blocking-back signal was introduced a few years ago, and the use of this signal is really a partial reversion to methods which were in use in the earlier days of block signalling, when the line was regarded as normally clear.

When a signalman requires to occupy a main line for a shunting operation, either from a siding or from another main line, he must first obtain the permission of the signalman in the rear, and the indicator for the line affected must be turned to train on line. Assuming that B wishes to occupy the down main line, there will thus be a visual indication in both A and B boxes of what is happening at B and this lessens by one degree the risk that there might otherwise be of B overlooking the shunted train. It is to be regretted that this departure from principle should be necessary, as it must tend to weaken the force of the "line blocked" indication, which should in theory afford all the protection necessary. With the adoption of means whereby trains standing on main lines can be automatically protected, the need for the blocking-back signal would disappear.

The blocking-back code is given in a different manner according to whether the obstruction is intended to take place within the protection of the home signal or outside the home signal. In practice, to employ the signal for the former purpose is found very inconvenient at busy places, and its use is therefore usually restricted to roadside stations and to certain level crossings. A movement outside the home signal must, however, in all cases be protected by the blocking-back signal being sent to the box in the rear. The effect of giving this signal from B back to A would be that A would not attempt to offer a train to B and, if the section were less than half a mile in length, A would himself refuse to accept a down train from the rear. This precaution is necessary where the section is a short one, in case the setting-back movement at B should extend to within the quarter-mile limit of the home signal for A when the requisite space interval at A would of course be destroyed. When the shunting movement is complete and the main line is again clear, the bell signal "Obstruction removed" must be sent by B and the indicator must be restored to its normal position.

Other Bell Codes and Regulations.

It does not come within the scope of this work to deal with every phase of block working or with the whole of the regulations and codes in connection. There are about 40 separate codes and as many regulations, many of the latter having several clauses. It is, therefore, obvious that to deal fully with the purposes and uses of the whole of the codes would be to go beyond the enunciation of first principles. Mention should, however, be made briefly of some of the more important codes which are used in cases of exceptional occurrence.

It sometimes happens that, after permission has been obtained for a train to enter the section, it is found that it will, after all, not go forward. It may, for instance, have to be shunted to make way for a more important train. The signalman will then cancel the train by sending eight beats to the box in advance, and the man there will acknowledge the signal and restore the block indicator to its normal position.

When a train is assisted by a bank engine in the rear, it is necessary that the signalman ahead shall be aware of the fact, so that he may not give "out of section" for the train until the bank engine has arrived. To give him this information the code signifying "bank engine in rear of train" is sent by the signalman in the rear immediately after giving "train entering section," and this special signal is acknowledged and noted by the man in advance.

It will be remembered that the earliest uniform bell code was six beats indicating "obstruction, danger." This signal is given immediately in each direction in the event of any mishap occurring by which the main line is fouled. The block indicators for the obstructed lines are also placed at train on line, and by these means additional security is afforded against a further mishap.

It is part of the duty of signalmen to watch each train as it passes them to see that it is travelling safely, and if a signalman observes that anything is wrong, such as an open carriage door, a passenger making signs of distress or a vehicle on fire, he must immediately forward the code meaning, "stop and examine train," to the box ahead, and the signalman there will place his signals at danger to stop the train.

Codes are also provided to indicate that a train is divided, that a train is running away, either in the right or wrong direction, and elaborate instructions are drawn up showing the steps to be taken under various circumstances by signalmen receiving such signals.

When the traffic on a given section of line is lighter than usual, as at nights and on Sundays, it is found possible to work it with longer block sections. Some of the signal boxes are then closed, and by means of a switch the block instruments are joined through between the adjacent boxes on either hand. This is known as "switching out" a block box and before the box is closed a code has to be exchanged with the boxes on either hand, while another code is exchanged when the box is again opened. During the time a signal box is closed the outdoor signals are left in the all-right position.

Block Signalling at Level Crossings.

When a signal box controlling a roadway level crossing is a block box, the ordinary regulations apply in respect of the railway traffic. Ordinary vehicular traffic over the crossing is not regarded as forming an obstruction from a block working point of view and the crossing may continue to be used after permission has been given for a train to approach. The gates must however be closed across the roadway and the signals lowered in time to avoid checking the approaching train. The passage of traction engines, loads of timber and other exceptionally heavy traffic over the crossing, however, involves risk to the railway traffic, and hence trains must not be accepted while such traffic is using the crossing. Special signalling arrangements have to be made when a tramway operated by power crosses a railway on the level.

Circumstances Under Which the Space-Interval Principle is Relaxed.

The strict principle of the space-interval is usually relaxed in connection with movements in which non-passenger trains alone are concerned, and also to a very much smaller extent in connection with passenger trains.

Such modification applies chiefly to the conditions which must be complied with before permission for a train to approach may be given. The principle is also modified to the extent of allowing more than one train in the same section at the same time. The latter modification is known as permissive block working and its use is usually restricted to lines used exclusively for non-passenger traffic. Permissive working is however adopted to a very limited extent, under special circumstances, on passenger lines. The plan frequently adopted in the United States where the block system is in operation of suspending it for freight train working is never adopted in this country except when a line is closed for passenger working.

The Warning Arrangement.

As a rule, when it is necessary for the usual conditions under which a train is allowed to approach a section post to be relaxed, the train is signalled under what is known as the "warning arrangement." The train is then allowed to enter the section, although the conditions as to a clear road ahead of the home signal for the box in advance are not assured. A train which is to be allowed to enter a section under this arrangement is stopped by the signalman at the entrance to the section and cautioned by the use of the words "Section clear but station (or junction) blocked." The driver is thus made aware of the necessity for using extreme care in approaching the signals for the box ahead. The employment of this method of working in connection with passenger trains is very jealously restricted by the railway companies to cases where circumstances render it essential for the satisfactory dispatch of the traffic, and, so far as passenger train working is concerned, it may be used only where specially authorised by the management. For goods train working, however, it is frequently employed, when trains are allowed to approach a blocked yard or junction ; and goods trains are sometimes allowed to approach under such circumstances without being warned.

As an example in which the use of the warning arrangement for passenger train working is unavoidable, the case may be quoted of a junction station where the next block boxes on the main and branch lines are several miles away. The branch and main line trains have to connect at the junction, and if strict block working were enforced one of the trains would have to be kept back at the box in the rear until the other had arrived at the station, and possibly had also been shunted. A long wait would then ensue while the second train was travelling towards the junction from the distant box. Under the warning arrangement, however, one of the trains is stopped and cautioned at the distant box and they can then approach the junction simultaneously, the necessary protection being given by the junction signals.

Like the blocking-back signal, the warning arrangement is anomalous and its necessity is to be regretted, both as constituting a breach of the strict space-interval principle and as implying that in the absence of the warning, drivers will exercise less care in stopping at signals. Both signals are a concession to human fallibility, and as such must be regarded as necessary pending the adoption of further mechanical checks against mistake.

The method of working the warning arrangement is as follows:— The signalman who desires to accept a train under this safeguard (when authorised), instead of repeating the "Is line clear?" code, returns 13 beats, meaning "section clear, but station (or junction) blocked," turning the indicator to "line clear" as usual. The signalman receiving this signal acknowledges it by repetition and stops and cautions the train as already described. It is usual when this signal is offered from the box ahead to decline it at first, so that should the circumstances alter before the train is ready to pass into the section, there may be an opportunity of its being accepted unconditionally.

It should be added that the warning arrangement is not usually employed during foggy weather, even in connection with goods trains, nor in fog are the strict block working arrangements relaxed for goods train working.

Permissive Block Working.

Lines which are used exclusively for non-passenger traffic are often worked on the permissive block system. Under this method of working, trains are allowed to enter a section when the section is already occupied. Each train is stopped at the entrance to the section and the driver is informed how many trains are in the section ahead of him, so that he may be prepared to stop when necessary. The method of signalling is similar to that used in absolute block working, except that a train may be offered forward while the block indicator still shows "Train on line." The mode of accepting a train under such circumstances is also necessarily different when the section is already occupied. Some permissive block instruments are provided with an indicator which is turned by the signalman and which shows the number of trains in the section.

Some form of permissive block working is also frequently adopted for passenger working at large stations where absolute block working is necessarily suspended within station or yard limits. Such arrangements, known as "Station yard working arrangements," vary very greatly on different railways and according to local conditions. The suspension of absolute block working upon passenger lines, even in a station yard, can only take place with the special authority of the Board of Trade.

CHAPTER VI.

THE WORKING OF SINGLE LINES.

Introduction.

On a double line of railway it is an inviolable rule in British practice that, except in case of emergency, each line shall be used exclusively for traffic in one direction. When, on account of the blocking of one road by reason of mishap or of the necessity for carrying out repairs or relaying, it becomes necessary temporarily to work the traffic in both directions over the other road, the most stringent precautions are taken to avoid two trains meeting on the single line. All considerations of dispatch give way to the requirements of absolute safety. And as the operation necessarily entails very considerable delay to traffic, every effort is made to keep the period of single-line working within the shortest possible limits. The utilisation of one of the lines of a double-line railway for the traffic in both directions is, in fact, regarded as a wholly abnormal condition of working; the ordinary signalling arrangements are to a certain extent in abeyance and the special methods employed to ensure safety are outside the scope of a normal signalling system. Hence the standard double line block regulations hardly contemplate the possibility of the space interval being destroyed by a train entering the section from the wrong direction. In the case of rising gradients this might happen accidentally by the running back of a portion of a train, and this is guarded against, as has already been seen, by the provision of runaway catch-points. In ordinary working it happens only in station yards, where setting back in the wrong direction is sometimes permitted for limited distances and is then provided for by special regulations and special signalling.

There is, however, in this country a considerable mileage of railway consisting of a single line and on such lines provision must be made for working the traffic in both directions with absolute safety and yet without unduly neglecting the requirements of expeditious working.

On single lines the necessity exists for maintaining the space interval longitudinally, in respect of following movements and laterally, in respect of converging and crossing movements, exactly as on double lines. In addition, however, it is necessary to guard against what the Americans picturesquely describe as "butting" collisions, by providing that the space interval shall not be destroyed by an opposing movement.

The Crossing-Order System.

The method of single-line working known as the crossing-order system, still used to a very large extent in the United States, was employed in connection with many single lines in this country prior to the passing of the Railway Regulation Act of 1889. Under the crossing-order system, when it became necessary for trains to cross one another at a point other than that appointed for them in the time table, telegraphic instructions were sent from some central point, and the receipt of such instructions by the train-men and station staffs formed the necessary authority for the regular crossing place to be changed. In the absence of such authority the train-men were required to satisfy themselves, at each crossing place, that the appointed train or trains from the opposite direction had arrived or passed before they entered on the single line. As a rule the use of the crossing-order system in this country was supplemented by the block telegraph.

In the United States the official by whom the crossing of trains on single lines is regulated is known as the train dispatcher and his functions loom very large in American railway working. The system of train despatching there has indeed been developed into a fine art and most elaborate instructions in regard to the working of the system are in force. The functions of the train dispatcher in America are not, however, confined to the control of working on single lines, as were those of the corresponding official in England when the crossing-order system was in operation here.

There are obvious weak points in the crossing-order system for single line working. Errors may arise in the transmission or interpretation of the crossing orders ; the train-men may neglect or disobey an order, or the dispatcher himself may make a mistake and issue contradictory orders. The addition of block working, of course, formed a valuable check on the crossing orders, but the consequences of a collision on a single line are so serious that no system that does not provide with certainty for a perfect understanding between the signalman at one end of a single line section and the signalman at the opposite end and between both and the train-men can be held to satisfy the high standard of safety adopted in this country.

The Three Authorised Systems.

Accordingly, when the Railway Regulation Act of 1889 gave the Board of Trade power to order the adoption of the block system generally, it included in the orders a requirement that single lines should be worked on one of three systems, recognised as affording full security. The three systems are :—(*a*) the ordinary train staff system, (*b*) the train staff and ticket system, and (*c*) the electric staff or tablet system. Each of the three systems is based on the simple law that the same object cannot be in two places at the same time ; and as the possession of that object is the sole authority for a driver to enter on the section of single line to which it applies, it follows that not more than one train can be on the single line at the same time. The first and third of the authorised systems afford security against trains overtaking as well as against their meeting ; the second does not provide against overtaking and has therefore to be supplemented by the block telegraph system.

Before describing the working of the three systems, it should be explained that single lines may consist either of a separate length of single line, without any intermediate crossing place, or of a series of lengths of single line separated from one another by short lengths of double line, forming crossing loops. The important distinction from a working point of view is as to whether a section of single line stands by itself, as in the case of a short branch leading from a trunk line, or whether it forms part of a through route.

The Ordinary Train Staff System.

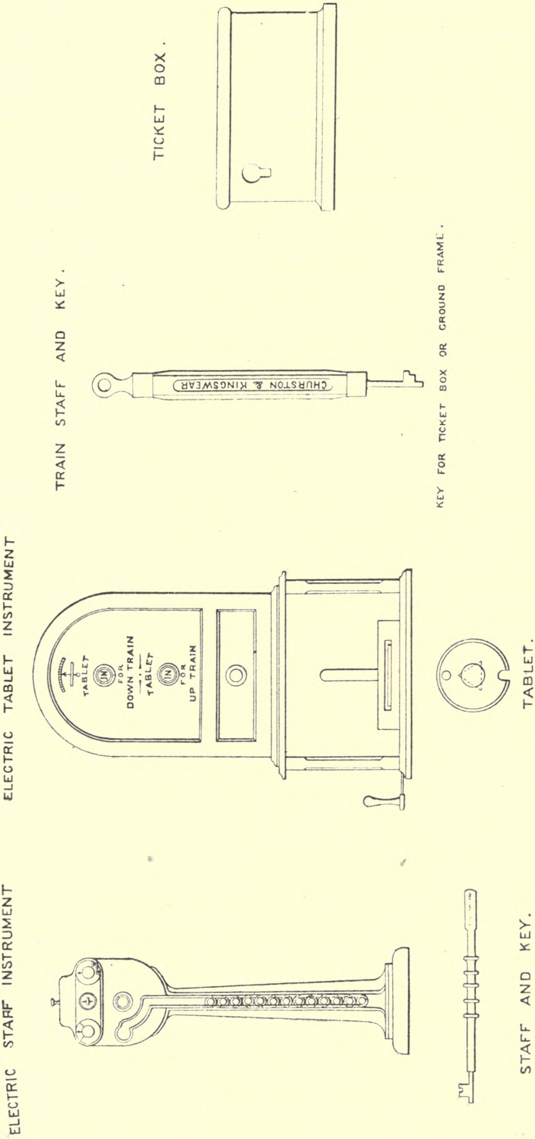
The ordinary train staff system can be used only for working lengths of single line over which a train works backwards and forwards alternately, and in practice this happens chiefly on short branch lines with a shuttle service. A wooden staff about two feet long and lettered with the name of the section is provided, and the possession of this staff is the sole authority to a driver to enter on the single line. As the staff can be in the possession of only one driver at the same time, it follows that only one engine can be on the single line to which it applies at the same time.

Two engines coupled together can, however, be allowed on the line, provided that they continue coupled during the whole time they remain on the single line. This is obviously an essential condition, and the system of working is referred to as that by "ordinary train staff with only one engine in steam or two engines coupled together."

The Train Staff and Ticket System.

If it is necessary to allow more than one train to pass over the single line section in the same direction consecutively, the train staff alone is not suitable, as means would have to be provided to bring back the staff from the opposite end for the use of the second train. To meet this difficulty the staff and ticket system is sometimes used. At the staff stations at either end of a section a series of specially printed coloured tickets are provided and are kept in a box locked with a spring lock. If more than one train has to pass through the section in the same direction before a train is to pass in the opposite direction, the driver of each of such trains except the last is merely shown the staff and is given a ticket which is his authority to travel through the section on the strength of having seen the staff. The tickets give authority for a movement in one direction only and are, therefore, of no use for an opposite movement. The last train of the series takes the staff, and when it is deposited at the other end of the section it is available for an opposite movement and can be used if required in connection with the tickets kept at that end, which are, of course, distinctively lettered.

The boxes in which the tickets are kept are unlocked by a key which forms part of the staff itself, and the staff cannot be withdrawn from the lock until the box has been closed and fastened. Provided the man in charge does not take out more than one ticket at a time, and provided the enginemen insist on seeing the staff when a ticket is presented to them (which they are strictly enjoined to do), the system is perfectly safe. It is not, however, an ideal method of working, especially when the traffic is irregular, as, should the staff be sent away by mistake when another train has to pass through the section in the same direction, the latter train has to be held up until the staff can be brought back by messenger or until a train movement in the opposite direction takes place. When a train has entered the section with a ticket, there is nothing so far as the staff system working is concerned to prevent a train following immediately with another ticket or with the staff itself. Hence,



Apparatus Used in connection with Single-Line Working.

in order to maintain the space interval for following trains, ordinary block working has to be established. In such cases there is frequently only one block indicator for the single line section, and this is capable of being moved by the signalman at either end. A better plan is, however, to provide two indicators, as on a double line, and to interlock electrically the two needles so that when a train is signalled in one direction it is impossible to move the needle applying to the opposite direction. The signalman thus has not only an indication before him of the direction in which the movement is taking place, but also is prevented from initiating an opposite movement.

When there are several adjacent sections of single line worked by train staff, it is important not only that each staff should be clearly lettered with the name of the section to which it applies, but that the staffs themselves should be of different shapes and colours so that there may be no risk of a staff being used for the wrong section. The tickets should be of the same form as the section of the staff to which they belong and should be similarly coloured. In order still further to guard against mistakes, the names of the sections and the colours and shapes of the corresponding train staffs and tickets should be clearly set out in the working time table.

The Electric Train Staff and Tablet Systems.

These two systems are identical in principle. The tablet is a disc of metal about six inches in diameter, and the electric staff is a metal staff of about the same size as an ordinary staff. The electric tablet system was the first of the two to be introduced, and the principles of that system were afterwards adapted to an arrangement whereby the more familiar staff was employed in place of the tablet.

To facilitate the handling of the tablets and also to avoid the risk of their being mislaid, they are placed in a leathern pouch before being handed to the drivers. The pouch has a large loop-shaped handle which enables the tablets to be exchanged while a train is travelling, and by means of which the pouch is hung up in the engine cab. The electric staff, being a more tangible object, is usually handled directly. Various kinds of apparatus have, however, been introduced to enable the staffs to be exchanged at speed. The tablets and the staffs are, like the ordinary train staffs, lettered with the name of the section to which they apply.

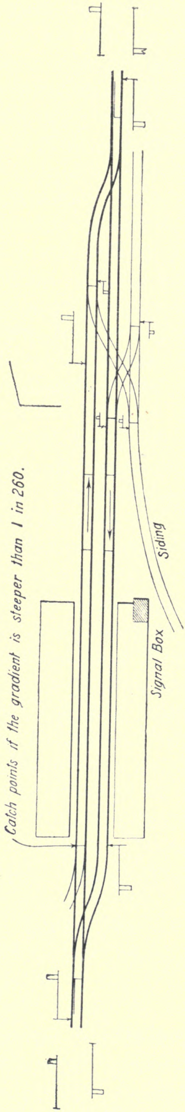
The methods of working are the same, whether tablets or electric staffs are employed, and the following description must be understood to apply to both systems. Taking a single-line section A—B, there is an instrument at A and a similar one at B, and in the two instruments together there is a certain number, say 20, staffs. The two instruments are electrically interlocked with one another in such a manner that when a staff is withdrawn from either instrument, a second one cannot be withdrawn either from the same instrument or from that at the opposite end of the section until the staff has been replaced in either of the two instruments. Thus if a staff has been withdrawn for a train which is to proceed from A to B, no second staff for that section can be withdrawn until either the train has arrived at B and the staff has been placed in the instrument there, or (should the train not go forward as intended) until the staff has been replaced in the instrument at A. It will, therefore, be clearly seen that, as a driver may not enter on to the single line without a staff, the system affords protection against trains meeting in the section, and also against trains overtaking. It is, in fact, a block system, and one, moreover, which is more efficient than the block system ordinarily employed on double lines, in that authority to proceed is given by the handing to the driver of a tangible object, and that it is mechanically impossible for such authority to be given without the consent of the signalman at the remote end of the section.

The standard block regulations and codes are adapted to the electric staff and tablet systems, and vary only so far as is rendered necessary by the fact of the line being a single instead of a double one. The signalman who accepts an "Is line clear?" signal must, of course, manipulate his instrument so as to give permission for a staff or tablet to be withdrawn at the other end of the section. Arrangements are made whereby, should the unequal flow of traffic in one direction cause the staffs to accumulate at one end of the section, the number may be equalised by the lineman, who under stringent precautions, unlocks the instrument and transfers the necessary number of staffs to the instrument at the opposite end of the section.

These systems enable single lines to be used to their fullest possible capacity, and at the same time give perfect security. For, except in the remote event of a driver entering a section without a staff or tablet, the risk of trains meeting or overtaking one another is entirely eliminated.

Signalling on Single Lines.

At all places on single lines which are staff or tablet stations—that is, at each place at the end of a section to which a staff is



Signalling at a Crossing Station on a Single Line.

allotted—it is obvious that (so far as the staff working is concerned) there may be more than one train present or approaching at the same time. Hence all such places must have a full equipment of signals. The signals must be provided according to the arrangement of the yard in accordance with exactly the same principles as apply on an ordinary double line. This is the case whether the single line is worked on either of the three systems, with the exception that signals are unnecessary at the terminal end of a single line branch on which only one engine in steam is allowed at a time and which is, therefore, worked by an ordinary train staff without tickets. Although such a station is actually a staff station, no second engine can possibly approach when one is already there and, therefore, the necessity for signals disappears. Protection for the points is afforded in the manner to be described later on.

The conditions under which trains may be allowed to approach a block or staff post on a single line are also the same as those applying on double lines, with one exception. Usually, but not invariably, there is a passing loop at a staff station. As it is necessary for two trains which have to cross one another to approach the loop simultaneously, it is clearly impossible to provide for the usual quarter-mile clearance. Trains are therefore allowed to approach provided the line is clear up to the signal at the end of the loop line into which they have to run. The signals at the entrance to the loop are kept at danger, and the train arriving first is admitted, and when it has come to a stand in the loop line and is clear of the opposite loop, the train from the opposite direction is allowed to enter. This arrangement will be clear from the accompanying diagram. If there is not a crossing loop at a staff post two trains are not allowed to approach simultaneously when strict block working is in force.

Junctions between single lines or between a double line and single line are usually formed as double-line junctions, and the ordinary signalling arrangements apply both in respect of block working and in the arrangement of the outdoor signals.

The Locking of Intermediate Siding Connections.

It has been explained that, at all places on single lines which are staff stations, there must necessarily be a complete equipment of running signals. When a connection leading to a siding occurs at an intermediate point within a staff section the conditions are different. A train, within the section, which is in possession of the staff is master of the situation and no other train can approach it from either direction. Hence a train while shunting at an intermediate siding is perfectly safe and no signals are required to protect the operation. There is, however, still the necessity to ensure that, when the siding is not in use, the points (which, it must be remembered, are always facing points in one direction) are lying securely in position for the main line and that the siding catch points are protecting the main line from vehicles which might be pushed along the siding. This security is very simply obtained by locking the lever working the siding points by means of the train staff. For this purpose the train staff (if there be but one staff) or each staff, in the case of the electric staff system, is fitted with a key. In the case of the tablet system the tablet itself is placed in a slide in the lever frame and there acts as a key. Until the staff-key or tablet is thus inserted in the lever frame the lever cannot be moved and when the lever has once been moved for the purpose of working the points the staff or tablet cannot be withdrawn. Thus the possession by a driver of the staff or tablet forms a mechanical assurance that the points of the intermediate siding are in the proper position for the main line. In practice the locking takes place in connection with the lever working the facing point lock. On the other hand as a train after completing its work at the siding must necessarily be accompanied by the train staff or tablet there is no risk of the train-men inadvertently going away and leaving the points in the wrong position.

It is obvious that this arrangement cannot be employed at junctions where a train may have to leave the direct route altogether nor, under ordinary circumstances, at points at which trains have to be shunted for others to pass, as under such circumstances after the train had been placed clear of the main line, the staff would have to be taken by hand to the nearest staff station. It should be added, however, that supplementary apparatus has been devised whereby the shunting of trains on single lines at other than staff stations can be effected. The use of such apparatus raises questions of method and equipment which it is hardly necessary to enter into in discussing first principles.

On single lines worked by the staff and ticket system, intermediate siding points if locked by the staff are perfectly safe and no signals are actually necessary, but, of course, the siding could not then be used by a train carrying a ticket. Hence it is usual when this system is employed to equip an intermediate siding with signals in both directions, instead

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of locking them by the staff, so that it may be used by a train with a ticket, and that there may then be suitable protection should a following train find its way into the section by mistake. If it is desired to shunt trains for others to pass at such places, they should, in addition, be equipped as block telegraph posts. The expense involved in thus equipping intermediate sidings with signals, and the measure of risk involved in the fact of such signals not being in regular use for each train, are among the strongest reasons in favour of equipping a single line with the electric staff or tablet system, thus enabling signals at intermediate sidings to be dispensed with entirely.

The circumstances under which signals can be dispensed with on single lines may be thus summarised. Signals are not required at any intermediate siding within a section worked by ordinary staff, electric staff or tablet when the points are locked by the staff or tablet. If a staff and tickets are in use, signals are necessary unless it can be arranged that trains requiring to call at the siding shall always carry the staff, and that the staff unlocks the points. Signals are not necessary at the terminal stations of lines on which only one engine in steam, or two coupled together are allowed at a time. If, however, more than one engine is allowed on the line, signals must be provided whether the working is by the ordinary train staff and ticket or electric staff or tablet system.

Under all other circumstances than those enumerated a full equipment of signals is necessary.

Gradients on Single Lines.

On a single line it is obviously impossible to guard against the risk of vehicles running back on inclines, by providing runaway catch-points, as such points would derail traffic proceeding in the proper direction. The possibility explained in Chapter 5 of trains breaking away after having come to a stand at a home signal or of breaking away while surmounting a brow or upon a change of gradient during the passage through a section cannot therefore be met as on double lines. If a crossing loop occurs on a gradient the risk of vehicles within the loop running back on to the single line is prevented by providing a catch-point worked from the signal box just clear of the converging point of the two loops. As the risk of a break-away is the greatest at places at which trains have necessarily to be brought to a stand, the Board of Trade does not allow a station or a siding connection on a single line where the gradient is steeper than 1 in 260, unless certain precautions are taken against the risk of vehicles running back indefinitely on the single line.

If it is necessary to erect a station on such a gradient, it must be formed as a double line station, catch-points being provided at the lower end of the loop as explained above. If circumstances render this arrangement impossible, a loop line with a catch-point must be provided lower down the incline. In this case the facing points would have to remain set for the ascending loop line, so that in the event of vehicles running back from the station they would be diverted into this loop and become derailed at the catch-points at the lower end. The loop would, of course, have to be properly signalled. It should be added that this alternative method is very seldom resorted to in the case of stations on gradients.

In the case of a siding connection on a gradient, there must either be a loop, as in the case of a station, in order that a train having to call at the siding may be left standing on the loop and within the catch-points when the engine is detached, or failing this, either of two other methods must be adopted. There must be sufficient room inside the sidings for the whole train to be placed there, clear of the main line, before the engine is detached for shunting operations, or the company must undertake to have an engine at the lower end of the trains calling at the siding. In most cases, the latter would be found an inconvenient method.

The chapter on Government regulation may here be anticipated so far as to explain that the Board of Trade regulations in respect of the arrangement and working of stations and siding connections on inclines apply only to such cases as have been brought into use since the requirement was first laid down. The Board of Trade has no power to order these arrangements at existing places which it may not have had occasion to inspect since then.

In concluding this chapter it may be mentioned that the methods adopted in the working of single lines offer a wide field for investigation. Many most interesting variations, for example, in the electric staff and tablet systems have been introduced to meet various contingencies. Some of these are in use in this country, while others are adapted to the conditions prevailing abroad where the standard of safety is less exacting than with us.

CHAPTER VII.

GOVERNMENT CONTROL—LEGISLATION, 1839-1878.

INTRODUCTION.

The signalling arrangements on Railways in the United Kingdom are to a certain extent subject to Government control exercised through the Board of Trade. This control extends, in the first place, to the signalling equipment, which has to be provided before a railway may be used for public passenger traffic, and to a less extent to the methods of working which have to be employed in the actual operation of the line. Considerable misconception exists, even among those who are concerned in railway working, as to the exact scope of the powers possessed by the Board of Trade in these respects, and particularly as to the sources from whence its powers are derived. The actual jurisdiction of the Board of Trade in respect of the operation of existing railways is, in fact, much more limited than is generally supposed. On the other hand the prestige of a Government department to which is entrusted the care of the public interests in respect of safety on railways is necessarily very great, and thus the moral authority of the Board of Trade adds considerable weight to its purely legal powers. And, when necessary in the public interest, the Board of Trade does not hesitate to exercise pressure, behind which there is little force beyond the merely moral force of public opinion. Another factor in the situation arises from the circumstance that the legislative requirements in regard to safety on railways are not always set out in the Acts of Parliament themselves, but are to a very large extent embodied in Orders made by the Board of Trade by virtue of powers delegated to them by the various Acts. The sections authorising these Orders are, as a rule, fairly comprehensive in their wording, and it would thus appear quite possible for the Board of Trade to issue fresh or amended

Orders under its existing powers should the necessity arise. Thus without any fresh legislation, there is at the disposal of the Board of Trade a certain reserve of power, and this naturally adds weight to its authority.

In order to make clear the nature of the authority exercised by the Board of Trade in respect of the safe working of railways, a brief account will now be given of the legislation on the subject and of the corresponding development of Government control. In doing so mention will be made in passing of some requirements in which the signalling arrangements are not actually concerned. These will be included with a view of setting out the whole of the matters in regard to which the Government have power to dictate in respect of the equipment or working of railways in this country.

It will be seen that the powers in respect of the equipment of a new railway must be distinguished from these in respect of the actual working of an existing railway; and in order to make this distinction a clear one the legislation coming under these two heads will be dealt with separately. It will be found further that the year 1889 marks an epoch in railway safety legislation and therefore the earlier period from the inception of railways up to but excluding 1889 will be disposed of first. It should also be understood that the private Acts of Parliament authorising the construction of the various railways have sometimes included special provisions for safety in the equipment or working of the railway; these provisions may have applied to the proposed railway as a whole or to particular portions. This was usually the case in early railway legislation when the whole of the requirements for public protection were repeated in each special Act. Subsequently the requirements common to all railways were embodied in general railways clauses Acts, the provisions of which are now embodied in their entirety in the private Acts. Hence practically all the requirements in respect of the safe working of railways are now to be found in the general legislation on the subject.

Early Legislation as to Railway Working.

The railway regulation legislation of the earlier period dealt to a very large extent with the working of the level crossings of public roadways, and approached the case from the point of view of the safety of the road user rather than from that of the railway passenger. One of the first general Acts was the Railway Level Crossings Act, 1839, which made it necessary for railway companies to fix gates at the level crossings of public roads and to provide a suitable person to attend to them. The Railway Regulation Act of 1842, repeats the provisions in regard to level crossing gates and gate-keepers, and provides also that the gates shall be so constructed as to fence in the railway at both ends of the roadway, and that the gates shall remain closed across the roadway when not actually required to be opened for roadway traffic. This provision for the normal position of the gates is contrary to the enactment on the subject in many earlier private Acts, which it therefore expressly reversed. The Board of Trade has, however, power to reverse the arrangement in any given case if it thinks fit, but this has seldom been done, and, therefore, in most cases the legal normal position of level crossing gates is across the highway. Thus the public have no legal ground of complaint if they are kept waiting while the gates are opened for them to pass through. By this Act, also, the railway companies must provide and maintain fences alongside the railway. By the Railway Regulation Acts of 1840 and 1842, the Board of Trade was first empowered to call for reports of accidents occurring on railways. By the 1840 Act, too, the Board of Trade was empowered to appoint Inspectors of Railways with power to make inspections of railways at any time, but whose chief functions were at first concerned with the opening of new railways, and will be referred to later. The provisions in regard to the inspection of railways were amended by an Act of 1871.

The Railways Clauses Act of 1845 gathered up the general legislation in regard to new railways with a view of its being embodied in future private Acts. Hence the provisions of this Act apply only to railways authorised after its passing unless they had already been contained in earlier special or general Acts.

The provisions of the earlier Acts in regard to the equipment and working of level crossings generally are repeated and amplified, and a somewhat curious enactment is made in respect of level crossings of turnpike roads adjacent to stations. In such cases the speed of trains passing over the crossing must be reduced to four miles an hour, and the Board of Trade is empowered to make regulations for the working of the crossing. This Act also gives the Board of Trade power, on the representation of the local authority, to require the erection of screens between railways and adjacent highways.

Another Railways Clauses Act was passed in 1863, and its provisions are additional to those contained in the earlier Clauses Act of 1845, and apply, therefore, to railways authorised since 1863 only, except where such provisions had previously been included in private Acts. By this Act further powers are given to the Board of Trade in respect of the working of level crossings. A lodge for the gate-keeper must be provided and the arrangements must be such that trains shall not stand on or shunt over the level crossing. The railway company may also subsequently be required by the Board of Trade to erect a bridge in place of the level crossing should the Board consider this necessary for the public safety. These additional provisions had, no doubt, been included also in many private Acts passed between the passing of the earlier Clauses Act of 1845 and that of 1863.

The next Act to be noticed is the Railway Regulation Act of 1868, which contains the earliest provision for the safety of passengers on existing railways. By this Act means of communication have to be provided between passengers and the company's servants in charge of the train, on all trains running 20 miles without stopping. The apparatus employed has to be approved by the Board of Trade.

The Railway Regulation Act of 1871 increased the powers of the Board of Trade in regard to the inspection of existing railways. The Board may appoint inspectors to inspect any railway and to inquire into the cause of accidents and to make a report thereon which must afterwards be published. The Board of Trade may hold such inquiry in any manner it thinks fit, and, if necessary, it may cause a formal investigation to be held, in which case the court of inquiry has the powers of a court of summary jurisdiction and the witnesses are examined on oath. A less formal form of inquiry is, however, usually adopted.

By this Act the definition of the accidents to be reported is extended, and the Board of Trade is given power to require practically any mishap on a railway to be reported, whether the mishap affects the trains, the works, passengers, the general public, or the railway servants. The Board of Trade has accordingly issued orders from time to time specifying the various kinds of mishap which it requires to be reported.

It has been mentioned in an earlier chapter that by the year 1870 considerable progress had been made with the introduction of interlocking and signalling, and of the block telegraph system. With a view of ascertaining the progress which was being made in these directions, and possibly also with the idea of exercising pressure on the less progressive railway companies, the Railway

Regulation Act of 1873 required returns to be made to the Board of Trade showing to what extent the railways were equipped with signalling and interlocking, and the mileage worked on the block system. Particulars had also to be given of the methods employed in working the single lines on each company's system.

The Railway Returns Act of 1878 requires similar returns in respect of the continuous brakes in use and the mileage of passenger trains run with and without continuous brakes and the failures which have occurred in the working of the brakes.

EARLY LEGISLATION AS TO THE EQUIPMENT OF NEW RAILWAYS.

Turning now to the legislation of the earlier period affecting the equipment of new railways, we shall find that the powers of the Board of Trade were much more ample in this respect than in respect of the working of railways already open for traffic. It will be remembered that the Act of 1840 empowered the Board of Trade to appoint inspectors of railways. By the Act of 1842 a railway company is required to give one month's notice of its intention to open a new railway for passenger traffic, and a second notice 10 days before the new railway will be ready for traffic. The Board of Trade is thereupon to cause the new line to be inspected, and if the inspector reports that the line is not in a safe condition to be brought into use, the Board may postpone the opening from month to month until the requirements deemed necessary for safety have been met. The Act of 1842 referred in this connection to "any new railway or portion of a railway," and it was not quite clear whether in these expressions was included any slight alteration or addition to an existing railway. Apparently, in the earlier days of railways, it was not the invariable practice to submit minor alterations or additions for inspection in all cases.

The Railway Regulation Act of 1871, which has already been referred to, made this point quite clear by stating definitely that the provisions of the earlier Acts, in regard to the opening of new railways, are to extend to any additional line, any deviation line, station, junction or crossing on the level of or connected with a line on which passengers are conveyed. Thus since the year 1871 all alterations, involving the interference with any existing passenger line, by way of additional or altered connections or otherwise, as well as new stations and new lines of railway, have had to be submitted to and passed by the Board of Trade before their use has been sanctioned. As the original procedure of the one month and ten days' notices, with an inspection before opening, would be unnecessarily cumbersome in the case of alterations and additions to existing railways, the Board of Trade is empowered by the 1871 Act to dispense with the notices in the case of such smaller works. Except, therefore, in the case of new railways, or parts of railways, the Board of Trade, on the application of the companies, usually gives provisional sanction for the work to be brought into use, on the understanding that an inspection will be made at the earliest subsequent opportunity, and that any requirements that the inspecting officer may make will be carried out.

Now it will at once be seen that the legislation referred to in respect of the bringing into use of new and altered railway works gave the Board of Trade practically unlimited powers in respect of their equipment with signalling and other safety appliances.

Indirectly also the department thereby obtained power to regulate the actual working of the railway when opened, inasmuch as if they consider it necessary, the inspecting officers can make the granting of their certificates contingent on an undertaking being given by the company to adopt any particular mode of working at any given place, or indeed, generally over the whole of the new line. Apart, however, from such undertaking by a railway company, it does not appear that the Board of Trade has any power to regulate the working of a railway or to compel the use of any apparatus, except as such regulation is expressly provided for by Act of Parliament. The Regulation of Railways Act of 1889 (which will be dealt with later) extended this power of regulation very considerably, but prior to that year the powers of the Board of Trade in respect of the working of railways, as distinguished from their equipment, was confined to the working of level crossings, passenger communication, and the other small matters which have been mentioned. Indeed, even since the passing of the Act of 1889 and subsequent Acts, the control of the Board of Trade in respect of the working of railways is dependent quite as much on the good will of the companies and their desire to provide for the safety of the public and their servants, as on any legislative sanction.

The Board of Trade Requirements.

In the earlier days of inspections of new lines by the Board of Trade, the companies were informed in each case beforehand what provisions for safety the inspecting officer would expect to be provided in readiness for his inspection. Subsequently these requirements were embodied in a general memorandum, which is revised from time to time and issued to the railway companies, as indicating the provisions for safety which the inspecting officers will expect to be made in connection with any new works which are submitted for inspection. The memorandum also gives particulars of the plans and other documents which must be furnished by a company in connection with works submitted for inspection. These documents include the fullest details of the works, permanent way and signalling, and enable the inspecting officer to know exactly the nature of the works submitted before he actually makes the inspection. When the inspection takes place a thorough examination of the whole of the work is made ; special attention is given to the signalling arrangements, and the interlocking of the lever frames is tested throughout.

The requirements of the Board of Trade in respect of the equipment of new railways have naturally expanded with the development of the railway system and with the evolution of safety appliances. Generally speaking, the memoranda of requirements, as they have been issued from time to time, have represented the best standard practice then adopted on the leading railways. Although, as has been pointed out, the Board of Trade has the power, on inspecting a new railway, to make any requirements for safety which it may think fit, there has never been any attempt to insist on appliances or methods which have not already stood the test of experience and which are not recognised as necessary in the best railway practice. And while in this matter consideration is usually given to the standard practice of the particular railway, the promulgation of the memoranda of requirements has undoubtedly assisted towards the standardisation of the methods adopted, particularly in signalling matters. This feature has been of great value more especially in connection with the smaller and less progressive railways.

The inspection of new railways from 1840 onwards, and the progressive nature of the requirements made by the Board of Trade in connection with such inspections, gave rise, however, to a curious anomaly. As new lines were opened they were equipped in the most modern fashion with all the safety appliances then recognised as necessary. Older lines, on the other hand, with possibly a far greater traffic, were in many cases worked without any of these safeguards, and the Board of Trade had no power to order their adoption in such cases, even if their absence was the cause of an accident.

Although most of the railways equipped their lines voluntarily with safety appliances and signalling at an early period, this anomalous condition of things existed to a very large extent down to the year 1889. And even since the passing of the 1889 Act, it may happen that appliances are required by the Board of Trade on new lines, the provision of which it has no power to insist upon on existing lines. So too, when an accident takes place, the Board of Trade has no power to require the provision of apparatus or the adoption of methods of working unless these are expressly provided for by legislation.

In the succeeding chapter an account will be given of the more recent legislation affecting Government control of railway working.

CHAPTER VIII.

GOVERNMENT CONTROL—LATER LEGISLATION.

The Railway Regulation Act of 1889, which has now to be considered, is an important one, as marking a new departure in the policy of the legislature in establishing Government control, to a far greater extent than in the past, over the working of existing railways. Hitherto, as we have seen, Government control had been restricted to the inspection of new and altered railways and to the regulation in respect of a few minor matters only, of the working of railways actually in operation. By the Act of 1889, however, powers were given to the Board of Trade whereby it is able to make regulations in respect of several matters intimately affecting the actual working methods on the whole of the railways in Great Britain and Ireland. The Act authorises the Board of Trade to make orders on the railway companies, from time to time, to adopt the block system on passenger lines, to interlock points and signals on passenger lines, and to adopt continuous brakes on trains carrying passengers. Orders were accordingly made on the railway companies, and a period was fixed within which the introduction of the necessary apparatus and methods must be completed on each railway. Hence, since the expiration of the time limit fixed by these orders, it has been obligatory on all railway companies in the United Kingdom, so far as passenger lines are concerned, that the traffic shall be worked on the block system, that points shall be properly equipped with signalling and interlocking plant, and that trains carrying passengers shall be equipped with a continuous brake system. The Orders attempt no definition of either a block system or of an interlocking and signalling system, and presumably it is left to the companies to choose their own methods of accomplishing the purposes which the two systems are generally recognised as fulfilling.

In regard to the working of single lines, however, the Board of Trade is more explicit and in its memorandum of requirements mentions the three systems of working which it authorises, and which were described in the chapter on single line working. In the case of the train staff and ticket system, the department goes further and gives a draft of the rules under which the system must be worked ; while in the case of the electric tablet and staff systems it requires the apparatus used and the rules of working to be submitted for its approval. In practice the apparatus employed in working single lines is of one or other of the two generally adopted systems which are well known to and approved by the Board of Trade, while the rules invariably conform to the Clearing House standard. If a railway company desired to adopt an innovation, either as to apparatus or rules, this would have to be submitted to the Board of Trade before being brought into use. It is somewhat curious that the Board of Trade should thus be so exact in its requirements in regard to single line working, while making no definition whatever of the apparatus or methods of block working to be employed on double lines, which, after all, form far the larger proportion of the mileage of railways in this country.

The Board of Trade is empowered to modify its orders under the Act, and it is by virtue of this that companies are sometimes granted exemption from block working on portions of lines where it would be impossible to maintain the strict space-interval principle. Such cases are submitted to the Board of Trade, who, if it considers that the circumstances warrant the relaxation of the Order will grant a certificate to that effect. In the absence of such exemption no departure from block working is, of course, permissible on passenger lines.

The Order in regard to signalling is also modified generally (that is without specific exemption) in the case of sidings on single lines locked by train staff in the manner described in Chapter VI, and also in the case of points on double lines locked by Annett's key or other arrangement approved by the Board of Trade.

The provisions of the Act in regard to continuous brakes require that the brake used shall comply with five celebrated conditions which, however, have now become axiomatic in brake practice. Its powers of modifying the Order enables the Board of Trade to make regulations in respect of the working of mixed trains, and in regard to working of a certain proportion of unbraked stock on passenger trains.

Another section in this Act gives the Board of Trade power to call for returns of overtime of railway servants whose duties involve the safety of the trains or passengers. The definition of the number of hours of duty constituting overtime rests with the Board of Trade.

The Railway Regulation Act of 1893 deals with the hours of railway servants. If representation is made to the Board of Trade as to excessive hours of duty, insufficient rest or insufficient relief on Sundays, the Board is to inquire into the matter and may afterwards order the company concerned to submit an amended schedule of working hours. This schedule may then be enforced by the Railway & Canal Commissioners. By this Act the Board of Trade has therefore a certain amount of control over the hours of duty of railway servants engaged in working the traffic.

Mention should also be made of the Light Railways Act of 1896, as by it the Board of Trade is empowered in the case of light railways to modify the statutory requirements in regard to safety. The Board of Trade has to consider all applications for light railway Orders under this Act, and unless it is satisfied that the proposed railway will come under the definition of a light railway the Order is not confirmed. Restrictions as to speed and the weight of vehicles are imposed, and this enables the usual requirements in regard to interlocking and signalling and other arrangements for safety to be modified. It is impossible to state exactly the requirements for safety on light railways, as such railways vary in character to a great extent. Speaking generally, however, on light railways, which are not merely tramways, but on which the traffic is similar to that on a small ordinary branch railway, the signalling arrangements required are of a very simple character ; distant signals and starting signals are often dispensed with, the point and signal levers are not concentrated, the points being worked on the ground instead of from a signal box. Level crossing gates are not always required, but, if not, cattle guards are provided in their place. When the line is a single one some recognised system of single line working is required. It should be added that the Board of Trade has the power, on application, to authorise the working as a light railway of any existing or authorised railway. By submitting to the necessary restrictions, a railway company can thus, if desired, adopt a simplified form of signalling arrangements on branch lines with small traffic. The value of this provision is, however, inconsiderable in the case of an existing line if it is already a passenger line, as all such lines are necessarily fully equipped with safety appliances already. Very little is, therefore, saved by altering the arrangements, especially as the staff or tablet apparatus, which is the most expensive part of the equipment, must in any case be retained.

The last Act to be mentioned is the Railway Employment (Prevention of Accidents) Act, 1900. This Act deals with methods and apparatus connected with the safety of railway servants. The Board of Trade is empowered to make rules in respect of 12 matters mentioned in the schedule to the Act and in respect of other matters of a similar character not mentioned in the Act, but in regard to which the Board of Trade may from time to time consider it necessary to intervene with a view to avoiding danger to railway servants.

A somewhat elaborate procedure, culminating with an appeal to the Railway & Canal Commissioners, is set up with a view to enabling the railway companies' side of the case to be fully considered in connection with each rule proposed. It may be added that of the 12 subjects scheduled to the Act two have not been dealt with by rules, and a proposed rule with respect to another one has been the subject of an appeal to the Railway & Canal Commissioners. The appeal was, as is known, decided against the Board of Trade. The only one of the rules under this Act affecting signalling is that requiring the effective protection of point and signal connections.

Summary of Powers of the Board of Trade.

It may be useful, in concluding this account of Government control, to give a summary of the powers possessed by the Board of Trade in regard to the equipment and safe working of railways.

Inspection and Inquiry by the Board of Trade.

First as to inspection and inquiry, the Board of Trade may appoint inspectors for the purpose of inspecting any railway and of making inquiry with respect to any railway. It may cause an inquiry of a formal or informal character to be held in connection with accidents, and may enforce the production of books and documents and the attendance of witnesses. The accidents which must be reported and which may thus be inquired into are set out in a memorandum issued by the Board of Trade, and include practically any mishap on a railway to persons (both company's servants and the public), works and trains. If an inquiry is held, a report must be published, but the Board of Trade has no power to require the adoption of any recommendation contained in the report unless it appears that any statutory requirements are not being complied with.

The powers of the Board of Trade in respect of inspection and inquiry are derived from the following Acts:—Railway Regulation Acts, 1842, 1871, and the Railway Employment (Prevention of Accidents) Act, 1900 (for the purposes of the Act).

The Equipment of New or Altered Railways.

New railways, and all alterations, however slight, to existing railways, if passenger lines, must be inspected by the Board of Trade, and it is open to the inspecting officer to make any requirement as to equipment which he may think fit. In practice, the usual requirements are standardised and issued to the railway companies in a memorandum which is revised from time to time (Railway Regulation Acts, 1842 and 1871).

The Equipment and Working of Existing Railways.

If the railway has been inspected by the Board of Trade before opening, the Inspecting Officer may have required an undertaking from the company as to the mode of working at some particular place or on the line generally. Apart from such special requirement, the regulations which apply to all railways are as follows:—

At level crossings of public roadways, gates must be provided which must fence in the railway on either side, and must be left across the roadway when not required to be opened for road traffic. A gate-keeper must also be provided. (Railway Level Crossings Act, 1839 ; Railway Regulation Act, 1842.)

If the railway was authorised during or since the sessions of 1845 or 1863, the Board of Trade has the further powers of regulating the working of the level crossings specified in the Railways Clauses Acts of 1845 and 1863.

Fences alongside the railway and screens (where ordered) for the protection of roadways must be provided (Railway Regulation Act, 1842 ; Railways Clauses Act, 1845).

Passenger communication must be provided on trains running 20 miles without stopping (Railway Regulation Act, 1868).

Passenger lines must be worked on the block system and, if single, on one of the three authorised systems, and must be equipped with interlocking and signalling. Passenger trains must be fitted with continuous brakes. (Railway Regulation Act, 1889.)

The Board of Trade may make rules as to methods and apparatus connected with the safety of railway servants. (Railway Employment (Prevention of Accidents) Act, 1900.)

The Regulation of the Hours of Labour.

The Board of Trade may require returns of overtime, and may request the Railway & Canal Commission to enforce a schedule of hours in certain cases. (Railway Regulation Acts, 1889 and 1893.)

(A synopsis of the legislation affecting the working of railways and the provision of signalling and safety appliances will be found in Appendix I.)

CHAPTER IX.

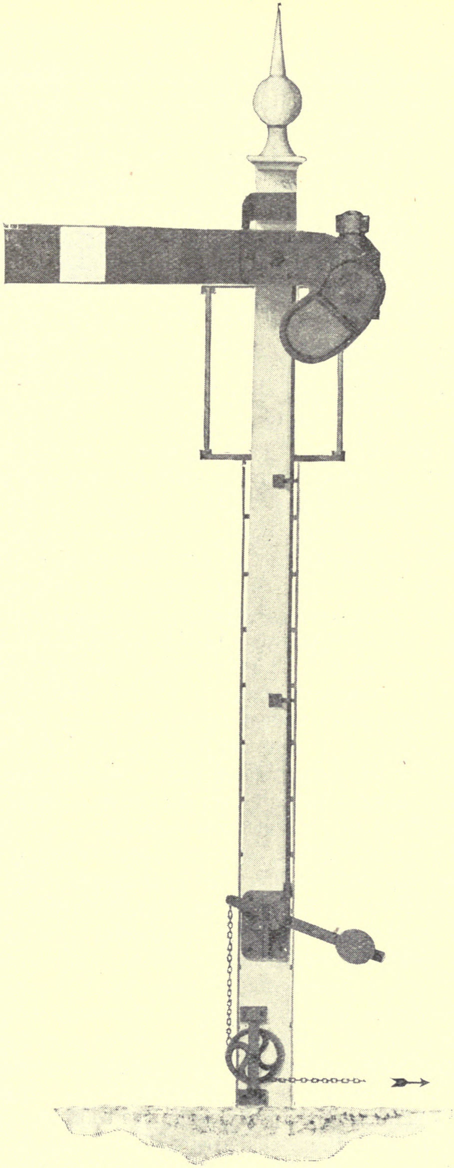
APPARATUS.

The signalling equipment of a railway system involves the provision of a great variety of apparatus and the apparatus employed takes again an almost infinite variety of forms and is used in many different combinations. Indeed to describe fully the apparatus used and to consider the circumstances under which it is or may be employed under the varying conditions which present themselves in dealing with the signalling of a large railway system would constitute a formidable undertaking. It is not however intended to make any attempt, in the present work, to deal in a technical manner with apparatus or methods. But, as many of the appliances used in signalling are constantly being referred to in connection with the working of a railway, and as some idea of their functions is necessary to an intelligent understanding of the principles of signalling, a brief account of some of the principal appliances and of the part performed by them in the signalling system will be given in this chapter. This, it is hoped, may assist the non-technical railwayman in avoiding some of the more palpable blunders to which he is often prone.

The Semaphore.

The ubiquitous semaphore itself calls for little description. In its early days it was made to give three indications, the all-right signal being shown by the arm lowered flush with the post and the caution and danger signals by the positions at 45 degrees and at right angles respectively. With the introduction of the block system, the caution signal became unnecessary and the former caution position now indicates all right. When the arm was lowered flush with the post it had practically the effect of making the signal invisible, and this was of course an objectionable feature according to modern standards. For many years, even after the introduction of the block system, the all-right signal was given by night by a white light. The white light is unsatisfactory as a signal light, as it is difficult to distinguish it from white lights used for other purposes. Further, in the event of the red spectacle being broken a white light would appear and thus give a false all-right signal. The Great Northern Railway was the first to adopt red and green lights only, for signalling purposes, and its example has since been followed by practically all the railways in the United Kingdom. For the guidance of the signalman who may require to see a signal from behind, a small white light is shown at the back and when the signal is lowered this is obscured by a blinker working with the arm. Some companies use a purple light for the danger indication in siding and other subsidiary signals. Formerly the signal arm was maintained in the horizontal position by the weight of the down rod and the balance lever at the foot of the post and thus, in the event of the rod fracturing, the signal might assume the all-right position improperly. A mishap arising from this cause about 1886 called attention to the matter and led to the adoption of balanced signal arms. The balancing of the signal arm is effected by giving sufficient weight of metal in the casting carrying the arm and spectacle to overcome the weight of the arm itself; thus even should the rod break the arm will retain the horizontal position. It should be added that the balancing of signal arms is a requirement of the Board of Trade in connection with works submitted for inspection.

It frequently happens that a signal cannot be seen from the signal box from which it is worked. As it is essential that a signalman shall know that a signal has responded to the movement of the lever, signals which are not visible from the signal box are fitted with electrical repeaters. The repeater consists of an indicator in the signal box with positions corresponding to the signal arm. The movement of the arm is made to actuate a commutator by means of which the direction of the current actuating the indicator is controlled. When the arm is properly in the danger position a current is transmitted which causes the indicator in the box to show "signal on" and when the arm is fully off the direction of the current is reversed and shows "signal off." Immediately the signal arm is deflected and until it is fully lowered the current is cut off and by the absence of current the repeater will show that the signal is neither properly on or off. Thus in the event of the failure of the electrical connections or of the improper working of the signal arm the necessary intimation will at once be conveyed by the repeater.



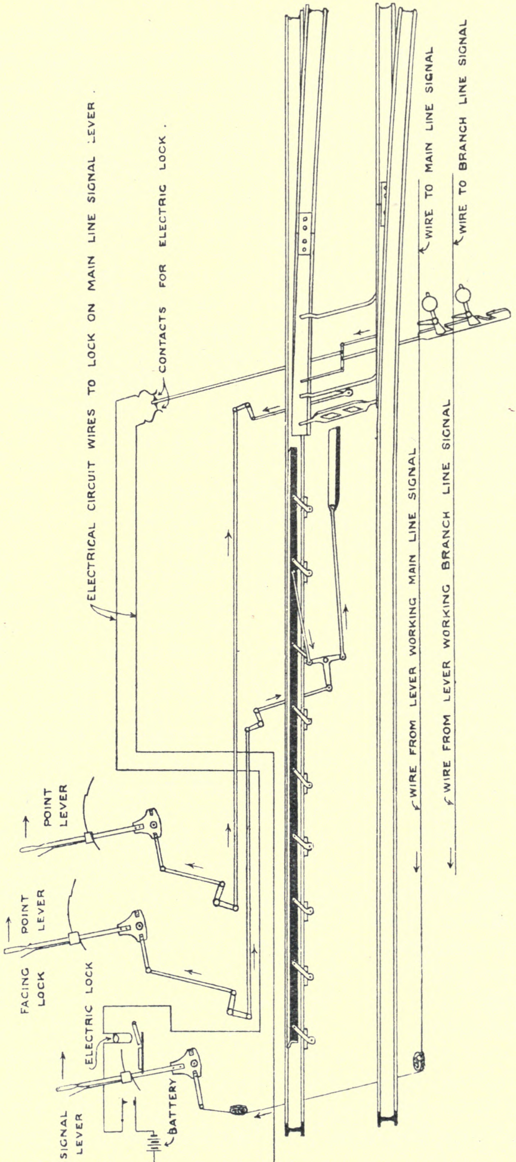
Main-Line Semaphore.

The commutator contacts working in connection with the signal are actuated in various ways, either from the down rod, from the arm spindle or by means of a connection attached to the arm itself. In the case of controlled signals, as the signalman is concerned not so much with the arm as with the balance lever worked by him, it is usual to attach the repeater contact to the controlling balance lever on the post. The best practice prescribes that, not only the signal arm, but also the signal light shall be repeated, so that the signalman may be kept aware that signal lights which he cannot see are burning properly. This is accomplished by means of an expansion bar within the lamp which, so long as the burning of the light gives sufficient heat, maintains an electric contact by means of which an appropriate indication is given in the signal box. Immediately, when, by the light failing, the temperature in the lamp is lowered, the expansion bar contracts, the current is cut off and the signalman is made aware by means of an indicator and a bell that a lamp has gone out.

Facing Point Equipment.

Among the most important appliances used in connection with signalling installations are those provided for the protection of facing points. There are three possibilities to be guarded against in connection with movements which take place through points in the facing direction and all points which become facing to the movements of passenger trains must therefore be fitted with apparatus designed to meet the risks thus arising. The possibilities are, firstly, that the tongues of the points may, instead of being firmly home against the stock rail, be partly open, in which case a train passing over them would be derailed ; they may, secondly, cause derailment by being moved while a train is passing over them and finally, although the points may be properly home, they may be lying for the position opposite to that in which it is intended that the approaching train shall travel. When points were worked by levers fixed on the ground close to them, the risks of the first two of these contingencies were not so great as with points worked from a signal box some distance away. Hence the adoption of the plan of concentrating point and signal levers actually introduced new elements of danger and in early locking installations these were partly guarded against by placing the signal box as nearly opposite the facing points as possible. A serious mishap to an express train at Wigan in 1873 called attention to the risks arising in connection with facing points worked from signal boxes and the opponents of concentration and interlocking were inclined to blame the new system. As frequently happens, however, the experience thus gained pointed not to the abandonment of innovations which had been made but to the adoption of further improvements in the same direction with a view to rendering the whole apparatus perfect. The result was the introduction of the facing point lock and locking bar, which are now fitted to all facing points on passenger lines and to a large extent to facing points on running goods lines and loop lines. The accompanying diagram will make clear the working of this apparatus. Attached to each switch is a blade with holes corresponding to the two positions of the points when firmly home in one position or the other. A plunger, worked by a rod from the signal box, is arranged so as to enter one of the holes when the points are firmly home against the stock rail in either position. Thus if the points are to the slightest extent open, the plunger cannot enter either of the holes in the blade and the movement of the lever in the signal box which works it will therefore be obstructed. When, on the other hand, the plunger enters one of the holes in the blade, this will securely hold the points in the position in which they are lying. Thus the plunger secures that the facing points shall be properly home one way or the other and locks them in that position.

But it is still necessary to ensure that the signalman shall not withdraw the plunger and move the points while a train is passing over them. To guard against this the lifting bar is provided. This bar is fixed along the rail (usually in front of the points), and when at rest the top of the bar is just below the flanges of passing wheels. The bar is connected to the rod which works the plunger, and any movement of the rod and of the plunger lifts the bar. The bar is longer than the greatest space between the wheels of any vehicles in use on the line, and thus it is impossible for the bar to be lifted, and consequently for the points to be unlocked while a train is passing over it. The bar in conjunction with the facing point lock thus fulfils the requirement that the points shall not be moved while a train is passing over them. This is substantially the arrangement of the facing point lock and bar in general use. Modifications are found in respect of the lifting bars, which are sometimes placed inside the rail and sometimes outside, and occasionally (in special circumstances) along the switches themselves. Some companies (notably the Midland Railway) work the facing point lock and the points by the same lever, while one company inserts a wedge between the switch and the stock rail in place of providing a blade and plunger.



Facing Point Equipment, showing Facing Point Lock and Bar and Electric and Mechanical Detectors.

The other contingency which must be provided against in facing-point apparatus, is that the points may be lying in the direction opposite to that in which it is intended that the train shall travel. It might happen, in the event of the point rod breaking, that the movement of the lever in the signal box failed to alter the position of the points, and then, although capable of being properly locked by the plunger, they would thus be locked in the wrong position. To meet this contingency the signal-point detector was introduced about 20 years ago, and has now become an essential part of facing-point equipment. Point detectors take a great variety of forms, but they may be described as, in effect, a means whereby the wires working the signals are threaded through a slide connected to the facing points in such a manner that, unless the points are lying for the direction to which the signal applies, the movement of the wire is obstructed and the signal cannot be lowered. A detector is sometimes employed to ensure by similar means, that the plunger of the facing-point lock has entered the hole in the stretcher, thus guarding against any possible failure of the connections working the facing-point lock. The detector for the plunger is required by the Board of Trade in connection with facing points which are above 200 yards from the signal box. In some cases, when the signal connections are complicated, it is found convenient to carry out the detection electrically. The diagram shows both a mechanical and electrical detector but, of course, in practice only one or the other is fitted to the same points.

The Interlocking Frame.

The signals and points are worked from a signal box by means of the levers grouped together in the interlocking frame. In manual installations the movement of the levers is transmitted to the points by means of rods and to the signals by wires. The practice of working points by wires, which is sometimes adopted abroad, is not permitted in this country.

The levers in the frame are interlocked in such a manner that it is impossible for an unsafe combination of lever movements to be made. For instance, a lever working a main-line signal cannot be moved unless the levers working the points on the route to which it applies are in their proper position and, if facing points, are properly secured by the facing point locks. This may necessitate some levers being in their normal or forward position and others in the reverse position. Conversely when the signal lever movement has been made all these levers are held in the required

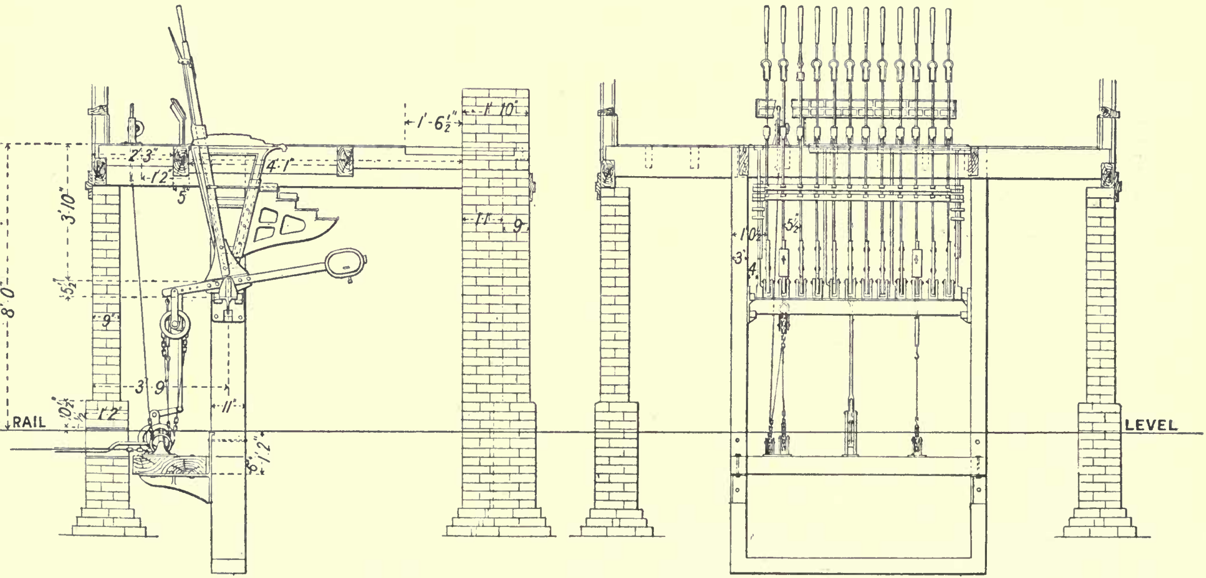


Diagram of Locking Frame and Connections in a Signal Box.

position. So, too, signals for conflicting movements must lock one another, and points must, as far as possible, lock other points the movement of which might lead to a conflicting train movement.

There have been innumerable devices adopted for effecting the interlocking of the levers since the idea of interlocking was first introduced, and many different kinds of locking frames are still in use. The present tendency is to effect interlocking of levers by means of what is known as the tappet or displacement system, a simple example of which is given in the illustration. The tappets or slides move horizontally, and are either attached directly to the lever itself or a movement is imparted to them by some intermediate device actuated by the lever or by the catch handle. The principle is the same in either case, the difference being in the extent to which the tappets are moved.

Between the tappets will be seen a lock which is displaced at right angles to the direction of the tappet when the latter is moved. Locks between levers not adjacent to one another are connected by means of bars. The position of the port in the side of the tappet determines whether the lever is locked in its normal or reversed position. Sometimes it is necessary to interlock two levers conditionally on the position of a third. An example of such conditional locking is shown on the diagram, where it will be seen that the conditional result is attained by giving one tappet (No. 2) a lateral movement as well as its ordinary movement to and fro. This, in conjunction with the port in No. 2 tappet, has the effect of interlocking Nos. 1 and 3 only when No. 2 is in its normal position. If No. 2 tappet is over, the port will give room for the lock from No. 1 to travel without causing the lock on No. 3 to enter the port in that tappet, and No. 3 will consequently remain free.

The interlocking in a large tappet-locked frame is simply an aggregation of the methods shown, but it need hardly be said that the arrangement of the locks and bars required for the interlocking of a large number of levers involves the exercise of considerable ingenuity.

Fouling Bars.

Sometimes it happens that the fouling point between converging tracks cannot clearly be seen from the signal box, and there is a risk, in consequence, of a signalman giving permission for a movement along one track which is partly obstructed by a vehicle standing on another. To guard against this risk fouling bars are provided. These are similar in form to the facing-point

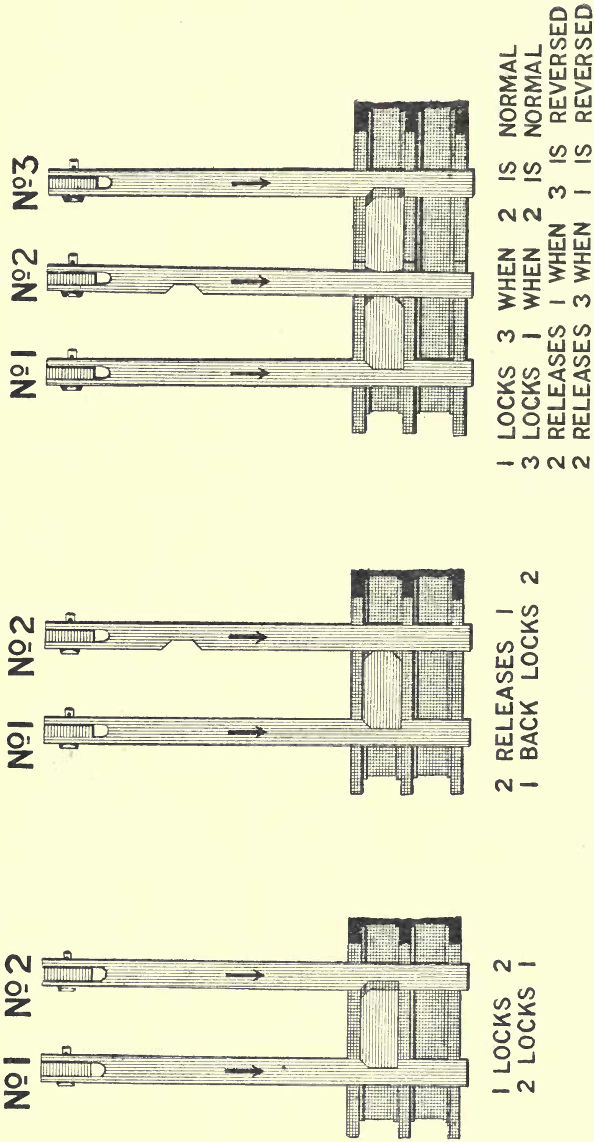


Diagram showing methods of Tappet Locking.

locking bars already described; they are fixed with one end at the actual fouling point and the length of the bar within the fouling area. Thus, so long as a vehicle is foul, the bar cannot be moved. Fouling bars are sometimes worked by the same rod which works the points leading to the route on which they are fixed, or they are worked by a separate lever suitably interlocked. In either case the result is, that before a movement is made on the route protected by the bar, the bar shall be lifted, thus ensuring that the fouling point is clear. If a vehicle is standing on the bar it cannot, of course, be lifted, and the conflicting train movement will thus be prevented. Fouling bars sometimes take the form of depression bars which stand normally at rail level and are depressed by the passage of wheels over them. The depression of the bar is caused to actuate a lock by which the movement of a point rod is prevented as with a lifting bar. Sometimes the depression bar is used to break an electric circuit, and by that means to apply a lock to a lever in the signal box working a conflicting signal or points. It should be observed that a fouling bar is designed to protect the actual fouling point only and that it is of no effect beyond its own length. If, for instance, a vehicle at a junction is completely foul of a main line, a fouling bar will not detect the fact unless some portion of the vehicle is sufficiently far on the branch as to be on the bar. Series of fouling bars, one behind another, have sometimes been employed to protect a length of plain line (as in a terminal station or bay platform). Such an arrangement is, however, exceedingly cumbersome and expensive, and unless the bars are placed fairly close together may fail to afford protection in the case of an isolated vehicle.

CHAPTER X.

THE PROBLEM OF THE DISTANT SIGNAL.

The Development of Distant Signal Practice.

Several problems of very great importance centre round the methods and usages connected with distant signals. When distant signals were first introduced, and for many years afterwards, the regulations provided that a driver, finding a distant signal at danger should bring his train to a stand at the distant signal itself. This was a rule which it was obviously impossible consistently to obey and it appears, in fact, to have been more honoured in the breach than in the observance. The occurrence of mishaps, in connection with which the difficulty of complying with the rule came under notice, drew attention to the desirability of framing a more practicable regulation and it was next provided that a driver, finding a distant signal at danger, should reduce speed so as to be able to stop at it if necessary, but that, if, on reaching the signal, he found the way clear, he might proceed cautiously past it, being prepared to stop at any obstruction between the distant and the home signals. This rule appeared in the standard regulations until a comparatively recent date, and, like the original rule, had in view the working of the time-interval system. Under that system of working there was always a possibility that a second train might approach a home signal before the train in front had passed within its protection and therefore it was necessary to give the train standing at the home signal such protection as could be afforded by the distant signal. Hence the necessity for the conditional stop at the distant provided for in the rule.

With the adoption of the block system, however, the need for this protection by the distant signal disappeared, and the signal has since assumed its modern function of a caution signal, indicating, when at danger that the corresponding home signal is at danger, and, when lowered that the line through the section ahead is clear.

The Need For a Distinctive Distant Signal.

Thus, unlike all other signals, the distant is not a stop signal; it may be passed when in the danger position. But, although its function is quite distinct from that of other signals, its appearance, save for the notch in the arm (which is visible by day only and then from a limited distance only) is exactly the same as that of a stop signal.

In actual practice the disadvantage arising from this fact is perhaps less than might be expected from so inconsistent an arrangement. When, as very frequently happens, a distant signal is a lower arm under a stop signal, there can be no possibility of mistake, as, in modern signalling practice, the lower arm of a two-arm main-line signal can be a distant signal only. When, on the other hand, a distant signal is isolated, its position, away from other signals serves to distinguish it from a stop signal and to indicate its purpose.

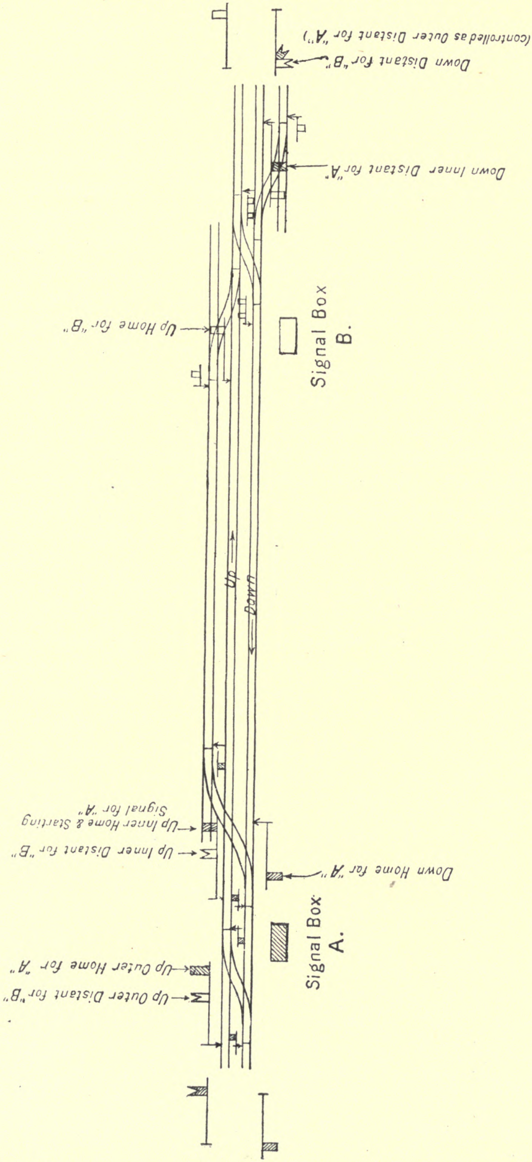
As therefore the necessity for a distinction is met, in the case of lower distant arms, by the presence of the upper arm and light, the actual need for some further means of distinction is confined to the case of separate distant signals. Nor can it be regarded as satisfactory, either theoretically or in practice, that there should be so little difference between a one-arm distant signal, signifying that a stop is to be made at a considerable distance ahead and a one-arm home or other signal demanding an immediate stop. And especially is it objectionable that a single red light may convey either of these indications.

Dismissing for the present the necessity for a day distinction, as being more or less met by the notch in the arm, the problem of a distinctive distant signal may thus be narrowed down to the necessity for providing a night distinction in the case of separate distant signals.

Attempts have been made to distinguish distant signals by night by means of a supplementary lens of a form corresponding approximately to the notch of the arm; such devices have however usually the disadvantage of being visible at comparatively short range only. In the United States and in parts of the European Continent, lights of different colours are used for distant signals, such as green and yellow in place of red and green and in some cases (as in Germany) white lights are used. Various circumstances render the adoption of such colour variations inadmissible in this country and the use for signals of a yellow light, in particular, would appear impracticable with us from climatic reasons. An eminently effective and simple plan is adopted in India, by which each distant signal which is not a lower arm on the post of a stop signal, is provided with a fixed green light placed above the ordinary light in the position which would be occupied by the light of an upper arm. A distant signal light may thus always be known by being the lower one of two lights on the same post. Such a plan has much to recommend it as being merely an adaptation and extension of the existing arrangement where distant signals take the form of lower arms on a two-arm post.

Distant Signals in Short Sections.

Another problem, in connection with distant signals, arises when the block sections are short. The reader will remember that, when, in locating a distant signal at the required distance in the rear of a home signal, it is found that such distance falls in the neighbourhood of a signal belonging to the box in the rear, the distant signal is placed, not on a separate post, but as a lower arm on the post carrying the starting or other signal for that box. If it is found that an arm on the post of the first signal encountered in going back will not give the required distance from the home signal, a second distant arm is fixed on the next signal for the same box (in most cases the home signal) and the two distants are then known as inner and outer distants respectively. In the accompanying diagram the distance between the up home for B box and the signal for A which is next in the rear is assumed to be too short to fulfil the requirements, having regard to the gradient and other circumstances. Therefore a second or outer up distant for B is provided under the up outer home for A. Sometimes, under such circumstances, the inner distant is omitted but it is better practice to provide it, as otherwise a driver brought to a stand inside the outer home for A would not have any knowledge of the state of things at B until he actually sighted the home signal for that box. Further it is very misleading for a driver (especially in foggy weather) having passed a distant signal under a home signal, to encounter another stop signal before reaching the home signal to which the distant applies. When distant signals have to be duplicated in this manner it is desirable to control the outer distant, not only by the upper arm on the same post, but also by the starting signal ahead. Otherwise there is a



Signalling Arrangements in Short Sections.

possibility of the outer distant being at all-right when the starting signal is at danger, which of course would be misleading. The necessity for this additional control applies particularly when the signal box from which the distant is worked is not open continuously.

But it sometimes happens that none of the signals for the box in the rear are sufficiently far back to give the required distance for a distant arm. Such a case is shown on the diagram on the down line where the only down signal provided at B is not far enough from the down home at A to give the necessary distance for the down distant for A. Theoretically the way to meet this contingency would be to provide a separate distant for A at the required distance back outside the home for B. This plan has been adopted by some railways in the past but it is now generally recognised that it is not a satisfactory arrangement as the multiplication of signals which it involves tends to confusion. In fact if the attempt were made to follow out such an arrangement on a line where there is a succession of short block sections, it would lead to something approaching chaos in the signalling arrangements. The practical alternative is to utilise the distant signal for B and to arrange for some form of control whereby that signal cannot be lowered without the consent of A. Thus, when A's home signal is at danger a distant signal will be maintained at danger the necessary distance back notwithstanding the fact that A's own distant signal is situated at less than the required distance.

THE CONTROLLING OF DISTANT SIGNALS IN SHORT SECTIONS.

The *crux* of the problem, however, is in the method by which the control is to be effected. Strictly speaking the control should be absolute, that is to say, A should have the same power of placing and maintaining at danger B's distant signal as has B himself. In practice the working of an ordinary mechanical signal slot on the post at the necessarily considerable distance presents difficulties which render it inadvisable to adopt this method except in simpler cases such as that shown in the diagram. In power-worked installations no such difficulties arise, as a power-worked distant signal can be controlled by any required combination at any distance with certainty and ease.

In manual work the next most effective plan is to control the distant electrically from A, in which case B would work the signal subject to the electrical control of A, the control being subject to any desired combination in A box. This is an economical and effective method, its only drawback being that A must always make the first movement before the signal is lowered and this may lead to slight delay by reason of B (when he has lowered his own home signal) having to return a second time to the frame to lower the distant signal after A has operated his electrical control.

A third plan is to enable A to release (preferably electrically) the locking on the lever in B box by which the distant signal for that box is worked. A can by this means prevent the distant for B being lowered, but, having once been lowered, A has no power to replace it at danger, and this method is therefore, to that extent, defective.

Another method, which is more extensively adopted than either of the foregoing, is to provide in B box an indicator (electrical or mechanical) by means of which B shall be informed when A can give permission for the distant signal to be lowered. This arrangement is less effective than any of the others, inasmuch as the control is dependent entirely on the observation by B of an indicator, and A has no actual power either to maintain or place the distant signal at danger.

It should be added that whatever form of control is employed or when an indicator alone is used, the actuation of the control or indicator can be made dependent on any desired combination in A box ; it may be operated by a separate lever suitably interlocked or by a lever used for some contingent movement such as the working of the home or distant signal. When electrical means of control are employed the required combination can, of course, be very simply effected.

When an indicator alone is employed it is usually actuated by the lowering of the distant signal for A. If there happen to be two or more short sections together this plan has the disadvantage that A may be precluded from lowering his own distant by the fact that the distant for the box ahead has not been lowered. Thus B's distant would be held at danger unnecessarily, and it will be seen that with a series of several short sections the distant at the commencement of the series could never be lowered unless the distants throughout the entire series were lowered first. The same thing applies in the case of control by means of an electric lock or electric signal control, and it is better in all these cases to operate the control by a combination of the stop signals in the controlling box ; A box will then be able to give permission for B's distant to be lowered immediately he himself has obtained line clear for the train, notwithstanding the fact that A's own distant may be held at danger in obedience to another short section requirement in advance of him.

Another method of controlling distant signals in short sections is by a special block-signal bell code. When this is used, A accepts a train from B by a special code when the section ahead of A is not clear, and B, receiving this code, maintains the distant signal at danger. There are several objections to this method, and it can at best be regarded as only a primitive expedient for use in the absence of efficient appliances.

The Use of Distant Signals for Other than Block Working Purposes.

A question in connection with distant signals, in regard to which there is considerable difference of opinion among railway officers, is as to whether they may legitimately be used for the purpose of checking the speed of trains when the road is actually clear but when other conditions call for a reduction of speed. For instance, it is sometimes held that a distant signal at a junction should not be lowered for a diverging route which is approached by a curve involving a considerable reduction of speed, or in fact for any route over which specially cautious movement is called for. It has been explained in an earlier chapter that a distant signal at a junction may be lowered for one direction only and therefore in the case of junctions this arrangement amounts simply to providing a distant signal for the route on which unchecked speed may be maintained and traffic passing on to the diverging route would pass this at danger. At places other than junctions, under this arrangement, a distant signal would be provided, but would be fixed in the danger position. It should be borne in mind that in making use of the distant signal for this purpose an attempt is being made to convey two indications by means of one sign and thus to add further complications in the interpretation of the signal. For, normally, a distant signal at danger indicates that a stop is to be made at the home signal, but this plan involves an alternative indication, "Proceed with caution," the caution being necessary, not with a view of stopping at the home signal, but in travelling over some section of line beyond the home signal. It is difficult to justify the authorisation of two alternative interpretations for a signal when in the same position, and much might be said to show that objections to such a method exist in actual practice.

On the other hand occurrences of recent years do appear to indicate that some form of reminder may be necessary to indicate to drivers the places at which, on account of the nature of the route, a reduction of speed is necessary. If such a need exists, a much more consistent method of meeting it, would be to provide an entirely different form of signal altogether to be used solely for the purpose of indicating the necessity for a speed reduction, as is the practice on the Prussian State Railways. The distant signal could then be confined to its own proper function of indicating the necessity or otherwise of stopping at a given point and the serious risk of weakening the significance of the signal which must arise when it is used for other purposes would be avoided.

It should be added that there is considerable discrepancy in the practice followed by railway companies in regard to this matter. Some companies provide a directing distant for every diverging route other than those leading to a yard or loop, the view held being that the form of the signals and the lower elevation of the arms leading to the inferior routes give sufficient indication of the nature of the route over which the train is being turned. Other companies decline to provide a distant signal for any direction involving a considerable speed reduction, holding that the presence of a distant signal at danger is necessary in order to ensure that the driver shall be aware of the necessity for reduction. It is greatly to be desired that, in a matter which after all is of so elementary a character, there should be greater uniformity of practice.

Fog Signalling.

In theory the necessity for providing means whereby the indications of the outdoor signals may be conveyed to the train-men during fog, arises, not only in the case of distant signals but in the case of all signals without exception, just as it is necessary to indicate the positions of the arms by night by means of coloured lights. In practice, however, the distant signal being the key to the situation in respect of every block signal post, it is usually considered sufficient to provide special means of indication during fog in connection with distant signals only. There are exceptions to this, applying under special circumstances, and to a greater or less extent on the different railways, but such may be stated as being the practice generally and certainly no serious proposal has ever been made, so far as ordinary railways are concerned, to equip all signals with apparatus for use in fog.

In its present stage therefore, the fog-signalling problem may be regarded as relating particularly to distant signal practice.

Probably no subject connected with railway signalling has given rise to so much controversy and investigation as has that of fog-signalling and certainly no branch of signalling has been the subject of so many inventions. The devices for fog-signalling which have been and which are being constantly brought to the notice of railway companies are simply innumerable, but unfortunately the vast majority of these are designed apparently without any reference to the conditions which they have to fulfil and are in consequence hopelessly impracticable.

The use of detonators for fog-signalling purposes is at present almost universal on railways in the United Kingdom. They consist, as is probably well known, of metal discs charged with an explosive and capable of being fixed by means of metal bands upon the top of the rail, where they are exploded by the passing over them of the engine wheels.

During the prevalence of a fog, the fogmen (who are usually drawn from the permanent way staff) are stationed at the necessary signals and it is their duty to keep a detonator on the rail so long as the signal to which they are appointed remains in the danger position and to remove the detonator when the signal is lowered. As each train passes they are instructed to give a hand signal to the driver (by lamp or flag) in accordance with the position of the signal. Thus when the signal is at all right and when consequently no detonator is exploded, the driver receives an assurance from the fogman that such is the case ; while when the signal is at danger the driver both hears the detonation and sees the fogman's danger hand signal. The fogman is required to place a detonator on the rail immediately after the passage of each train, to observe the working of the signal and to watch generally for any irregularity and to be prepared to take any steps for the safety of the traffic which may become necessary. The men who are appointed for fog-signalling are allocated each season to the signals at which they have to attend ; their names and addresses are posted up for ready reference at the stations and signal boxes and arrangements are made for calling them out immediately they are required and for relieving them by a second relay of men should the fog continue after they have been on duty for a given period.

Such briefly is an outline of the fog-signalling arrangements in operation generally on British railways. The system has from time to time been subjected to a considerable amount of criticism and that there are certain objections to it is not denied. These are found in the difficulty which is occasionally experienced in getting the fogmen to their posts on the sudden occurrence of a fog, in the noise caused by the detonations, and in the cost of the detonators and of the men. On the other hand there are undoubted advantages in a system whereby, during the prevalence of the trying conditions of foggy weather, men are stationed at intervals along the line who are able to keep in touch with the traffic and who can if necessary take action which it would be impossible to provide for by means of machines.

Apparatus to Take the Place of Fogmen.

It is beyond the scope of this work to enter into any details of the numerous devices for fog-signalling without fogmen which have been tried. These may be grouped roughly into three classes as follows : (*a*) apparatus by which a detonator is automatically placed on the rail when the signal is at danger and is replaced after the passage of a train, and in this class fall also appliances whereby the warning is given by means of a whistle, horn or bell instead of by a detonation ; (*b*) apparatus actuated from the signal box whereby warning is given by detonators or other means ; (*c*) apparatus whereby it is sought to give a signal (by whistle or bell or otherwise) on the cab of the engine itself. Devices coming under each of these heads are in use to a limited extent on various railways but, except in one case, the probability of any considerable extension of their use would appear remote. There are two fundamental requirements which it is absolutely essential should be fulfilled by any fog-signalling apparatus if it is to be regarded as sufficiently reliable to take the place of the present system. It must, in the first place be so constructed that the failure of any part shall cause the danger indication to be given and, secondly, there must be a definite all-right signal which must be given, not merely by the absence of the danger indication, but by positive means actually dependent on the conditions prevailing at the signal or in the signal box. It is on one or other of these rocks that a large majority of the proposals for fog-signalling apparatus come to grief and many of the devices which do succeed in fulfilling these two conditions accomplish the object by means so elaborate as to render them quite unsuitable for the purpose.

Apparatus for Placing Detonators on the Rail.

There is one class of fog-signalling apparatus which is used to a very considerable extent in the working of the present system, and to which reference should be made. It frequently happens that, on account of want of space, the fogman cannot be stationed immediately alongside the track to which he has to attend, and considerable risk to the men has arisen in the past, in consequence of their having to cross one or more tracks each time a detonator has to be replaced. To obviate this an apparatus is provided consisting of a continuous runner fitted with a carrier for the detonator. This extends from the fogman's hut across as many tracks as may be necessary to the rail on which the detonator has to be placed. A wheel and chain are provided and the fogman is thus enabled, having placed a detonator in the carrier, to move it across to its position without leaving his hut. When the signal is lowered, he simply turns his wheel sufficiently to move the detonator clear of the rail and should a detonator be exploded he draws back the carrier and re-charges it. This form of apparatus is exceedingly useful in the case of four-track main lines and in other cases in which several signals are in close proximity, as it enables one man to attend to the signals applying to two or perhaps three lines with perfect safety to himself. It is possible also by its means to withdraw a detonator, if necessary, immediately in front of a train without any risk, thus saving delay and unnecessary consumption of detonators. Another class of machine fulfilling a similar object is provided with a magazine of detonators, and, as the carrier is removed from the rail by the fogman it is automatically re-charged and the fogman has then merely to move the lever working the machine (which as with the wheel in the other case is placed near his hut), to place the fresh detonator on the rail. Such apparatus is sometimes worked directly from a signal box instead of by a fogman, but as many contingencies might arise to prevent the detonator being placed in the right position, it is hardly desirable to adopt this method unless the apparatus is actually under the signalman's observation, which, of course, it would not be in the case of a distant signal.

The Use of Cab Signals.

An important question in connection with any proposal for a mechanical fog-signalling system is as to the relative advantages of one in which the indication is given externally (as in the present system) and of one in which the signal is given within the engine cab itself. Much might be said in support of either method, but it may be explained that the principal objection which is urged against a cab signal is that it has a tendency to divert the attention of the driver from the road. There is of course also the difficulty that, unless the whole of the engines which may have to travel over the line are fitted with the cab apparatus the arrangement is incomplete and would have to be supplemented by other means. This would be a serious obstacle in the way of adopting a cab apparatus in the case of railways over which are worked the engines of several companies. On the other hand there are undoubted and obvious advantages in exhibiting a signal upon the engine itself in foggy weather and it would not appear impossible that, with the introduction of a thoroughly reliable cab signal arrangement, the difficulties of common user may be overcome, as has been the case with the brake systems and with the passenger communication system.

In this connection mention should be made of the driver's cab signal which has been introduced by the Great Western Railway Company, and which is now being installed to a large extent on their system. Unlike the great majority of inventions for fog-signalling this one has been worked out by practical railway officers and in its present form is the result of several years of experiment and improvement. By its means positive indications for both danger and all-right are given on the engine by audible and visible means, and any possible failure in the apparatus or connections can result only in the danger indication being given. The apparatus is actuated by an electrical circuit controlled by the distant signal or, if necessary, direct from the lever in the signal box, in which latter case (provided none but fitted engines are in use) the semaphore distant becomes superfluous, except perhaps at junctions. The track portion of the apparatus consists merely of a fixed ramp between the rails by means of which a suspended lever on the engine is caused to break contact in an electrical circuit, and the whole apparatus is eminently practical and reliable. There certainly appear to be great possibilities in a system designed on these lines and fulfilling these requirements, and it is not too much to say that in the general adoption of such a device, not only the fog-signalling difficulty, but most of the other problems connected with the distant signal, which have been discussed in this chapter, would find their solution.

CHAPTER XI.

POWER AND AUTOMATIC SIGNALLING.

Definitions.

A brief outline will now be given of some of the more recent developments in the methods employed in signalling, particularly in respect to power and automatic signalling. A distinction should be drawn between the methods usually included in the two expressions. In power signalling installations, the initiation of a point or signal movement rests with the signalman exactly as in an ordinary manual installation; but, whereas in the manual installation the necessary motive force is supplied by the signalman's own effort, in the power installation the power is derived from an outside source which the signalman merely introduces by a comparatively slight physical effort. A signalling plant so operated is thus in no sense automatic.

In a power signalling plant, the power is usually applied to the working of both points and signals. In an automatic signalling installation, on the other hand, the working of signals alone is concerned, the controlling of the signals resulting automatically from the movement of the trains themselves. Some form of power must of course be employed for the purpose of operating the signals but as the controlling of the power and the consequent movement of the signals are independent of any outside agency such an arrangement may properly be described as an automatic signalling installation.

It frequently happens that the signals operated by a signalman from a power interlocking plant are controlled also by the trains themselves. So, too, isolated automatic signals established for block working purposes are often controlled from adjacent signal boxes. Signals which are thus subject to the joint control of the trains and of a signalman are known as semi-automatic signals. Such are the arrangements usually understood in the three expressions "power signalling," "automatic signalling" and "semi-automatic signals" and while the methods employed under each designation are too varied to render the definitions exact ones, the terms may be usefully employed in stating the broad principles of the systems in question.

A further variation is found in the case of manually operated signals which are controlled by the presence of a train on the track. Such signals do not properly come under either of the three designations given above but may perhaps be referred to as "track-controlled manual signals."

Power Signalling.

The outstanding feature of all power signalling systems is that the power is applied directly at the point of operation, that is to say, at the points or locking bar or signal which has to be moved. The loss of power consequent on mechanical transmission is thus avoided. The power employed is usually either electricity or compressed air. The manipulation of the power is effected by miniature levers arranged in an interlocking frame on principles similar to those of an ordinary manual frame. These levers actuate valves or electrical contacts as the case may be. In some systems the operating power itself is introduced through the valve or switch of the interlocking lever. In others the interlocking lever actuates a controlling power which is transmitted to the point of movement and there introduces the actual working power. This controlling power may either be a different pressure of the main operating power or a different kind of power altogether. In the Westinghouse electro-pneumatic system, the controlling power is electricity at a pressure of about 15 volts. This electric current, when operated by the lever in the frame actuates a pin-valve by means of which compressed air at a pressure of about 60 to 70 lbs. is admitted to a piston-motor connected directly with the point or signal required. This system is in use on the North-Eastern Railway at Hull and Newcastle, on the Caledonian Railway at Glasgow Central, on the Lancashire & Yorkshire Railway at Bolton, on the Great-Eastern Railway at Bethnal Green, on the Metropolitan-District Railway, and on the tube railways in London operated by the Underground Electric Railways Company.

In the low-pressure pneumatic system the controlling power is compressed air at about 8 lbs. per square inch which by means of an air relay valve at the points and signals, admits air from a main at a pressure of about 20 lbs. for working the motors. This system is employed to a large extent on the London & South-Western main line between Woking and Salisbury and on the Great Central main line in the neighbourhood of Manchester.

In the Siemens and in the Crewe systems, electricity alone is employed and the interlocking levers directly control the operating current which is usually at a pressure of about 100 volts. Another all-electric system is known as the Taylor system, the principles of which, so far as the means of control are concerned, are similar to those of the two others mentioned. The Siemens system is in use on the Midland Railway at Derby and is being introduced at several places on the Great Western Railway. The Crewe system is largely employed on the London & North-Western Railway at Crewe, Euston and elsewhere, and there is an installation on the North-Eastern Railway at York. A modification of the Taylor system has been installed on the Great Western Railway at Yarnton Junction near Oxford.

The next important feature common to practically all power systems is the "check-lock." In a manual plant reliance is placed to some extent on the rigidity of the transmitting rods, for ensuring the correct movement of points and locks, although, as has been seen, this is supplemented by detection between the signals and points. In a power plant, on the other hand, the movement of a lever can under no circumstances be relied on as giving assurance of the corresponding movement of the points, as the only mechanical result of the movement of the lever is the opening of a valve or switch in the locking frame itself. In power plants, in order to ensure correspondence in this respect the check-lock is employed. When a point lever is moved backwards or forwards its movement is arrested by means of the check-lock before the stroke is actually complete. Immediately the desired movement of the points has been properly effected, a secondary current (of air or electricity, according to the system employed) is transmitted back to the frame and releases the check-lock, thus enabling the stroke of the lever to be completed.

The mechanical interlocking in the frame ensures that, so long as the stroke of the lever is incomplete, no contingent movement of other points or signal levers can be made. Hence, until the points have actually obeyed the lever and, in the case of facing points, are securely locked in addition, the interlocking of all other necessary point and signal levers is held, and no movement of such levers can take place. In the case of signal levers the check-lock is applied to the normal position only, so that the lever cannot be put completely back until the signal arm has responded and has assumed the danger position. Thus, should a signal fail to go properly to danger, no movement of points protected by it and no movement of a conflicting signal could be made. In some systems the movement of the levers or, in some cases, of the interlocking is completed automatically on the releasing of the check-lock, but in most cases the movement has to be completed by the signalman himself, and this involves a certain amount of delay in working with a power plant as compared with a manual plant.

It is usual in power plants, notwithstanding the use of the check-lock, to detect facing points directly with the signals governing them and this is very simply effected by threading the signal circuit through contacts or valves worked by the points. By thus detecting the points, assurance is given that no movement of the points has been caused by extraneous means since the last movement from the box and that the points continue to lie in the correct position.

From the foregoing general description of power signalling plants, it will have been gathered that the rods and wires which are employed in manual work are replaced by air pipes or electric conductors. These are usually carried underground to the point of application and in the consequent absence of ordinary rods and wires is found one of the advantages which may arise from the use of power. As the locking frame is composed of miniature levers a very much smaller signal box is required, and the signalman has therefore a shorter distance to move from end to end of the frame and has, of course, to put forth less effort in working the levers.

Power installations lend themselves very readily to complicated combinations of signals and points, such as the controlling or "slotting" of signals from two or more boxes, the controlling of signals by the trains and combinations of points and facing point lock and fouling bars. In the case of signal combinations, the cumbersome arrangements of mechanical slotting and the difficulties in connection with the adjustment of signal wires are avoided altogether, while in the case of point combinations one lever can frequently be employed for work which in a manual plant would take two or more levers. A saving of levers of more doubtful advantage can frequently be effected by using one lever for working several conflicting signals, in which case the selection of the correct signal is effected by combinations of contacts or valves operated by means of the point levers concerned. A further advantage, but of an artificial and possibly temporary character is found in the provisional permission given by the Board of

Trade that power-worked facing points may be 300 yards from the signal box, a gain of 50 yards on the distance permitted in manual work. It should be added that, both in installation and maintenance the cost of power signalling is at present greatly in excess of that of manual work and therefore an unusual combination of circumstances is necessary to justify the additional outlay involved in the use of power plant.

Automatic Signalling.

Turning now to automatic signalling, we have seen that, although the employment of some form of power is necessary, the root idea is the control exercised automatically by the trains themselves. The primary object of automatic signalling is the working of a block system without the aid of signalmen. But as the presence of a signalman is necessary for the working of the points of junctions and sidings, where such exist, it follows that automatic signalling, properly so-called, will usually be confined to lengths of line on which there are no sidings or junctions but which, in order that the through traffic may be accommodated, require to be divided into convenient block sections. In the United States there are many such stretches of plain line and these in many cases are divided by means of automatic section posts at suitable intervals. In this country, on the other hand, such lengths of plain line are not numerous and automatic signals are useful in isolated cases only and chiefly for the purpose of dividing, perhaps by one section post only, a section which is found too long to accommodate the traffic.

An automatic signalling system may be regarded as consisting of three distinct parts, as follows : (*a*) the signals and signal operating plant, (*b*) the means by which the control by the trains is effected and (*c*) the wiring combination or methods by which the train control is combined with the signal movements. In arranging an automatic installation these three parts can be combined in many different ways to suit the particular circumstances of the case. The features peculiar to any system of automatic signalling are not found in the particular combination of these parts but in the form of the apparatus employed.

Dealing first with the means by which the control by the trains is effected it will be found, in practically all automatic work both in this country and in the United States, that these are provided by a track-circuit system. There are a few exceptions to this rule but these need not here be furthur referred to as they have arisen out of exceptional circumstances and are not likely to be repeated.

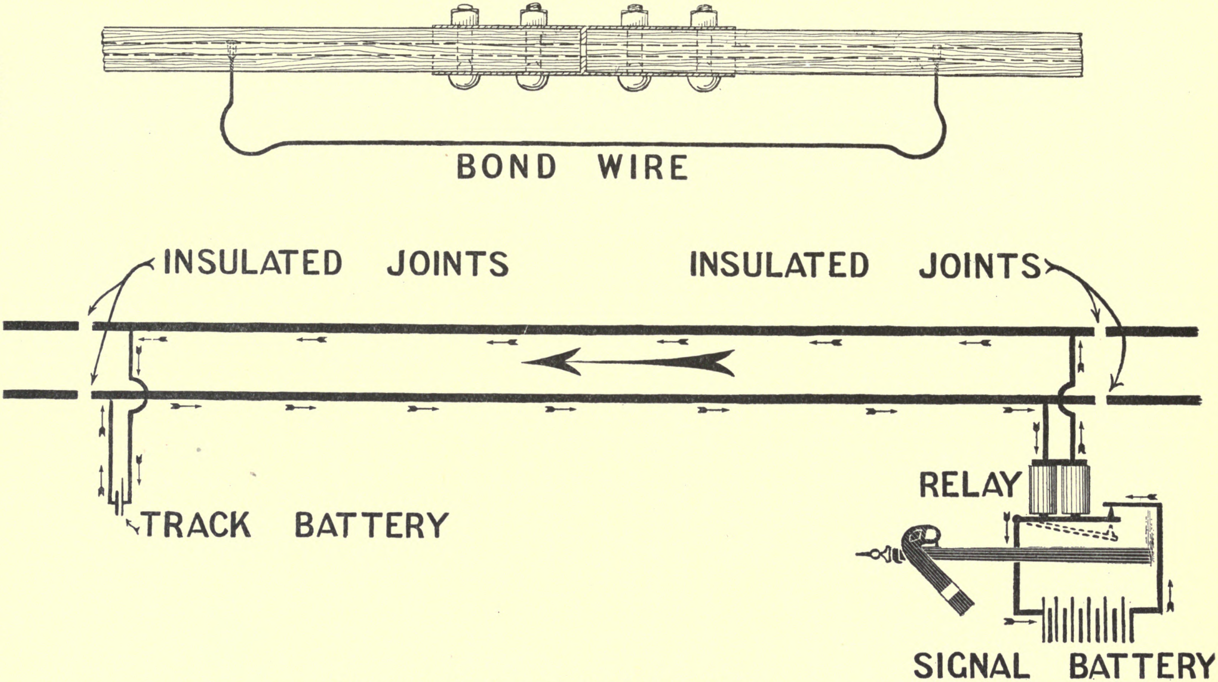


Diagram showing the Track-Circuit Arrangement.

The principle of the track-circuit arrangement will be clear from the accompanying diagram. The rails comprised in a given section of track circuit are insulated electrically from the adjacent rails in either direction by means of special insulating rail joints. Within the section the adjoining rails are connected together at the joints by means of bonds of iron or copper. This is necessary in order to maintain electrical conductivity from rail to rail, as the fish-plates cannot be relied on for this purpose. At one end of the section, is a battery, one pole of which is connected to each rail and at the opposite end is a relay one terminal of which is similarly connected to each rail. Thus a path is given from the battery, along the rails on one side, through the relay and back through the rails on the opposite side to the battery, and while the current is flowing the relay will remain energised, and contact will be made through the relay points in another circuit. Immediately, however, a train enters on the insulated section of track, the track current is diverted from the relay through the wheels and axles of the train, the relay drops, and the contact points open and cut the extraneous circuit. Thus, it will be seen, the track relay *reflects*, as it were, the state of the track; when the track is clear the relay is energised and makes contact in the extraneous circuit; when the track is occupied this contact is broken. Having once provided an apparatus which is actuated by the presence of a train on the track it is obvious that it may be utilised, either alone or in combination with other relays, to effect any desired control of signals or other apparatus. The relay may be made to control any number of circuits, or the operation of any number of relays may be made the condition of control of any one circuit. The combinations which may be effected are in fact innumerable, and can be designed to meet practically any set of conditions which may arise. In an automatic installation, the closing of the relay points (caused by the track being clear) is employed to introduce the power by means of which the signal is lowered. In the absence of the power the signal will remain at danger by gravity, and thus any disconnection or failure in the track circuit or connections will result merely in giving a danger signal. In a simple automatic signalling installation, each signal would be controlled by two relays, one of which would be in connection with the track up to the next signal in advance and the other in connection with a supplementary or overlap section of track extending about a quarter of a mile beyond the next signal. The overlap is necessary in order to ensure the necessary space interval between the head of one train and the tail of a train ahead.

It should be added that the track-circuit system is not without its limitations due to imperfect conductivity in the wheels or in the surface of the rails. The difficulties arising from this cause are being eliminated by various means and, except under exceptional conditions (which have to be specially provided for) a track-circuit system may be relied on to fulfil the purposes for which it is employed. The combinations in which track circuit may be employed in connection with signalling are, as has been already stated, very numerous and must form the subject of special consideration in each case. The simple arrangement of automatic signalling described above is known as the "normal clear" system, as under this arrangement the signals remain at all right where no traffic is passing. In the "normal danger" system, on the other hand, the signals remain in the danger position except when a train is approaching them. The track relay in such cases not only maintains the protecting signals at danger but is caused to lower the signals ahead, subject to the control of the track which such signals protect. The only example in this country of a normal danger system carried out in this manner is that on the North-Eastern Railway between York and Northallerton. In some automatic installations track circuit is employed to lock the levers working points. This is known as "approach locking," and has the effect of preventing a signalman at an interlocking plant from moving any points when a train is approaching on the track concerned.*

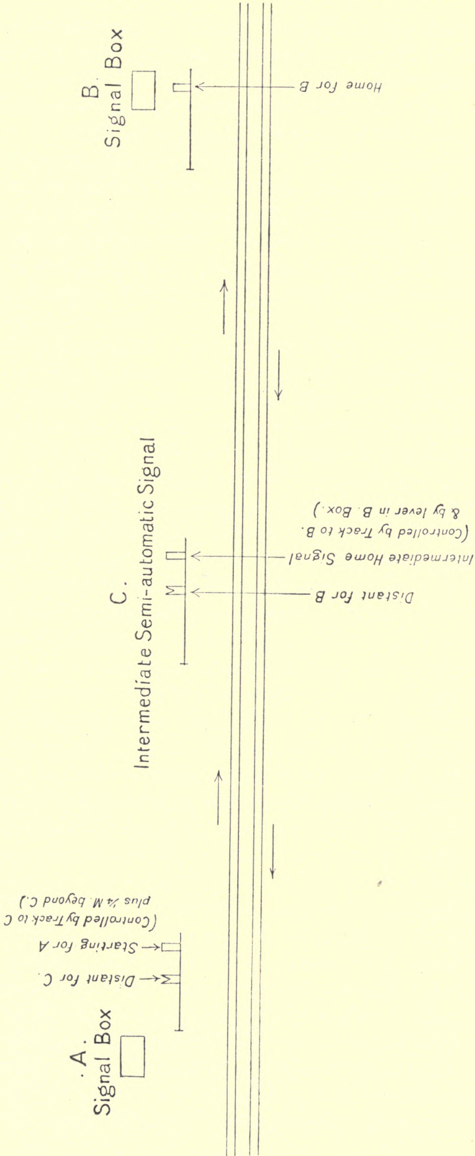
Having thus dealt with the track-circuit arrangement as the basis of automatic signalling and with the combinations of wiring by means of which the track circuit controls the signalling, the last point for consideration is the power employed for the actual movement of the signal arms. When automatic signals are installed in the neighbourhood of a power signalling plant, the power there employed can be made use of, and the same form of signal motor can be used in both cases. When, however, as is more usually the case, the automatic signals are isolated and are remote from any existing source of supply of electrical or other energy, it becomes necessary to find special

* Track circuit is employed also to a large extent in connection with manual signalling, both to indicate to the signalman the presence of a train on a portion of line which may be out of his sight, and to control the signals or block instruments. The possible applications of the system in these and similar ways are very numerous.

means of working them, as it would obviously not be worth while to provide a special generating plant. To meet this difficulty several forms of self-contained power-worked signals have been introduced, the power being supplied by primary batteries, portable accumulators, or compressed gas in portable cylinders. Electric motors, capable of operating signals of the ordinary form and driven similarly from primary batteries, have also been designed. Such signals are independent of any outside power supply, and can be used separately or together at any place at which they are required. In view of the fact that automatic signalling in this country is likely to be employed less in continuous lengths than in isolated sections, these forms of power signals appear to be the most suitable for the purpose. An extensive installation of automatic signals is that already referred to on the North-Eastern main line, where the Hall Signal Company's electro-gas signals are used. Automatic signals, operated by the low pressure air system, are installed on the London & South-Western main line near Basingstoke and on the Great Central main line near Manchester. In both cases the power is supplied from the same source of supply as for the adjacent interlocking plants. The Westinghouse Company's all-electric signal (operated by primary batteries) is in use in connection with automatic signals on the Great Western Railway and on the Lancashire & Yorkshire Railway. On the Metropolitan District and on most of the tube railways, the automatic signals are electro-pneumatic, and the power for them is supplied for the whole line in conjunction with the interlocking plants.

Semi-automatic Signals.

In many of the installations of automatic signalling referred to above some of the signals concerned do not strictly speaking come within the definition of automatic signals but are really semi-automatic, that is to say they are subject to the joint control of the train and of a signalman. In fact cases of entirely automatic signals, subject solely to the control exercised by passing trains are very few so far as the standard railways in this country are concerned, although there are many such installations in the United States. On inter-urban railways devoted exclusively to a heavy passenger traffic there is considerable scope for entirely automatic signalling, and thus we find that with the exception of a few isolated cases on ordinary railways, the use of purely automatic signalling in this country is confined to the underground and tube railways of London. Nor does it appear that the employment of



Sketch showing Arrangement of a Semi-Automatic Block Section Post.

strictly automatic signals here is likely to be extended, as the conditions are much more effectively met by the use of semi-automatic signals.

It has been explained above, that the chief cases in which automatic signals are found of advantage in this country are where it is necessary to divide a long block section by establishing an intermediate section post without the necessity for manning an intermediate signal box. In such cases the most convenient plan has been found to make the intermediate signal semi-automatic instead of wholly automatic, the control being placed in the hands of the signalman in the adjacent signal box at one end of the original section.

Assuming that it is desired to divide a long section A—B, a semi-automatic signal will be fixed midway at C, as shown on the sketch. The whole section A—B will be track-circuited, and the track will control not only the new intermediate signal C (in respect of the length C—B), but will control also the starting signal (and also the distant) for A in respect of the track A C. But in order that the signal at C may not be lowered without the permission of B (who will, of course, be responsible for seeing that the ordinary block regulations at his box are complied with first), the signal at C is controlled either from A or B. If the control be from A, ordinary block working must be maintained between A and B boxes, the effect being that the signal at C would act as a starting signal for A who would not lower it (even if the track C—B were clear) without permission from B.

A better plan, however, is to control the intermediate signal from the box ahead, as the signalman at B then has it in his own hands to detain a train at C, if the conditions at his box prevent him allowing it to approach and as the control is usually exercised by a lever in the frame, this can then be properly interlocked so as further to ensure this result. With this arrangement, ordinary block working between A and B can, if desired, be dispensed with.

With either method of control, indicators are provided in each signal box showing whether the intermediate sections are clear or are occupied by a train, and it will be seen that, quite independently of ordinary block working, trains enjoy full protection, through the track circuit, whether they are between A and C or between C and B. To put it briefly, the signalman to whom the control of the intermediate signal is entrusted is made responsible for two sections on that side of him instead of one. He is enabled to work the intermediate signal at any required distance from his box by the employment of a power signal, which he controls by a lever contact in his frame. The presence of a train in either section is automatically indicated in his box, and he is prevented from allowing more than one train in either section by the control exercised by the trains themselves on the intermediate signal and on the starting signal for the next signal box. This method of establishing an intermediate section post is well suited to the conditions of signalling practice in this country, and the installation of such block posts is not unlikely to be considerably extended in the future.

In addition to isolated semi-automatic signals it is often found convenient, when installing a power signalling plant, to control the signals by the track. With power-worked signals it is a very simple matter to introduce track-control and the comparatively small additional expense involved is fully justified by the greater security which is obtained. In a power signalling plant with track control, all the signals become semi-automatic and the signalman is thus unable to lower the signals unless the routes which they govern are actually clear. A useful and quite ideal elaboration of this system is sometimes provided by an illuminated diagram of the tracks which is placed in the signal box and on which, by means of light and shade on the respective tracks, the signalman is able to observe the presence and passage of trains within the area of his control.

When there is a series of power signalling plants on a section of line it is found of advantage to make the track circuit continuous throughout, when all the signals become automatic or semi-automatic and ordinary block working is dispensed with. An extensive arrangement of this kind is the equipment already alluded to on the Great Central main line between Ardwick and Godley, near Manchester.

CHAPTER XII.

THE ELIMINATION OF THE HUMAN ELEMENT.

In considering the subject of accidents to railway trains it will be found that the causes leading to accidents may be grouped in three main divisions as follows:—(*a*) deliberate or chance obstruction from extraneous sources, (*b*) failure of the track or works or of the rolling stock, and (*c*) mistake or negligence on the part of those responsible for the movement of trains.

Accidents due to deliberate obstruction are practically unknown in this country and those due to chance obstruction from extraneous sources are so few as to be an almost negligible quantity, the notable instance of this class of accident in recent years being that at Wellingborough in 1898, already alluded to.

The high standard of efficiency which is now attained in the maintenance of the works and rolling stock, on railways in this country, has rendered the number of mishaps due to defective equipment in either of these respects a small one. Such accidents have in fact shown a steady decrease in numbers for many years past and they now form an exceedingly small proportion of the total number of accidents which take place*. The majority of the accidents which occur fall into the last of the three divisions mentioned above, being due to the mistake or negligence of those engaged in the manipulation of the traffic; in other words they are due to the failure of the human element.

* For example; of the accidents inquired into by the Board of Trade in 1906, the causes were in 8 cases attributed to rolling stock or works as compared with 49 other causes. In 1907 the figures were 5 and 38 and in 1908 1 and 25 respectively. It is unfortunate that the Board of Trade returns give this information in respect of those cases only in which inquiries are held. It would be of great value if the causes of all mishaps without exception could be tabulated in the same way.

In view, therefore, of the relatively small number of accidents, the causes of which fall into the first two divisions, we may, in the present consideration of the subject, leave these out of account and deal only with accidents due to the failure of the human element. The purpose of the present chapter is to consider to what extent the signalling arrangements of a railway are intended as a check on human fallibility at the present time and to what extent they may be expected to act in the elimination of the human element in the future.

Two observations should perhaps be made for the benefit of those to whom the subject of accidents on British railways is an unfamiliar one. In the first place it should be remembered that statistics as to the numbers of persons killed and injured in railway accidents have no bearing on an investigation as to the causes of accidents or as to the possibilities of prevention. It is no doubt distressing to contemplate the suffering and death caused by a big railway accident, just as it is statistically re-assuring to feel (as is undoubtedly the fact) that a seat in an express train is one of the safest places in existence. The experienced investigator however will not allow himself to be led astray by either of these aspects of the case. He will realise that the tragedy of the big disaster may be due simply to a coincidence of circumstances or to a combination of local conditions whose recurrence is in the highest degree improbable. While on the other hand, in the trivial and perhaps unnoticed mishap he may detect possibilities of danger which are constantly present and which must sooner or later inevitably lead to disaster. Thus, in considering the question of accidents and their prevention, it is necessary to disregard effects and devote attention exclusively to causes and moreover to consider these, not in relation to the individual occurrences, but in their bearing on the prevailing and future conditions, as a whole. This attitude of mind would help to avoid those panic measures which there is a tendency to recommend upon the occurrence of a startling railway disaster.

The second point which it is well to bear in mind in considering the subject is that, so far as the railways of the United Kingdom are concerned, the total number of mishaps which take place is extremely small. Thus, in the year 1908, the total number of collisions and derailments reported to the Board of Trade amounted to 874, which equalled one mishap for 423 million train-miles. The cases reported include mishaps of the most trivial character, and include not only those in connection with passenger trains but those in connection with goods trains and light engines, a large portion of which would occur during shunting operations. Of the 874 mishaps reported, only 294 occurred in connection with passenger trains and, of the latter, only 22 were regarded by the Board of Trade as of sufficient importance as to render necessary the holding of an inquiry. It is thus apparent that the need for adopting further means for the avoidance of railway accidents is by no means a pressing one, and in fact, statistically considered, it may be regarded as almost negligible. The ideal which is always present in the minds of those responsible for the working of railways is that of complete immunity from accident ; and to this fact is no doubt due the large degree of actual immunity from accident which is attained. But in considering the necessity for adopting further means for securing complete immunity, we are justified in having regard to the comparative value of the security already obtained and the relation of the un-realised balance to the sacrifice (of expedition or convenience or money outlay) necessary to secure it. Nor must it be forgotten that when the risk has been reduced to such infinitesimal proportions, there is at least the possibility that it might be reproduced in other ways under the new conditions which would prevail with the adoption of other methods. This conclusion is, however, subject to the obvious proviso that, in order to maintain the present standard of security, any increase of pressure in the operating conditions (due to increase in speed, volume, weight, or otherwise) may nevertheless have to be met by the adoption of further safety appliances.

Assuming, for the reasons already given, the stability of the track, the efficiency of the rolling stock and its equipment, and an immunity from chance obstruction, we have now to consider in what respects human fallibility is a factor in the condition of the safety of railway trains, and to what extent it is possible to eliminate it.*

Consideration of the causes of railway accidents which have been due to the failure of the human element will show that in the large majority of cases these come within the scope of the signalling system as defined in these pages. It was shown in an earlier chapter that under present conditions the responsibility for the safety of a train in motion is divided almost entirely

* It should be borne in mind that, by substituting mechanical for human agency as a means of control, the human element is not entirely eliminated. There is still a possibility of improper manipulation, by inadvertence or design, and although the risk of this is remote, it exists, and must be considered.

between the driver and the signalman, and it will be found further on reference to the reports of mishaps inquired into by the Board of Trade that of these two sets of men, each is responsible for about an equal share of the mistakes leading to mishap.

Now, in following the sequence of operations for securing the safety of a moving train, it will have been observed that some of the movements are not subject to any mechanical check, and are therefore dependent for their accuracy on the human factor. Taking first the signal box towards which a train is approaching, there are, as a rule, no mechanical means of preventing the signalman there from accepting a train from the next block box even although the main line within the section or at his own box is obstructed, and having thus accepted the train there is nothing, notwithstanding this condition of things to prevent him from lowering his signals. Or, assuming the line to be clear when the train is first accepted, the signalman can proceed to obstruct the main line in the face of the approaching train. In the latter case, however, if any point movement were involved he would be compelled, by the interlocking, to place the signals to danger, although this might not be done in time to stop the train before running into the obstruction. The signalman, on the other hand, who desires to send a train forward may, in turn, lower his signal for the train to depart, although the block indicator may be showing that the line is not clear. Finally, the driver may disregard the signal and pass it when in the danger position.

Such are the links in the chain of operations which depend for security on the human element. At the first glance they would, perhaps, appear as forming a source of considerable weakness in the working of the system, but it should be remembered that each of the several movements is covered by simple regulations which it is easy to carry out, and the observance of which will ensure perfect security. Further, the whole of the signalling equipment is so arranged that it is difficult for the signalman to make a mistake, and so that, instead of being dependent on memory, he may, under all circumstances, have a reminder before him of the conditions prevailing. While, so far as the driver is concerned, the signals are so placed and grouped that they may be easily read by him, and that there may be ample margin to enable him to stop at the required point. And the fact that the occurrence of mistakes leading to accident is actually so rare is the best possible evidence that the signalling system, as at present carried out, is adequate to fulfil the present requirements of the case.

In the introductory chapter it was stated that in an ideally perfect signalling system it would be made actually impossible for a train movement to take place, unless the condition of the track were such that that movement would be a safe one. The extent to which this ideal requirement has already been fulfilled under ordinary conditions of working has been explained in earlier chapters. We have now to consider what further steps have been or may be taken in this direction, with a view to eliminating the human element as a factor of safety.

The simplest step is one whereby the signal for entering the section is interlocked with the block instrument so that the former cannot be lowered unless the latter shows "line clear." This arrangement avoids the risk of a signalman sending away a train until it has been accepted by the box ahead and to this extent is a satisfactory one. It does not give any additional security as between the signalman who accepts the train and the track conditions.

The next development (with which the first is usually combined) is to ensure that a train shall not be signalled on the block instrument as having cleared the section until this is actually the case. This arrangement which is adopted to a considerable extent on some of the southern railways, is usually dependent for its action, in controlling the clear indication, on a rail treadle operated by passing trains. There is always a difficulty about the position of this treadle, as if placed too far ahead it is not actuated by trains which may have been shunted clear of the main line and if placed too far back it is actuated and clears the section too early, as of course it is operated by the first wheel which passes over it, irrespective of the length of the train. There is also the more serious objection that the depression of the treadle does not indicate that the section is clear, but merely that a vehicle of some sort, which may have come from a siding or elsewhere has passed over it. These difficulties make it necessary in all treadle systems to provide means whereby the signalman can himself effect the releasing of the block instruments independently of the train. The releasing arrangement (or cancelling key as it is sometimes called) is an extremely objectionable feature, and its use goes far to modify any security which is obtained by the system.

The true solution of this part of the problem is found in the combination of a track-circuit system, with block instrument and signal control. Such an arrangement has been for some time in successful operation on an important main line in the north of England. By means of it the signal controlling the entrance to the section and also the block instruments are controlled both by the signalman ahead and by the actual presence of the train in the section. The necessity for any cancelling arrangement is entirely avoided, as the control operates only so long as the line is occupied, and operates also from whatever direction the movement may take place.

By the means just described the human element as a factor of safety is eliminated to the extent that a signal to enter the section cannot be lowered unless the section is actually clear. A further stage is reached by means of the arrangement known as "approach locking," to which reference was made in the chapter on automatic signalling, by means of which the presence of a train in a section is made to hold the points, at any required distance ahead, until the train has passed over them. By this means the signalman, having accepted a train, is prevented from obstructing the line in front of it. Such an arrangement, in combination with track control of the signals, completes the elimination of the human element as a factor of safety so far as the signalman is concerned. It has hitherto been employed in this country only in combination with power and automatic installations.

But, although the signalman's movements may thus be completely checked, there is still the possibility that a driver may pass a signal at danger, in which case all the precautions would be of no avail. No serious attempt has been made on ordinary steam railways automatically to ensure the stoppage of a train when a signal is at danger. On most of the electric underground railways of London, however, an automatic train stop is employed. This consists of a lever fixed at the side of the track which, when the signal is at danger, is raised so as to engage a valve connected with the brake system. By this means the brake is automatically applied and the train stopped. Other arrangements having a similar object in view have also been employed, but the brake valve system is that which is now most usually adopted.

The arrangements on many of the underground railways of London afford an example of a theoretically perfect signalling system. The signals are automatically controlled by the presence of the trains in the sections ; co-acting with each signal is a train-stop, by means of which a train, passing the signal at danger, is immediately brought to a stand automatically, while in many instances approach locking is provided whereby the signalmen are prevented from interfering with points or from making any attempt to obstruct the route in front of an approaching train. It may be added that the track control operates not only in respect of obstructions on the direct route, but ensures also that fouling points of converging routes are clear. Thus the whole of the operations for the protection of moving trains are effected without any dependence for security on the human element.

The conditions of working on the ordinary steam railways of this country do not at present appear to demand the elaboration of the signalling system to this standard of theoretical perfection ; there is no evidence, statistical or otherwise, to show that the system, as at present carried out, does not satisfactorily meet the necessities of the case. Nor must it be overlooked that what is a comparatively simple problem on an inter-urban underground railway would become a problem of great complexity and difficulty in connection with ordinary railways with their varying kinds of traffic conducted under all conditions of weather. The conditions prevailing in connection with ordinary steam railways and particularly the fact that goods trains are not, as a rule, equipped with continuous brakes would, for example, appear to preclude the adoption on such railways of automatic train stops.

It is not improbable, however, that the near future will show further progress in the co-ordination of the block system and the outdoor signalling on standard railways in this country, so that the operations dependent on the signalman may be checked to a greater extent than is usual at present. Such progress may, however, be looked for rather in particular instances, where the operating conditions tend to impose too great a strain on the existing arrangements, than on the railway systems generally.

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APPENDIX I.

SYNOPSIS OF LEGISLATION

Affecting the Working of Railways and the Provision of Signalling and Safety Appliances.

1839-1901.

A.D.

1839. THE RAILWAY LEVEL CROSSINGS ACT.

2, 3 *Vict.*, *c.* 45.

(The Act applies to then existing and to subsequent railways.)

Section 1.—Level Crossings.

Railway companies to erect and maintain gates at level crossings of public roadways and to employ a suitable person to open and shut the gates.

1840. RAILWAY REGULATION ACT.

3, 4 *Vict.*, *c.* 97.

(The provisions of this Act applied to then existing and to subsequent railways. Sections 1, 3, and 5 have, however, been repealed, and their provisions have been embodied in an amended form in the later Acts referred to below.)

Section 1.—Opening of New Railways.

One month's notice to be given to the Board of Trade of the intention to open a new railway for passenger traffic.

Section 3.—Accidents Causing Personal Injury.

The Board of Trade may order returns to be made of such accidents, the returns to be uniform for all the railway companies.

Section 5.—Inspectors of Railways.

The Board of Trade may appoint inspectors who may inspect railways at any time.

Section 13.—Punishment of Railway Servants.

Provides penalties for railway servants guilty of misconduct or neglect, or who are drunk when on duty.

Section 19.—Junctions or Sidings with other Parties.

The Board of Trade is to decide cases of dispute as to place for junction, having regard to the requirements of safety.

(Sections 1, 3 and 5 were amended by the Railway Regulation Acts, 1842 and 1871. Section 13 was amended by the Railway Regulation Act, 1842.)

A.D.

1842. RAILWAY REGULATION ACT.

5, 6 *Vict.*, *c.* 55.

(This Act is to be construed with the 1840 Act which it extends. Its provisions apply to then existing and to subsequent railways.)

Opening of New Railways.

Section 4.—The requirement as to the one month's notice to the Board of Trade before opening is repeated and a further notice of 10 days before the new line is expected to be ready for traffic is required.

Section 6.—If the Board of Trade inspector reports that the new line is unsafe, the Board of Trade may postpone the opening from month to month until it is satisfied that the requirements for safety have been complied with.

Accidents.

Section 7.—Those causing serious personal injury to be reported to the Board of Trade within 48 hours.

Section 8.—Returns of serious accidents may be ordered by the Board of Trade whether personal injury is caused or not.

(Sections 4, 7 and 8 were repealed and amended by the Railway Regulation Act, 1871. Section 6 was amended by the Railway Regulation Act, 1873.)

Section 9.—Level Crossing Gates.

The requirements of the 1839 Act, as to the provision of gates, are repeated. The gates to be kept constantly closed across public road, when not required to be opened for road traffic, unless the Board of Trade order otherwise.

(Note.—This was contrary to and annulled the provisions of many earlier private Acts.)

The gates to be so constructed as to fence in the railway at both ends of the public road.

Section 10.—Fences Alongside Railways.

Fences to be erected and maintained alongside railways.

Section 11.—Junctions with Other Lines and Running Powers.

Disputes as to arrangements for safety to be decided by the Board of Trade.

Section 13.—Bridges in Place of Level Crossings.

The Board of Trade may authorise companies to construct bridges in place of level crossings at their own expense.

Section 17.—Punishment of Railway Servants.

The provisions of the 1840 Act are extended to include those engaged on the maintenance of the way and works.

A.D.
1845.

RAILWAYS CLAUSES ACT.

8 *Vict.*, c. 20.

(The object of this Act was to consolidate the provisions usually inserted in private Acts, with a view to these being embodied in all subsequent Acts. Its provisions, therefore, apply to railways authorised during the session of 1845 and since that year only, except in cases where they form part of earlier private Acts.)

Section 47.—Level Crossings.

Gates to be provided across roadway on each side of railway, to fence in railway when closed across railway, to be kept constantly closed across roadway when not required to be opened for road traffic, unless the Board of Trade order otherwise. A competent person to be employed to open and close gates before and after the passage of roadway traffic.

Section 48.—LEVEL CROSSINGS ADJACENT TO STATIONS.

The speed of trains passing over the level crossings of turnpike roads adjacent to stations to be reduced to four miles an hour. The Board of Trade may from time to time make regulations for the working of such level crossings.

Section 63.—SCREENS FOR THE PROTECTION OF ROADWAYS ADJACENT TO RAILWAYS.

The road authority may apply to the Board of Trade in cases where roadways are adjacent to railways, and the Board of Trade may order the railway company to erect screens, if these appear to be necessary for the safety of traffic on the roadway.

A.D. 1846–1851. TEMPORARY TRANSFERENCE OF RAILWAY POWERS OF THE BOARD OF TRADE TO A RAILWAY COMMISSION.

The railway powers of the Board of Trade were transferred to a Railway Commission, established in 1846. The Railway Commission was abolished in 1851, and its duties were re-transferred to the Board of Trade.

1863. RAILWAYS CLAUSES ACT.

26, 27 *Vict.*, c. 92.

(This Act is embodied in subsequent private railway Acts, and its provisions are additional to those of the 1845 Act. It applies therefore to railways authorised since 1863 only, except in cases where its provisions form part of earlier private Acts.)

PROVISIONS AS TO LEVEL CROSSINGS WHEN THESE ARE AUTHORISED BY THE SPECIAL ACT.

Section 5.—STANDING OR SHUNTING OVER NOT TO BE PERMITTED.

Trains may not stand upon or shunt over level crossings.

Section 6.—LODGE TO BE PROVIDED; BOARD OF TRADE TO CONTROL WORKING.

The company to erect and maintain a lodge at each level crossing. The working of the level crossing and the speed of trains passing over it to be subject to the regulation of the Board of Trade.

Section 7.—ERECTION OF BRIDGE IN PLACE OF LEVEL CROSSING.

The Board of Trade may subsequently require the company to erect, at their own cost, a bridge, over or under the railway, in place of the level crossing, if this appears necessary for public safety.

A.D.

1868. REGULATION OF RAILWAYS ACT.

31, 32 *Vict.*, *c.* 119.

Section 22.—PASSENGER COMMUNICATION.

All trains travelling a distance of more than 20 miles without stopping to be provided with a means of communication between the passengers and the servants of the company in charge of the train. The apparatus provided is to be approved by the Board of Trade.

Section 24.—REMOVAL OF TREES GROWING AT THE SIDE OF THE LINE.

Trees at the side of a railway which involve risk of danger may be removed by an order of two Justices.

LIGHT RAILWAYS.

Section 27.—The Board of Trade may license a railway company to construct or to work any railway or section as a light railway.

Section 28.—The Board of Trade may make regulations for the working of light railways. A light railway is defined as one where the load does not exceed 8 tons on any pair of wheels and where the speed does not exceed 25 miles per hour.

(NOTE.—These definitions do not hold in the case of light railways constructed under the Light Railways Act, 1896.)

1871. RAILWAY REGULATION ACT.

34, 35 *Vict.*, *c.* 78.

(This Act is to be construed with the Railway Regulation Acts of 1840, 1842, 1844 and 1868, and its provisions apply to then existing and to subsequent railways.)

Section 3.—INSPECTORS OF RAILWAYS.

The Board of Trade may appoint inspectors :—

a. To inspect any railway.

b. To make inquiry in respect of—

i. any railway.

ii. the cause of any railway accident which has to be reported to the Board of Trade.

Section 4.—POWERS OF BOARD OF TRADE INSPECTORS.

The inspector may enter on and inspect any railway, may summon officers or servants as witnesses, and may enforce the production of books or documents.

Section 5.—THE OPENING OF NEW RAILWAYS.

The provisions of the Railway Regulation Act, 1842, as to inspection, to extend to the opening of :—

a. any additional line of railway
b. deviation line
c. station
d. junction
e. crossing on level

forming part of or connected with a passenger line.

But the Board of Trade may dispense with the notice required by the 1842 Act in respect of the works mentioned in this section.

ACCIDENTS ON RAILWAYS OR WORKS CONNECTED THEREWITH.

Section 6.—Railway Company to make reports to the Board of Trade of accidents :—

a. Causing loss of life or personal injury.
b. Collisions between trains, if either train is a passenger train.
c. In which any passenger train, or part of a train, leaves the rails.
d. Any accident not comprised in foregoing, but of a kind causing or likely to cause loss of life or personal injury, and specified in an Order made by the Board of Trade.

The notice is to be in the form ordered by the Board of Trade and to be sent by the earliest practicable post or (if so ordered) by telegraph.

(NOTE.—By the latest Order issued by the Board of Trade under the powers of this Act and of the Railway Employment (Prevention of Accidents) Act, 1900, railway companies are required to report practically every mishap whether affecting goods or passenger trains, works, the public or railway servants.)

Section 7.—The Board of Trade may direct an inquiry by an inspector to be held as to the cause of any accident. It may also direct a more formal inquiry to be held by a magistrate with a Board of Trade inspector as assessor.

The inspector or Court to report to the Board of Trade the result of the inquiry, with all the circumstances of the case, and the Board of Trade is to make the report public.

Section 8.—In the case of fatal accidents the Board of Trade may, at the request of the Coroner, send an inspector to assist him in holding the inquest.

A.D.

1873. RAILWAY REGULATION ACT (RETURNS OF SIGNAL ARRANGEMENTS, WORKINGS, &c.)

36, 37 *Vict.*, c. 76.

Section 4.—RETURNS OF SIGNALLING ARRANGEMENTS.

The railway companies to make annual returns to the Board of Trade showing the progress made in respect of signalling and interlocking, block telegraph working and single line working.

(NOTE.—This section has not been repealed, but the returns are no longer necessary as, in accordance with the Railway Regulation Act, 1889, the railways of the United Kingdom have since been equipped throughout with the apparatus referred to in the return.)

Section 5.—ACCIDENTS ON RAILWAYS.

Coroners to make special returns of the deaths of persons killed on railways.

Section 6.—OPENING OF NEW RAILWAYS.

After an inspection of new lines, &c., the Board of Trade may, if the equipment is incomplete, postpone the opening from month to month without further inspection.

1878. RAILWAY RETURNS (CONTINUOUS BRAKES) ACT.

41 *Vict.*, c. 20.

Section 2.—RETURNS OF CONTINUOUS BRAKES.

The railway companies to make half-yearly returns to the Board of Trade showing the number of vehicles fitted with continuous brakes, the description of brake used, the failures which have occurred, and the mileage of passenger trains run without continuous brakes.

(NOTE.—The Railway Regulation Act, 1889, now requires all passenger trains to be fitted with continuous brakes.)

1889 REGULATION OF RAILWAYS ACT.

52, 53 *Vict.*, c. 57.

(This Act applies to then existing and to subsequent railways.)

Section 1.—EQUIPMENT FOR SAFE WORKING.

The Board of Trade may from time to time order a railway company to do, within a period fixed by the Order, any of the following :—

a. To adopt the block system on passenger lines.
b. To provide for the interlocking of points and signals on passenger lines.
c. To equip passenger trains with continuous brakes.

NOTE.—In accordance with the powers conferred on it by this Act, the Board of Trade made Orders on the railway companies in the United Kingdom to carry out the requirements of the Act within a period of two years of the dates of the Orders.

Section 4.—RETURNS OF OVERTIME.

Railway companies to make returns of overtime worked by their servants whose duties involve the safety of trains or passengers. The definition of overtime rests with the Board of Trade.

A.D.
1893.

RAILWAY REGULATION ACT.

56, 57 *Vict.*, *c.* 29.

HOURS OF RAILWAY SERVANTS.

Section 1 (i.)—If representation is made to the Board of Trade as to excessive hours, insufficient rest, or insufficient relief on Sundays of any railway servants engaged in working the traffic, the Board of Trade shall inquire into the matter.

(ii.)—The Board of Trade may order the company to submit an amended schedule of hours for the servants in respect of whom complaint is made.

(iii.)—The amended schedule of hours may be enforced by the Railway and Canal Commissioners.

2.—An annual return of all proceedings under this Act to be made to Parliament by the Board of Trade.

1896.

LIGHT RAILWAYS ACT.

59, 60 *Vict.*, *c.* 48.

REGULATIONS FOR SAFE WORKING.

Sections 9 and 11.—The Board of Trade is empowered, in confirming Light Railway Orders under this Act, to modify or dispense with any of the requirements for safety contained in the various Railway Regulation and Railway Clauses Acts.

(The Board of Trade imposes regulations for safe working on light railways, which vary according to circumstances in each case. These regulations deal with permanent way, rolling stock, level crossings and signalling, and with matters connected with the working of the line, including the maximum speed, and are scheduled to each Light Railway Order.)

Section 18.—AUTHORITY TO WORK EXISTING RAILWAY AS A LIGHT RAILWAY.

The Board of Trade may authorise the working as a light railway of any existing or authorised railway.

(Such authority would be subject to any necessary restrictions as to speed of trains, weight of rolling stock, &c.)

A.D.

1900. RAILWAY EMPLOYMENT (PREVENTION OF ACCIDENTS) ACT.

63, 64 *Vict.*, *c.* 27.

(This Act applies to then existing and to subsequent railways.)

Section 1.—THE BOARD OF TRADE MAY MAKE RULES IN REGARD TO WORKING AND APPARATUS.

The Board of Trade may make rules in respect to certain subjects with the object of reducing or removing danger to railway servants. (The list of subjects is scheduled to the Act.)

It may also make rules in respect of matters not scheduled to the Act, and may require the use or disuse of any plant or appliance.

Section 2.—RULES TO BE PUBLISHED.

Any rules proposed under the Act must first be published, and any objections must be considered by the Board of Trade. The rules are subject further to an appeal before the Railway and Canal Commissioners, who may disallow any rule if they are satisfied that there is ground for reasonable objection to its being made.

Section 13.—(i) ADDITIONAL POWERS OF INSPECTION BY BOARD OF TRADE.

The powers of the Board of Trade in regard to the inspection of railways are extended to include the power of inspection to ascertain whether there is necessity to proceed under this Act, and whether any rules made under the Act are being complied with.

(ii) ACCIDENTS OCCURRING OFF RAILWAY PROPERTY TO BE REPORTED.

The duty of a railway company to report accidents is extended to apply to accident to railway servants when employed on a siding or branch line not forming part of the company's property.

APPENDIX II.

RAILWAY CLEARING HOUSE STANDARD BLOCK SIGNALLING CODE.

	Beats on bell.	How to be given.
Call attention	1	1.
Is line clear for express passenger train or breakdown van train going to clear the line, or light engine going to assist disabled train?	4	4 consecutively.
Is line clear for ordinary passenger train or breakdown van train not going to clear the line?	4	3, pause, 1.
Is line clear for branch passenger train?	4	1, pause, 3.
Is line clear for fish, meat, fruit, horse, cattle, or perishable train composed of coaching stock?...	5	5 consecutively.
Is line clear for empty coaching stock train?	5	2, pause, 2, pause, 1.
Is line clear for fish, meat, or fruit train composed of goods stock, express cattle or express goods train, Class "A"?...	5	3, pause, 2.
Is line clear for express cattle or express goods train, Class "B"?	5	1, pause, 4.
Is line clear for light engine or light engines coupled together, or engine and brake?	5	2, pause, 3.
Is line clear for through goods, mineral, or ballast train?...	5	4, pause, 1.
Is line clear for ordinary goods or mineral train stopping at intermediate stations?	3	3 consecutively.
Is line clear for branch goods train? ...	3	1, pause, 2.
Is line clear for ballast train requiring to stop in section?...	5	1, pause, 2, pause, 2.

	Beats on bell.	How to be given.
Is line clear for platelayers' lorry requiring to pass through tunnel?	5	2, pause, 1, pause, 2.
Train entering section	2	2 consecutively.
Bank engine in rear of train	4	2, pause, 2.
Train out of section, or obstruction removed	3	2, pause, 1.
Obstruction danger	6	6 consecutively.
Blocking back	6	*Inside* home signal: 2, pause, 4. *Outside* home signal: 3, pause, 3.
Stop and examine train	7	7 consecutively.
Cancelling "Is line clear?" or "Train entering section" signal	8	3, pause, 5.
Train passed without tail lamp	9	9 consecutively TO BOX IN ADVANCE. 4, pause, 5 TO BOX IN REAR.
Train divided	10	5, pause, 5.
Shunt train for following train to pass ...	11	1, pause, 5, pause, 5.
Vehicles running away on wrong line ...	12	2, pause, 5, pause, 5.
Section clear, but station or junction blocked	13	3, pause, 5, pause, 5.
Vehicles running away on right line ...	14	4, pause, 5, pause, 5.
Opening of signal box	15	5, pause, 5, pause, 5.
Testing of bells	16	16 consecutively.
Closing of signal box	17	7, pause, 5, pause, 5.
Time signal	18	8, pause, 5, pause, 5.
Lampman or fog-signalman required ...	19	9, pause, 5, pause, 5.

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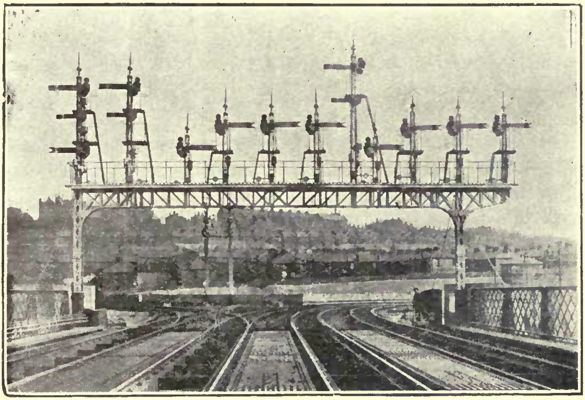

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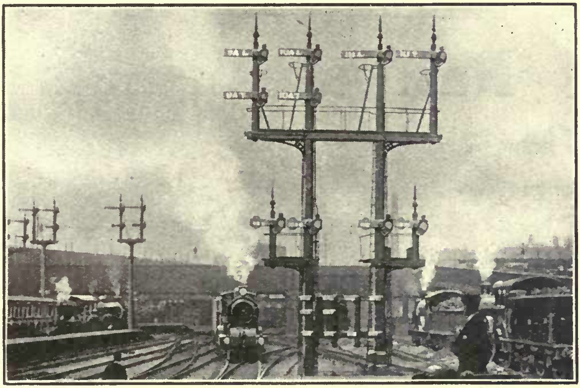

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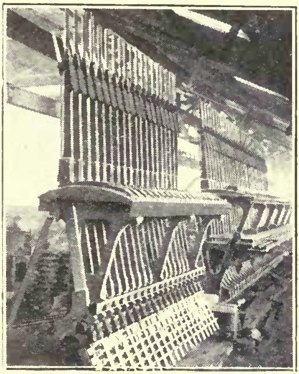

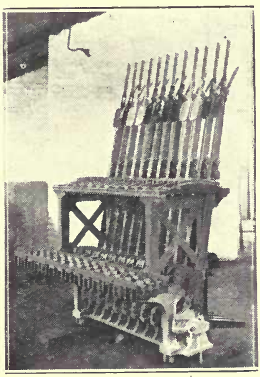

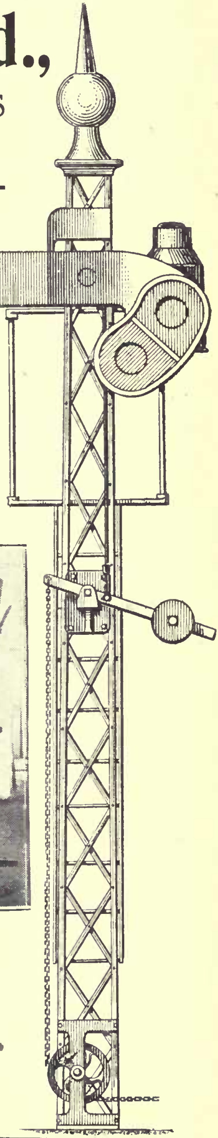

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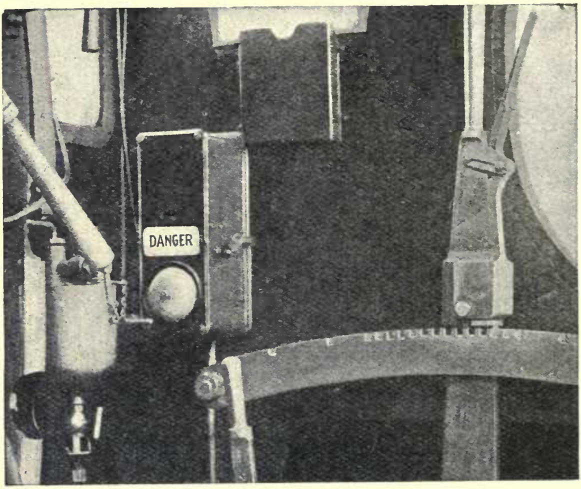

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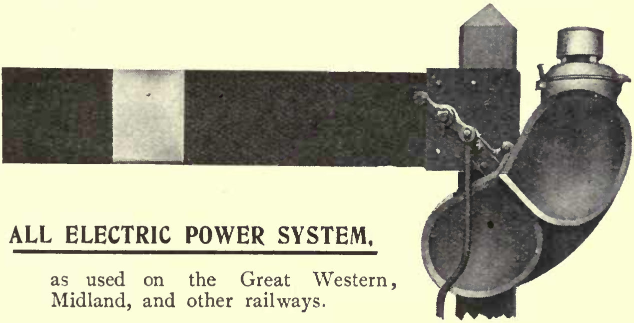

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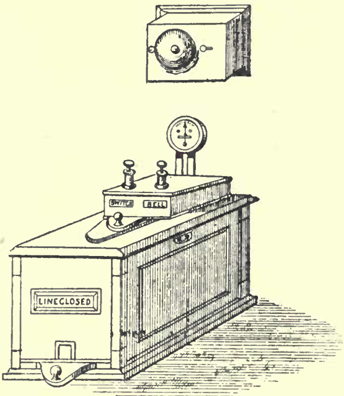

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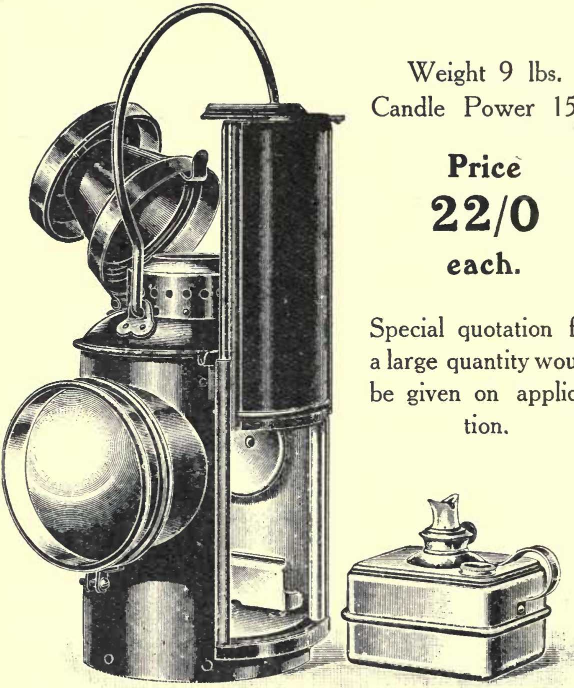

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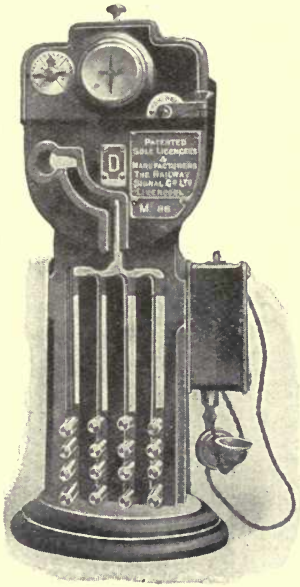

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