RAILWAY "BLOCK" SIGNALLING

THE PRINCIPLES OF TRAIN SIGNALLING

AND

APPARATUS FOR ENSURING SAFETY.

BY

JAMES PIGG, A.I.E.E.

ILLUSTRATED.

LONDON:
BIGGS AND CO., 139-140, SALISBURY COURT, FLEET STREET, E.C.

DEDICATION.

To the Author's Father.

(An "I. O U.")

PREFACE.

A considerable portion of this book appeared as a serial in *The Electrical Engineer* during the latter half of 1896. Since then the matter has been revised and considerably extended by the inclusion of descriptions of other apparatus, and by the insertion of examples of the codes used, and the regulations and rules under which signalling is carried out.

Railway signalling appears to have now reached a stage at which some departure from the present methods seems probable. The lines upon which changes will be made will, in all probability, result in a greater degree of automatic control than obtains at present. The degree of control is, however, difficult to predict; and, moreover, the degree of such control desirable is a debatable subject.

A study of the lines along which developments are proceeding shows at least two marked divisions. In one, the apparatus is entirely automatic; in the other, the apparatus is so inter-connected with the operations involved in the movement of traffic, as to act as a check upon the actions of the controller of the traffic, for the time being, in such respects as experience shows to be desirable. The first is by far the more ambitious of the two, and adoption of such methods would constitute a revolution in signalling. The second is the most adaptable to present-day methods and apparatus. Which will be the survivor is difficult to indicate, but completely automatic systems admit of none of the selection which is the chief feature in the movement of heavy traffic of mixed character.

The subject of signalling in all its branches is a most important one; and it is because of this importance and the difficulty of thoroughly estimating all the requirements in connection with railway signalling without an accurate knowledge of details, that the author has included the codes, regulations, and rules under which the work is carried out. A glance at the records of the Patent Office speaks volumes for the necessity of a study of detail before undertaking to supply apparatus for a given purpose, or to meet such circumstances as have at some time given rise to accident. The applicability of apparatus to all circumstances that experience shows may arise is of quite as much importance, or more, than its applicability to circumstances which are the result of neglect or inadvertence.

It only remains to be said that the author's thanks are due, and are herewith gratefully tendered, to Mr. Preece, Messrs. Siemens, Messrs. Saxby and Farmer, Mr. G. Edwards, Mr. W. R. Sykes, Mr. I. A. Timmis, and others, for information respecting the apparatus they are interested in, and to Mr. Clement E. Stretton for information respecting the earlier days of railway signalling.

CONTENTS.

RAILWAY SIGNALLING.

CHAPTER I.

The "block" telegraph system in use for regulating traffic is probably the most extensive of all the adaptations of electricity to railway work, and its "use-value" is undoubtedly greater than that of any other form of electrical apparatus in use upon railways. The development of the "block" system has been the work of the last thirty years approximately; previous to that time traffic was worked in quite a different fashion to that in use at present.

The fundamental principle of the "block" was at first derided, and the name chosen was considered as characteristic of the condition traffic was likely to get into under any such system of working. That there should be any reason to prevent a driver from proceeding as far as his visionary powers assured him the line was clear, or that any train should be prevented from "bumping" a preceding train—gently, of course—was considered absurd, and there were not wanting those who predicted the early demise of this or any other system which involved restrictions being put on the free passage of traffic. This, of course, was before the era of express trains travelling at rates varying between 60 and 70 miles per hour.

In those days it was no uncommon thing for agile persons to boast of their ability to leave trains at any point that was most suitable. At that date railways were small concerns compared with what they have, by extensions and amalgamations, now become, and the volume of traffic handled by one railway was correspondingly small.

The prophecies referred to have, however, been falsified, and railway traffic is now carried with a regularity and freedom from accident which is remarkable when the quantity of material handled and the area covered is taken into consideration. To this precision, and the safety resulting therefrom, the "block" has undoubtedly contributed quite as much as any other branch of engineering.

Necessity for Regulating Traffic.—It was at a very early period of railway history that the necessity for some means of regulating and controlling the passage of trains became apparent; and electricity, which was then really "in its infancy," as a means of communication between those engaged in working traffic, promised such excellent results, from the ease with which it could be established and maintained, and its comparative independence of distance, as led to its early employment.

The time and place at which block working, as known at present, was first introduced, is not known with any certainty, owing to the vague accounts available of the methods of working of the earlier instances of the electrical signalling of trains. Most of the earlier applications of electricity for this purpose were brought into operation between special points on lines where the ordinary time interval, in use at other places, was considered insufficient for the requirements of that part of the line. Such places were those parts of the line where tunnels were in use, or inclines, and similar places. These were all isolated sections of line; other parts of the same line being worked without any means of notifying the passage of trains from point to point. Reliable records of the use of electrical means of signalling are by no means common, although its use for this purpose seems to have been contemporaneous with the introduction of electrical telegraphy. It is, however, by no means certain that any of the earlier systems are entitled to the name of "block," although the title is claimed for many of them.

Much of this confusion arises, as already stated, from the absence of the regulations defining the methods of working adopted with the earlier systems; but part of it is undoubtedly due, also, to the want of a definition of what is meant by the "block" system. A study of the progress made, as shown by the scanty records available, shows that, whilst the origination of the main principle may be credited to some particular person or persons, the means taken to carry out the idea were of the most rudimentary character, and were subject to considerable alteration and extension, as the continual process of trial and error to which they were subject showed to be necessary. There would be no difficulty in defining the block system as it is used to-day; but at what stage of its evolution from the earlier methods to present-day practice, shall the term "block" be first applied? Something like fifty-seven years have passed since the first application electricity to this purpose, and the progress from that time to the present has been gradual and constant, and is not yet completed.

Historic.—Mr. Clement E. Stretton, C.E., the well-known expert on railway matters, in an interesting letter to *The Electrical Engineer* of November 13, 1896, throws considerable light on the inception and development in its earlier stages of what is now known as the "block" system, and, as the result of his research, has shown that the germ of the present system was brought into use between Paddington, West Drayton, and Hanwell, on the Great Western Railway, at the instance of Cooke and Wheatstone, as early as December, 1839. The system there brought into operation was an adaptation of the ordinary telegraph system—the departure and arrival of trains being *telegraphed*, and instructions issued to stop a second train on its arrival at any of the telegraph stations until the arrival of the first train at the advance station was telegraphed back. This is the earliest record from official sources of the application of electricity to the preservation of a *space* limit between successive trains on the same line of rails.

In 1840, as recorded in Mr. Langdon's "Applications of Electricity to Railway Working," electricity was used for signalling trains on the cable railway between Minories and Blackwall. The instruments used were a form of needle instrument; but the character of the signalling was different to that on the Great Western, as would necessarily be the case from the difference in the methods of working the lines. On the Blackwall railway the signals were transmitted to the driver of the stationary engine at either of the termini as required, and indicated to him when the carriages at the opposite terminus, and at the intermediate stations in turn, were ready to proceed, or, on the other hand, when circumstances rendered it necessary to stop the engine. The indicator at each of the termini consisted of six dials, each of which was capable of indicating two signals—"Ready" and "Stop." The instrument at each of the intermediate stations was provided with one dial only, having the same indications; and both these and the instruments at the termini were adapted for sending as well as receiving signals. Thirty wires were provided for this method of signalling, several of which, however, were spare wires for use in case of failure of others in use.

Reverting to Mr. Stretton's records, we are told that Cooke and Wheatstone introduced, in 1841, independent instruments for the signalling of trains, which were intended to show the condition of the line at all times. They also introduced at the same time an electric bell communication in order to call attention. This arrangement possessed the most important distinctive features of electrical apparatus for train signalling—viz., independent instruments, distinct apparatus for different purposes, continuous indications of the condition of the line, and a means of communicating instructions for the working of traffic by a pre-arranged code. The instruments of 1841 were lettered "Stop" on the upper left-hand corner, and "Go on" on the right-hand upper corner. The same inventors introduced a form of instrument between Norwich and Yarmouth in 1844, on which this lettering was replaced by "Line blocked" and "Line clear" respectively.

The Brighton Company is said to have worked a form of block through the Clayton Tunnel in 1841.

During the winter of 1843-4, signalling of trains by telegraph messages was carried out on part of the old Birmingham and Gloucester Railway. Mr. Stretton quotes the following quaint instance of the signalling, as taken from the records of the working between Blackwell and Bromsgrove.

BLACKWELL TELEGRAPHS :	BROMSGROVE REPLIES :
Bristol goods is approaching here	Right ; let her come.
Bristol passenger is approaching here ...	Keep her back ; goods not here yet.
	Right now ; send her on.

In 1845, the Bristol and Gloucester Railway Company is said to have worked absolute block through Wickwar Tunnel by means of electric bells and a bell code.

In 1846, the Midland Railway Company is said to have worked absolute block through Thackley, Clay Cross, and Duffield Tunnels, by the three-wire block, with needle instruments.

In 1848, the Manchester, Buxton, and Midlands Junction Railway Company is said to have worked a three-wire block through all the tunnels between Ambergate and Rowsley.

In 1849, the Midland Railway Company had the following code in use between Desford and Bagsworth on a three-wire block circuit :

To call attention	1 stroke of bell.
Passenger train approaching here	2 strokes of bell, 2 beats of needle to left.
Goods train approaching here	3 ditto, 3 ditto.
The West Bridge train......................	4 ditto, 4 ditto.

On a train *leaving* either Desford or Bagsworth, the following signals were given:

To call attention	1 on bell.
Passenger train leaving......................	6 ditto, 6 on needle to right.
Goods train leaving	7 ditto, 7 ditto.
West Bridge train	8 ditto, 8 ditto.

On arrival of a train at either end, the signal given was:

To call attention..................................	1 on bell.
Passenger train arrived	2 on needle to left.
Goods train arrived	3 ditto.
West Bridge train arrived..................	4 ditto.

In 1851, the Great Northern Railway Company are said to have worked absolute block through all tunnels between King's Cross and Hitchin.

In 1851, the South-Eastern Railway Company established block working by means of bell signals. Continuous indicators having the form of miniature semaphore signals, and worked in a similar way, were introduced on the opening of the Charing Cross Railway.

Tyer's first form of block apparatus was brought out about 1852, and it is worthy of note that this was the first attempt at automatic signalling. Treadles were provided at the entrance and exit of the section, and the passage of a train over these treadles intimated its approach and exit from the section respectively. The automatic arrangement was subsequently abandoned, and was replaced by hand signalling. The indications provided in this apparatus —as in Bartholomew's, which was introduced at about the same period—were two in number: "Train on line" and "Line clear." The lettering on Bartholomew's instrument was "Clear," "Closed."

In 1853, Mr. Edwin Clark adapted the double-needle speaking instrument, in combination with a separate bell communication, to train signalling on the London and North-Western Railway Company's line, using one needle as an indicator for the up line, and the other for the down line. The two instruments, although in one case, were quite independent, were worked by separate wires, and were arranged to give continuous indications *by means of continuous currents*, the handles of the instruments being pegged over constantly in either one or the other of the two positions provided. Each dial indicated three positions, thus: upper part of needle deflected to left, "Train on line"; upper part of needle deflected to right, "Line clear"; needle vertical, "Line blocked."

This system was, in so far as the instruments, their lettering, and the method of using them is concerned, substantially the same as any of the three-wire single-needle systems in use at present. Whilst this is the case, the lettering "Line blocked" had a different meaning to that given to it at present, and the "Line clear" indication was also of a different character. As an adjunct to the apparatus as already described, it is stated that "the telegraph wires were brought down the posts, so that in case of the breakdown of a train the driver or guard could run to a post and cut the wire and block one or both lines as necessary." From this extract and the statement that the indications "Line clear" and "Train on line" were maintained by continuous currents, it is evident that the "Line blocked" indication was an emergency signal, and not used during normal working. Practically it partook of the nature of an intimation to the signalman from outside of something out of the normal order of working, but not necessarily under his cognisance, which rendered it expedient to take further steps to protect the line or lines for which the indication "Line blocked" was being exhibited.

Hence this system, as with others in which indicators were provided, recognised only two conditions of the line, but it is worthy of record that it was a three-wire system in which the continuous indications were maintained by continuous currents.

In 1862, Mr. W. H. Preece devised his three-wire system of train signalling, in which he used a miniature semaphore arm to indicate the condition of the line at all times. Much interesting information on the subject of the earlier methods of train signalling is given in a paper read by Mr. Preece at the meeting of the Institution of Civil Engineers on January 13, 1863; and the discussion which ensued, and lasted four successive meetings, is also of a most interesting character, since it exhibits the opinions of most of those who took a prominent part in the introduction of electrical signalling on railways. Amongst those who took part in the discussion are the names of C. V. Walker, Tyer, Bartholomew, Fleeming Jenkin, Captain Huish, and several others; and, as might be expected, considerable difference of opinion was shown.

In this paper, Mr. Preece, after commenting upon the liability of the various forms of needle instruments to be reversed by atmospheric disturbances (a very common occurrence at the period previous to the introduction of the induced needle), and the disturbances due to earth currents and similar causes—"At certain times and seasons immense masses of electricity pass through the crust of the earth from the equator to the pole, and *vice versâ*, traversing the telegraph circuits in their course and causing great annoyance and trouble"—strongly urged the desirability of assimilating the visible signal for the benefit of the signalman to that exhibited for the guidance of the drivers of trains of which the signalman was charged with the control. He also recognised the relatively subordinate position occupied by the signalman at the sending end of the section; and his apparatus was designed with a view to show, in addition to the semaphore indication, the position of the signal at the distant station. Curiously enough, this indication (the position of the signal at the distant station) is shown, by the illustrations accompanying the paper, to have been made by a needle.

With respect to the general lines on which the design of apparatus for train signalling should be based, the following extract from Mr. Preece's paper is of some interest:

"Mr. Edwin Clark, M.Inst.C.E., in an interesting report addressed to the London and North-Western Railway Company upon improvements in their telegraphic system, remarked: 'The following conditions should, I think, be insisted upon in any application of a telegraph to railway purposes:

"'First. The machinery employed must be of the most simple and evident description, not liable to derangement, and easily repaired.

"'Second. The signals must be simple and few, and so distinctive that no mistakes can occur.

"'Third. No dependence must necessarily be placed on the memory of the person in charge, and the signals should be permanent and not temporary, or liable to misconstruction or neglect from the absence of the attendant.

"'Lastly, and more particularly, no accident should be actually caused by the derangement of the apparatus or the absence of the signalman, but such absence or derangement should merely cause delay.'"

Much interesting information was elicited during the discussion on Mr. Preece's paper; and it was stated that Mr. C. V. Walker had used a form of indicator for a short time on the South-Eastern Railway, in 1854, in which the indication was given by the position of a small semaphore arm attached to the axis of an ordinary needle instrument, one of the two indications being maintained by a continuous current.

The inventor of the form of semaphore indicator and bell combined (Mr. C. V. Walker, F.R.S.) used on the South-Eastern Railway contributed a series of articles, entitled "Train Signalling in Theory and Practice," to the *Popular Science Review*, which were subsequently extracted by the *English Mechanic.* In these articles, Mr. Walker described in most minute detail the various operations involved in the system of bell signalling in use, under his supervision, on the South-Eastern Railway. As the articles afford a most interesting glimpse of the line of reasoning on which the pioneers of the block system based their conception of the requirements of railway signalling, the following extracts are taken from the issues of the *English Mechanic* for July 6 and 20, 1866:

"In order to illustrate the laws of train signalling, it will be better to take the simple case of a railway like the Ramsgate-Margate, for instance, having two pairs of rails, an up line and a down line, with a signal station at each end, but no intermediate station. The fundamental law is—'Two trains or engines are not to be allowed to run on the *same* line, between two signal stations at the *same time.*' In order to carry out this important regulation, upon which the security of those who travel so largely depends, 'every train or engine must be signalled *out* to the next station, before it *leaves* or *passes* a station.' So that when the business of the day, for instance, commences, station B knows that train No. 1 is asking permission to come to him from station A; and, to prevent all misunderstanding, 'the train or engine must not be started, or allowed to pass, until the next station has *taken* the *out* signal.' It is not enough for the first station to *give* the signal, the other station must *take* it; for 'no signal given by one station is complete until *taken* by the other station *repeating* it,' by which process a clear understanding is established between the signallers, that the precise signal *sent* by one is *received* by the other. The next rule applicable is that 'every train or engine that *arrives* at or *passes* a station is to be immediately signalled *in* to the last station'; and it follows, from what has been already stated, that 'no second train or engine is to be allowed to follow until the *in* or *arrival* signal of the *previous* train has been taken'—that is to say, has been repeated back blow for blow.

"And in order that there may be no mistake as to whether or not the whole of the train is safely in, it is not to be signalled as *in* until 'after it has been clearly ascertained by actually seeing the tail lamps, or communication with the guards, that no portion of the train from any cause has been left behind.'

"Next in simplicity to a signal-box at either end of a line with two pairs of rails, is that of an intermediate station on a similar line. In this case the signal-box is provided with a pair of bells of different tones, or a bell and a gong or steel spiral. They are placed on either side of the box, each being at the side nearest to the station with which it is in communication. . . . The rules already given are equally in force here, and are carried out precisely in the manner described. . . . On the day of the Foresters' fête (August 19, 1862) no less than 535 trains were signalled at one intermediate station in the London Bridge yard on one pair of bells from early morning till late at night, all signals also being booked.

"There is a rule essential to intermediate stations, but, of course, not required at a terminus, that the '*out* signals of passing trains are to be made as they *approach*, in order to let them pass without check *if the line is clear,'* because, unless the *out* signal, as we have already stated, be replied to—that is, unless the *out* signal, which means 'May I send the train,' be repeated back, which means 'You may send the train,' it would have to be checked; for, under such circumstances, from whatever cause arising, 'the train must be brought to a stand, and the driver cautioned to keep a good look-out, because he is running by sight and fixed signals, and not by telegraph signals.'

"I have heretofore confined myself to the code which is established for the simplest case of train signalling, and which is applicable and is applied to and in force on five-sixths of the railway in question; and before passing on to give one or two illustrations of special codes provided for mixed traffic, which requires distinctive signals, I may here give certain constant signals that are universal in their application, and may always have the same meaning. When a bell is struck *five* times, it indicates that the line is *blocked*, and that nothing must be allowed to come on until a signal has been given that the line is *clear* again, which latter signal consists of *three* blows given and taken *twice*. The telegraph inspectors give sign of their presence and test the condition of the apparatus by exchanging *six* blows, and an erroneous signal is cancelled by *seven* blows.

"The simplest case of deviation from 'a general code' of signals is when the trains of two companies travel on the same lines, as the South-Eastern and the Brighton trains between London and Redhill. In this case one blow indicates a South-Eastern train, whether up or down, and two blows, a Brighton train;

all other signals remaining unchanged. Or, to take a case somewhat more complex, and which is the oldest of the codes, dating as far back as October 29, 1851, and provided originally for up trains on the half-mile of line intervening between Spa-road and the entrance to the joint station at London Bridge—*one* blow for a Croydon train, *two* for a Brighton train, *three* for a South-Eastern train.

"It has been further thought advisable, especially where the trains up and down are very many in number, that the signalman should be reminded by some signal visible to the eye that he has given or taken a certain bell signal; and this visible signal is further turned to account by being used in combination with the audible signal, and thus diminishing the number of sounds necessary for carrying on traffic. The visible signals at a glance show the actual state of the line, whether a train is coming on or not, whether a train is still going on or is safely in; in fact, whether the lines in either direction are free of trains or not.

"The Charing Cross Railway, where a system of this kind has been in full operation since the opening, will give a very perfect illustration of the joint service of the eye and ear in interpreting what the hand has given.

"The illustration shows the manner in which the signal-box at Waterloo is fitted up. This box is intermediate between Belvedere-road and Blackfriars. At the front of the box, in the right and left hand corners respectively, are placed a bell and an "electromagnetic telegraph semaphore." Externally, this instrument presents to the eye a signal-post on a small scale, similar to those in use on the railway in question, with a red arm on the left side and a white arm on the right side, in like position with those on an actual signal-post, and capable of being worked by an electric current *up*, indicating danger, or *down*, indicating caution, as required; and the regulations for working them are such that the arms at all times indicate the state of the line. Looking *towards* a semaphore, whether actual or electromagnetic, the red and left arm has reference to trains receding, the white and right arm to trains approaching; and when an arm is up it indicates that a train is on the line, and when down that a train is not on the line. So that, looking at the position of the arms as they stand in the page engraving, it is evident that no train is going from Waterloo to Belvedere, and no train is coming from Belvedere to Waterloo; both lines on this side of Waterloo are clear. On the other side, there is no train going from Waterloo to Blackfriars, but a train is on its way from Blackfriars to Waterloo. These semaphore instruments are connected up in pairs—the one on the right-hand side of the signal-box is connected with its companion at Blackfriars and works in sympathy with it, the arrangement being that 'the red arm at one station and the white arm at the other station work up and down together. When the red arm at one station is up the white arm at the other station is up also; when the one is down the other is down.' If an observer were at Blackfriars he would find the companion semaphore in question on the *left* side of the box there and labelled Waterloo, and would see the left—the red arm—*up* in sympathy with the white, the right arm of the semaphore in the engraving, and the white arm *down* in sympathy with the red or left arm in the engraving; and the signalman at Blackfriars would make no attempt to signal on another up train until the red arm at his station had been put down by Waterloo.

"The principle upon which the electromagnetic semaphores are here connected up and arranged is that 'each station can put the white arm only at his own station, and the red arm only at the other station, up or down.' No signalman in this arrangement, which may be varied to meet other cases, has power to alter the position of his own red arm; it is put up behind a train by the next station, and put down when the train is at that station.

"It will be convenient here in explanation of the manner of working these instruments to describe the whole process of signalling a train by bell and semaphore, and we can then pass on to the description of the electrical arrangements that are employed for bringing about the result.

"'The ordinary position of the arms of the electromagnetic telegraph semaphores will be down,' that is to say, when the line is all clear of trains and business begins, say in early morning, all the arms will be down, indicating that no train is moving. When the first train is ready to depart, say from Charing Cross, the signalman will give the proper bell signal to Belvedere on the bell, two, three, or four blows, according as the train is for Greenwich, for the

North-Kent, or Mid-Kent, or the main line, and the Belvedere man will acknowledge this by one blow on the bell in reply, and without raising the Charing Cross red or left arm; this is the signal that the train may go on, and when the train has passed so that the Charing Cross man can see the tail lights he gives the out signal a second time, which the Belvedere man acknowledges, at the same time raising the red arm at Charing Cross behind the train, and so protecting it until it has passed him at Belvedere, when he signals to that effect to Charing Cross, at the same time pulling down the red arm there as an indication that the line is again clear. While these operations are going on for down trains, others precisely similar, but in the reverse direction, are going on for up trains. The separate functions, as well as the combined office of the bell and semaphore, will thus be readily appreciated. The bell, the basis, as we have said, of all the mere sound systems, as heretofore speaks to the ear, and asks not only if *a* train may come, but defines the particular kind of train that is ready to come, and it also tells at the proper time that the train is in. The semaphore arm has two motions and communicates alternately, and puts on record two facts only, and most important facts they are—either that a train is on the line, or that a train is not on the line; and as either one or the other of these things must always be the case, it is a standing record at any and at all times of the actual state of the line, and is of very great service to the signalman in regulating the enormous traffic with which he has to deal. The combined office of the bell and semaphore is now evident. It is not enough, as we have seen, that the arm of the semaphore indicates the line clear; before a train is allowed to go, ideas must be interchanged by bell signal, and if the reply is combined with still displaying the all-clear signal—that is, the red arm down—the train may proceed. Nor is this enough, for it would be a contradiction after the train had passed, and is therefore on a certain length of rail, for the all-clear signal to remain displayed; and hence it is that a second interchange of out bell signals is made, this time indicating that the train has come on as allowed, and the reply in recognition of this is combined with raising the red arm behind the train and retaining it there until the train is safely in. It is then lowered without any further interchange of signals, and so on. It takes far longer to describe these operations than to perform them. The bell semaphore signal is the result of a single act—one and the same pressure on the key sends the bell signal and raises or depresses the semaphore arm as the case may require, a single telegraph wire only being required for the combined system as for the more simple bell system."

Careful consideration of the records available show clearly the gradual growth in the number of applications of electricity from the time of its introduction by Cooke and Wheatstone in 1839; and also, incidentally, some of the disadvantages attendant upon isolated effort, without knowledge of the results obtained and methods employed by previous workers in the same field.

In Cooke and Wheatstone's adaptation of the telegraph (which must have been immediately on its completion, as it is recorded elsewhere that the telegraph wires were laid from Paddington to West Drayton only in September, 1839) to train signalling, the fundamental principle of the existing block system—the space limit—is imposed, but no special apparatus is provided for the purpose; and there existed no permanent indication of the actual condition of the line other than that afforded by a comparison of the times at which messages were despatched and received. Two years later the same inventors provided instruments of a distinct character for train signalling alone; and these instruments were not only adapted for communication between different points, but were capable of indicating the condition of the line. In these instruments, and in those fixed by the same inventors between Norwich and Yarmouth in 1844, only two conditions of the line are recognised. To Cooke and Wheatstone belongs the honour of having originated the present system of train signalling; and, from the fact that they employed independent instruments for indicating the condition of the line to those used for intimating the requirements at various times, they certainly seemed to have gauged the requirements to a greater degree of perfection at this early date than some of the later workers in this field.

It must, however, be pointed out that Cooke and Wheatstone's system did not in all respects correspond to the present methods of signalling. As used between Norwich and Yarmouth as late as 1844, the instruments did not break up the line into separate and distinct (as far as the signalling instruments are concerned) portions as is done at present.

In the paper read by Mr. Preece before the Institution of Civil Engineers in 1863, he says of this system: "But each station contained as many needles as there were stations (five in all) on the line, and thus the position and the progress of every train could be seen at any moment." We are also told in the same paper that the system was ultimately abandoned on account of the difficulty in maintaining the large number of wires required to work it.

Cooke and Wheatstone's system apparently aimed at much more than is comprised in the present method of block working, in that they proposed to show the progress of a train throughout the whole of the line at all the signal stations. Such a method as this would be unworkable at the present day for other reasons than the maintenance of the wires, although that would be a much greater item now than then, owing to the much shorter sections in use.

The method of signalling adopted by the Birmingham and Gloucester Railway Company, at the instance of Mr. McConnell, in 1843, was a distinct reversion to the method adopted by Cooke and Wheatstone in 1839. The code of signalling used by the Midland Company between Desford and Bagsworth gives no indication of the use of the instruments as indicators. At the same time, it is not probable that they were intended solely for the purpose of train description, which was adequately provided for by the bell signals. In this code we find evidence of the recognition of the necessity for preparing the line before the actual arrival of the train at the entrance to the section protected by block working. One important feature of the system is supplied by Mr. Stretton, in the letter referred to, which is that the outdoor mechanical signals were *always* kept at danger, except when used to indicate to the driver of an approaching train that the line was in order for him to proceed.

It is somewhat difficult to decide in how far some of the systems of signalling referred to are entitled to the name of "block" systems as the term is understood now. The absence of the codes in many cases, and the regulations for the guidance of those entrusted with the work, makes comparison with present-day methods difficult. There is some reason to doubt whether the systems did, in particular instances, impose a space limit; and it also appears that in some instances after trial of the space limit, it was abandoned on account of the delay caused by the sections being too long.

Thus, speaking of the system in use on the London and North-Western Railway in 1853, and much later, Mr. Preece, in the paper referred to, says: "It must be observed that in working this system on the London and North-Western Railway, that company do not strictly adhere to what is termed the block system. They allow two, three, and sometimes four trains to be on the same length at the same time. The signal 'Train on line' is simply received as a cautionary signal."

The system of bell signalling brought into use on the South-Eastern Railway in 1851 was to all intents and purposes a block system, as is shown by the extracts from Mr. Walker's articles. Whilst no indicators were provided originally for showing the condition of the line at any stage of the operations, the rules under which the system was worked were such as to ensure perfect safety, *if invariably observed.* This is all that can be said of any of the systems in use at present.

A study of the rules under which the South-Eastern system was worked shows how fully the requirements had been reasoned out and met so far as was possible by a purely aural system of signalling. The absence of continuous indications of the condition of the line was an undoubted defect, in that it relied too much upon the signalman's memory and attention to his train-book entries. The introduction of the electro-magnetic telegraph semaphore remedied this defect, but a closer study of the articles will show that the instrument did not afford an indication for what Mr. Walker considered an important point—the exchange of signals preliminary to the entrance of a train into the section.

It is not necessary to follow all the different methods of signalling for which the title of "block" is claimed. In many instances the title, as at present understood, is not justified. Even where needle instruments were used, the signals in many instances were mere momentary deflections of the needle, intimating in one case the entrance, and in another case the exit, of trains from the section of the line over which the communication extended.

Speaking of the system of signalling in use on the

Great Northern Railway, Mr. Preece, in the paper so often referred to already, characterises it as a system that was understood by no one but themselves. Referring to the system used by the Brighton Company between the ends of Clayton Tunnel, he states that the signals are *momentary* deflections of the needle; and he cites an instance where the system broke down and led to an accident of some magnitude.

Enough has probably been said on this point, however. Whilst instances of earlier methods of working are of some interest and value in enabling us to trace the growth and general line of progress, they are not, for the purpose under consideration, of so much value in indicating the lines of progress from present-day methods, except in the most general sense, on account of the great changes that have been made in railway management as a whole; and also on account of the immense increase in the volume and variety of traffic to be dealt with, and the greater importance for its speedy transit.

Of the advantages obtained and the safety ensured by the system of block signalling of trains, of which the foregoing are examples of the initiatory work, it is not necessary to speak. The extraordinary development of the habit of travel during the last thirty years, the necessity for the quick transit of imported food-stuffs to and from the centres of distribution, together with the immense growth of trade, rendered the adoption of some method of safe control not only expedient but necessary. How successful the block system has been in effecting these objects may be best seen by comparing the number of accidents for a given quantity of traffic in two equal periods before and after its establishment. At the same time it must be admitted that occasions do occur where, owing to no defect in the system itself, but on account of causes which cannot always be foreseen, accidents, involving loss of life or limbs, and considerable destruction of property do occur. Under the rigorous enquiries to which these accidents, and the events leading to them, are subjected by the Board of Trade officials, it is usually found that the occurrence is due to some lapse on the part of the individual entrusted with the working of the apparatus. Not only is this the case with the more serious accidents, but also with those which, whilst the result of an infraction of the rules of the service, have not had such consequences as to call general attention to them. Hence, we find that the reports of the inspectors of the Board of Trade teem with suggestions and recommendations, the ultimate object of which is control of the controller. The block system owes its inception to the recognition of this necessity; and the various stages of its progress, from its earliest form to the present period, has been rendered necessary in consequence of the liability of the human machine to break down at critical or inopportune moments.

In his pamphlet entitled "Telegraphic Railways," published in 1842, Sir W. F. Cooke says:

"It may be considered that the maximum degree of safety and efficiency attainable by subsidiary regulations is already secured on the great double lines of railway," and that "to the comparatively high degree of safety now attained (1842) in railway travelling, depending then, as I have said, upon vigilance and punctuality in the conduct of the trains, it is proposed to superadd a physical certainty of their relative places on the line at any moment."

Even now, fifty-five years after these words were written, and with the aid of appliances not then conceived of, and with rigid codes and equally rigid regulations not then considered necessary, it is not too much to say that they are the words of an optimist whose aspirations have only partially been fulfilled.

CHAPTER II.

Object of Apparatus.—The principal object aimed at by the use of all the complex apparatus employed in signalling the passage and controlling the movements of trains, in their due order of importance, is safety. A second object of only slightly less importance at the present day, is the speedy transference of passengers and goods to their respective destinations. Both these objects are promoted by the system of signalling to which the general name of "block" is almost invariably applied in this country. The safety of traffic is promoted by the preservation of a space between successive trains on the same line of rails. The speedy transfer of traffic from point to point is promoted by the use of regulations which direct what shall be done under almost all conceivable conditions, and by careful arrangements of traffic in accordance with the fixed regulations.

The space provided between successive trains is not uniform on all lines, nor is it uniform throughout the lines of any one company, neither is the space so preserved always constant over the same division of the line. Consideration will show that there is no necessity for either uniformity or constancy. If *a* space can be ensured between one train and the preceding or following train, the magnitude of the space is immaterial. Theoretically this position is unassailable; and so long as work is carried out in the spirit in which the system is conceived, no mischievous effects can or will be felt.

The term "block" is frequently applied to the electrical portion of the apparatus used only; and it is rather too often assumed that this form of signalling is the be-all and end-all of railway working. Whilst too much importance cannot be given to the due performance of the duties entailed by electrical signalling, it should not be forgotten that it is simply a means to an end, and not the end itself; and that there are other forms of apparatus which play an equally important part, and are equally as indispensable for the safe and speedy working of traffic.

Classification.—Railway signalling may be divided into distinct classes:

(*a*) The electrical part, by which arrangements for, and notification of, the passage of traffic are made; and

(*b*) The fixed signals, by which the actual movements of trains are controlled.

Both classes of signals are operated by the same person; the location of the cabins or boxes (in which the apparatus is placed), which determines the lengths of the sections into which the line is split, being fixed in accordance with local conditions or considerations connected with the volume of traffic. Where traffic is light and junctions are not numerous, the length of a block section may be several miles. On the other hand, if junctions are numerous and traffic heavy, or if special conditions have to be taken into account, the length of sections may be only two or three hundred yards; and a cabin and its outdoor signals may be within sight of the next one or two cabins in either direction. The shorter length of sections naturally facilitates traffic, more especially if the line is fed from one or other of those points.

With reference more particularly to ordinary double lines of railway, it may be said that there are two methods of working, both of which are designated as "block" systems. One of these may be termed a positive block; the other is a negative one. In the first the length of line comprising any section is always considered as blocked against traffic, until permission has been asked and given for a train to enter at the sending end. With the second, or negative system, the line is considered as clear for the entrance of a train as soon as, and at any time after, the previous train has been signalled as clear from the advance end of the section. The second system is in use on only very few and comparatively unimportant lines. All the larger lines have adopted the absolute block, or positive system of working.

Responsibility. — The responsibility for correct working on the absolute system is not, for any one line of rails, equally divided between the signalmen controlling the section. Since the signalman at the sending end must ask, and receive permission, before allowing a train to proceed to the cabin in advance, his responsibility is necessarily less than that of the signalman who, by according such permission, assures him that the line is clear o previous traffic. Under such circumstances the signalman at the entrance to a section becomes, practically, a look-out man, more advantageously situated in respect to the direction from which trains may be expected, for the actual controller of that line of rail, and confines himself, generally, to acting upon the instructions received from his *confrère*. This rule, like most others, is not without its exception, and there are occasions, as will be seen, when the signalman at the entrance of a section transmits a definite order, for certain purposes, to the signalman at the exit of the section. The responsibility for the *whole* of the traffic through any section is, of course, fairly averaged, since the cabin which marks the entrance to the section for down-line trains, also marks the exit of the same section for up-line trains.

Whilst this is the case with regard to the signalling previous to the entrance of a train, the responsibility of the signalman at the sending end is the greatest for the exhibition of the correct outdoor signals for the guidance of the drivers of trains; and this responsibility is, theoretically at least, equally great whether the section is occupied or not. Any neglect or mistake on the part of the sending signalman, in allowing trains to pass without the requisite permission from the other end, is liable to produce consequences equally as serious as those which would result from a mistake on the part of the receiving signalman, in accepting a train before the previous one was clear of the section, and under the protection of his signals. Practically speaking, there is not the slightest difference between the two cases, except that they are made in working different classes of signals.

Very slight consideration will show that responsibility does not rest with the signalman alone. It is equally as important that drivers of trains should be as accurate in their interpretation of the signals exhibited for their guidance. Any misapprehension or carelessness on the part of a driver is calculated to produce results equally as disastrous as any that can ensue from the mistakes of the signalmen; and the chance of minimising the consequences by subsequent action are less, since they have lost their only means of control over the driver and his train. Since drivers must necessarily depend largely for their efficiency upon, at least, one of their physical powers being of the highest possible class, railway companies rightly insist upon drivers and firemen being possessed of the most perfect vision. The importance of good eyesight to drivers and firemen cannot be over-rated. It is necessary that they shall be able not only to see the positions of signals at some distance ahead, but they must also be able to distinguish the signal relating to themselves from amongst a number of others, in similar positions, at points where signals are numerous. Over and above this is the necessity for picking up the various signals on a long run, in regular rotation, in order that the driver may localise his position when circumstances prevent him from noting familiar landmarks as he passes. During foggy weather this is a most important desideratum, and under any circumstances accurate localisation enables the driver to distinguish his signal with greater facility, on account of his knowing exactly where to look for it, and adds to the comfort of his position.

Hence we see that, considered as a whole, the responsibility for such accidents as are due to infraction of the signalling rules is fairly evenly divided amongst the three persons actively engaged in the working of traffic. All have, at one time or other, contributed their quota to the chapter of accidents: the first line of defence has been broken by the receiving signalman accepting a second train when the first was in the section; the second line has been broken by the signalman at the sending end allowing trains to enter the section without first obtaining the necessary permission; and the third line of defence has been broken also by engine-drivers running past signals at danger; and it must by no means be considered that those cases which have received prominent attention in consequence of the results following them are the only cases that occur.

Besides the possibilities of accident due to incorrect signalling, accidents are liable to occur from other causes. Malicious attempts to derail trains—fortunately, generally unsuccessful—are not altogether unknown. Accidents are sometimes due to hidden and unsuspected defects in the permanent way, in the locomotive, or in some of the rolling-stock; trains become divided occasionally from various causes; vehicles run away in the right direction for the line they are on, or in the wrong direction, as the case may be and the gradient serves. Accidents due to such causes as these, and others of a similar character, may take place anywhere on the line. If they do not foul the other line, and block rules are followed, nothing further occurs beyond the consequences due to the accident itself. If the other line is fouled, the accident may be doubled by a train on the other line running into that to which a mishap has already occurred. Such possibilities as these call for the utmost vigilance, promptitude, care, and nerve on the part of the drivers of trains; and the necessity is not lessened by the occurrence of such cases being comparatively rare. The heavy responsibility attached to the position of an engine-driver in this and other respects justifies railway companies in imposing the most rigorous tests, in order to ensure the highest qualities in this class of their service; and at the same time stamps the driver with a hall-mark which it should be his greatest pride to maintain.

Analysis of Block Signals.—The electrical signals used in the working of traffic on the absolute block system are, in all cases, of two kinds: (*a*) Those which are of a permanent character, and indicate, in accordance with the conventions under which the instruments are used, the condition of the line more or less completely. (*b*) Those which are transient only, and which are intended to convey information upon which subsequent actions are to be based. The latter signals are invariably made by a bell code, or a combination of bell and dial signals where the needle form of instrument is in use; the former are made by instruments which are capable of exhibiting continuous indications of different characters. There are not many varieties of the instruments used for this purpose; most of them convey their information by the position of a needle in accordance with the lettering of its dial, or by the relative position of a miniature semaphore arm. Whilst this is the case with the *form of indicator*, the variety of methods employed to produce the required results is very great, each instrument, no doubt, being characteristic of its designer's opinion of the best method to be employed.

REGULATIONS FOR TRAIN SIGNALLING BY BLOCK TELEGRAPH SYSTEM.

BELL SIGNALS.	Number of Beats of the Bell.
To call attention	1
Train on line	2
Be ready for an ordinary goods, mineral, ballast train, or light engine	3 (Double the usual pause between the beats must be given for trains which have to stop to work in the section.)
Be ready for a passenger train	4
Be ready for express goods, fish, cattle, through goods, through mineral, through ballast train, or through engine and van	5
Be ready for express London and Scotch goods, meat, fish, butter, or yeast train (.........), special butter or yeast train (...........), or breakdown van train or engine, sent to assist in case of breakdown	5 (Double the usual pause between the beats.)
Obstruction danger signal	6
Stop and examine train	7
Signal given in error (cancel signal last sent)	8
Train passed without tail lamp	9
Train divided	10
Shunt train for following train to pass	11
Vehicles running back on *wrong* line	12
Section clear and station or junction blocked	13
Vehicles running away on *right* line	14
Opening of signal cabin	15
Testing	16
Closing of signal cabin	17
Time signal	18

DIAL SIGNALS.	Number of Beats of the Needle.
Express or special passenger train	On line, 2 left.
Ordinary or through goods, mineral, ballast train, or through engine and van	On line, 3 left.
Ordinary or excursion passenger train	On line, 4 left.
Express goods, fish, or cattle train	On line, 5 left.
Express London and Scotch goods, meat, fish, butter, or yeast train (...........), special butter or yeast train (...........)	On line, 5 left. (Double the usual pause between the beats.)
Shunting	6 left.
Light engine	On line, 1 right, 3 left.
Two engines or trains coupled	On line, 3 right, 3 left.
Line clear of train or engine	2 right.
Caution	4 right.
Line clear of shunting	6 right.
Breakdown van train	On line, 5 left, 3 right.
Engine sent to assist in case of a breakdown ...	On line, 5 left, 3 right. (Double the usual pause between the beats.)
Platelayer's lorry entering a tunnel	On line, 3 left, 4 right.
Goods, mineral, or ballast train which has to stop to work in the section	On line, 3 left, 3 right.
Pilot engine assisting at the rear of a train......	On line, 1 right. (Given immediately after the proper signal for the train assisted.)

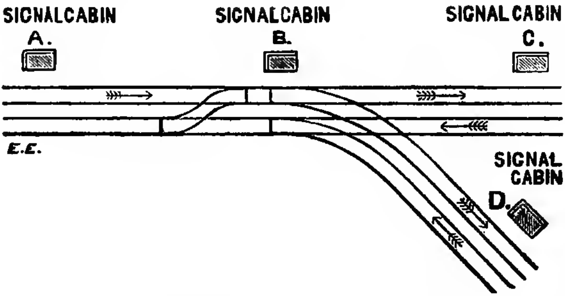
1. When the instruments are not in use the handles must be kept upright; the needles will then hang vertically, and when in that position will indicate **"line blocked."**

2. When commencing to signal a train, the **"call attention"** signal must be the first signal given; all signals must be acknowledged by repeating them, and no signal must be considered as understood until it has been correctly repeated to the sending station. When a signal is not promptly acknowledged, it must be constantly repeated, except in the case of the signal **"be ready,"** which must be repeated at short intervals, and in the case of the signal **"section clear and station or junction blocked,"** which is not repeated by the sending cabin.

3. (*a*) If the line *is not clear at the time the signal* **"be ready"** *is received*, the signalman *must not repeat the signal, or acknowledge it* in any way, until the line *is clear*, and after having pegged the needle to **"line clear,"** the line must *not be allowed to be fouled* until the

train for which the signal "**be ready**" has been given has been brought to a stand at or has passed the section home signal.

(*b*) When the signal "**be ready**" is offered to an advance cabin whilst the section is occupied by a train previously signalled, and it is afterwards found necessary to cancel such signal "**be ready,**" the "**signal given in error (cancel signal last sent)**" must not be given until the signal "**line clear,**" or the signal "**section clear and station or junction blocked**" for the first train has been received from the advance cabin.



4. For the purpose of illustrating the course to be adopted, let A, B, and C represent three block signal cabins, and the process of signalling a train is as follows: On the approach of a train to cabin A, the signalman will "**call attention**" of the signalman at cabin B, and then give the signal "**be ready,**" and the signalman at cabin B, after having, in accordance with Rule 7, *ascertained that the line is clear upon which the train is to run*, must repeat the signal, and peg the needle to "**line clear.**" As soon as the train has passed cabin A, the signalman there must give the bell signal "**train on line,**" upon which the signalman at cabin B must acknowledge the signal and unpeg the needle. The signalman at cabin A must then indicate to the signalman at cabin B the kind of train that is approaching by giving the proper dial signal, which the signalman at cabin B must acknowledge by repeating, and having received the intimation that his acknowledgment is correct, by the signalman at cabin A holding the needle over to "**train on line,**" he must peg it in that position, and then "**call attention**" of, and give the signal "**be ready**" to, the signalman at cabin C. As soon as the train has passed cabin B, it must be signalled in a similar manner to the signalman at cabin C, who must forward the signal "**be ready**" to the next cabin, and so on throughout the block.

When the train has *passed* the advance signal at cabin B, and is continuing its journey in the next section, or has been shunted clear of the main line, the signalman at cabin B must "**call attention**" of the signalman at cabin A, and give the proper signal, indicating that the line is clear of the train, which must be duly acknowledged by the signalman at cabin A. *When the distance between the home signals at cabins B and C is less than 400 yards,* the signalman at cabin B must not, when a passenger train is signalled, acknowledge the signal "**be ready**" to the signalman at cabin A until after he has sent the signal "**be ready**" to the signalman at cabin C, and received its acknowledgment, unless special instructions exist to the contrary.

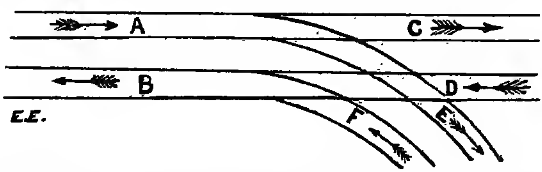
5. No train must be allowed to pass or start from any station or junction where the block system is in operation, nor any obstruction of the line be allowed to take place, without the signals having been previously made and acknowledged as herein directed.

6. The "**danger**" signal must always be exhibited at the home, distant, and advance or starting signals, except when required to be lowered for a train to pass; and before any signal is lowered, care must be taken that the line on which the train is about to run is clear. So long as the advance section is not clear, the signals must be kept at danger until the speed of an approaching train has been so reduced as to admit of it stopping before reaching the home signal: the home signal may then be lowered to allow the train to draw within it towards the advance signal. When a light engine, or a train not conveying passengers, arrives at a cabin before the advance section is clear, and has to be run into an independent or be sent forward to an advance or starting signal, the driver must be verbally instructed to proceed to the next cabin with caution when the advance, starting, or independent signal is lowered. Where advance or starting signals are not provided, the engine or train must be brought to a stand at the cabin, and the driver must then be verbally instructed to draw his train fully within the home signal, and to proceed to the next cabin with caution, as soon as he receives permission from the signalman, by hand-signal, to go forward. This will be given by green flag by day, and by green light by night.

7. (*a*) In dealing with trains of every description, except as provided for in clauses (*b*), (*d*), and (*e*), the line in the rear section must always be kept blocked until the preceding train has either been shunted clear of the main line or has passed the advance signal, and is continuing its journey in the next section, or, where there is no advance signal, has passed the home signal at least 400 yards, or the cabin in advance, if within this distance, and is continuing its journey in the next section.

(*b*) In dealing with light engines or trains not conveying passengers in clear weather, and under ordinary circumstances, should the signal **"be ready"** be offered whilst another train not conveying passengers or a light engine is standing or shunting within the home signal, or when the line will be occupied by shunting before the train signalled will arrive, the **"be ready"** signal must not be acknowledged, but the signal **"section clear and station or junction blocked"** must be given and acknowledged. The signalman receiving such signal must stop the approaching train, and verbally instruct the driver to approach the cabin in advance with caution, informing him why it is necessary to do so, and then give the bell signal **"train on line,"** upon which the signalman at the cabin in advance must unpeg the needle, and the sending signalman must give the proper dial signal. When the last train dealt with under this regulation has passed out of the section, the signal **"line clear"** must be given and ordinary signalling resumed. When some time is likely to elapse before the train for which the signal **"be ready"** has been sent is ready to enter the section, the **"section clear and station or junction blocked"** signal must not be acknowledged, but when the train is ready to enter the section, the signal **"be ready"** must be again sent, so as to give the signalman at the cabin in advance an opportunity of receiving the train under Rule 4. Trains signalled as having to stop to work in the section must only be accepted under the provisions of the signal **"section clear and station or junction blocked,"** and the driver must in all cases be cautioned as herein required.

(*c*) In reference to all trains approaching junctions, the principle must be strictly acted upon, except as provided in the next clause of this rule, that they must not approach a junction at the same time on sections which converge to a fouling point, either by running into one line or by crossing each other to different lines ; and the diagram below is given as an illus-



tration : Whenever a train is signalled as having entered section **D,** no engine or train must be permitted to proceed beyond the junction home signal on its way from section **A** to section **E,** or to enter section **F,** but may be permitted to pass from section **A** to section **C;** and whenever a train has been signalled as having entered section **F**, no engine or train must be permitted to enter section **D**, but may be permitted to pass from section **A** to section **C**, or from section **A** to section **E**.

(*d*) *In dealing with trains, neither of which conveys passengers, in clear weather, and under ordinary circumstances,* when approaching a junction on sections which converge to a fouling point, either by running into one line or by crossing each other to different lines, the mode of signalling given in clause (*b*) of this rule must be adopted. When the bell signal **"train on line"** and the proper dial signal have been given and acknowledged, the needle must be pegged to **"train on line."**

(*e*) In dealing with passenger trains which have to connect at a junction or junction station, if one such train be standing at a junction or junction station, whilst another is signalled to it, the signalman at the junction or junction station, as the case may be, must give the signal **"section clear and station or junction blocked,"** whereupon the signalman at the rear cabin, after duly acknowledging this signal, must stop the approaching train and warn the driver to go forward with caution, informing him why it is necessary to do so, and then give the bell signal **"train on line,"** upon which the signalman at the cabin in advance must unpeg the needle, and the sending signalman must give the proper dial signal; after receiving acknowledgment of this, he must note the circumstance in the remark column of his train register book, and the station signalman must not give the signal **"line clear"** until the last train has cleared the section. Where there is an intermediate cabin between the junction cabin and the station cabin, this rule will apply as between the intermediate cabin and the station cabin, and not as between the junction cabin and the intermediate cabin.

8. (*a*) Should a train or light engine pass a cabin without having a **"tail lamp"** in the rear by day, or the usual signals by night, the signalman must not give **"line clear"** to the rear cabin, but at once give the signal **"train passed without tail lamp"** to the advance cabin. This signal having been acknowledged, he must call the attention of the rear cabin, and on gaining attention, must give the signal **"caution,"** and, after acknowledgment, peg the needle over to **"train on line"**; the rear cabin signalman will thereupon stop any train following, and verbally instruct the driver to proceed cautiously towards the cabin in advance, informing him why it is necessary that he should do so; the signalman must then give the bell signal **"train on line,"** upon which the signalman at the cabin in advance must unpeg the needle, and the sending signalman must give the proper dial signal. As soon as the train, the driver of which has been cautioned, has passed the cabin from whence

the signal "**caution**" was received, the signalman there will recommence signalling in the ordinary manner.

(*b*) Should a light engine pass out of a section when the signal for a train has been received, the signal "**stop and examine train**" must be given, and the same precautions taken as set forth in the preceding paragraph; and the signal "**stop and examine train**" is also to be used in the event of a signalman observing anything unusual on a train passing his cabin which might cause an accident. Any signalman receiving such signal must immediately exhibit the danger signals, to stop any train coming from or going towards the cabin from which the signal was received. The train, when stopped in obedience to the signal "**stop and examine train,**" must be carefully examined, and dealt with as occasion may require. Should any train going in the opposite direction have been stopped, it must be allowed to proceed after satisfactory evidence has been obtained that the line on which it is about to run has not been obstructed. Where practicable, and speaking instruments or telephones are provided, the signalman must also advise the cabin in advance the cause of sending the signal "**stop and examine train.**"

(*c*) If a signalman has reason to suppose that a train which has arrived at or passed his cabin has left any portion of the train on the line, he must, in addition to carrying out the instructions with respect to the line on which the train is running, stop the first train that arrives on the other line, inform the driver what has occurred, and instruct him to proceed cautiously lest any portion of the train which has broken loose has fouled the line on which he is running; and the same precaution must be taken as to stopping a train on the other line whenever any train which has been signalled "**on line**" is unusually long in passing through a section.

9. The "**obstruction danger**" signal must be given to the cabin in the rear whenever, after permission has been given for a train to approach, it is necessary, owing to an unexpected obstruction of the line, that the train should be stopped at the cabin in the rear. The signalman, on receiving this signal, must at once place his signals at "**danger,**" put detonators on the rails, and exhibit the hand danger signals to stop the train; after the train has been brought to a stand, he must give the bell signal "**signal given in error,**" and not allow the train to proceed until the signals have again been given and acknowledged.

10. "**Train Divided.**"—The "**train divided**" signal is only to be used in the event of a signalman observing that a train has become divided, and is running in two or more parts. The signalman receiving the signal must stop any train travelling in the opposite direction; and if the divided train is running on a falling gradient, where the stoppage of the first part

would risk a collision by the second part overtaking it, the signalman, if the line be clear ahead, must not exhibit the danger signal to stop the first portion, but must give the driver a green signal, either by flag or hand-lamp, waving such signal slowly from side to side, and endeavour to advise him of the circumstances as he passes; but if the line be not clear ahead, or if the train is running on a rising gradient, or where the line is level, the signalman must stop the first portion and deal with it as expeditiously as possible to prevent the second portion coming into collision with it. Should any train going in the opposite direction have been stopped, it must not be allowed to proceed until satisfactory evidence has been obtained that the line on which it is about to run is not obstructed.

11. (*a*) "**Vehicles Running Back on Wrong Line.**"—Should any vehicle or portion of a train be running back in the wrong direction, the signalman must call the attention of the signalman at the next cabin towards which the vehicle or portion of a train may be running, by giving the signal "**vehicles running back on wrong line.**" The signalman receiving this signal must immediately exhibit the danger signals, to stop any train coming from or going towards the cabin from which the signal was received, and take any other protective measures that may be necessary, such as turning the runaway vehicles across to the other line, or into a siding, as may be most expedient under the circumstances. In the event of vehicles being turned across to the other line, the signal "**vehicles running away on right line**" must be passed on to the next cabin.

(*b*) The signalman sending the signal must stop any train on the other line, tell the driver and guard what has occurred, and, when the proper signals have been given and acknowledged, instruct the driver to proceed cautiously.

(*c*) On single lines, vehicles running towards the station or cabin where the train staff is, must be considered running back on the wrong line, and treated accordingly.

12. (*a*) "**Vehicles Running Away on Right Line.**"—If any vehicle or portion of a train has escaped, and is running away in the proper direction on the right line, the signalman at the cabin in advance must be advised of the fact by the signalman at the cabin in the rear giving the signal "**vehicles running away on right line.**" The signalman forwarding this signal must immediately exhibit the danger signals, to stop any train coming from or going to the cabin towards which the vehicle or portion of train is running; and the signalman receiving this signal must immediately exhibit the danger signals, to stop any train coming from or going towards the cabin from which the signal was received, unless

there is a train in block in the same section as the runaway vehicle and in front thereof, in which case, if the line is clear, such train must be allowed to pass before the signals are exhibited to stop any train coming from the cabin in the rear. The signalman must arrange for the line on which the vehicles are running to be cleared, and, if necessary, send the signal forward, and take such other measures as he may consider expedient under the circumstances.

(*b*) On single lines, vehicles running away from a station or cabin where the train staff is, must be considered as running away on the right line, and dealt with accordingly.

13. (*a*) Before shunting a train from one main line to another, or obstructing the line by shunting operations, the signalman at whose cabin the shunting has to be done must give the "**call attention**" signal and then the dial signal "**shunting,**" and, after acknowledgment, the signalman at the receiving cabin must hold the needle to "**train on line,**" in which position the signalman at the sending cabin must peg and keep it until the shunting is over and the line clear, when he must give the signal "**line clear of shunting,**" and receive its acknowledgment.

(*b*) When the shunting is being done within the home signal, the signals for an engine or train not conveying passengers may be accepted under clause (*b*) of Rule 7. It will not then be necessary to give the signal "**line clear of shunting**" to the cabin in the rear.

(*c*) Trains or engines approaching a junction on a line converging to a fouling point, or when leaving a siding to proceed on their journey, or crossing directly over another running line, are exempted from the operation of clause (*a*) of this rule, and must be dealt with under Rule 7, clauses (*c*) and (*a*).

14. If, from any cause, the necessary signals cannot be forwarded and received, no train must be allowed to pass a cabin and enter upon that section of the line where the failure exists, without having been previously brought to a stand, and the driver informed of the circumstance, and how many minutes the preceding train is in advance. When this has been done, the driver must be instructed to proceed cautiously to the cabin in advance, and this rule must be acted upon until the signal communication is restored. An entry must be made in the Train Register Book of the arrival and departure of all trains worked in this way.

During the time that block working is temporarily suspended, from any cause, the number of each engine entering the section must be entered in the remark column of the Train Register Book. As soon as the signalman at either end of the section where the interruption has been, becomes aware that the instruments are again in order, or that block working may be resumed, he must give the testing signal, which must be acknowledged by repeating, after which, the needle of the instrument that has been out of order must be worked quickly from side to side. This signal must be repeated to show that the instruments at each cabin are in order. The needle or needles of the instruments must then be pegged to **"train on line."** After the needles have been pegged to **"train on line,"** the signalman must stop the next train or engine entering the section, and give the driver an extract, on which must be written **"Engine No. — is the last one cautioned."** The driver must stop at the next cabin then open, and hand the extract to the signalman, upon receipt of which the signalman must give **"line clear"** to the rear, and the signalman giving the extract must not allow another train to enter the section until he has received this signal. The signalmen on each side of the defaulting cabin must at once report the case to the station master, and record it also in his Occurrence Book.

15. The signalmen, on giving signals, must see that the needles are firmly and completely pegged over; and when the needles are pegged over at the opposite end, they must see that the handles of the instruments are perfectly upright. The pegs must not be placed on the handles, except when required for the purpose of pegging the needles over. *The needles and bells must not be moved quickly, each movement being made slowly and distinctly.*

16. All signals as received and forwarded must be entered, *at once*, in the proper column of the train register book. When the exact time is under half a minute, the half minute is not to be counted; when half a minute or more, the time is to be recorded as a minute. Thus, a signal at $30\frac{1}{4}$ minutes must be counted as 30 minutes; and a signal given at $30\frac{1}{2}$ or $30\frac{3}{4}$ minutes, as 31 minutes.

17. **Opening and Closing Signals.**—At a signal station or cabin which is closed during the night, the signalman, on commencing duty in the morning, and when going off duty at night, must give the appointed signals in each direction, and an entry of the time these signals are sent and acknowledged must be made in the books at each cabin. Any defect in working must be noted in the Occurrence Book, and at once reported by the signalman to the station master, who must immediately acquaint the telegraph lineman of the circumstance.

18. Where speaking instruments are provided the signalmen are required to look for the time telegram, which is sent daily at 10 a.m., and on its receipt immediately to send the **"time signal"** to the advance and rear cabins where these are unprovided with speaking instruments. The timepieces to be corrected if necessary.

Consideration of the code of signals on page 34—which was a re-issue in 1891, but is not now in use—with the explanatory regulations accompanying it, shows that a great variety of signals has to be provided for. The system with which this code was used is a three-wire needle system, and a study of the conditions under which the various signals are applicable suggests a convenient division for purposes of analysis.

Confining our attention for the moment to the bell signals, and leaving out of account the "Call attention" signal, we find that the third, fourth, fifth, and sixth signals are all varieties of one and the same signal, and are intended to intimate a desire to send different classes of traffic through the section. These may be called the "preliminary" signals, since upon the response to them depends the future movement or detention of the train to which they refer. The title of this signal gives the impression of a command; it is, however, really a request, and the title is not really applicable, for, quoting the regulations respecting the signal, we have "If the line *is not clear at the time the signal* 'Be ready' is received, the signalman *must not repeat the signal, or acknowledge it in any way*, until the line *is clear*."

The bell signal "Train on line" is also a form of preliminary signal, but it should be classed with the "Call attention" rather than the "Be ready," since it is practically a signal by which the sending signalman intimates to the man at the advance cabin the necessity of changing the position of the block *indicator* from "Line clear" to "Train on line."

The second division of signals may be called "emergency" signals, and includes all such signals as are intended to notify departures from the normal order of working, necessitating exceptional means being taken to meet the emergencies they represent in an adequate manner. In this class may be included the "Obstruction danger signal," "Stop and examine train," "Train passed without tail lamp," "Train divided," "Vehicles running back on wrong line," "Vehicles running away on right line," and also the "Cancel signal last sent" signal.

A further division of the bell signals consists of such as are required for deviations from ordinary straight away running of trains, and would include the "Shunt train for following train to pass," and "Section clear but station or junction blocked." The first of these signals is an intimation to the signalman at the advance end of a section of the approach to the sending end of a train of a more important character than that of the train which is occupying the section; and this signal is so clear as to have been ignored in the regulations attached to the code. The second signal included in this class is an important one, on account of the limitations imposed on its use. It can only be used for trains which do not convey passengers, and, practically, when advantage is taken of it, the section is worked at caution. If the *length* of a block system is defined as the distance between the signal controlling the entrance to that section, and the signal controlling the entrance to the next section in order, the adoption of such a rule of working constitutes an infraction of block working where "The object of the system of block telegraph signalling is to prevent more than one train being in the section between two block signal cabins on the same line at the same time."

The fourth division into which the bell signals may be separated consist of "special" signals for objects other than the routine work of signalling passing trains, or marshalling them as may be necessary. Included in this division are the "Opening of signal cabin," "Testing," "Closing of signal cabin," and "Time signal," which are subsidiary signals, which have their origin in motives of economy or convenience.

Turning next to the dial signals, we find that the majority, whilst indicating the fact that the permission accorded by the acceptance of the preliminary "Be ready" signal has been acted upon, are also used to confirm the intimation conveyed by the particular form of "Be ready" employed of the class of traffic that is being forwarded; and in all cases we find that the information imparted is given in greater detail than by the more general "Be ready" signal. Of the sixteen signals provided for transmission on the dials, twelve are used to indicate the character of the traffic being forwarded: one notifies the clearance of the line for *all* classes of trains, one is a "caution" signal, and the other two relate to temporary fouling of the lines at a block station or cabin owing to shunting operations, which involve crossing from one line to the other.

It is not proposed to analyse this code further, since, as already stated, it has been superseded;

but attention is called to the great proportion of the signals which are considered necessary for the *description* of traffic, and also of the order in which the details are given. A further point that may be referred to is that at least two of the bell signals have no complement. Thus, the "Obstruction danger signal" is not supplemented by any signal indicating the removal of the obstruction. Similarly, there is no signal provided where it is required to intimate that a proffered "Be ready" cannot be accepted. In this case the refusal to accept a "Be ready" may appear to be of a negative character, and liable to confusion with a failure of the bell circuit. As, however, the "Call attention" signal precedes the "Be ready," and must be acknowledged, the difference between this and a failure of apparatus is evident. At the same time, there seems no valid reason for the omission from the code of a signal which indicates inability to accept the preliminary signal.

REGULATIONS FOR TRAIN SIGNALLING BY BLOCK TELEGRAPH SYSTEM ON DOUBLE LINES OF RAILWAY.

The object of the system of block telegraph signalling is to prevent more than one train being on the section between two block signal cabins on the same line at the same time.

The signalling of trains on the block telegraph system does not in any way dispense with the use of fixed, hand, or fog signals, whenever and wherever such signals may be requisite to protect obstructions on the line.

The signal cabins at which the block telegraph working is in operation are furnished with instruments to signal for each line of rails, and the system under which these instruments are to be worked, and the mode of indicating the description of approaching trains, will be as given in the following code of regulations.

All fixed signals must be kept at **Danger,** except when it is necessary to lower them for a train to pass; and, before any signal is lowered, care must be taken to ascertain that the line is clear, and that the block telegraph and other regulations have been duly complied with.

When the block instruments are not in use, the handles must be kept vertical; the indicators will then hang vertically, and when in that position will indicate **Line blocked.**

The block instruments must be used exclusively for the purposes shown in the block telegraph regulations, and must not, except in case of accident, be used for conversing. They must only be used by the signalman or other person specially appointed for the duty.

The movements on the block instruments and bells must be made slowly and distinctly, and the pauses between the sets of beats clearly marked.

Bell Signals.

See Regulations.			Beats on Bell.	How to be given.
1		Call attention	1	
3 and 4	Is Line Clear for	Express passenger train, or break-down van train going to clear the line, or light engine going to assist disabled train?	4	4 consecutively.
		Ordinary or excursion passenger train, or breakdown van train *not* going to clear the line?	4	3, pause, 1.
		Branch passenger train? (applicable only where special instructions are given)	4	1, pause, 3.
		Fish, meat, fruit, horse, cattle, or perishable train, composed of coaching stock, or for S. W. B. train?	5	5 consecutively.
		Empty coaching stock train?	5	2, pause, 2, pause, 1.
		Fish, meat, or fruit train, composed of goods stock, express cattle, or express goods train?	5	1, pause, 4.
		Ordinary goods, or mineral train stopping at intermediate stations?	3	3 consecutively.
		Branch goods, mineral, or ballast train? (applicable only where special instructions are given)	3	1, pause, 2.
		Through goods—mineral or ballast train?	5	4, pause, 1.
		Light engine, or two light engines coupled, or engine and not more than two brakes?	5	2, pause, 3.
3, 4, 8, and 9		Ballast train, or other train requiring to stop in section, or platelayers' lorry requiring to pass through tunnel?	5	1, pause, 2, pause, 2.

3	(*a*) Train entering section	2	2 consecutively.
6	(*a*) Assistant engine in rear of train	4	2, pause, 2.
12 and 13	Obstruction removed	3	2, pause, 1.
12	Obstruction danger	6	6 consecutively.
13	Blocking back	6	Inside home signal—2, pause, 4. Outside home signal, 3, pause, 3.
17	Stop and examine train	7	7 consecutively.
18	Cancelling signal	8	3, pause, 5.
19	Train passed without tail lamp	9	9 consecutively to cabin in advance. 4, pause, 5, to cabin in rear.
20	Train divided	10	5, pause, 5.
21	Shunt train for following train to pass	11	1, pause, 5, pause, 5.
22	Vehicles running away on wrong line	12	2, pause, 5, pause, 5.
5	(*a*) Section clear but station or junction blocked	13	3, pause, 5, pause, 5.
23	Vehicles running away on right line	14	4, pause, 5, pause, 5.
24	Opening of signal cabin	15	5, pause, 5, pause, 5.
27	Testing block indicators and hells...	16	16 consecutively.
24	Closing of signal cabin	17	7, pause, 5, pause, 5.
28	(*a*) Time signal........	18	8, pause, 5, pause, 5.
29	Lampman or fog-signalman required	19	9, pause, 5, pause, 5.
30	Testing controlled or slotted signals	20	5, pause, 5, pause, 5, pause, 5.

See Regulations.

Dial Signals.

2	Signal correctly repeated	1 beat to right.
	Signal incorrectly repeated	1 beat to left.
10	Train out of section	2 beats to right.
	Express passenger train; breakdown van train going to clear the line; fish, meat, fruit, horse, cattle, or perishable train composed of coaching stock; engine and not more than two brakes, or S.W.B. train entering section	2 beats to left.
3 and 4	Ordinary or excursion passenger train; breakdown van train *not* going to clear line; empty coaching stock train; fish, meat, or fruit train composed of goods stock; express cattle, or express goods train entering section	3 beats to left.

	Through goods, mineral, or ballast train entering section	4 beats to left.
3, 4, 8, and 9.	Ordinary goods, mineral, or ballast train stopping at intermediate stations, or platelayers' lorry going through tunnel entering section	5 beats to left.
3 and 4	Light engine	1 beat to right and 3 to left.
3, 4, and 7	Two engines or trains coupled entering section	3 beats to right and 3 to left.
17	Caution	4 beats to right.
13	Blocking back for passenger trains	2, pause, 2, pause, 2 to left.
13	Blocking back except for passenger trains	6 beats to left
13	Line clear after blocking back	6 beats to right.
25 and 27	Testing	16 beats to right and left alternately.

1. **Call Attention.—The call attention** *signal must always be given before any other signal, except those marked (a), and must be acknowledged immediately on receipt.*

2. **Repetition and Acknowledgment of Signals.**—Except where special instructions are issued to the contrary, no signal must be considered as understood until it has been correctly repeated to the signal cabin from which it was received, and, in the case of dial signals, the acknowledgment given that such repetition is correct. When the **is line clear** signals are not acknowledged, they must be given again at short intervals.

3. **Mode of Signalling by Block Telegraph.**—A, B, and C represent three consecutive block signal cabins, and the process of signalling a train is as follows:

Prior to the dispatch of a train **conveying passengers** from A, the signalman there, provided he has received the **train out of section** signal for the previous train, and the block indicator be in its normal position, must call the attention of B, and, having obtained it, must give the proper **is line clear** signal; if the line be clear at B, the signalman there must acknowledge the signal and peg the block indicator to the **line clear** position.

The signalman at A may then, if the line be clear, take off his signals for the train to leave A.

On the train leaving A the signalman there must send the **train entering section** signal to B, and the signalman at B must acknowledge the signal and peg the block indicator to **train on line.**

B must then, provided he has received the **train out of section** signal for the previous train, and the block indicator be in its normal position, call the attention of C, and, having obtained it, must give the proper **is line clear** signal to C. On receiving permission from C for the train to approach, B may take off his signals for the train to proceed to C, and as soon as the train has passed the advance signal at B, or, where there is no advance signal, has passed the home signal at least 400 yards, and is continuing its journey in the next section, or has been shunted clear of the main line at B, the signalman there must call the attention of A, and, having obtained it, give the **train out of section** signal to A.

Where the sections are short, the **is line clear** signal must be sent forward, where necessary, to avoid delay to the train, as soon as it has been acknowledged and before the **train entering section** signal has been received from the rear, when this can be done in accordance with the regulations under which the **is line clear** signal is to be forwarded.

The same mode of signalling must be observed in regard to trains not conveying passengers, except that the **is line clear** signal may be offered to the advance cabin before the **train out of section** signal has been received for the preceding train, provided the latter is also a train not conveying passengers.

In foggy weather, or during falling snow, every train must be dealt with as prescribed for passenger trains.

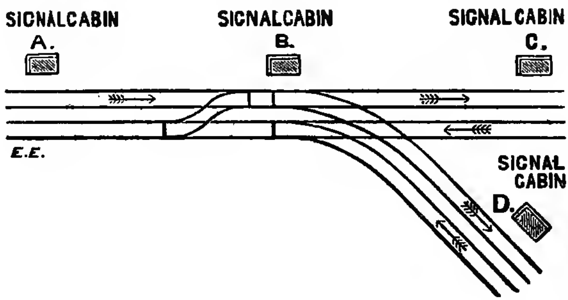
4. **Line Clear, or Giving Permission for a Train to Approach.—** Unless special instructions are given to the contrary, the line must not be considered clear, nor must a train be allowed to approach from the signal cabin in the rear, in accordance with Regulation 3, except as prescribed in Regulation 5, until the preceding train has passed the advance signal, or, where there is no advance, has passed the home signal at least 400 yards, and is continuing its journey in the next section, or has been shunted clear of the main line, nor until all the points over which the approaching train has to pass have been placed in their proper position, and the line is clear for at least 400 yards ahead of the home signal.

Where the home signal at the signal cabin in advance is less than 400 yards ahead, permission for a train to approach must not be given to the signal cabin in the rear until permission for the train to proceed has been received from the signal cabin in advance, except in the case of a train not conveying passengers, which may be accepted under Regulation 5, when the advance section is not occupied by a train conveying passengers.

After permission has been given for a train to approach in accordance with Regulation 3, no obstruction of the line on which such train requires to run must be allowed until the train has been brought to a stand at the home signal, or has passed into the section in advance, or the **cancelling** signal has been received from the signal cabin in the rear.

If the line be not clear, or if from any other cause the signalman be not in a position to give permission for the train to approach when the signalman in the rear forwards the **is line clear** signal, that signal must not be acknowledged until the signalman to whom the signal has been sent is prepared to receive the train, when he must give permission for it to approach in accordance with the prescribed regulations.

At Junctions, except where otherwise provided, the approach of trains, which can cross or foul each other, is regulated as shown below.



When permission has been given by B for a train to approach from C, no train must be allowed to leave D until that from C has been brought to a stand at the home signal or has passed through the junction, and is beyond the advance signal, or, where there is no advance signal, has passed the home signal a distance of 400 yards, and is continuing its journey, or where the next signal cabin ahead is within 400 yards, until the **is line clear** signal has been accepted by the signalman at that cabin, except as provided for in the second clause of this regulation; nor in such a case must a train be allowed to leave A for D unless the junction facing points at B are set for C, and the line towards C is clear to the advance signal, or, where there is no advance signal, is clear for a distance of 400 yards beyond the junction points, or, where the next signal cabin ahead is within 400 yards, until the **is line clear** signal has been accepted by the signalman at that cabin, except as provided for in the second clause of this regulation.

When permission has been given by B for a train to approach from D, no train must be allowed to leave C until that from D has been brought to a stand at the home signal or has passed through the junction, and is beyond the advance signal, or, where there is no advance signal, has passed the home signal a distance of 400 yards, and is continuing its journey, or, where the next signal cabin ahead is within 400 yards, until the **is line clear** signal has been accepted by the signalman at that cabin, except as provided for in the second clause of this regulation.

When permission has been given by B for a train to approach from A for D, no train must be allowed to leave C until that from A has been brought to a stand at the home signal, or has passed clear of the junction, or the junction facing points have been set for C, and the line towards C is clear to the advance signal; or, where there is no advance signal, is clear for a distance of 400 yards beyond the junction points, or, where the next signal cabin ahead is within 400 yards, until the **is line olear** signal has been accepted by the signalman at that cabin, except as provided for in the second clause of this regulation.

When a train has been sent to the advance or starting signal and the rear of the train is well clear of the junction, permission for a following train to approach may be given by the signalman to the signal cabin in the rear if the points are set for the following train to pass on to another line, and that line is clear, and the instructions given in the preceding paragraphs can be complied with.

In dealing with trains, neither of which conveys passengers, in clear weather, and under ordinary circumstances, when approaching a junction on sections which converge to a fouling point, either by running into one line or by crossing each other to different lines, the mode of signalling given in Regulation 5 must be adopted, except that if the block indicator be in its normal position when the **is line clear** signal is offered for a second train, the junction signalman must, after accepting that signal by giving the **section clear but station or junction blocked** signal, and after *that* signal has been acknowledged, peg the indicator to **train on line**, and after the **train entering section** *bell* signal has been received and acknowledged, unpeg the indicator, when the dial signal must be given in the usual way.

5. **Section Clear, but Station or Junction Blocked.**—(*This signal must only be used in the case of trains conveying passengers where it is specially authorised by instructions from the general manager or the superintendent of the line, and so far as regards light engines and trains not conveying passengers is only applicable in clear weather and under ordinary circumstances.*) **When** the line is clear to the home signal, and it is necessary for a train to be allowed to approach cautiously for the purpose of connecting at a junction or junction station, or in consequence of an obstruction existing within the home signal, or owing to shunting operations within the home signal, or from any other cause, the **is line clear** signal must not be acknowledged in accordance with Regulation 3, but the **section clear but station or junction blocked** signal must be given, and acknowledged if the circumstances admit of this being done, when, if the indicator be in the vertical position, it must be pegged to **train on line.** The signalman receiving this signal must (if the train has not already passed the home signal towards the starting or advanced starting signal) bring the train to a **dead stand** at the home signal, and verbally instruct the driver that the section is clear to the next home signal, but that the station or junction ahead is blocked. A green flag by day and a green light by night must at the same time be exhibited to the driver, and the necessary fixed signals lowered to give permission for the train to proceed. The **train entering section** bell signal must then be given, and acknowledged, after which the block indicator must be unpegged, and the proper dial signals given and acknowledged, and the indicator again pegged to **train on line.** The **train out of section** signal must not be given until both trains have passed out of the section. *Even for connecting purposes two passenger trains must not be allowed to approach a junction at the same time on lines which converge to a fouling point.*

Where authority is given for passenger trains to be allowed to enter the advance section under this regulation, the **is line clear** signal, for the train which requires to be sent forward to make the connection, may be offered before the **train out of section** signal has been received for the train with which the connection has to be made.

Where the home signal is at such a distance from the signal cabin that it is not possible for the signalman to communicate verbally with the driver when the engine is standing at the home signal, the signalman must, after bringing the train to a **dead stand** at the home signal, lower it to allow the driver to draw up to his signal cabin, and must stop the train at the signal cabin by exhibiting a red flag by day and a red light by night. The driver must then be verbally instructed that the section is clear to the next home signal, but that the station or junction ahead is blocked; after which a green flag by day and a green light by night must be exhibited to the driver, and the necessary fixed signals lowered to give permission for the train to proceed.

If a train is assisted by an engine in the rear, a green flag by day and a green light by night must also be exhibited to the driver of the engine in the rear of the train.

Except where special instructions are issued to the contrary, when a train has passed the signal cabin and is brought to a stand at the starting signal or the advanced starting signal, the driver must understand that the lowering of the starting signal or the advanced starting signal is an indication that the line is only clear to the home signal at the signal cabin in advance, and that he must regulate the speed of his train in the same way as if he had been verbally instructed to proceed under the **section clear but station or junction blocked** signal.

When some time is likely to elapse before the train for which the **is line clear** signal has been sent will be ready to enter the section, the **section clear but station or junction blocked** signal must not be acknowledged, but when the train is ready to enter the section, and before it is allowed to do so, the **is line clear** signal must be again sent in order to give the signalman at the cabin in advance an opportunity of receiving the train under Regulation 3, if the circumstances are so altered as to admit of his doing so; if they are not, he must again give the **section clear but station or junction blocked** signal, which must be acknowledged, and the signalman at the rear cabin must not allow the train to proceed until this has been done.

6. **Assistant Engine in Rear of Train.**—After the **train entering section** signal has been given to the signal cabin in advance, and the indicator has been pegged to the **train on line** position for a train that is assisted by an engine in the rear, the **assistant engine in rear of train** signal must be given to the signal cabin in advance, to indicate that an engine is assisting the train in the rear. The **assistant engine in rear of train** signal must be acknowledged by being repeated, and a note of the signal must at once be made in the train register book at the signal cabin in advance, and the **train out of section** signal must not be given until the assisting engine has arrived. (*This regulation only applies at places where the use of assistant engines is specially authorised.*)

7. **Engines or Trains Coupled.**—Whenever it may be necessary to detach one engine or train from another on the main line, *the driver of each engine* requiring to be detached must, *before uncoupling*, verbally

communicate with the signalman and make him clearly understand what is about to be done, and in what direction the uncoupled engine or train will proceed. *Engines or trains must only be coupled or uncoupled at signal cabins and then only during daylight.*

8. **Ballast Train requiring to Stop in Section.**—When a ballast train has to stop in a block section for permanent-way purposes, the signalman must give the prescribed **is line clear** signal, and the signalman at the cabin in advance must, if the line be clear to the home signal, give permission for the train to approach his cabin in accordance with Regulation 5. When a ballast train, which has been signalled as a through ballast train, requires to stop in the section for permanent-way purposes, and comes to a stand at a signal cabin to enable the guard to inform the signalman that his train is going to stop on the main line in the section in advance (*see Rule* 320 *in the Book of Rules and Regulations*), the signalman must give the **cancelling** signal, and when the signal has been acknowledged, he must signal the train as a **ballast train requiring to stop in section.** *This regulation also applies to goods or mineral trains stopping at sidings between stations.*

9. **Platelayers' Lorries going through Tunnels.**—When it is necessary for a platelayers' lorry to go through any of the tunnels specially enumerated in the appendix to the working time table as coming within the application of this regulation, it must be signalled on the block instruments in accordance with the authorised code, and the signalman at the cabin in advance must, if the line be clear to the home signal, give permission for the lorry to approach his cabin in accordance with Regulation 5. No train must be allowed to enter the tunnel on the same line until the **train out of section** signal has been received from the signal cabin in advance to indicate that the lorry has left the tunnel and has passed the next block signal cabin, or been taken off the rails. Should the lorry, after passing through the tunnel, be removed from the rails before reaching the next signal cabin, the ganger must go forward and inform the signalman that the lorry is clear of the line.

If, however, time would be saved, the ganger must return to the signal cabin in the rear and inform the signalman that the lorry is clear of the line; the signalman must then send the **cancelling** signal to the signal cabin in advance.

10. **Train Out of Section.**—Trains must not be considered out of section and the **train out of section** signal must not be given to the signal cabin in the rear until the last vehicle of the train (or the last vehicle of the slip portion of the train or the assistant engine) with tail lamp attached, has passed the advance signal, or, where there is no advance

signal, has passed the home signal 400 yards, and is continuing its journey in the next section, or has been shunted clear of the main line.

When the last vehicle of a train does not **pass** the signal cabin before it has been shunted into a siding, the signalman must, before giving the **train out of section** signal, ascertain from the guard or shunter in charge of the train that the whole of the train, with tail lamp attached, has arrived, and the guard or shunter will be held responsible for giving this information to the signalman ; the fireman being similarly responsible in the case of a light engine.

11. **Course to be pursued when a Train is an unusually Long Time in a Section.**—Should an unusual time elapse after the **train entering section** signal has been received without the train so signalled coming in sight, the signalman must, if there is a tunnel in the section in which the train is running, prevent any train in the opposite direction proceeding on its journey until he has ascertained that the line on which it has to run is clear ; and if there is no tunnel in the section, the signalman must stop the first train proceeding in the opposite direction, and inform the driver of the circumstance, and, after the necessary signals have been sent and acknowledged, instruct him to proceed with caution.

12. **Obstruction Danger Signal.**—Should it be necessary, in consequence of obstruction or other cause, for an approaching train to be stopped at the signal cabin in the rear, the **obstruction danger** signal must be given to that cabin, and the signalman there must immediately exhibit the **danger** signal and take the necessary measures to stop the approaching train ; he must not allow the train to proceed until he has received from the signal cabin in advance the **obstruction removed** signal, nor until the proper block signals have been sent and acknowledged.

The signalman forwarding the **obstruction danger** signal must place the block indicator for the line or lines affected to **train on line** if not already in that position, and must also place or maintain his signals at danger to protect the obstruction.

Should there be reason to suppose that both lines are fouled, the signalman must send the **obstruction danger** signal in both directions, and where there are parallel running lines the requisite steps must be taken to stop the trains running on any line that may possibly be obstructed.

Should a signalman receiving the **obstruction danger** signal succeed in stopping a train for which the **is line clear** signal has been accepted by the signalman at the cabin in advance, he must at once advise the signalman at that cabin by giving the **cancelling** signal. This signal must be acknowledged, but the block indicator must be maintained at the **train on line** position until the obstruction has been removed.

13. **Blocking Back.**—When it is necessary, after the passing of one train and before giving permission for another to leave the signal cabin in the rear, to obstruct the line **inside** the home signal, by crossing a train or vehicles from one line to another for shunting purposes, or by allowing vehicles, or a train which is not about to proceed on its journey at once, to leave an independent line, or a siding, for the main line, the **blocking back** signal (2—4) must be given to the signal cabin or cabins in the rear, and, on this being acknowledged, and the dial signal given and acknowledged, the block indicator for the line or lines intended to be occupied must be pegged to the **train on line** position.

The same course must be pursued before the line is obstructed **outside** the home signal.

When a signalman asks permission to occupy the line **outside** his home signal, he must give the **blocking back** signal (3—3) to the signalman at the cabin in the rear, and the latter must, before acknowledging the **blocking back** signal (3—3), satisfy himself that he can with safety give such permission, and that he has not allowed a train to approach his signal cabin from the signal cabin in the rear under Regulation 3, unless there be a distance of at least half a mile between his home signal applicable to such train and the signal cabin from which he has received the **blocking back** signal, or, if at a junction, unless he has set his facing points for another line, and that line is clear according to these regulations.

If a signalman has allowed a train to approach his cabin from the signal cabin in the rear under Regulation 3, and there is not at least a distance of half a mile between his home signal and the home signal at the cabin from which he has received the **blocking back** signal (3—3), he must not acknowledge the latter until the approaching train has been brought to a stand at his home signal. Should he not have accepted a train, he must not acknowledge the **blocking back outside home signal** signal (3—3) until he has offered the **blocking back inside home signal** signal (2—4) to the cabin in the rear and it has been acknowledged.

When a signalman offers the **blocking back** signal, and the signalman at the cabin in the rear is not in a position to give permission for the line to be occupied, he must not repeat the **blocking back** signal, or acknowledge it in any way, and until the signal has been acknowledged, the line must not be occupied.

When a passenger train, or vehicles containing passengers, is about to be shunted from one main line to another, or a passenger train which is not about to proceed on its journey at once is allowed to pass from an independent line or a siding to the main line, the signalman must give the **blocking back** bell signal to the rear cabin and the following distinctive dial signal: six beats of the indicator to the left, divided into 2 pause, 2 pause, 2, so that the rear signalman may know with what kind of train the line in advance is occupied. The block indicator for the line or lines intended to be occupied must then be pegged to the **train on line** position.

Trains or engines approaching a junction on a line converging to a fouling point, or when leaving an independent line, or a siding, to at once proceed on their journey, or crossing directly over another running line, are exempted from the operation of blocking back, and must be dealt with under Regulation 4.

Unless special permission be given by the general manager or the superintendent of the line, no train or vehicle must be placed outside a home signal where the line is on a falling gradient towards the signal cabin in the rear.

When the obstruction has been removed and the main line or lines are again clear, the **obstruction removed** bell signal must be given to the signal cabin in the rear, and on acknowledgment the dial signal **line clear after blocking back** must be given and acknowledged. Should a train have been accepted under Regulation 5, and in addition to the obstruction having been removed the train has passed out of the section, the **obstruction removed** bell signal and the **train out of section** dial signal must be given.

When shunting operations have ceased outside the home signal, and are required to be continued inside that signal, the **obstruction removed** bell signal (2—1) and the dial signal **line clear after blocking back** must be given and acknowledged. The signal for **blocking back inside the home signal** must then be offered and accepted.

The signalmen forwarding and receiving the **blocking back** signal must make a note of the circumstance in their train register book.

14. **Section Obstructed by Accident or by Disabled Train.**—Should a signalman receive information from the fireman or guard of a disabled train that a second train is required to enter the section to assist the disabled train, or should it be necessary for the breakdown van train to enter a section obstructed by accident or otherwise, the second train or breakdown van train, as the case may be, may, after having been brought to a stand and the driver informed of the circumstances, be allowed to enter the section under the following arrangements:

The signalman must inform the signalman at the cabin in advance of the circumstances, and give the **train entering section** signal on the bell to the signal cabin in advance, and, after it has been acknowledged he must note the circumstances in his train register book, and then allow the second train to enter the section. The signalman at the cabin in advance must also note the circumstance in his train register book, and must not give the **train out of section** signal until both trains have passed out of the section in accordance with Regulation 10. The guard of the train requiring assistance must ride on the engine of the second train, and point out to the driver the position of the disabled train. The second train must run at reduced speed, and great caution must be observed by all concerned. When the **train out of section** signal is received from the signal cabin in advance, and permission has been obtained for another train to proceed, such other train must be stopped at the signal cabin in the rear, and the driver instructed to proceed cautiously through the section.

15. **Breakdown Van Trains and Engine Replacing or Assisting Disabled Engine.**—To prevent delays, breakdown van trains when proceeding to clear the line must be signalled as express passenger trains, the **shunt train for following train to pass** signal being given whenever the sections in advance are occupied by trains which the breakdown gang must pass to reach the scene of accident.

The same course must be adopted in the case of one engine proceeding to take the place of another that has failed, or of an engine, with or without a train, when sent forward to render assistance in case of failure or accident to preceding trains.

16. **When Block Telegraph may be Suspended for Single-Line Working.**—Should any obstruction occur necessitating the working of single line, and it is necessary to suspend block telegraph working, this must be done only by an order in writing from the person in charge who arranges the single-line working; but during foggy weather or falling snow, or when a tunnel intervenes, or the gradients are heavy on the section ot the line where the traffic has to be worked on a single line, block telegraph working must be maintained, the up trains being signalled on the up-line block telegraph circuit, and the down trains on the down-line block telegraph circuit, or the pilotman must accompany every train passing over the single line. On the working of the double line being resumed, any order suspending the working of the line by block telegraph is to be cancelled by a written notice in the same manner and at the same time as the order for working single line is cancelled. The same process must be observed as in the case of resumption of block working after failure of instruments or bells.

17. **Stop and Examine Train.**—If a signalman observes anything unusual in a train during its passage, such as signals of alarm by a passenger,

goods falling off, a vehicle on fire, a hot axle-box, or other mishap, *except a tail lamp missing or out, or a train divided, for arrangement as to which see Regulations* 19 *and* 20, or if a light engine should pass out of a section when the signal for a train has been received, he must give to the signalman at the signal cabin in advance the **stop and examine train** signal, and must himself exhibit his signals to stop any train coming in the opposite direction; and the signalman at the signal cabin in advance must acknowledge such signal, and immediately exhibit the danger signals to stop any train coming from or going towards the signal cabin from which the signal was received. The train, when stopped, must be carefully examined and dealt with as occasion may require; should any train going in the opposite direction have been stopped, it must be allowed to proceed after satisfactory evidence has been obtained that the line on which it is about to run is not obstructed.

The signalman sending the **stop and examine train** signal must not give the **train out of section** signal to the cabin in the rear, but, after calling attention, give the **caution** signal, and again peg the indicator to **train on line.** Before the next train or engine is allowed to enter the section, the signalman at the rear cabin must offer the **is line clear** signal, and if the signalman at the cabin in advance is in a position to accept the train or engine he must again give the **caution** signal, which must be acknowledged by the signalman at the cabin in the rear, who must stop the train or engine and warn the driver to proceed cautiously, informing him why it is necessary that he should do so. He must then give the bell signal **train entering section,** which must be acknowledged, whereupon the signalman at the advance cabin will release the indicator, and the dial signal according to the description of train entering the section must be given by the signalman at the rear. When the train or engine which was cautioned into the section has passed out of the section at the advance cabin, the signalman there will recommence signalling in the ordinary way.

Should either signalman have reason to believe in the case of a vehicle being off the rails, or goods falling from the train, that the permanent way has been damaged or fouled, he must not allow any train to proceed in the direction of the obstruction until the line has been examined and he is satisfied that it is safe for the passage of the train.

Should the signalman who receives the **stop and examine train** signal be unable to ascertain after examination of the train why the signal was sent, he must inform the driver of the first train travelling in the opposite direction of the circumstances, and instruct him to proceed cautiously to the next signal cabin.

Where practicable, the signalman must also telegraph or telephone the signal cabin in advance the cause of sending the **stop and examine train** signal. Signalmen must be careful to notice each train as it passes, to ascertain whether there is any apparent necessity for having it stopped at the next signal cabin for examination.

18. **Cancelling Signal.**—Should it be necessary to cancel the **is line clear** or **train entering section** signal, the **cancelling** signal must be forwarded, and the signalman receiving the signal must, after acknowledging it, place the block indicator in the vertical position, unless the **cancelling** signal has been forwarded to cancel a signal accepted under Regulation 5, in which case the indicator must be kept at **train on line** until the section is clear, and an entry must be made in the train register book showing what signal was cancelled, and at what time. The **cancelling** signal must not be used unless the **is line clear** or **train entering section** signal has been accepted or acknowledged.

19. **Train Passed without Tail Lamp.**—All trains and light engines will carry a tail lamp in the rear, both by day and by night, to indicate to the signalmen that no vehicle has become detached on the journey, and signalmen must carefully watch each train as it passes, and satisfy themselves that it is complete before giving the **train out of section** signal to the signal cabin in the rear. Should a train pass a signal cabin and the signalman be unable to satisfy himself whether or not the tail lamp is on the train, he must immediately exhibit the danger signal, and stop the first train going in the opposite direction, informing the driver what has occurred, and instructing him to proceed cautiously so as to avoid danger in the event of any portion of the train having fouled the line on which he is running. The signalman must also send the **train passed without tail lamp** signal (*nine consecutive beats*) to the signal cabin in advance, and must not give the **train out of section** signal to the signal cabin from which the train without tail lamp has arrived, but must call the attention of the signalman there in the usual manner, and, on gaining his attention, must give the **train passed without tail lamp** signal (4—5).

In such a case the signalman at the cabin in the rear may offer the **is line clear** signal for a following train although he has not received the **train out of section** signal.

The signalman at the cabin in advance, on receiving the **train passed without tail lamp** signal, must acknowledge it, and place the signals at danger to stop the approaching train, advising the guard and driver of the circumstances. If, where the sections are short, a signalman receiving the **train passed without tail lamp** signal of nine consecutive beats, finds that he cannot stop the train except by bringing it to a sudden stand, he must not place his signals to danger, but, as the train is approaching, send the **train entering section** signal to the signal cabin in advance and *immediately* follow it with the **train passed without tail lamp** signal.

When the signalman who sent the **train passed without tail lamp** signal (4—5) receives the **is line clear** signal for the next train or engine requiring to enter the section (unless in the meantime he has received intimation from the signal cabin in advance that the train has arrived complete), he must not acknowledge it in the usual way, but if he be in a position to accept the train or engine, he must repeat **train passed without tail lamp** signal (4—5), the indicator remaining pegged at **train on line.** The signalman in the rear receiving this signal must stop the train and verbally instruct the driver to proceed cautiously to the next signal cabin in advance, informing him why it is necessary that he should do so, and then give the bell signal **train entering section.** The signalman in advance must then unpeg the indicator, upon which the proper dial signals will be given from the rear cabin, and after they have been acknowledged, the indicator must be again pegged to **train on line.** As soon as the train, the driver of which has been cautioned, has passed the signal cabin from which the **train passed without tail lamp** signal was sent, the signalman there must give the **train out of section** signal, and the signalling of the trains must then be resumed in the ordinary manner.

Should, however, the signalman sending the **train passed without tail lamp** signal receive an intimation from the signal cabin in advance that the train has arrived complete, he must, if he has not in the meantime given permission for a following train to leave the signal cabin in the rear, call the attention of the signalman at that cabin and give the **train out of section** signal.

If a train should pass with a tail light out when it should be burning, and the signalman can plainly see the lamp, and is satisfied that the train is complete, he must give the **train out of section** signal to the signal cabin in the rear, and the **train psssed without tail lamp** signal (*nine consecutive beats*) to the signal cabin in advance, and, where practicable, also telegraph or telephone to the signal cabin in advance, stating that the lamp is not missing, but out. In such a case it will not be necessary for the signalman sending the signal to stop any train going in the opposite direction, but the signalman in advance must stop the approaching train and inform the guard of the circumstances.

Should a train that is appointed to convey a slip portion pass a signal cabin short of the proper slip tail signals (unless it be the cabin immediately preceding the station where the portion has to be slipped, for instructions as to which see following clause), the signalman must assume that the slip portion has become detached, and send to the signal cabin ahead the **train divided** signal, and to the signal cabin in the rear the **train passed without tail lamp** signal; if the signalman in advance finds on the arrival of the train that the slip portion has broken away, he must telegraph or telephone to the signal cabin ahead, **slip portion broken away, train travelling without it**; and this message must be repeated from signal cabin to signal cabin, as the train passes, as far as the slip portion would have run, the train itself being signalled and the line cleared in the usual way. Should the slip portion be afterwards sent on by special engine it must be signalled as a passenger train.

Should a train that is appointed to convey a slip portion be short of the proper slip tail signals when it passes the signal cabin next in rear of the station at which the portion is to be slipped, the signalman must not send forward the **train divided** signal, but must only send the **train passed without tail lamp** signal to the signal cabin in the rear. He must then ask the signalman in advance on the speaking instrument, **has slip portion arrived complete?** If the reply is "Yes," he must send the **train out of section** signal to the signal cabin in the rear; but if the answer is "No," he must *immediately* telegraph or telephone to the signal cabin in the rear, **slip portion not arrived.**

20. **Train Divided.**—This signal must be sent to the signal cabin in advance in the event of a signalman observing that a train has become divided, and is running in two or more parts. If the train is assisted by an assistant engine in the rear, or is running on a falling gradient or between short sections, where the stoppage of the first part would risk a collision with the second part, the signalman receiving such signal must *immediately* exhibit the danger signal to stop any train going towards the signal cabin from which the signal was received, but if the line on which the divided train is running is clear ahead for it to run upon, he must not exhibit the signals to stop the first portion, but must give the driver a green signal either by flag or hand lamp as occasion may require, waving the signal slowly from side to side. The driver, on seeing the green signal waved slowly from side to side, will understand that his train is divided and must exercise great caution by looking out for the second portion, and unless he has reason to believe the line is not clear ahead, must not stop the portion attached to his engine until he is satisfied that the rear portion has been stopped, or is running very slowly. He must, however, observe and obey any signals that may be exhibited against him. So soon as the first portion of the train has

passed, the signalmen sending and receiving the **train divided** signal must take proper measures for dealing with the second portion, and place detonators on the rails to attract the attention of the guard, or of the assistant engine-driver should there be an assistant engine in the rear.

If the divided train is running on a rising gradient, or where the line is level, and is not assisted by an assistant engine in the rear, the signalman receiving the signal must exhibit the danger signal to stop any train coming from or going towards the signal cabin from which the signal was received. The first portion of the divided train, when stopped, must be shunted into a siding as expeditiously as circumstances will permit, or otherwise dealt with as may be necessary to prevent the second portion coming into collision with it.

Should any train going in the opposite direction have been stopped, it must not be allowed to proceed until it has been ascertained that the line on which it is about to run is not obstructed. Should a train become divided in starting, and the driver run forward with the first portion, leaving the rear portion stationary, the **stop and examine train** signal must be sent to the signal cabin in advance, and not the **train divided** signal.

21. **Shunt Train for Following Train to Pass.**—This signal must be used to prevent important trains being delayed by less important trains. When, before the **train out of section** signal has been received from the signal cabin in advance for the last train, the signalman receives a signal from the cabin in the rear for a more important train, the **shunt** signal must be sent to the signal cabin in advance, and the signalman there, on receiving this signal, must take the necessary measures to clear the line so as to prevent delay to the second train. He must use his discretion as to the best means of effecting the object in view, and if he is unable, from any cause, to shunt the train at his signal cabin, or if he thinks it inexpedient to do so, he must allow the train to proceed, and send forward the **shunt** signal to the signal cabin in advance. The signalmen forwarding and receiving the **shunt** signal must make a note of it in their train register books.

22. **Vehicles Running Away on Wrong Line.**—Should any vehicle or portion of a train be running back in the wrong direction, or should a train be proceeding on the wrong line, the signalman must immediately exhibit the danger signal and call the attention of the signalman at the next cabin towards which the vehicle, train, or portion of the train, may be running, by giving the **vehicles running away on wrong line** signal; he must also stop the first train going in the same direction on the right line, and, after informing the driver what has occurred, instruct

him to proceed cautiously. The signalman in the rear receiving this signal must immediately exhibit the danger signal to stop any train coming from or going towards the signal cabin from which the signal was received, and take any other measures that may be necessary, such as turning the runaway train or vehicles across to the other line, or into a siding, as may be most expedient under the circumstances. In the event of a runaway train or vehicles being turned across to the other line, the **vehicles running away on right line** signal must be passed on to the next signal cabin. Should the signalman be unable to take such protective measures. he must pass on the **vehicles running away on wrong line** signal to the next cabin in the rear; he must also place detonators on the rails to attract the attention of the men in charge of the train or portion of the train.

Should any train travelling in the opposite direction be stopped, it must not be allowed to proceed until it has been ascertained that the line on which it is about to run is not obstructed.

The signalman at the cabin from which the runaway train has started, or any other signalman whose cabin may be passed by the runaway train, must immediately give the **obstruction danger** signal to the signalman in the rear before giving the **vehicles running away on wrong line** signal, as prompt action on the part of both signalmen may prevent a mishap. Should the signalman receiving the **obstruction danger** signal succeed in stopping the train or engine for which he has given the **is line clear** signal, he must at once advise the signalman in advance by giving the **cancelling** signal.

23. **Vehicles Running Away on Right Line.**—If any train, vehicle, or portion of a train has escaped and is running away in the proper direction on the right line, or has entered the section without authority, the signalman at the cabin in advance must be advised of the fact by the signalman at the cabin in the rear giving the **vehicles running away on right line** signal. The signalman forwarding this signal must immediately exhibit the danger signal to stop any train coming from or going towards the signal cabin towards which the vehicle or train is running, and the signalman receiving the signal must also immediately exhibit the danger signal to stop any train coming from or going towards the signal cabin from which the signal was received (unless there is a train in block in the same section as the runaway vehicle or train and in front thereof, in which case, if the line be clear, such train may be allowed to pass the signals before they are exhibited to stop the runaway train), and he must arrange for the line on which the vehicle or train is running to be cleared, and, if necessary, send the signal

forward, and to take such other measures as he may consider most expedient under the circumstances. Should any train travelling in the opposite direction be stopped, it must not be allowed to proceed until satisfactory evidence has been obtained that the line on which it is about to run is not obstructed.

24. **Opening and Closing of Cabins.**—At a signal station or cabin which is closed during the night, the signalman, on commencing duty in the morning, and when going off duty at night, must give the appointed signals in each direction, and an entry of the time these signals are sent and acknowledged must be made in the train register books at each cabin. Any defect in working must be noted in the occurrence book, and at once reported by the signalman to the stationmaster, who must immediately acquaint the telegraph linemen of the circumstance.

Opening and Closing of Signal Cabins and Stations where there are Telegraphic Switches.—The signalman, before switching the telegraphic apparatus **out of circuit,** must see that all the block indicators are in a vertical position ; he may then give the closing signal in both directions, and upon acknowledgment turn the switch handle down to the right-hand side. Immediately after a cabin has been closed, the testing signals must be given by the signalmen at the cabins placed in circuit.

No engine, train, or vehicle must under any circumstances be allowed to pass from one main line to another, or to enter upon the main lines at a cabin which is switched out of circuit.

On resuming duty the signalman must examine the block instruments to ascertain if any trains are signalled on the through section ; this will be shown by the block indicators which are not turned out of circuit. If a train is in the section he must, before switching the telegraphic apparatus into circuit, peg the block indicator corresponding with the line on which the train is travelling in the proper position, and then turn the switch handle to the vertical position and give the opening signal in both directions. The signals received for the train in question must be transmitted to the next cabin then open in the direction the train is proceeding.

25. **Failure of Instruments or Bells.**—In the event of any failure of the instruments or bells, so that the necessary signals cannot be forwarded and received, no train must be allowed to pass a signal cabin into that section of the line where the failure exists, without having been previously brought to a stand, and the driver and guard or guards advised of the circumstance, and how many minutes the preceding train is in advance. The driver must then be instructed to proceed cautiously,

in order to stop short of any obstruction there may be on the line. Where there are no speaking instruments or when the speaking instruments have failed, the driver of the first train thus warned must be instructed to stop at the signal cabin in advance, and inform the signalman there that the bells or instruments have failed at the signal cabin in the rear.

No train must be allowed to follow another train within *five* minutes, unless the signalman sees that the section ahead is clear, and when a tunnel intervenes in a block section, not within *ten* minutes, unless the signalman can satisfy himself that the tunnel is clear; in both cases the driver must be stopped and cautioned as above directed. Steps must be immediately taken to have the telegraphic apparatus put into working order, and when the failure has been remedied, and the instruments are again in working order, the **testing** signals must be given and acknowledged, after which the indicator must be pegged to **train on line.** The driver of the next engine allowed to proceed through the section cautiously must be supplied with a written notice to the effect that it is the last engine cautioned; the number of the engine must also be given, and the driver instructed to stop at the next signal cabin then open, and hand the notice to the signalman. The signalman receiving this notice must give the **train out of section** signal to the signal cabin in the rear, and the signalling must then be recommenced in accordance with these regulations.

26. **Recording Time when Signals are Forwarded and Received.**—Except where special instructions to the contrary are issued, the time at which all signals are forwarded and received must be made legibly, with a pen, in the train register book, and the signalman on duty must place his name immediately under the last entry made by him at the expiration of his hours of duty.

If an incorrect entry be made, a line must be drawn lightly through it, and the correction made above or below it, so that the original entry may be clearly seen.

In recording the time at which signals are received and forwarded, fractional parts of a minute less than half a minute must not be counted, and the half minute and fractional parts more than half a minute must be reckoned as a minute, thus: $15\frac{1}{4}$ minutes must be entered as 15 minutes only, and $15\frac{1}{2}$ minutes as 16 minutes.

27. **Testing Block Bells and Indicators.**—This signal must be used to ascertain whether the bells and indicators are in perfect order, and only when no train has been signalled. The bell **testing** signal must precede the block indicator **testing** signal.

28. **Time Signal.**—Signalmen receiving this signal on the speaking instruments at 10 a.m. must communicate the information to the signal cabins which do not receive it on the speaking instruments, by giving the **time** signal on the bell. Signalmen must regulate their clocks accordingly.

29. **Lampman or Fog-Signalman Required.**—At cabins where a lampman or fog-signalman cannot be communicated with by the signalman on duty, the signal **lampman or fog-signalman required** must be given to the cabin where the man required can be communicated with. The signalman receiving such signal must at once inform the stationmaster or person in charge in order that the necessary assistance may be given.

30. **Testing Controlled or Slotted Signals.**—Signals which are slotted from another block signal cabin must be tested as soon after the signalmen change duty as the running of the trains, or, where there are level crossings, the road traffic will permit. The signalman in charge of the controlled or slotted signal, after releasing the lever so far as he is concerned, must give 20 strokes on the bell (thus : 5—5—5—5) to the signalman at the block signal cabin from which the signal is slotted. This must be repeated, and the signal lever worked three times slowly. Each signalman must make an entry in his train register book of the transaction, and if the wire working the slot requires adjusting, the signalman going off duty must walk to the other block signal cabin and see it put right, unless he can get this done by sending a message on the speaking instrument or otherwise. Controlled or slotted signals must not be tested after the **is line clear** signal has been received for a train on the line to which they refer.

31. **Parallel Lines.**—With reference to Regulations 12, 17, 19, 20, 22, and 23, where there are parallel running lines, the necessary steps must be taken to stop or caution the trains running on any lines that may possibly be obstructed by what has occurred.

32. **Mixed Trains** conveying passengers and goods must be signalled and dealt with as passenger trains.

33. **Public Level Crossings.**—Traction or other heavy engines, or heavy loads of timber, etc., must not be allowed to pass over level crossings at block signal cabins after permission has been given for a train to approach from the signal cabin in the rear, nor until the line has first been blocked back in all directions in accordance with Regulation 13. The **is line clear** signal must not be accepted after permission has been given for a traction or other heavy engine, or a heavy load of timber, etc., to cross until the obstruction is clear of the line.

34. **Travelling Cranes.**—The lines must not be allowed to be fouled by the jibs of travelling cranes, nor by the loading or unloading of round timber, long timber, angle iron, or other articles of great length, until the **blocking back** signal has been given and acknowledged in all directions.

The sample code and regulations given on pages 46 to 69 was issued early in 1896, and superseded the code which has just been considered, and forms on close acquaintance a striking contrast with its predecessor. The thirty-five signals which form the total of the 1891 code for all purposes are in this code replaced by a total of forty-five, or an increase of over twenty-seven per cent. on the former number. The number of regulations respecting the use of the code is increased from eighteen to thirty-four for all purposes, an increase of nearly eighty-nine per cent. on the former number. The salient points of difference in the two codes will be found in the number, character, and order of the descriptive signals employed. The four "Be ready" signals of the 1891 code are replaced by eleven "Is line clear" signals in that of 1896, whilst the twelve descriptive dial signals of the former are replaced by six similar signals in the latter. Practically the change amounts to a complete inversion of the order of importance of the descriptive signals. In the 1891 code a descriptive signal, indicative of a certain general class of train, was sent first on the bell, and more detailed information was afforded by the more distinctive dial signal. In the 1896 code we find this order completely reversed: the detailed signals are given by the preliminary "Is line clear" signal, and the corresponding dial signal is merely confirmatory in a general way.

The change of title of the preliminary bell signal from "Be ready" to "Is line clear," and of "On line" to "Train entering section," is an instance of the recognition of the necessity for precise language in drawing such codes; and the ample description of the object and limits of such signalling, the precise and decided instructions for their use, show to what an extent the requirements have been studied.

Another point of difference is the character of the signalling by which the bell signals are increased from nineteen in the old code to thirty-three in the new, without making the latter cumbrous by the use of an inordinate number of blows of the hammer of the bell. In the old code the greatest number of blows constituting one signal was eighteen; in the new code the maximum number of blows is twenty, although the number of distinctive signals to be sent is seventy per cent. greater than with the older code. There is of course nothing new in giving distinctness to a signal by breaking it up into sections, as is here done, and as had been previously done in other places; but its effect in producing the very necessary distinctness might be made marked. Take, for instance, the two signals relating to vehicles running away in both codes. These two signals are so obviously the counterpart of each other, that they should naturally follow each other in the code. We find, however, sandwiched between them a signal relating, not to an emergency, as these two do, but to what is a common incident of working; and the arrangement is obviously necessary in order to obtain the necessary distinction to ensure the difference being noticed.

At the same time it must be admitted that in the instance given full advantage has not been taken of the distinctness that may be obtained from this method of breaking up a signal into regular or irregular sections, since the *difference* between the two is precisely the same as in the older code.

Many of the signals which appear in the 1891 code are of course reproduced in that of 1896. Of the fourteen additional bell signals, seven are additional preliminary signals, one is a transference from the dial signals of the old code ("Assistant engine in rear of train"), two are additions to the emergency signals, two are connected with temporary fouling of the line by shunting operations, and two are of the class which is not directly connected with the working of traffic.

Of the dial signals, the title of "On line" has been altered to "Train entering section," which more nearly expresses the actual condition of things, and we find that the number of such signals has been reduced from twelve to seven. Two new signals involving a change of procedure ("Signal correctly repeated," "Signal incorrectly repeated") are introduced. In the old code, the first of these was given by the signalman at the sending end holding the needles to "Train on line" during the time the signalman at the receiving end pegged the handle at his own end to do the same. The introduction of these signals has resulted in the discontinuance of this method. Three dial signals replace two formerly used in connection with shunting, the difference in the number arising from the distinction made between passenger trains and others, a distinction not recognised by the shunting signals of the older code.

The regulations for guidance in the use of the 1896 code call for no special comment other than is involved in directing attention to the clear and precise language used in describing the method of signalling, the definition of the limits of the section, and the difference of practice to be observed in offering the "Is line clear" signal when the section is already occupied, where passenger trains are or are not involved.

Block Indicators.—Besides the system of signalling already alluded to, which consists of train-distinguishing or train-position signals, and which are invariably given by a bell code, electrical block instruments of another class perform the equally important duty of indicating at all times the actual condition of the line, whilst the bell signalling of trains may be said, generally, to deal with the marshalling of traffic and notification of its progress through the several stages incidental to the usual working. The indicators, of whatever form, are a reminder at all times of the stage that has been reached, and are therefore entirely connected with the *safety* of the operations.

Examples of the earlier forms of indicator, taken from the illustrations accompanying the report in the "Proceedings of the Institution of Civil Engineers" of Mr. Preece's 1863 paper are given by Figs. 1 to 7.

A brief analysis of the various conditions of the line and the indications required from block indicators may be useful.

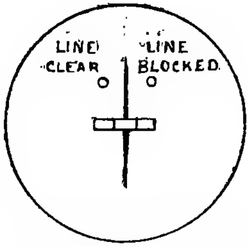


FIG. 1.—Cooke and Wheatstone's Indicator.

Theoretically, there are only two conditions of the line—line occupied by train, and line clear of trains. Practically, the exigencies of traffic demand the pre-

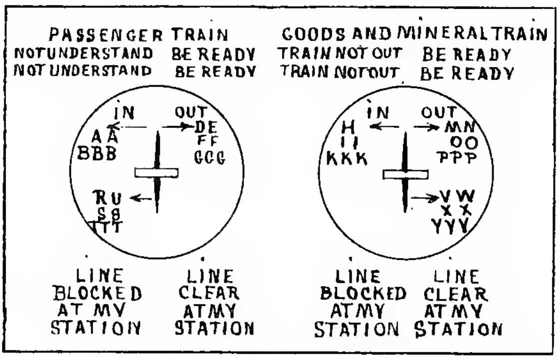


FIG. 2.—Great Northern Railway Indicator.

paration of a section some time in advance of the actual entry of the train into the section in order to obviate the delay that would otherwise take place.

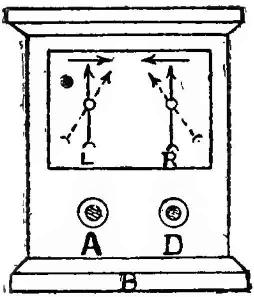


FIG. 3.—Regnault's Indicator.

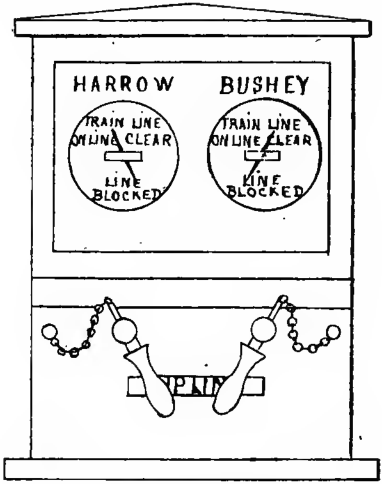


FIG. 4.—London and North-Western Railway Indicator.

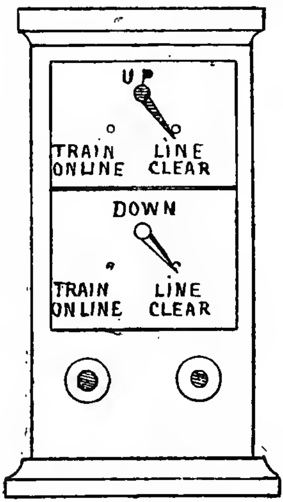


FIG. 5.—Tyers' Indicator.

If block indicators shall be required to show the condition of the line at *all* times, these must be provided with some means of showing an indication which shall differ from "Train on line," or any other indication as completely as the state of preparation differs from the conditions indicated by the "Train on line," or other indication.

A study of the code given on pages 48 to 50, together with the regulations framed for working it, shows that the indication exhibited by pegging to "Line

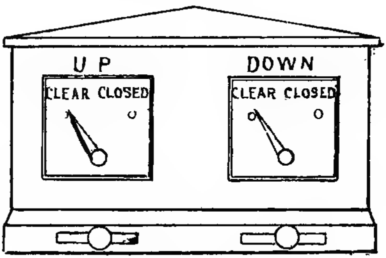


FIG. 6.—Bartholomew's Indicator.

clear" is intended to show an intermediate stage between "Line blocked" and "Train on line." The indication intimates the readiness of the signalman at the receiving end of the section to accept a train of the character indicated by the particular form of "Is line clear" signal sent, which is known to be approaching the point of entrance to the section; and it further intimates that no operations involving the occupation of the line represented, by any other train than that signalled, will be undertaken at the receiving end of the section. This indication is not cancellable by the signalman at the receiving end of the section for his own purposes, except for the most exceptional occurrences outside his control. On the

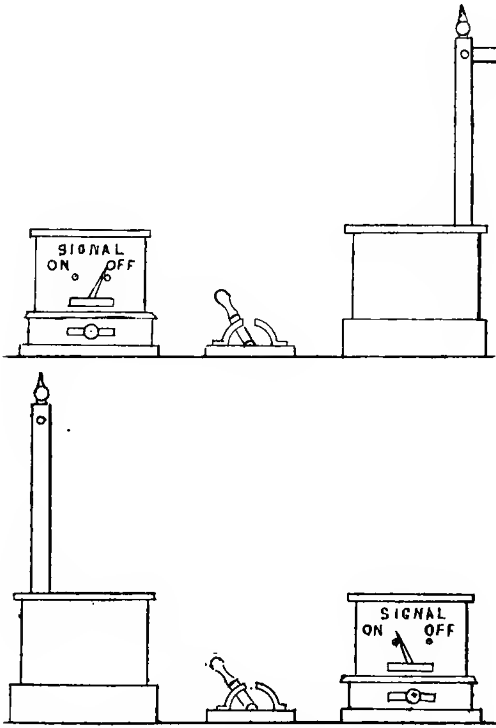


FIG. 7.—Mr. Preece's Apparatus.

other hand, cancellation of the indication may be obtained by the signalman at the sending end of the section, but only by the concurrence of the receiving signalman, who controls all the indications exhibited. Hence, "Line clear" is a positive indication of the most important character, and shows a stage of working to which neither "Train on line" or "Line blocked" is applicable. The continuous indication is a reminder to the signalmen at either end of the last stage of the operations performed by them jointly.

If we consider the indication next in order, "Train on line," we find that it is a subsidiary indication, more of the nature of an intimation of the progress of the train than of any other character; and signifies, generally, that the train is under the control of the signalman at the receiving end of the section, and that he is aware of the necessity for taking steps to deal with it as its character, as given by the distinguishing signals, demands. To the signalman who has dispatched the train, as well as the signalman who is to deal with it during its further progress, the continuous indication exhibited intimates simply the occupation of the line by a train and its passage beyond a certain point. Practically, then, the "Train on line" indication is simply the complement of the "Line clear," and intimates merely a change of position on the part of the train.

The next indication in order is "Line blocked." This is the normal position of the indicating needle after the "Train out of section" signal has been given and acknowledged. This indication is a most important one, and a reference to the regulations will show that, under normal conditions of working, the intimation conveyed is "Line clear of trains, but blocked until permission is given for further traffic." From this we see that the ruling principle of block working is the asking and receiving permission to forward traffic before its dispatch from any point.

Further consideration of the code and regulations shows that the "Train on line" indication is made to do duty on other occasions than those of the simple passage of trains from one end of the section to the other. The "Blocking back" signals are an instance of this use of the "Train on line" indication. Careful examination shows that the intimation conveyed under such circumstances is not essentially different from that conveyed in the case previously considered. In both cases the indication shows the presence of a train between the two block stations concerned, in such a position as does not warrant the "Line blocked" indication being exhibited.

Relative Importance of Indications.—Consideration of the relative importance of the three indications, "Line clear," "Train on line," and "Line blocked," shows the first to be the most important, since it is the only indication which must be secured *before* action is taken to dispatch a train. Under normal circumstances of working, we find that before "Line clear" can be given for a train, the previous train must have reached points on the line which are defined with some precision in the regulations. The limitations on the exhibition of "Line clear" for trains which have to approach fouling points at junctions, show the importance attached to the indication; and the restrictions under which the "Is line clear" signal may be offered to the advance station *before* the previous train has been signalled out of the section, shows how the possibilities that may arise in connection with irregular working are recognised.

It will be noticed that a distinction is drawn between signals and indications; and the distinction is a most necessary one. By indications, is meant the more or less permanent intimations conveyed by the position of the block indicators of the condition of the line for the time being; by signals, is meant the transient intimations, given either on the bell or indicating apparatus, which relate to other matters than the condition of the line. It seems necessary to call attention to this distinction, since there seems to be a tendency in some quarters to confuse the two classes by substituting "Train entering section" for "Train on line," as the title of one of the indications of the condition of the line. "Train entering section" is not so clearly indicative of what is intended to be conveyed by the permanent deflection of the needle as "Train on line." The *entrance* of a train into a section cannot well be considered as being continued during the whole time the train is passing through the section. Entrance into a section is complete when the signal controlling such entrance has been put to "Danger" behind the train; and the intimation of the performance of the operation should be of the nature of a signal, as here distinguished from an indication. It is desirable in all cases that the title of an indication or a signal should, in the fullest manner, indicate the nature of the operation. "Train on line" is more nearly representative of the actual condition of things during the passage of a train through a section than "Train entering section," which represents a merely momentary operation.

The cancellation of signals, or of indications being exhibited as the result of previous exchange of signals, is a question of considerable importance. Cancellation becomes necessary at junctions where, through misapprehension, the wrong line has been prepared for an approaching train; and at other places from various causes, such as its being found necessary to shunt a train for one of greater importance to pass. A study of the regulations to be observed will show that, theoretically at least, cancellation should only be necessary in the case of a "Line clear" indication being exhibited. Cancellation of a "Train on line" indication ought never to be necessary, since the preceding "Train entering section" is not supposed to be sent until the train is *leaving* the block station at the entrance to the section; and the "Train on line" indication indicates the completion of the operations sanctioned by the exhibition of the preceding "Line clear" indication.

Form of Instrument.—At one time considerable discussion centred on the most suitable form of instrument for indicating the condition of the line. Some inventors pinned their faith to instruments in which the indicator was a small semaphore arm, or a facsimile in miniature of the outdoor mechanical signal, and argued that the train-distinguishing signalling apparatus should be of a different character to the indicating apparatus, but not necessarily a separate instrument, since they served distinct purposes, and that uniformity in design of the mechanical signals and the block indicator was desirable in many respects. Others, again, preferred some form of the "needle" instrument, so familiar on railways, and contended that the indication was in any case arbitrary, and, consequently, when once established and understood the character of the indication was immaterial. It was further contended by the advocates of the single-needle instrument that it allowed a greater variety of signals to be sent, and that it also possessed the further advantage of cheapness.

Intimately connected with the most suitable character of block indicator is another point which seems to have been considered of some importance by inventors of block apparatus, and upon which much ingenuity has been exercised. This is the reduction of the number of line wires to one; and the ability to perform all the operations required for double-line block working by one line wire, is still often urged as a recommendation on the score of smaller cost for erection of wires and their maintenance.

Roughly, instruments for block working may be placed in one of two divisions. In the first, the indicating apparatus is stable in either of the positions it can take up, the current is transient, and is only used to effect a *change* of position. In the other division, the indicating apparatus is stable in one position only, and change of position from the normal can only be *maintained* by a continuous current.

An example of instruments of the first division may be seen in the block instrument invented by the late C. V. Walker (Fig. 8), which was at one time in general use on the old Stockton and Darlington Railway, now a division of the North-Eastern Railway, and is still to a limited extent.

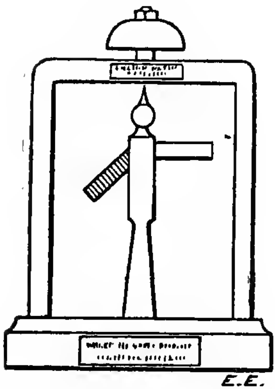


FIG. 8.—Walker's Block Indicator, One Wire.

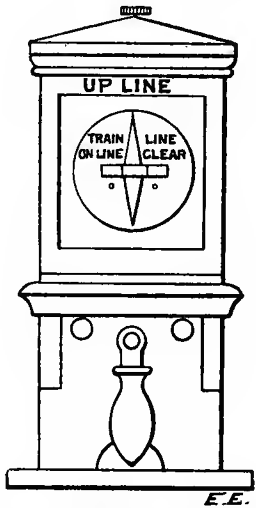


FIG. 9.—Single-Needle Block Indicator, Three Wires.

This instrument was also in use on the South-Eastern Railway, of which Mr. Walker was at one time the electrical engineer. A further example of this class of instrument, but of different construction, is the one-wire needle instrument of Tyers (Fig. 10) now in use on the London and North-Western Railway.

Examples of instruments of the second division are furnished by the single-needle three-wire block instruments in use on the North-Eastern, Great Northern, Midland, London and North-Western, and other railways (Fig. 9).

Instruments of the first division indicate two conditions of the line only—viz., "Line clear" and "Line blocked," or "Train on line." Instruments of the second division indicate three conditions of the line—

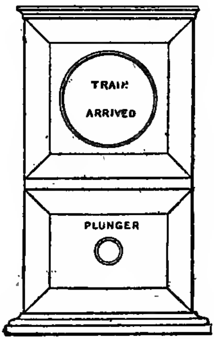


FIG. 9A.—Spagnoletti's Indicator.

viz., "Line blocked" (the normal position), "Line clear," and "Train on line." The difference just shown may seem to be of minor consequence, but it is, in reality, of the first importance to the proper indication of the exact position of affairs at any stage of block working. "Line clear," with instruments of the first division, indicates that there is no train in the section of line to which the instrument refers. With instruments of the second division, however, it not only indicates that there is no train in the section, but also that the signalman at the receiving end *has given permission* for a train to be sent forward, and *has made* preparations for its arrival.

As an illustration of the difference in working with the different classes of instruments, the following

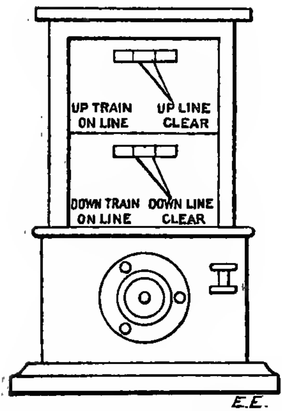


FIG. 10.—Tyers' Block Indicator, One Wire.

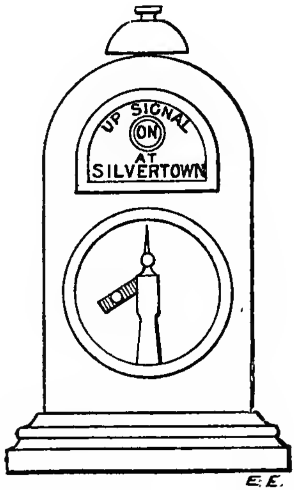


FIG. 11.—Preece's Block Indicator, One Wire.

extracts from the regulations setting forth the methods of working are given:

"Prior to the dispatch of a train from A, the signalman there, provided he has received the 'Train out of section' signal for the previous train, and the block indicator is in its normal position, must call the attention of B, and having obtained it, must give the proper 'Is line clear' signal; if the line be clear at B, the signalman there *must acknowledge the signal by repeating it.* The signalman at A may then, if the line is clear, take off his signals for the train to leave A.

"On the train leaving A, the signalman there must

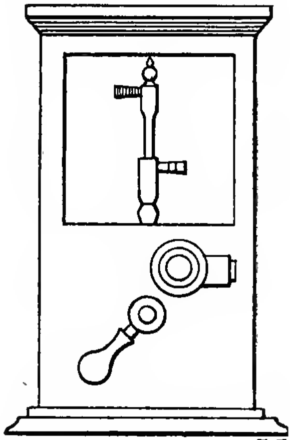


FIG. 12.—Hodgson's Block Indicator (Saxby and Farmer's Lock and Block), One Wire.

send the 'Train entering section' signal to B, and the signalman at B must acknowledge the signal by placing the block indicator to 'Train on line.'"

"Prior to the dispatch of a train . . . from A, the signalman there, provided he has received the 'Train out of section' signal for the previous train, and the block indicator be in its normal position, must call the attention of B, and, having obtained it, must give the proper 'Is line clear' signal; if the line be clear at B, the signalman there *must acknowledge the signal and peg the block indicator to the 'Line clear position.'* The signalman at A may then, if the line is clear, take off his signals for the train to leave A. On the train leaving A the signalman there must send the 'Train entering section' signal to B, and the signalman at B must acknowledge the signal and peg the block indicator to 'Train on line.'"

Mode of Working.—The first of these quotations represents the mode of working a single-wire system with instruments of the first division. In this case the signalman at the sending end has nothing to remind him that he has, or has not, obtained permission to send a train forward to the advance cabin, and the signalman at the receiving end has nothing to remind him that he has given, or not given, such permission. In both cases the signalmen have to rely on their memories, or their booking, for reminders of the "Is line clear" signals that have passed between them.

The second quotation is for a three-wire system, with indicating instruments of the second division. In this case the "Is line clear" signal, and its acceptance by the signalman at the advance cabin, is recorded at both ends of the section until the permission has been acted upon, and the "Line clear" indication is superseded by "Train on line."

With either class of instrument the line is considered "blocked" until permission is given by acknowledging, by repetition, the "Is line clear" bell signal, but the fundamental difference between the two modes of working is the ability, with instruments of the second division, to record the acceptance of the "Is line clear" signal, so that the signalmen at both ends can, from the indications of their respective instruments, obtain reminders of the signals that have passed, and the position of the line at any time. Obviously, the condition of a section cannot be the same after permission has been given to forward a train as before that permission was given, even if the train has not actually entered the section. The acceptance of the preliminary "Is line clear" signal indicates that the line is clear to the advance cabin, that previous trains are fully protected by signals, and that no operations involving the fouling of the line will be undertaken at the advance cabin until the train accepted is clear. Hence, it would appear that instruments of the first division fail to take cognisance of what is without doubt an important condition of the line. How important it is that the operations of the two signalmen, who must necessarily co-operate in the working of traffic, should be perfectly synchronised, need not further be commented upon.

Generally, it may be said that instruments which require only one line wire for all the operations involved in double-line block working are those which use transient currents only, whether employed as train-distinguishing signals or as indicators, since the line may be required for the former signals whilst the instruments are indicating "Train on line" for one or other of the lines of rails for which it is used. Conversely, it may be said that instruments which require continuous currents for the maintenance of their indications are those which will require three wires, since the indicators must work independently of each other and of the bell-signalling apparatus.

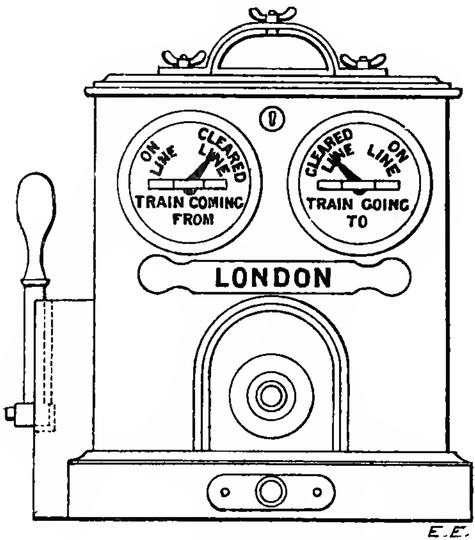


FIG. 13.—Winter's Block Indicator (Siemens).

From what has been said it follows that the number of independent batteries required will be less for instruments of the first division than for those of the second division, since under actual conditions of work currents are not likely to be used in any one cabin in both directions simultaneously. Where transient currents are used only, the number of batteries required may be reduced to the number of operations that may be carried on simultaneously. With instruments using continuous currents for maintaining the necessary indications, the number of independent batteries required will necessarily be greater owing to the greater number of operations which may require to be carried on at the same time.

It would therefore appear that block instruments using transient currents, and requiring not only one line wire but a smaller number of independent batteries, would be preferable considered from an economical standpoint. Against this advantage it is urged that cutting down the line wire to one, and reducing the battery power to an absolute minimum, is an operation of the nature of putting too many eggs in one basket. If a fault occurs on the line wire, both lines of rails are affected, and must be worked at "Caution" until the defect is removed. If the telegraph lineman is not immediately available, the disorganisation of traffic may be considerable.

On the other hand, with instruments of the second division, a failure of one line wire affects that instrument and the line it represents alone, the other line being worked as usual. It by no means follows that the number of line faults on a three-wire block will be three times that on a one-wire.

An important point in connection with the class of instrument most suitable for block working is the indication the apparatus will give when, through a defect, the instruments are not available for use. With instruments of the first division the indication will remain in the position it happened to occupy at the time the defect occurred. This may be either "Line clear" or "Line blocked," according to the condition of the line at the time. With instruments of the second division, where any indication other than "Line blocked" is only maintained by the use of a continuous current, a defect of the line wire or battery will at once cause the indicators to show "Line blocked."

When a defect arises in the block apparatus for any section, involving the suspension of block working, the ordinary space limit is replaced by a time limit, and every train which is sent through that section must be first brought to a stand and the officials in charge of the train advised of the breakdown and instructed to proceed cautiously. Practically, the section of the line where the failure exists is treated as if blocked on the *approach* of any train which may require to pass through that section. With instruments of the first division the indications of the faulty block instruments may, or may not, correspond with the theoretical condition of the line; with instruments of the second division, the defect ensures the indications being such as will correspond with the conditions under which the line is being worked. Instruments of this class may therefore be fairly considered as more reliable under the conditions cited than those of the first division, and the indicators have the further advantage of being self-testing to a large extent when in use.

Disturbance of Instruments.—Instruments of the second division are subject to a class of disturbance which does not affect those of the first division. In consequence of the generally lighter construction and greater sensitiveness of the former, they are affected to a much greater degree by the presence of earth currents or the occurrence of "magnetic storms." Whilst the latter class of disturbance are of rare occurrence and never for prolonged periods, the former are nearly always present, and the selection of an earthing point which will allow of the block indicators keeping their normal position exactly is frequently a puzzle of no mean order. Earths which are made within a few yards of each other often give quite different results, and combinations of different earths will often give results which cannot be obtained from any of them separately. Moreover, there is no certainty that uniform results will be obtained from any earth or combination of earths which, on being first connected, are found to work satisfactorily; indeed, it is no uncommon experience for them to change before the man leaves the place.

At places where the earth connection has to be made in rocky or sandy soils, the resistance to earth is sometimes considerable, and "contact" between the different instruments ensues. It is not always possible to obviate this defect by utilising the rails as the return, more especially during dry weather and in places where junctions intervene. The remedy for these defects is obvious, and consists in diminishing the sensitiveness of the block indicators; and since "the movements of the block instruments and bells must be made slowly and distinctly," there is no necessity for so great a degree of sensitiveness in instruments for block working.

Cost and Maintenance.—The relative cost for construction and maintenance of the three-wire continuous-current and the one-wire transient-current systems is a subject upon which, as has already been stated, considerable emphasis has at different times been laid. Where the instruments for use with one line wire are not overweighted with patentees' royalties there can be no doubt of the smaller cost for construction, and, other things being equal, for maintenance also. But it should not be forgotten that a complete block section includes, besides the electrical equipment, the lines themselves, the necessary buildings, and the mechanical signals and points, with their interlocking mechanism, and that, of these items, the electrical is probably the least expensive. Hence, the *difference* in the cost between a three-wire and a one-wire system is likely to be an almost inappreciable fraction of the *total* cost of the section, and this is rendered still more apparent when it is considered that the most expensive item of the electrical equipment—the construction of the pole line—is invariably used for other purposes than block working proper.

Hence, whilst it may be said that block circuits using one line wire and transient currents may be somewhat cheaper to maintain than circuits requiring three wires and continuous currents, yet the difference is small, and its importance is discounted by the greater variety of signals that may be used on the latter without an unnecessarily intricate code; the additional indication provided between the accept ance of the "Is line clear" signal and the "Trai entering section" signal; the greater certainty c the indicators being in accordance with the condi tions under which the line is worked when a defec exists in the block apparatus; and the self-testin character of the apparatus used.

Considerations for Choice of Instruments.—Fron the foregoing it will be seen that the consideration regulating the choice of block instruments are numerou and of great importance. The first consideration is of course, their ability to provide a separate indicatio for each of the conditions to which the line is liable The instruments must provide for the use of a extensive code, without its being intricate or th signals liable to misinterpretation. The indicatin instruments must not be liable to reversal or dis turbance from external causes. They should be sel testing when in use, of simple construction, and no liable to get out of order easily; but whenever an instrument, line, or battery fault develops, it shoul result in the indicating instruments occupying posi tions in accordance with the conditions under whicl traffic will be dealt with during the continuance c the fault. Further, as will be seen from the remark on the cancellation of signals and indications, th system, whatever it may be, must provide for thi being done, but it should only be done by th concurrent action of the two signalmen concerned Besides these considerations, there is the questio of the independence of the two lines of rail con stituting any section of double line. This independenc is complete in so far as the movements of traffic is concerned, and any system of block working which does not under any circumstances preserve this independence is defective. Such a consideration as is here adduced would limit block working to some form of three-wire system, since, as we have already seen, failure of the line wire of any single-wire system involves both line of rails.

The extensive use of three-wire systems with some form of single-needle instrument as the indicator, involving the use of continuous currents for the maintenance of the active indications, shows that this form of instrument is much in favour with those responsible for the recommendation of apparatus for this purpose; and the infrequency of breakdown due to defects of apparatus justifies the choice. The variety of signals that can be sent on three-wire single-needle instruments is very great, and the instruments are simple, cheap, and easily maintained. The indications are maintained by continuous currents; the methods of working and the indications exhibited are not easily mistaken; and failure of line, battery, or instrument results in the indication exhibited at the sending end being in accordance with the conditions under which subsequent trains are dealt with until the defect is removed. The chief defect, which in earlier days caused the needle instrument to be regarded with suspicion, the reversal or demagnetisation of the needle, was removed by the adoption of the induced needle, and the five or six pound magnet, which at one time constituted an indispensable part of the lineman's equipment, is now a thing of the past.

It must be understood that these remarks are mad on a system of signalling which depends entirely upo the man operating the instruments, attention havin hitherto been directed exclusively to non-automati systems. Instruments and appliances in which automatic working is obtained in a greater or less degre are described in the section devoted to instruments At the same time it is not admitted that th requirements of *indicators* for automatic workin differ in any way from those required for non-automatic working.

CHAPTER III.

TELEGRAPHING OF TRAINS—SIGNAL WHISTLES—HEAD, TAIL, AND TRAIN SIGNALS.

In addition to the signalling of trains on the block instruments as described, the signals for which, with one exception, relate to the dealing with trains as they arrive, the telegraph systems of railways are used as important adjuncts to train signalling. Railway trains of any class do not invariably run to their schedule times throughout their journeys, in consequence of the innumerable chances of delay involved in the conduct of a large mixed traffic under all circumstances of weather, and irregularities consequent upon delay in receipt of traffic. Under such circumstances, traffic on railways would soon be completely disorganised if no other means of imparting information of the movement of trains to those who have the control of various portions of the line were provided. In order to meet the irregular movements of trains, the times of departure of the more important are telegraphed from point to point, so that in the event of important trains being delayed beyond their booked time, other traffic, which otherwise would be kept waiting at some point on the line for its passage, may be allowed to proceed as far as possible on its journey as the time available, and the facilities ahead for disposing of it, admit.

Train Messages.—These messages are of considerable importance, and rank second in the order of importance of railway messages, and constitute fifty five per cent. of the messages at certain importan telegraph centres. Inattention to the information con veyed by these messages, or neglect of attention to th instrument when they are offered, whilst not likely t be a source of danger under any but the most peculia combinations of circumstances, is likely to caus unnecessary delay; and as a consequence we fin from a copy of the instructions for telegraphing suc trains (given below) that the time allowed for non attention is limited.

INSTRUCTIONS FOR TELEGRAPHING THROUGH AND LOCAL PASSENGE TRAINS.

1. All regular trains must be reported by their numbers as pe working time tables, and so entered on the train slips.

2. No train must be telegraphed from a station until the time of it departure has been reported to the telegraph office by the stationmaster c the person appointed by him to that duty. *Such report must in no cas be made by the telegraph clerk*, except in signal cabins, where the cler may do so at the request of the signalman, who must tell him the time the trains leave.

3. Trains must be reported forward immediately after their departu has been reported. Should the instrument be engaged with oth service, the station having a train to report will, after three minut have elapsed from its departure, interrupt with the prefix M. T. D. G messages must not be interrupted with the M. T. prefix. If from an cause trains are not reported, a report of the circumstance must b forwarded the same day.

4. When two stations have a train to report at the same time on th same instrument, each station must convert the *time the train left* int a code, which must be exchanged between them, and preference given t the one which left first.

5. After calling a station for three minutes unsuccessfully the clerk at th sending station must call the next to which the train has to be reporte and so on until it has been reported to all the others in order, aft which he must again call the station passed over.

6. Whenever a train cannot be telegraphed owing to the time

departure not having been reported, the telegraph clerk must within ten minutes of the time it was due to leave report the circumstance to the stationmaster.

7. In case information of the departure of any train, except those which stop at all stations, shall not have been received within ten minutes after the time at which it is due, the telegraph clerk or signalman may ask for it. All other enquiries, except by message, are strictly prohibited.

8. All cases of non-reporting or delays, from whatever cause, as well as every case of inattention to calling, exceeding three minutes, must be reported by letter, in addition to a note of the irregularity being made upon the train slips. To denote that the circumstance has been reported, the letters "ex" must be written near the remark.

9. The "understand" signal must be given at the end of every word in the train reports.

10. Mixed and slow trains are only to be signalled when running ten minutes and upwards late. If, after receipt of such notice, it is found they have made up or lost time, they must be signalled forward accordingly.

Note.—The term "slow trains" applies to those trains which stop at all stations on their journey. The term "mixed trains" applies to those trains which stop at the majority of stations only.

11. Special and excursion trains, including special goods, cattle, etc., must be designated by the name of the station from and to which the special is running.

12. All train reports must be entered on the respective train slips.

A.M. or P.M. must be inserted opposite each entry.

13. The names of all stations must be written in full on the train slips. Those stations which receive trains that have to be retransmitted to them must insert the name of the station the train left as well as the transmitting station.

14. Stations must keep their train slips on hand twelve months.

The whole of a line is divided into districts according to the run of the circuits, and the trains are telegraphed as per the general instructions given and the special instructions provided for each district.

Telegraph circuits have, of course, other objects in view, and their route and calling points are not always such as is most desirable for the purpose of train signalling; and, in consequence, messages relating to one train having frequently to be sent on more than one circuit. Where important traffic is large and the points to be informed of the movements of trains are numerous, such messages as these are no doubt responsible in a large measure for the congested state of railway companies' telegraph lines in general; and in any case entail a large amount of work in the detail arrangements to meet the requirements. Much has been done to meet the difficulties encountered by the provision of local cabin circuits, but a revision of arrangements and circuits would do much to increase the efficiency of this part of railway signalling.

Use of Telephone.—The telephone, has, of course, been largely adopted by railway companies, and one of its uses is in the transmission of information from point to point for the telegraphing of trains, and, as might be expected, it is much more expeditious than the telegraph. As with the telegraph, however, other considerations have been taken into account in making circuit arrangements, and, practically, much of the experience which is available from consideration of the defects observable in telegraphic arrangements is being ignored in the provision of telephonic communication, in that the latter are also being provided to suit purely departmental purposes.

It should be said that M. T. messages, such as are here referred to, are in no way connected with arrangements for safety. The safety of trains depends entirely upon the block signalling in so far as electrical signalling is concerned or capable of affording safety by its rules being adhered to. M. T. messages are entirely concerned with the convenient marshalling of traffic for rapid transit.

Complete System.—We have hitherto confined our attention to the electrical signalling for the marshalling and passage of traffic. Such signalling, however, forms only a part of the whole system, and any consideration of one part only must necessarily be incomplete. The signalling not already alluded to may be conveniently divided into two classes:

(*a*) Signals to the signalman from outside.

(*b*) Signals by the signalman to the outside.

The first class comprises the signal whistles provided for intimating to the signalman the intention or desire of the driver of an approaching train to proceed in some particular direction or to some particular point controlled by the signalman, and the head and tail lights, head-boards, etc., which are used to distinguish different classes of traffic from each other, and for other purposes of a similar nature. As no two parts of a railway are exact counterparts, the number of *general* instructions for signal matters are a minimum, and for one particular line are as given below.

Signal Whistles to be given by Drivers of Engines with or without Trains.

In reference to all junctions whether of main, branch, or independent lines, and to all cross-over roads and sidings, not otherwise hereafter specially provided for, the following general rules will apply:

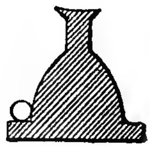
—	No. of Whistles. Long.	Short.	Long.
JUNCTIONS.			
For a train approaching a junction on a main or continuous running line, and intended to proceed beyond the junction on the same line....	1		
For a train approaching a junction on a main or continuous line, and intended to proceed beyond the junction upon a branch or other line diverging from the main or continuous line, or *vice versâ* ...	2		
STATIONS.			
As an indication that a goods or mineral train which is timed to stop has no wagons or goods to leave, and will not stop unless required by station	2	2	
CROSS-OVER ROADS.			
For permission to use a cross-over road between main lines, or between the running lines of a branch or independent line, and after using the cross-over road, as an indication that the engine or train is clear of the points			1 crow
SIDINGS.			
For permission to enter a siding, and as an indication that the train is clear of the points, and ready to enter		2	
As an indication that the whole of the train has entered the siding, and is clear of the safety points	1	1	
For permission to return from a siding to the main line, and as an indication that the engine or first vehicle is within the safety points and ready to leave		3	
As an indication that the whole of the train has left the siding, and is clear of the points	1	2	

The signal whistles for particular places are very numerous, and entail careful arrangement, as will be evident when it is stated that for the line referred to the details cover over one thousand eight hundred and fifty different signals, the greatest *consecutive* number at any place to form a signal being six. Of course many of these are repetitions, but the number gives some idea of the minuteness with which the details have to be worked out.

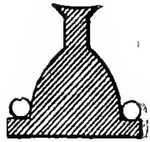
Head Lights.—The head lights or boards and the tail lights or lamps of trains are important signals transmitted to the signalman, and advise him in the case of the head lights or boards of the character of the traffic he is dealing with, and in the case of the ordinary tail lamp that the train is whole. The objects of the two divisions are of course entirely different. Whilst the latter is a necessity if safety is to be assured, the former serves the subsidiary but still important function of indicating the relative importance of trains.

The head-boards carried on the engines by day differ in shape and colour, and the intimation conveyed varies with their position on the engine also. The shapes vary between circular, elliptical, rectangular, and rhombic; the colours are generally white or green, whilst the positions are at the foot of the engine chimney on one or both sides of the smoke-box, or in the middle, and in some cases in all these positions. Every line has its own combinations for indicating the character of trains in this way. Examples of these are given below:

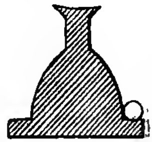
Every engine, except as specified under this heading, must have a **white light** fixed on the **right-hand** side of the buffer beam, thus:



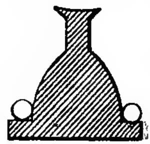
Engines of fast passenger trains, fish trains, and break-down van trains... Two white lights—one over each buffer, thus :



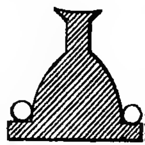
Engines of slow passenger trains and light trains .... A white light over left-hand buffer, thus :



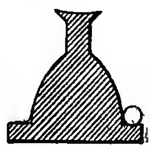
Engines of express goods and through trains of cattle, perishables, and shipment traffic............ A white diamond board at bottom of engine chimney during day, and one green light over right-hand buffer and one white light over left-hand buffer at night, thus :



Engines of fast goods trains not having to stop at intermediate stations and sidings.. A white diamond board over left-hand buffer of engine during day, and two green lights, one over each buffer, at night, thus :

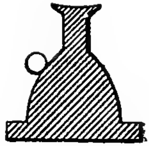


Engines of stopping goods, mineral, and ballast trains One green light over left-hand buffer, thus :

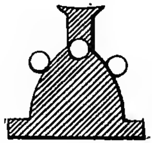


Engines of fast passenger trains ...... One white light at foot of chimney, thus :

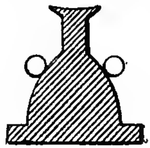
Engines of slow passenger trains and light engines ...... One white light on right-hand side of smoke-box, thus:



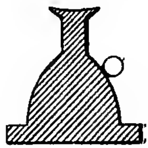
Engines of most important **goods trains**, including **fish**, **fruit**, **yeast**, and **cattle trains**... One white light at foot of chimney, one white light on right-hand side of smoke-box, and one green light on left-hand side of smoke-box, thus:



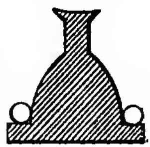
Engines of express goods trains ...... One white light on right-hand side of smoke-box and one green light on left-hand side of smoke-box, thus:



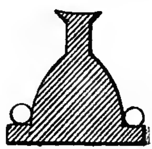
Engines of other goods or mineral trains................. One green light on left-hand side of smoke-box, thus:



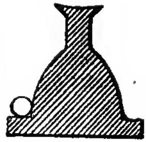
Engines of passenger trains................. One white light on each side of buffer beam, thus:



Engines of fast goods One green light on each side of buffer beam, thus:



Engines of slow or pick-up goods ...... } One green light on right-hand side of buffer beam, thus :



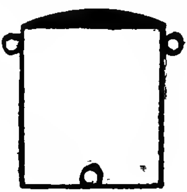
Tail Indicators.—"Train following boards" are attached by day to the last vehicle of a train when circumstances render it necessary for another, of the character of a "special," to follow immediately after. At night an additional tail lamp is added in such a position as will prevent its being confused with the ordinary tail lamp or "Last vehicle" signal, which is usually fixed to the lower framework of the last vehicle.

Other special arrangements of side and tail lamps are necessary where more than one pair of running lines are in use, and an arrangement of lamps for the purpose of enabling drivers to distinguish trains on their own line from trains on a line parallel to theirs, the direction of trains on both being the same, as shown below.

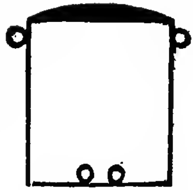
TRAIN TAIL AND SIDE LAMPS.

To enable drivers to know whether a train in front of them is on the line on which they are running or on the line parallel with it, the following arrangement of train tail and side lamps must be carried out on those portions of the railway where there are other running lines besides the up and down passenger lines :

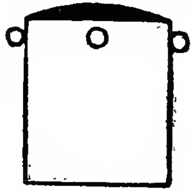
1. Trains running on the passenger lines must carry three lamps in a triangle, thus :



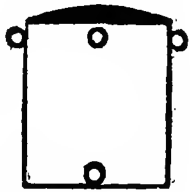
2. The signal to indicate that a special is following on the passenger lines must be shown by an additional lamp being placed at the bottom of the last vehicle, thus:



3. Trains running on the goods lines must carry three lamps in a straight line, thus:



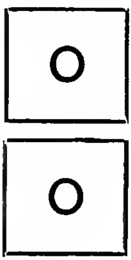
4. The signal to indicate that a special is following on the goods lines must be shown by an additional lamp being placed at the bottom of the last vehicle, thus:



The tail lamps must be carried in their proper positions by day as well as by night.

The signal lamps indicating "slip" carriages are another important example of the class of signals exhibited to the signalman from outside.

A method of distinguishing a train which carries a slip carriage is shown below.



The *two* tail lamps carried are arranged in a vertical line, and upon the presence or absence of these lamps on the last vehicle of trains which signalmen know are intended to carry slip carriages, depends the action that must be taken by signalmen, as thus—

13. Should a train that is appointed to convey a slip carriage pass a station or cabin showing *wrong tail lamps*, the signalman in the first signal box which the train passes (unless it be the box immediately preceding a slip station, for instructions as to which see Rule 14) must conclude that the slip carriage has become detached, and must signal to the next signal box ahead "to stop and examine train"; and if the signalman at that box finds on the arrival of the train that the slip carriage has broken away, he must telegraph on to the next box, "*Slip carriage broken away, train gone on without it,*" which message must be repeated from box to box as the train passes as far as the slip carriage would have run, the train itself being signalled and the line cleared in the usual way. If when the signal "Stop and examine train" is given the train has passed the signal cabin in advance, the signalman in that cabin must instantly repeat this signal to the next signal box, and the signalman there must stop the train, and act as shown in preceding paragraph. Should the slip carriage be afterwards sent on by special engine, it must be signalled as if it were another or special train.

14. Should a train that has a slip carriage on pass the station or cabin immediately preceding the station *at which the carriage is to be slipped* showing *wrong tail*

lamps, the signalman *must not* send on to the station at which the carriage is to be slipped the signal "*Stop and examine train*," but must keep the block on and send the "*caution*" signal to the station in the rear, and then ask the station at which the carriage should be slipped, "*Has slip carriage with signals arrived?*" If the reply is, "*Slip carriage with signals has arrived*," he must immediately clear the line to the station in the rear, but if the answer is "*No*," he must immediately telegraph to the station in the rear "*Slip carriage has broken away.*" Should the train pass the station or cabin showing no tail lamp, the signal "*Stop and examine train*" must be sent to the station at which the carriage should be slipped in the usual manner.

Visual and Aural Outdoor Signals.

Of equal importance to the different classes of signals already enumerated are those exhibited by, or on behalf of, the signalman, for the guidance of the drivers of trains. All other apparatus used in railway signalling have this object in view, and are simply means by which the signalman is kept informed of the necessity or desirability of exhibiting certain signals for the guidance of drivers of trains.

Such signals are of different kinds and of different degrees of importance; they are mainly visual signals depending upon differences in material, shape, colour, and position, but under certain circumstances aural signals are substituted for the visual. Such signals may be temporary hand signals exhibited from the signal cabin, or they may be fixed signals actuated at a distance from the cabin.

Hand Signals.—Dismissing the signals which are made by holding the hands and arms in different positions, we may start with the temporary hand signals which are exhibited by signalmen under certain conditions. These may be made by the use of different coloured flags in the daytime, and by different coloured hand-lamps at night. The practice on different lines in the use of colours for signalling purposes varies to some extent; but in nearly all cases the "danger" signal when exhibited by a colour is red; green is a "caution" signal, and white is an "all right" signal. The purposes for which flags and hand-lamps are used as signals are various, and their uses are set forth in their proper positions in the extracts from "General Regulations" relating to signals given further on. Generally, it may be said that hand signals are used in cases where the use of the fixed signals is liable to lead to an incorrect interpretation. Hand signals are therefore subsidiary signals, made use of for exceptional circumstances.

Fixed Signals.—The fixed signals are usually placed on posts at such a height and in such positions as careful examinations of the line indicate as most suitable. The first necessity is that it shall be clearly visible to the driver of an approaching train, at such a distance as will allow him to act upon its indication. The greater the distance at which the signal can be clearly made out, the more time the driver has to act upon it. At the same time there is a limit to this when, in order that the signal may be seen at a considerable distance under normal conditions of weather, the signal arm is so high or the post placed at such a distance from the running line that drivers have difficulty in seeing the position of the arm or the colour of the light exhibited during such conditions as obtain during a heavy fog.

The signals are usually of the semaphore pattern, and the indications are given by the position of the arm during the day and by the colour of the light shown at night. The number of indications shown by the positions of the arm are generally two—"danger" and "all right," or "danger" and "caution." During the day the "danger" signal is indicated by the horizontal position of the arm, or the "all right" or the "caution" signal, as the case may be, by the arm being more or less inclined towards the post. At night the "danger" signal is exhibited by a red light, caused by a spectacle of red glass covering the front of the lamp, and the "all right" or the "caution" signal is exhibited by a green or white light in the same way, the spectacles moving with the arm and showing the signals corresponding to the position of the arm.

The normal position of all fixed signals of the semaphore type is at "danger," and the arrangements are such that most defects, to which the means of actuating such signals are liable, result in the signal being placed to "danger." One important exception should be noted. The contraction of the wire used to actuate the signal by decreased temperature, tends to pull the signal arm towards the "all right" position. Many attempts have been made to compensate for this, and for the expansion of the wire due to increase of temperature, with but little result so far. The majority of signal wires are still adjusted by hand, when the signalman observes that it is necessary, either from the signal arm failing to drop to "off" or return to "on" completely.

The green light used as the all right signal is preferable to a white light for that purpose, in that damage to a red spectacle would cause an "all right" signal to be exhibited when the arm was at "danger," and for certain signals the signalman would have no means of knowing that any but the right signal was being exhibited. Where red and green lights are used for the "danger" and "all right" signals respectively, the exhibition of a white light where either of those should be seen is treated as a "danger" signal. Incidentally it may be noted that green as an "all right" signal is displacing white for other methods of signalling than those under consideration. At one time the exhibition of a white light by the guard of a train to the driver indicated "all right." Such a signal was almost universally used by guards to intimate to the driver that all was ready for a train to start from a station, say. Owing to the liability of the driver to mistake a light carried by another person for the signal he was expecting, a green light has been substituted for this signal. Generally, it may be said that where a light is required as a signal for a special purpose, it should be so distinctive as to prevent its being confused with a light used for any other purpose where both are likely to be in operation at the same place at the same time.

In addition to the semaphore signals, ground discs, so called, are used, generally in places where it is inadvisable, owing to want of room or similar causes, to erect the usual semaphore posts. Such discs are not used as signals for main-line running, but for sidings, cross-over roads, etc., where the traffic they control is never in rapid motion.

Fixed signals are divided into "distant," "home," "starting," "advanced starting," or, more shortly, "advance," siding, and "calling on" signals. Distant signals, as their name implies, are fixed at considerable distances from the signal cabin, the distance varying from one thousand yards, or more on occasion, to a few hundred yards where the block sections are short. A glance at the rules to be observed in connection with "distant" signals will show that, although its movements are similar, one of the indications at least differs from that conveyed by other signals when in the same position, in that it does not mark the limit that must not be passed by a train. The "distant" signal is the first signal that a driver sees belonging to the signal cabin he is approaching, and its indication is a preliminary notice to him of the condition of things at the signal station from which the "distant" is controlled. The "distant" is not a "stop" signal, but may be passed if the driver is assured that, notwithstanding the signal exhibited, the line is clear to a certain point. He must, however, according to rule be prepared to stop at the signal if necessary, or at any subsequent point between it and the next signal.

On the other hand, there are reasons why drivers of trains should not assume that, *because* the "distant" signal is "off," the following signals are also in the same position, notwithstanding the usual arrangement of the lever interlocking. Each signal of a section should be observed independently of any of the others; even a "distant" signal, when indicating "all right," should only be considered as referring to the portion of line between it and the next signal in order of progression. The "distant" signal is a most important signal for main-line work—not necessarily for that alone—where fast traffic is great; and affords drivers of such, and other trains, evidence of the condition of the station, intermediate cabin, or junction, in ample time to draw up at the first stop signal in advance if necessary. At one time, trains approaching a junction on the divergent line had only one distant signal to guide them, and were therefore in doubt, until the home signals came into view, whether the road prepared for them was that upon which they wished to go. The usual practice is now to provide as many "distant" signals as there are home signals, or, practically, as many as there are divergent roads at the junction. By this means the doubt and uncertainty has been removed.

"Home," "starting," "advance" and siding signals are of a different class, in that they are "stop" signals, and mark the limit of advance for the time, unless supplemented by other signals of an authorised nature.

"Home" signals are usually set as close as practicable to the cabin from which they are controlled, and so as to protect the entrance to sidings, junctions, and cross-over roads, so that shunting operations are carried out under the immediate observation of the signalman and within his control. Consideration of the rules relating to "home" signals shows that there are occasions when these signals are passed when at "danger," but on these occasions the indication exhibited is superseded by authorised hand signals, or their substitute, the "calling-on" signal. It is worthy of note that these signals only take effect after the "home" signal has practically done its work by bringing the train to a stand, or nearly so. It will be noticed that a train standing at a "home" signal is not under the protection of any "stop" signal belonging to the signal station from which the home signal is actuated; and the only protection to such a train, beyond the cautionary signal of the "distant," is that afforded by the signals of the rear cabin. Home signals are, of course, provided for each of the divergent lines at a junction, all such signals being generally upon one post in the order laid down in the general regulations. Similarly, all convergent lines are provided with "home" signals fixed in such positions that trains, when standing at them, do not foul either of the other converging lines.

"Calling-on" signals, as will be gathered from the preceding remarks, are merely an adjunct to the "home" signal, and are intended to obviate the difficulties often found in busy places to be attendant upon the use of hand signals. With these signals the liability to error from the hand signal not being seen, or to its being taken as a signal by another train, is obviated. Its use, however, is dependent upon the non-operation of the "home" signal, and in all cases it is a "caution" signal.

Attention is called to the different conditions under which trains are allowed to pass "home" signals at junctions where starting signals are in use; at places other than junctions where starting signals are in use; and at places other than junctions where starting signals are *not* provided. In the first case, the "home" signal can only be superseded by a "calling-on" signal. If the latter is not provided, the "home" signal must not be passed at "danger" under any circumstances. In the second case, the "home" signal must only be passed by lowering the "calling-on" signal, or by a train or engine which, for special purposes, are running in the opposite direction to that for which the line is intended.

In the third case, the driver obeys the "calling-on" signal or the hand signal, but only to draw his train within the protection of the home signal.

"Starting" or "advance" signals, when either is used alone, represent the last point at which any signalman has control over trains. Such signals mark the end of one block section and the beginning of the next, and they are proportionally important, since any train once past such signal is out of the control of the signalman. Hence we find that great attention has been paid to this signal in systems of working which have an automatic or semi-automatic basis, and generally the control of it, but not necessarily all the working, is vested in the signalman at the cabin in advance, and becomes practically the first signal for that section, or a duplicate "distant" of a slightly different character.

"Starting" signals and "advanced" starting signals may be both used at the same block station, or either may be used alone as circumstances may require. Where both are used, the first is generally a "stop" signal for a particular purpose, such as that exhibited to stop a passenger train at the platform of a roadside station, or for controlling the exit of trains from different points at more important points. Under such circumstances the "advance" signal becomes the signal controlling the entrance of the train into the next section, and the "starting" signal only allows the passage of the train to the next or "advance" signal.

Of "siding" signals, whether semaphore or ground discs, nothing particular can be said. They are "stop" signals for local purposes connected with the marshalling and distribution of traffic.

Fog Signalling.—Consideration of the extracts given from the general rules for outdoor signalling shows that occasions arise when the outdoor visual signals are replaced by aural signals owing to circumstances causing the former to become invisible. It will also be gathered from the regulations respecting fog signalling that the men employed for this purpose are at other times engaged in other work, and must be specially called for fog signalling as occasion requires. The duty of calling out these men devolves nominally upon the stationmaster for such places as he is in charge of, but practically depends upon the signalman, who has to decide when it is necessary to supersede the usual form of signalling to drivers of trains. This responsibility is no light one, since much depends upon the necessity being promptly met.

Fogs are not all of the same character, and they do not as a rule give previous notice of their appearance or of their probable duration. A fog may be a ground fog, which obscures sight at a distance of a few feet from the ground only, and signals may be quite visible from the driver's elevation whilst the line itself may be invisible to him. On the other hand, the fog may be such as to totally obscure sight of objects at any of the heights at which signals are placed generally. Whilst there is this difference in the character of fogs it is no unusual occurrence for a ground fog to change to one of a more serious character, nor is it unusual for a fog which threatened to be serious to suddenly disappear, and thus obviate the necessity for the special form of signalling. Under such circumstances the responsibility for calling out men is likely to be somewhat onerous. If the men are not called out promptly, considerable delay will be inevitable if the fog becomes serious, if nothing worse occurs. On the other hand, if the fog is of a mild character, or disappears quickly, the necessity for the fog-signallers' services will have, in all probability, ceased before they commenced work.

If the fog occurs at night, when it is more than usually dangerous, the length of time that may elapse between calling out the fog-signalmen and their actually commencing work may be considerable, since messengers must necessarily be sent to their homes to call them out. Under such circumstances the change in the character of the signalling is not likely in all cases to be so prompt as is desirable. It is true that the regulations provide for fog signals being placed on the lines opposite the cabin "when practicable" during the time between calling out the fog-signalmen and their arrival. This is not in all cases practicable, and, even when done, it should not be forgotten that the train which explodes the detonators has passed two signals at "danger," one of which is a "stop" signal.

Leaving the question of calling out the men, which is inseparable from the system, and which, as will be seen, leaves something to be desired, we may consider the question of who, amongst those more immediately concerned, is the most suitable person to say when the ordinary visual signals shall be superseded by others more adapted to the circumstances obtaining at the time. Drivers and signalmen are equally interested in the exhibition of suitable signals, but the former differs from the latter, in that it is for *his* guidance that the signals are exhibited, and that it is he alone who controls that by which mischief may be wrought in consequence of a misinterpretation of, or failure to see, the signals exhibited. Hence it would appear that the driver is the most suitable person to say when *he* requires additional means to enable him to obey the signals shown; and considerations such as those just adduced are alone sufficient to stamp as inadequate any system of signalling, under exceptional circumstances, that cannot be brought into operation at any time the person requiring it may consider necessary.

It might be thought that the absence of any signal at a point where a signal is usually displayed should, of itself, be taken as a "danger" signal. This is the usual practice, but it should not be forgotten that, when running at a high rate of speed, the signals passed are, during clear weather, one of the means by which drivers of such trains localise their position. If these and other landmarks, by which their position might be noted, are obliterated, the difficulty of determining the precise spot at which a signal may be expected becomes enormous. Another point in conjunction with this localisation of position is that the method of fog signalling by detonators is partly negative—*i.e.*, the "all right" signal is given by the absence of an explosion, and the exhibition of certain *visual* signals by flag or hand lamp, which the driver may or may not see. The localisation of their position at any time is a matter of very great importance to drivers of fast trains, especially during unfavourable weather, the more particularly as the time-table takes no notice of fogs.

It is not necessary to pursue the subject further at this point. Consideration will show that however suitable the present system of fog signalling may have been in times when traffic was smaller, and trains ran at less speed, and carried considerably less passengers than at present, the arrangements it permits of being made are not in keeping with the importance of the subject.

Attempts have been made at various times to place the fog-signalling apparatus entirely in the hands of the signalman by providing him with special apparatus, by means of which he is able to place detonators in position for explosion as occasion may require. The usual means of doing this is a lever, similar to those used for actuating the points and signals, communicating by a wire with mechanism by which detonators may be withdrawn one at a time from a watertight box, in which they are placed, at a point near the signal to be repeated. The rules for the working of one form of such apparatus are given below:

INSTRUCTIONS FOR WORKING THE AUTOMATIC FOG-SIGNAL APPARATUS.

1. A recorder in connection with the apparatus is fixed in the signal cabin in order that the signalman may at all times know how many unexploded detonators there are in the tube.

2. The ganger of platelayers is responsible for keeping the apparatus charged with detonators, and he must always inform the signalman the number of detonators placed in the tube, so that the signalman may set the record to the correct number. When the signalman finds the stock diminishing he must warn the ganger. A gong is attached, which sounds as an indication that the tube is empty.

3. Before commencing fog signalling, if the apparatus has not been used for some time, it will (or may) be found necessary, for the purpose of adjusting the wire, to pull the lever over two or three times; the distant signal must be off while this is being done.

4. To commence fog signalling the fog-signal lever must be pulled over and replaced in its normal position; by these movements a detonator is placed under the hammer ready for explosion, and will remain so while the lever stands in its normal position.

5. If on the approach of a train the line is clear, the home, distant, and fog-signal levers must be pulled over in the order named. By this movement the detonator is removed; to replace it the fog-signal lever must be returned to its normal position, followed by the distant and home signal levers.

6. When a detonator is exploded, the fog-signal lever must be pulled over and returned (as directed in paragraph 4); this movement removes the exploded signal and places another detonator under the hammer.

7. When the apparatus is not required for use, the fog-signal lever must remain in the normal position.

The number of such appliances in actual use is only a small proportion of the number of places where they might be used, and it cannot be denied that in some cases they have done good work. The construction of the mechanism, however, is such as to place only one detonator in position for explosion. A reference to the rules for ordinary fog signalling will show that *two* detonators are always put in position by the fog signalman. This, of course, is to prevent misapprehension arising from the report of one being weak or from one missing explosion, as will occasionally occur.

The third instruction relating to adjustment previous to commencing fog signalling after a period of disuse, indicates a disadvantage which arises from the variation of the length of the wire with differences of temperature. Where the detonator must be placed in an exact position for explosion, the possibility of doing this without chance of error becomes less as the distance increases.

Consideration of the rules for working this apparatus shows that there is nothing of an automatic charcter about it, although it is so designated.

Interlocking of Points and Signals.—Although forming no part of the signals exhibited, the interlocking of points and signal levers plays so important a part in the safe working of railways as to make a reference to it, however slight, indispensable. The assemblage of the means of actuation of a large number of signals and points in one cabin, and under the control of one man or more, offers numerous opportunities for mistake unless the levers of the various points and signals are so arranged as to prevent the road being set for trains converging to a common fouling point.

It is difficult to give more than a general idea of the principles of interlocking, as each important centre differs from others in its requirements. There are, however, certain broad principles connected with the order of interlocking that are followed in all cases, which may be indicated thus:

The interlocking of a frame must be such as to prevent the signals for any line being lowered to "all right" until the points have been made right for that road. In the case of ground discs the movements are simultaneous.

The interlocking of a frame must be such as to prevent a "distant" signal from being lowered to the "all right" position whilst the "home" signal is at "danger," and in some cases whilst the "advance" is in that position also.

Where cross-over roads are used, the interlocking must prevent the points being set for the cross-over roads whilst any of the signals for either of the lines are showing all-right signals.

At junctions the interlocking must prevent the signals being set for one line whilst the signals for another line are in such a position as would lead a train approaching on that line to a fouling point. The points interlocking must be such that when the points for one line are set, no train or engine which may pass signals at "danger" can foul the train for which the line has been set.

Siding points and signals leading to main lines must be incapable of operation when other signals are off for trains on the main line.

The converse of all these requirements holds good, of course. Generally, it may be said that the interlocking of the signals and points' levers is one of the many devices adopted for controlling the controller, and its importance to the general working of railways cannot possibly be over-estimated.

EXAMPLES OF RULES AND REGULATIONS RELATING TO FIXED, HAND, AND DETONATING SIGNALS AS USED IN RAILWAY SIGNALLING.

HAND SIGNALS.

1. These signals will be made by hand or with flags by day, and with lamps by night or in foggy weather.

2. *In the absence of flags.*—Both arms raised above the head denotes "danger."

3. One arm raised above the head denotes "caution."

4. One arm held in a horizontal position across the line of rails denotes "all right."

5. In the absence of a red light, any light waved violently denotes "danger"—stop.

6. In shunting operations by night, a white light waved slowly up and down means "move forward"—*i.e.*, go away from the person giving the signal; a white light moved slowly from side to side across the body means "move back"—*i e.*, come towards the person giving the signal

A green light used instead of a white light as above means "move forward slowly" or "move back slowly."

A red light in all cases, or any other light waved violently, means "stop."

7. Hand lamps and hand flags when used as signals, except where they are employed for the purpose of marking the actual point of obstruction, must always be held in the hand, and not placed upon or stuck into the ground.

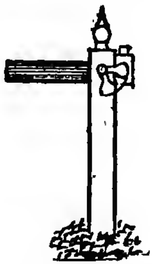
FIXED SIGNALS.

1. Fixed signals consist of home signals, distant signals, starting signals, and siding signals, and also of calling-on signals, which have been adopted by some companies.

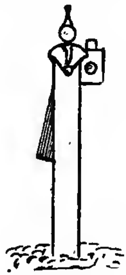
2. On the majority of lines semaphore signals are adopted, but other forms of signals are used by some companies.

3. The semaphore signals are constructed with arms for day signals and lamps for night.

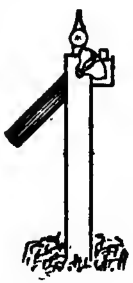
4. The signal is invariably made by the arm on the left-hand side of the post as seen by the driver of an approaching engine.



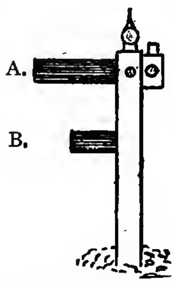
SEMAPHORE DANGER SIGNAL.



SEMAPHORE ALL-RIGHT SIGNAL.



SEMAPHORE CAUTION SIGNAL.



A.—ORDINARY SEMAPHORE.
B.—CALLING-ON ARM.

5. The semaphore "danger" signal is shown in the daytime by the arm on the left-band side of the post being raised to the horizontal position (as shown above), and by the exhibition of a RED light at night.

6. The semaphore "all-right" signal is shown in the daytime by the arm on the left-hand side being lowered to the post (as shown above), and by the exhibition of a WHITE light by night.

7. On those lines where the semaphore "caution" signal is in use,

it is shown on a fixed post in the daytime by the arm on the left-hand side of the post being placed half-way to the horizontal position, and by the exhibition of a GREEN light by night.

8. On lines worked on the block telegraph system two signals only are exhibited at the semaphore—viz., "danger" and "all right," the *red* light being in all cases the "danger" signal and the *white* light generally the "all-right" signal; but some companies use the *green* light as the "all-right" signal in all cases, and others (who use the red and white light signals) use a red and a green light in the case of junction signals in order to mark the position of the junctions.

9. On . . . . short "calling-on" arms are fixed upon some of the home signal posts, as shown above, for the purpose of avoiding hand signalling. When a "calling-on" arm is lowered, the engine driver must draw forward past the post of the signal on which the "calling-on" arm is fixed as far as the line is clear. If the signalman is ahead of the "calling-on" arm, and the signalman in the box wants to communicate with the driver, he must show a hand danger signal from the box to stop him. The lowering of the "calling-on" arm is not, in any case, an authority for the starting signal to be passed at danger.

10. Home signals are placed at stations, junctions, sidings, and signal boxes, and when at danger no train or engine must pass them or foul the crossings or points to which they apply, except as prescribed in 13 and 23, or where "calling-on" arms are in use.

Home signals at junctions are, as a rule, so placed as to indicate by their positions the lines to which they apply, and when more than one are fixed to the same side of a post they apply generally as follow—viz.:

The first or top arm to the line on the left.

The second arm to the line next in order from the left, and so on.

11. Home signals at junctions must never be passed at danger, except where "calling-on" arms are in use.

When a train has stopped at a junction home signal, and it is necessary to bring it within the home signal before the section ahead is clear, the signalman may, where a starting signal is provided, and that signal is at danger, lower the home signal for the train to draw ahead. The engine driver of any train which has thus been stopped at a junction home signal must, after that signal has been lowered, go slowly forward towards the starting signal, but must not pass the starting signal until it is lowered.

12. Home signals at stations, sidings, and signal boxes (other

than at junctions) where there are starting signals must never be passed when at danger, except as stated in 23 or where "calling-on" arms are in use.

When a train has been stopped or brought nearly to a stand at the home signal of a station, siding, or signal box (other than at junctions) where starting signals are provided, and it is necessary to bring it within the home signal before the block section ahead is clear, the signalman may, if the starting signal is at danger, lower the home signal for the train to draw ahead.

13. Home signals at stations, sidings, and signal boxes (other than at junctions) where starting signals are not provided must never be passed when at danger, except as follows, or where there are "calling on" arms.

When a train has been stopped, or brought nearly to a stand at the home signal, and it is necessary to draw it within such signal before the line ahead is clear, the engine driver must, on receiving verbal instructions from the signalman, draw past the home signal, *so as to bring his train under its protection*; if the signalman is too far from the engine driver to be able to communicate verbally with him, the engine driver must, upon the receipt of the necessary signal by hand lamp or flag from the signalman, pass the home signal, and draw cautiously towards the signal box as far as the line is clear, and there await the verbal instructions of the signalman. The hand signals for this purpose must be given only by a green light or a green flag.

Engine drivers must not go forward until they clearly understand the verbal communication which the signalman has made to them as to the state of the line ahead, and then only with their engines under the needful control to ensure safety.

14. Signalmen must not lower the home signal for an approaching train which has to stop at the starting signal until the train is close to the home signal, and has been brought quite, or nearly, to a stand at it. In foggy weather, or during falling snow, the engine driver must, when practicable, be verbally informed that he is only to draw forward to the starting signal.

The engine driver of any train which has been thus stopped, or brought nearly to a stand at a home signal, must, after the signal has been lowered, go slowly forward towards the starting signal, but must only proceed so far as is necessary to leave the last vehicle well clear of the points and crossings, and within sight of the signalman. The starting signal must not be passed until it is lowered, except as provided in 21.

In case of detention at a home or starting signal the engine driver must sound his whistle, and if still detained, the guard or fireman must go to the signal box and remind the signalman of the position of the train or engine, and remain there until the signalman can give permission to go forward. In foggy weather, or during falling snow, the guard or fireman must, immediately upon the train or engine coming to a stand, proceed to the signal box.

When a train or engine has drawn past a home signal and is waiting to be crossed to another line, or to be let into a siding, or has been shunted on to the opposite running line, or has been placed on either a main or branch line at a junction for another train or engine to pass, the guard or fireman must, in all cases, when the train or engine comes to a stand, proceed immediately to the signal box and remind the signalman of the position of the train or engine, and remain there until the signalman can give permission to proceed.

The duty of going to the signalman must be performed under the following instructions:

(*a*) In the case of a light engine, or of a passenger train with only one guard, by the fireman; the guard in the latter case remaining *in charge of the train.*

(*b*) In the case of a goods train with only one guard:

(1) When stopped at a home signal, by the fireman.

(2) When stopped at a starting signal, *or at an advanced starting signal,* by the guard.

(3) When waiting to be crossed on to another line, or to be let into a siding, by the guard.

(4) When crossed to the opposite side, by the fireman.

(5) When drawn ahead on to a main or branch line at a junction, by the guard.

(6) When backed on to a main or branch line at a junction, by the fireman.

(*c*) In the case of a train with two or more guards, by the guard whose van is nearest the signal box; *if there is only one van on the train,* by the underguard or brakesman.

The guard in charge of the train must satisfy himself that the man whose duty it is to do so has gone to the signal box.

(*d*) In the case of a train or vehicles in charge only of a shunter, the shunter must go to the signal box.

Sufficient time must be allowed for the guard, shunter, or fireman to rejoin his van or engine before the home or starting signal is lowered.

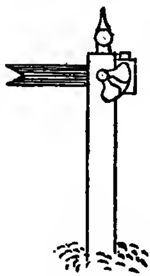
The man who goes to the signal box as a reminder to the signalman must satisfy himself by personal enquiry that the signalman is aware of the obstruction, and has protected the train or engine.

Where mechanical or other appliances are supplied to serve as a reminder to the signalman that certain signals must not be lowered or turned off, he must make prompt use of such appliances; and, in addition, where the company's regulations require it, must "block-back" to the signal box or boxes affected by the obstruction before allowing the line to be obstructed.

When a home signal has been lowered for the passing of a train, it must not (except in case of accident or obstruction) be again placed at danger until the last vehicle of the train has passed it or the train has been brought to a stand, nor, in the case of a junction, until the last vehicle of the train has passed it and is clear of the junction points.

15. Distant signals are fixed at a considerable distance from the point at which the home signal is placed. They are constructed to exhibit the danger and all-right signals only, except in some cases where they are constructed to exhibit the danger and caution signals only.

16. Where the semaphores are used as distant signals, the arms are constructed thus:



SEMAPHORE DISTANT SIGNAL.

17. Where it is found necessary to place the distant signal arm from a signal box in advance on the home or starting signal post of the box in the rear, applicable to the same line, the distant signal will be the lower and the home or starting signal the upper arm of that post.

18. Distant signals must be placed at danger immediately they are passed by a train or engine, and must not, where block working is in operation, be again taken off, except as prescribed by the block telegraph regulations. They must also be placed at danger whenever any obstruc-

tion or danger exists upon the line they are intended to protect, and so remain until the obstruction or danger is removed.

19. Whenever the distant signal is at danger, the danger signal must also be exhibited at the home signal, except when a train has passed the distant signal at danger, or in the case of an approaching train, for which both signals have to be taken off. In the latter case the home signal must be taken off first, and the distant signal placed at danger as soon as the train has passed it ; and in the former case the home signal only must be lowered to allow the train to pass.

20. When an engine driver finds a distant signal at danger, he must immediately reduce the speed of his train, *so as to be able, in case of need, to stop at such signal;* but if he sees that the way in front of him is clear, he must proceed slowly and cautiously within the distant signal, having such control of his train *as to be able to stop it short of any obstruction* that may exist between such signal and the home signal, and must bring his train to a stand as near the home signal as circumstances will allow.

Starting and Advanced Starting Signals.

21. Where these signals are used, they are intended to control the departure of trains into the section ahead, and must never be passed when at danger, except as follows—viz.: Where the points of sidings or cross-over roads are so near to a starting signal or advanced starting signal as to render it necessary for the signal to be passed for shunting purposes, engine drivers may, for the purpose of shunting operations, pass the starting signal when at danger upon being directed to do so by the signalman, either verbally or by hand signal, which must in all cases be given by a green hand lamp or a green flag, but they must not, under any circumstances, proceed on their journey until the starting signal or advanced starting signal has been lowered, indicating that the section ahead is clear.

22. When the line is clear between the starting and advanced starting signals, the signalman may, when necessary, after a train has been brought to a stand, lower the starting signal to allow such train to proceed towards the advanced starting signal.

If the advanced starting signal be not lowered for him to proceed, the engine driver must, after arriving at it, sound his whistle at short intervals, and, if still detained, the rear guard, or the fireman in the case of a light engine, must proceed to the signal box and remind the signalman of the position of the train or engine, and remain there until the signalman can give permission to go forward. Sufficient time must be allowed for the guard or fireman to rejoin his van or engine before the starting signal is lowered.

In foggy weather, or during falling snow, no train must be drawn forward past the starting signal towards the advanced starting signal except for station duties and shunting purposes. Advanced starting signals must not be used in foggy weather or during falling snow for a train to draw up to or stand at waiting "line clear."

23. Home, distant, and starting signals apply only to trains or engines running in the proper direction on the main lines, and must not be used for any other purpose. Trains or engines running in the wrong direction on either line must be signalled by hand lamp or flag. Trains or engines shunting from one main line to the other, or shunting into or out of sidings connected with the main line, must, unless fixed signals are provided for the purpose of signalling such operations, be signalled either verbally or by hand lamp or flag as occasion may require, it being necessary in such cases that the "danger" signal should be exhibited at the home signal as well as at the distant signal for the protection o the train or engine so employed.

24. When the exit from sidings is controlled by ground disc or dwarf semaphore signals, no train or engine must leave the siding unless the signal is turned off or lowered.

Defective Signals.

25. Every stationmaster, signalman, gateman, or other person must, in the event of any home, distant, or starting signal under his charge becoming defective, strictly carry out Regulations 34 and 35, and a competent man, or, if necessary, two or more competent men, must be selected, provided with the necessary hand signals and detonators, and appointed to signal in place of such defective signal until it is again in proper working order.

Where the circumstances of the case admit of such an arrangement, the stationmaster must select proper men from his own staff for the purpose; but where this cannot be done, he must apply to the nearest ganger for competent platelayers.

26. The absence of a signal at a place where a signal is ordinarily shown, or a signal imperfectly exhibited, must be considered a danger signal, and treated accordingly, and the fact reported to the signalman or stationmaster.

Detonating Signals.

27. Every guard, signalman, engine driver, gateman, and ganger of platelayers will be provided with detonators, which he is always to

have ready for use whilst on duty; and every person in charge of a station must keep a supply of these signals in a suitable place known by and easy of access at all times to every person connected with the station. All persons above named will be held responsible for keeping up the proper supply of detonators.

28. Detonating signals are to be used for the purpose of attracting the attention of engine drivers. They must be placed on the rail (label upwards), and the clasp bent round the upper flange of the rail to prevent their falling off, and must be observed by engine drivers as follows :

When an engine explodes a detonator in clear weather, the engine driver must immediately shut off steam, reduce the speed, and bring his train under such complete control as to enable him to stop at once if required, and then proceed cautiously to the place of obstruction or until he receives a further signal for his guidance.

When an engine explodes a detonator in foggy weather or during falling snow, the engine driver must immediately shut off steam and bring his train under complete control, so as to be prepared to obey any signal that may be exhibited. If he receives a red or danger hand signal, unless he be satisfied that the signal is exhibited for the purpose of repeating a distant signal at danger, he must at once bring his engine to a stand, and then proceed cautiously to the point the hand signal is intended to protect, or until he receives a signal to proceed; and if he receive a green or caution hand signal, he must act in accordance with 36. If the red or danger hand signal be exhibited to repeat a distant signal at danger, the engine driver may, after having shut off steam, proceed cautiously in the direction of the home signal.

The absence of any signal after the explosion of a detonator must be considered equal to the exhibition of a danger signal.

When used to repeat fixed signals and call attention to the fact of their being at danger, the detonators must be observed in the same way that such fixed signals would be observed if clearly seen to be at danger.

Signalling in Foggy Weather or During Falling Snow.

29. In the event of a fog or snowstorm occurring during the day between 6 a.m. and 8 p.m., the men appointed to act as fog-signalmen must at once report themselves to the stationmaster and take his instructions; those who have to do duty at junctions or intermediate signal boxes away from a station must report themselves to the signalmen on duty at the respective boxes.

30. When it is necessary to employ fog-signalmen during the

night between 8 p.m. and 6 a.m., the stationmaster must arrange to have the men called and sent to their respective posts. If the fog-signalmen become aware from their own observation, or from information given to them, that their services are required during the night, or at any other time when off duty, they must at once report themselves to the stationmaster, or to the signalman at any junction or intermediate signal box away from a station, without waiting to be called; but this will not relieve the stationmaster from the responsibility of sending for the fog-signalmen when necessary.

When the fog has sufficiently cleared away or the snowstorm ceased, the fog-signalmen must go to the signalman at the box in connection with which they are employed, and take his instructions as to whether their services are any longer required for fog-signalling duties.

31. A list of the names and addresses of the fog-signalmen, showing the post to which each man is appointed, must be kept exhibited in a conspicuous position in the stationmaster's office, signalman's box, or other convenient place.

32. Each fog-signalman must, before proceeding to his post, be supplied with detonators (not less than twenty-four), a hand signal lamp, trimmed and lighted, and a red and a green flag. If signalling for a distant signal, he must place himself outside the signal in connection with which he works, and as far from it as is consistent with his keeping it well in sight; and whenever a train or engine has passed him in the direction of the signal box from which the signal is worked, and so long as the signal exhibits the danger signal, he must place and keep two detonators fixed, ten yards apart, on one rail of the line for which he is signalling, and exhibit a red hand lamp signal to the engine driver and guard of an approaching train or engine, and when the signal is lowered or taken off, he must remove the detonators from the rail, and exhibit to the engine driver and guard an all-right hand signal (in accordance with 1, "Hand Signals,") by day, and an all-right signal by hand lamp at night. If he become aware of any obstruction existing on the line in the immediate neighbourhood of the signal for which he is signalling, either from a train or engine not having gone forward, or from any other cause, he must leave the detonators on the rail and go back along the line, showing a red light with his hand lamp, a sufficient distance to protect such obstruction, and must there place on one rail of the line for which he is signalling two detonators, ten yards apart, and return to within sight of the distant signal; and when he is satisfied that the obstruction has been removed, he must take up the more distant detonators, and then return to his post.

When fog-signalmen are employed in connection with home or starting signals, they must place two detonators, ten yards apart, on one rail of each line for which the signal is at danger, and carry out any instructions they may receive from the signalman on duty.

Men employed for fog-signalling, after having fixed the detonators on the rails, must, when practicable, place themselves about thirty yards within them—that is, nearer the fixed signal or obstruction for which they are signalling—and so exhibit the hand signals that they may be seen by drivers after the engine has exploded the detonators.

In repeating fixed signals when at danger, a red hand signal must, in all cases, be used.

When a fog-signalman is unable to see the signal for which he is fog-signalling, he must assume that it is at danger.

33. At all signal boxes (whether intermediate or otherwise) where no fog-signalmen are appointed to repeat fixed signals, or where such men are appointed but have not arrived, the signalman must, when he requires to stop an approaching train, in addition to keeping his signals at danger, place opposite his signal box, when it is practicable to do so, two detonators on each line to which the danger signal is intended to apply, sufficiently apart to give two distinct and separate reports.

Repairs to Signals, Points, Interlocking Frames, Lock Bolts, Bars, or Facing Points.

34. The signalman must frequently examine and try his fixed signals to see that they work well, are kept clean, and show properly. Great care must be used in putting on a distant signal: it is not sufficient merely to move the lever, but the signalman must at the same time watch the signal or its repeater, so as to ascertain that it obeys the lever and goes fully on to danger. He must take care that the signal wires are kept at the proper length by means of the regulating screws or links, so as to compensate for the expansion and contraction caused by variations of temperature.

In the event of a home or starting signal becoming defective or not working efficiently, a competent person must be placed outside such signal with hand signals and detonators, and act under the instructions of the signalman.

In the event of a distant signal becoming defective or not working efficiently, a competent person must be stationed just outside the distant signal with hand signals and detonators, and act under the instructions of the signalman; and when such person is out of sight of the home signal one man or more must be stationed between that and the defective signal for the purpose of repeating, by hand signals, to the man stationed at the distant signal the signals exhibited at the home signal.

35. When the interlocking of any lever frame, or any facing point, bolt, or bar is out of order, or when any point or signal lever, or any home, starting, or advanced starting signal, or siding signal applicable to a siding not protected by safety points, is defective and not working properly, one competent man or more, as may be necessary, provided with hand signals and detonators, must be appointed to act under the instructions of the signalman in charge of the signal box; and the distant signals applicable to the lines affected must be kept at danger by being disconnected from the levers by which they are worked, and must remain in that position until the defect has been made good, and all is again in working order.

When the interlocking of any signal box, or any facing point, bolt, or bar is being altered or repaired, the fitter in charge of the work must give to the signalman in charge of such signal box, an exact statement of the signals and points which it will be necessary to work temporarily without the safeguard of the interlocking, or the facing point, bolt, or bar.

The hand signalman appointed to signal in place of a defective signal, or in consequence of the interlocking of a lever frame, or a facing point, bolt, or bar being out of order, must ascertain from the signalman in charge of the signal box what train he is to bring forward, and when such train has to run over points other than facing points he must satisfy himself by personal observation that the points are in the proper position for the train to pass. If the train which is to be brought forward is approaching facing points, the hand signalman must, before signalling it forward, inform the signalman in charge of the signal box the position of such points, and satisfy himself that they are open for the line on which the signalman in the signal box intends the train should run.

The hand signalman must, when signalling a train forward, stand near to the signal in place of which he is acting, in order that his signal may not be mistaken by an engine driver on any other line, and all trains must run past the place where the defect exists at a slow rate of speed, the engine drivers being cautioned.

The signalman in charge of the signal box must take care that the hand signalman is properly instructed as to his duties, and understands what he has to do.

When any fixed signal is out of order, or is disconnected for purposes of repair or otherwise, and the interlocking of the point and signal levers is all right, the signalman must, to enable him to obtain the security of the interlocking, use the lever applicable to such signal as if the signal was in work, and the signal and counter-balance weight must, when necessary, be disconnected from the lever to admit of this being done.

When the interlocking frame at a junction is out of order, the facing points must, except when required to be otherwise placed for the passage of trains, be so set that no engine or train can cross the path of a train travelling in the opposite direction upon the adjoining line.

Platelayer's Caution Signal.

36. A green flag or a green light exhibited by platelayers indicates that trains and engines must reduce speed to fifteen miles an hour over the portion of line protected by such green signal.

CHAPTER IV.

The first example of an electrical signalling instrument in use with which the writer became acquainted is that shown by Figs. 14 and 15. These instruments were patented by Alex. Bain, and were in use between the ends of a tunnel on the old Stockton and Darlington Railway, and were replaced by C. V. Walker's block instruments about 1868. The instruments were provided with bells, not shown, the hammers of which were held up by trip-gear, which was released on the first deflection of the needle, the hammer being raised again, by hand, after every stroke.

CODE OF SIGNALS AND ALPHABET.

Yes	A	I	IVI	O	Is an engine near
Engine out	B	II	IVII	P	Send train on main-way
Two engines	C	III	IIVI	Q	Stop traffic on main-way
Three engines	D	IIII	VVI	R	Repeat the last letter
I understand	E	V	IVV	S	Do you understand
Engine entered	F	VV	VIV	T	Wagons left in
Stop traffic on by-way	G	VVV	VVVI	U	Is all out
	H	VVVV	IVVV	V	No tail signal
No	I	IV	VIVV	W	Hagger leases
I am going to speak in			VVIV	X	Train on main-way
letters	J	IIV	VVII	Y	All is right
Engine returned back	K	IIIV	VIVI	Z	I am showing the telegraph to a friend
Is all right	L	VI			
Train on by-way	M	VII	IVIV		Stop traffic on by-way
Sent train on by-way	N	VIII			

RULES TO BE OBSERVED.—1st. The bell is to be rung at the commencement of every conversation.—2nd. The V in the course of conversation always to form part of it and to be considered as the bell.—3rd. At the close of every conversation the bell handles must be set for ringing.—4th. The plates of the battery must be put into the trough at the beginning of the conversation and taken out when finished.

The code of signals in use for ordinary work and the alphabet for conversation on matters not provided for in the code are given, together with the rules. The signal, "I am showing the telegraph to a friend," and

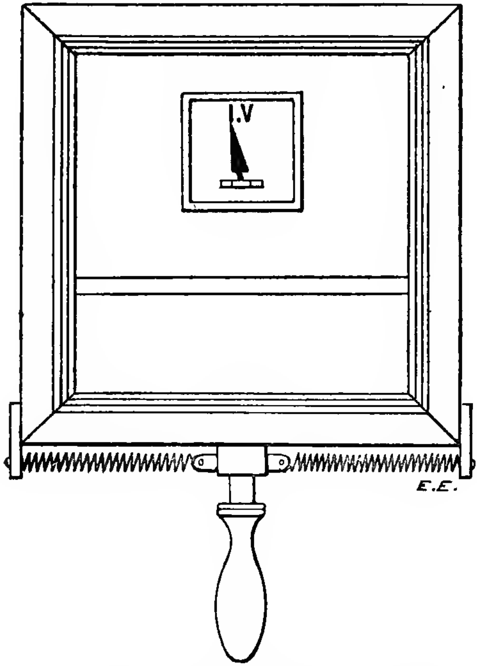


FIG. 14.—Alexander Bain's Signalling Instrument.

the rule, "The plates of the battery must be put into the trough at the beginning of the conversation and taken out when finished," are very quaint, and would be difficult to duplicate at present. The signal,

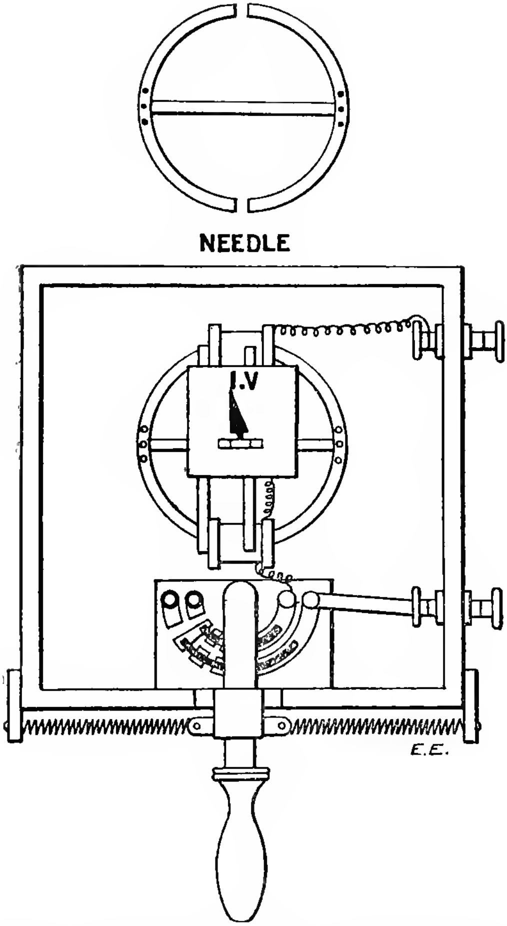


FIG. 15.—Interior of Instrument, showing Commutator.

"Engine returned back," is also significant of the free and easy manner in which things were carried on in the earlier days of railways.

Block Working.—"Block" working may, for convenience, be divided into two main parts, "absolute" and "permissive." "Absolute" block may again be divided into "double-line" and "single-line" working, as the requirements for these are somewhat different.

Absolute block working consists essentially in preserving a certain space between successive trains on the same line of rails, this space varying in different localities from a few miles to, perhaps, three hundred or four hundred yards, or less, according to the amount of traffic, the number of junctions, and the distance between them.

Permissive block working imposes a space limit, not between individual trains, but between groups of trains only. With absolute block working, two trains in one section on the same pair of lines are not permissible; with the permissive block, any number of trains up to a prearranged limit may be admitted into a section.

The essential qualifications of block instruments for ordinary double-line work are—reliability; complete independence of the indicating instruments for the two lines of rails constituting the section; distinctive and easily understood signals; continuous indication of the condition of the line at all times, of such a character that the indicating instruments will, in the event of failure, synchronise with the conditions under which the line or lines will be worked during the existence of the fault; simplicity of construction and consequent freedom from derangement; capability to deal with the code of signals without imposing a great degree of intricacy; freedom from chance of error from outside influences, such as atmospheric discharges, earth currents, or magnetic "storms," etc.; flexible enough to allow of deviation, when necessary, from the normal order of working; and last, but not least, the apparatus must be cheap and easily worked.

Probably no forms of block instrument fulfil so many of these requirements as the ordinary single-needle instrument and bell block apparatus. For simplicity of construction, flexibility, reliability, and distinctness of signals it cannot be beaten. Being essentially a three-wire apparatus, failure of one indicator affects the line it represents alone, and the indications which represent the active conditions of the line being maintained by continuous currents, the indicators are self-testing to a very large degree when in use for either "Line clear" or "Train on line." Failure of the battery or line wire results in the indication "Line blocked" being exhibited; contact between a block indicator line wire and another non-working earthed wire results in the indication at one end, when an active condition is being exhibited, being such as to call attention to the fault and to afford an intimation of its character; whilst if the wire which is in contact with the block wire is a working one, the effects are quite different to the ordinary indications of the block instrument, owing to the disturbing currents being discontinuous and of irregular direction or duration.

Reversals due to lightning discharges, which at one time constituted the most serious defect of the needle instrument, are now, by the use of induced needles, unknown; and the chief effect produced is, generally, such as to render the instrument affected inoperative by the short-circuiting of the lightning protector, or when the effects are greater, owing to the "protector" being part of the instrument it protects, by shattering it from the explosive force developed by the discharge at the sparking point.

The effects of earth currents, or disturbances of the earth's magnetic field, are more marked, and from the standpoint of the effects upon the block indicators are of a more serious character, since they may cause either of the active indications to be exhibited when the condition of the line does not warrant either of them being exhibited. Earth current effects may, as already stated, be minimised by diminishing the sensibility of the needles, and they are never of such strength as to cause *great* deflection of the needle, or such a deflection as is comparable with that due to the working current. Disturbances of the earth's field, however, produce much greater deviations at times, but their occurrence is rare, and they are, moreover, seldom of long duration, or perfectly steady. The most striking instance of this class of phenomena which has come under the author's observation occurred about seven years ago, when the whole of the needle circuits in a district extending over thirty miles in length were affected for about three hours. The instrument needles oscillated from side to side, having a period of about three minutes, during the whole time. That the disturbance was due to magnetic variations, as distinguished from earth currents proper, or atmospheric inductive effects, was shown by the continuance of the movements of the needles of any circuit when the line circuit was broken at any point.

This disturbance was not sufficiently strong to interfere with the *indications* of the block instruments under the influence of the working currents, but it caused considerable difficulty in ascertaining the character of the *signals* sent, and completely

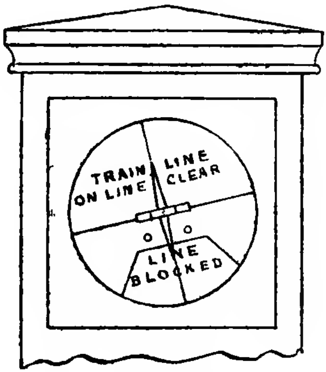


FIG. 16.

disorganised the telegraph service in the locality in which it occurred. In general, however, such effects are easily recognised by the signalmen, and it is always possible to adjust the instruments so that the needle when unaffected by the working current shall stand on the centre line betwen "Line clear" and "Train on line." This is effected by making the dial-plate adjustable round the axis of the needle, as shown by Fig. 16.

The outer form of needle block indicator is generally as shown by Fig. 9, which represents a sending or non-pinning instrument. Fig. 17 is a diagrammatic representation of the instrument showing the internal

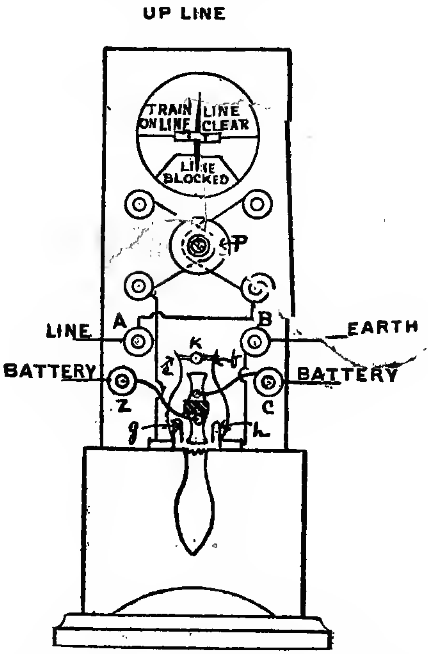


FIG. 17.—Diagram of Single-Needle Instrument.

connections, which, as will be seen, are of the simplest possible character. The commutator consists of a horizontal barrel divided into two parts, which are insulated from each other, and which by means of flexible connections from the battery terminals, C *Z*, form the poles of the battery. The two vertical springs, *e* and *f*, which are connected together by the bridge piece, *k*, above the barrel, are the "line springs," whilst the horizontal springs, *g* and *h*, are the "battery springs." Movement of the instrument handle in one direction, say to the right, causes C to be brought into contact with *e*, breaking the latter's connection with *k* at the same time, and *Z* in contact with *h*. The current passes from

HOME STATION.	DISTANT STATION.
C to *e*, through lightning protector, P, instrument coils to A, and line.	
	B to *h*, *f*, *k*, *e*, lightning protector and instrument coils, to A and earth.
B, *h*, and Z.	

It will be noticed from the path of the current that if one end of the line wire is connected to A at the home station say, the other end must be connected to B at the distant station in order that the deflections of the needles may be similar, assuming that the windings of the coils are the same in direction, which is desirable for considerations connected with the manufacture of the apparatus, and to make it interchangeable to the fullest possible extent. Reversal of the instrument handle reverses the direction of the current, and the deflection of the needle is reversed in consequence.

The line springs, *e* and *f*, and the battery springs, *g* and *h*, are the points at which mechanical failure in this class of instrument is most frequent.

The continuous indications are maintained by the handle of the instrument being held over in the proper direction by a peg inserted through the horizontal portion outside the case, as shown by Fig. 42. In some cases a trigger arrangement is substituted for the peg. In both cases, however, the action is mechanical, and dependent upon the proper use by the signalman of the means provided. The pegging of the needle in either of the active positions is done by the signalman at the receiving end of the section as an

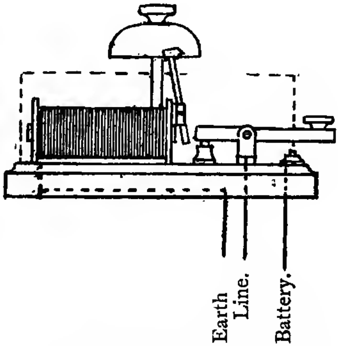


FIG. 18.—Diagram of Block Bell.

indication that he understands the signals previously exchanged and acquiesces in what is being done by the sending signalman, and also as a permanent indication to both men of the state of things until the conditions represented have been changed.

The bell used for exchanging code signals is the usual single-stroke bell, and is shown diagrammatically by Fig. 18.

The whole of the operations involved in signalling the passage of a train through a section are very simple, and the order of working being fully set forth in the code and regulations given on pp. 49 to 70, it is not necessary to refer to them further here.

The simplest case of block working is shown in the diagram (Fig. 19), in which the cabin, A, is an

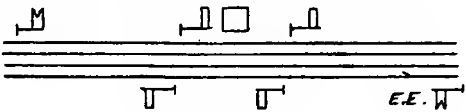


FIG. 19.

intermediate point between two others of more importance. Such a cabin is a mere passing place, and is only of use for shortening what would, otherwise, be too long a section for the amount of traffic passing, and is, generally, to be found in connection with some road crossing, or at a point near distributing sidings, or for stopping trains at a conveniently situated point to a junction where two or more lines converge.

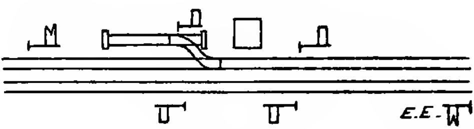


FIG. 20.

veniently situated point to a junction where two or more lines converge. The next case in order of importance is shown by Fig. 20, where a relief siding is provided into which a train may be shunted in order to allow more important trains to pass. Fig. 21 shows a junction where three lines converge, and Fig. 22 shows a particular case where the lines connecting junction points form a triangle.

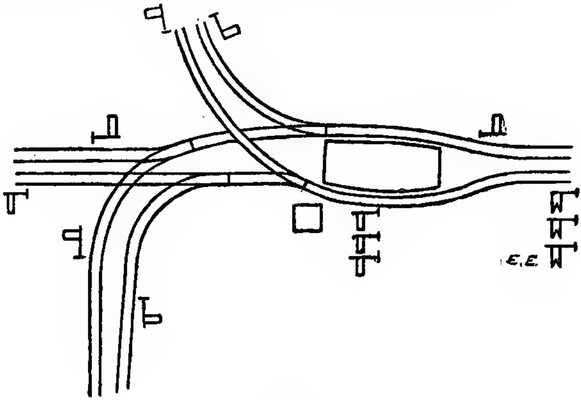


FIG. 21.

The diagrammatic representation of the wires and instruments for such cases as Figs. 20 and 21 are

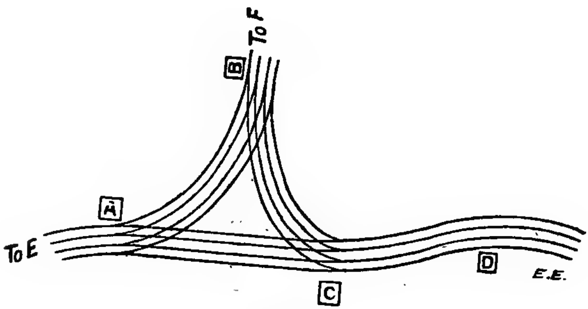


FIG. 22.

shown in Figs. 23 and 24 respectively for a three-wire single-needle system.

The case represented by Fig. 22 introduces the four hundred yards rule by which signalmen, in cases

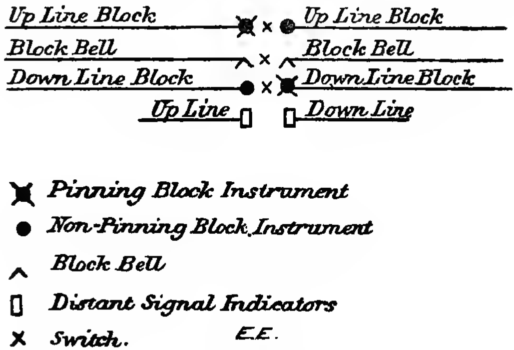


FIG. 23.

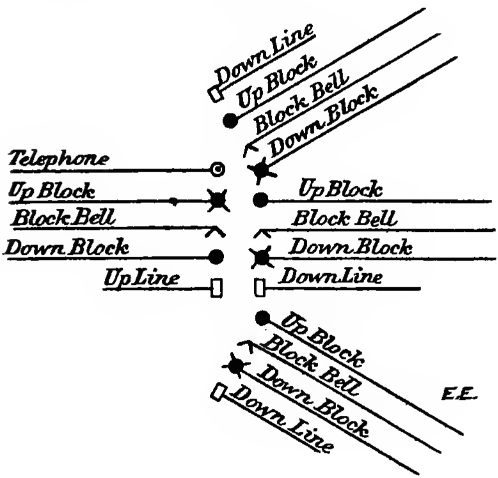


FIG. 24.

where the distance between successive cabins is four hundred yards, or less, must, before accepting the

"Is line clear" signal from the rear cabin, obtain its acceptance from the advance cabin.

The arrangement of apparatus for the case represented by Fig. 22 is given by Fig. 25, and is peculiar for the means taken to obviate accidents likely to arise from local conditions. In general, however, the

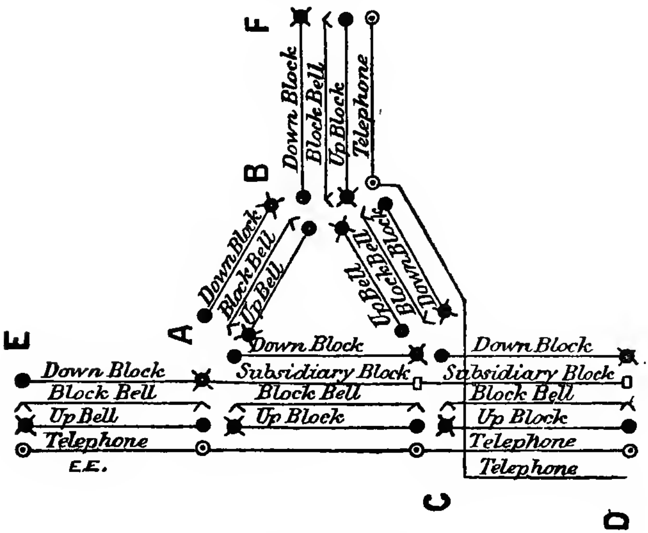


FIG. 25.—The words "Up Bell" in the centre of the diagram should be "Up Block."

difference between an ordinary section, and one under the four hundred yards rule, is in the rule for the acceptance of the "Is line clear" signal only, and does not involve any difference in the apparatus.

In the case under consideration the "down" line between E and D is on a falling gradient, and passes through a long tunnel between E and A. The block cabins, A, B, C, and D, are each within four hundred yards of the next, and the acceptance of an "Is line clear" signal by A, for a train passing to D, is conditional upon its acceptance by both C and D, the latter being offered the "Is line clear" signal by C before accepting it from A. Hence, before a train can leave E for D, the line must be quite clear to the latter point, or through three sections, and in order that A may not accept a train from E without the knowledge of C and D, the "down" line instrument

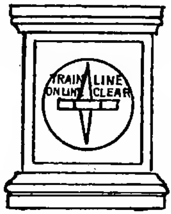


FIG. 26.—Subsidiary Block Indicator.

circuit between E and A is continued through indicators fixed in C and D, which reproduce at those places the indications of A's "down" line instrument at any time. Hence there are two independent checks on A's actions in accepting an "Is line clear" signal, and the indications are also of considerable value to C and D for the regulation of traffic to and from the section C B.

The form of indicator connected in the continuation of the "down" line wire between E and B, at C and D, is shown by Fig. 26. The dials are divided and lettered in the same way as those of the block instruments, but the signalmen at C and D have no control over the indicators. They are merely used to indicate the condition of the line between E and B in order that the signalmen at C and D may not undertake any operations involving the fouling of the "down" line under such conditions as, by an error

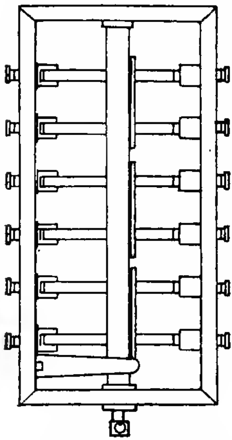


FIG. 27.—Switch (Plan). Instruments in Circuit.

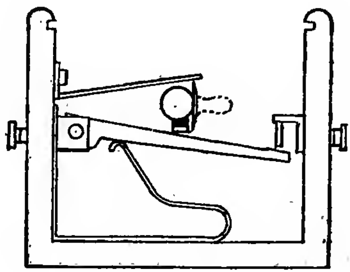
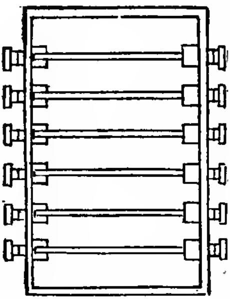


FIG. 28 —Switch (End View). Instruments out of Circuit.

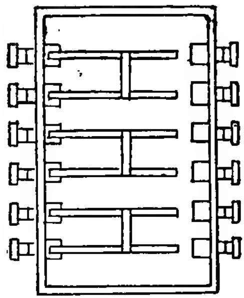
of judgment or failure of apparatus, would lead to an accident.

Switching Block Apparatus. — It frequently happens that a block cabin is not required to be open during the whole twenty-four hours, owing to the traffic being less than ordinary during part of the time. Advantage is taken of this, wherever possible, to economise labour by closing certain cabins at stated periods, and working the traffic between the cabins on each side as a block section. Thus, of three successive cabins, A, B, and C, B may be closed from ten p.m. to six a.m., say, and the section between these times would be from A to C. The alteration in the lengths of the section would be effected by a switch placed in B, which would be turned to the appropriate position by the signalman before leaving, and after giving notice to A and C by the signals provided in the code for such purpose.

FIG. 29 AND 30.—Three-Wire Block Switch.



Handle Vertical. Instruments in Circuit.



Handle Horizontal. Instruments out of Circuit.

The form of switch generally used for switching three-wire circuits is shown by Figs. 27 and 28, and the diagrams (Figs. 29 and 30) show the connections in the switch for the two positions it can occupy.

The connections for a complete block cabin of the simple character indicated by Fig. 19 are given, diagrammatically, in Fig. 31, in which the switch is shown with the connections arranged as when

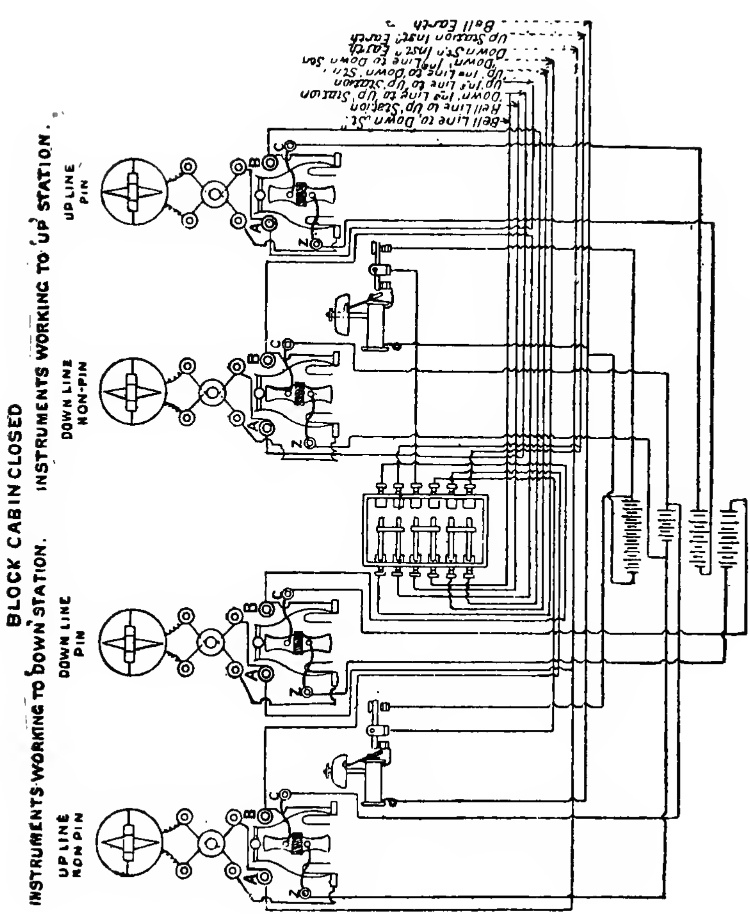


FIG. 31.—Diagram of Connections.

the cabin is closed. It will be noticed that the two indicating instruments working to the "up" station are in circuit, and will, therefore, reproduce all signals sent from the cabins on either side. The object of this arrangement is to enable the signalman to ascertain, when opening out the cabin for ordinary working, whether any trains are in the section he is about to divide. If the block indicators show that trains are in the section, or that the preliminary signals for trains entering the section have been acknowledged, the signalman at the cabin which is being opened pins the instruments at that place appropriately. If he gets the "Train passing out of section" signal from the advance cabin, he also gives that signal to the cabin in the rear, and afterwards takes all succeeding signals himself. The code provides signals which indicate to the cabins on either side when an intermediate cabin is being closed or opened, so that the signalmen at the ends of the long section know when they are working to each other, and when to the intermediate cabin.

Another method of switching instruments in and out of circuit, with a switch of similar construction, is shown in diagrams Nos. 32, 33, and 34. In Fig. 32 all instruments are earthed at that cabin which is open. In Fig. 34 all instruments are cut out of circuit, and the cabin is closed. In Fig. 33 the block indicators are in circuit, but are working through between the cabins on either side. With the switch in the latter position the signalman is able to ascertain whether there are any trains in the section he is about to divide, in order that he may arrange to exhibit the

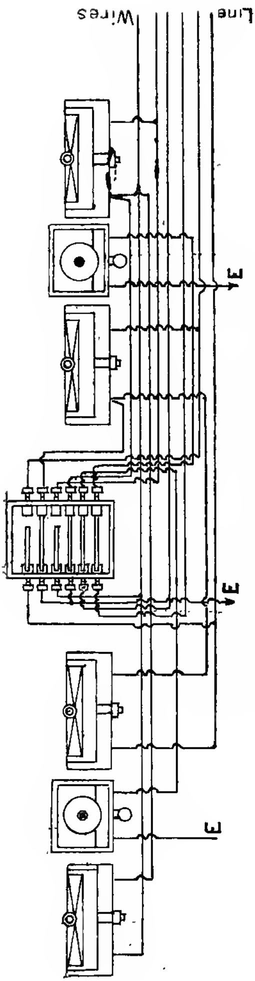


FIG 32.—Instruments in Circuit—Cabin Open.

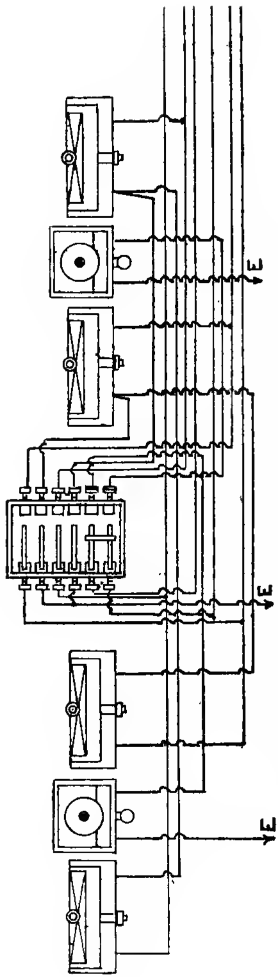


FIG. 33.—Intermediate Position—Cabin about to be Opened.

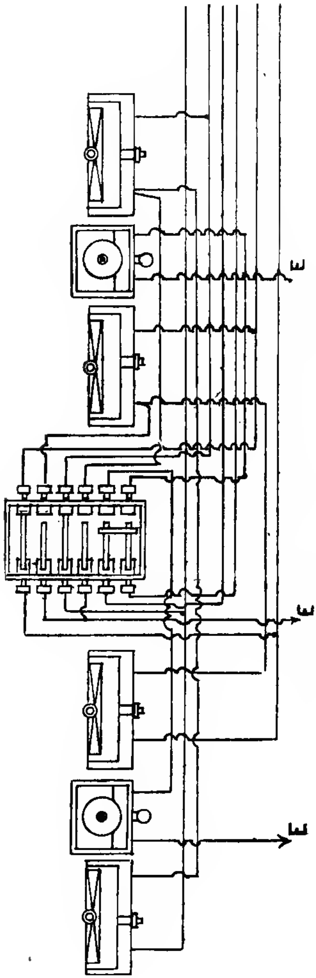


FIG. 34.—Instruments out of Circuit—Cabin Closed.

proper indications on the block instruments at the two cabins he will work to.

The essential difference between the two methods of switching is that with the switch shown in Fig. 31, one instrument for each line is constantly in circuit; with the switch shown by Figs. 32, 33, and 34, all instruments are cut out of circuit until such time as they are required to be brought into operation. It will be noticed that with either form of switch no alteration of battery power is made at the cabins which are working through another which is closed. The batteries are always installed with a margin sufficient for the maximum distance they have to work through.

Walker's Block Instrument.—The external appearance of this instrument is shown by Fig. 8. The connections for a block section are shown by Fig. 35, and further details of the mechanism are given by Fig. 36. Details of the construction of the signalling key are given by Fig. 37. The upper electromagnets work the white arm, and the lower work the red arm and bell. The current passes through the upper coils at the home station, and through the lower coils at the distant station. The signalman at any station, therefore, works the white arm at his own station, and the red arm and bell at the distant station simultaneously. The signalling key is simply a current reverser. The upper, or white, knob sends a current through the upper coils at the home station, earth, lower coils at the distant station, line, to zinc at the home station. The result is to raise the white arm and red arm at the home and distant stations respectively, and the bell at the latter place is also rung. The lower, or black, knob reverses the direction of the current and lowers the arms at the two stations and also rings the bell at the distant station. Both sets of electromagnets actuate polarised and non-polarised armatures. The V-shaped permanent

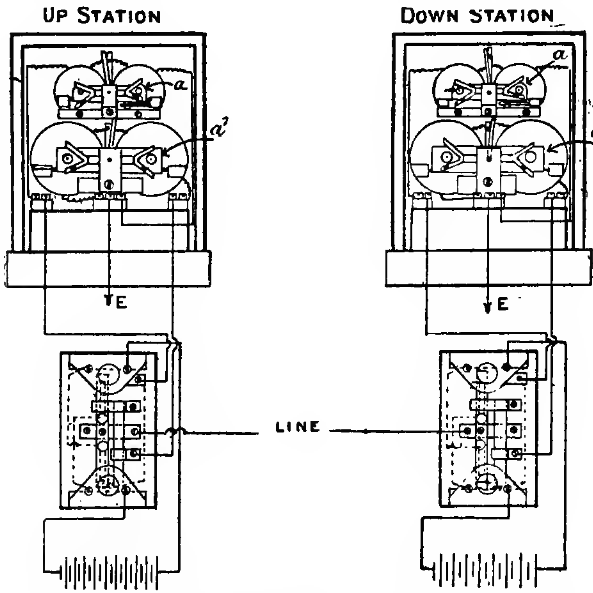


FIG. 35.—Double-Line Block Circuit—Walker's Instruments.

magnets actuate the arms when a current passes in the proper direction. The non-polarised armature, *a*, of the upper electromagnet locks the polarised armature in position. The non-polarised armature, *a'*, of the lower electromagnets carries the bell hammer, and also locks the polarised armature in position.

It will be noticed that descriptive signals must be given by a bell code; and, also, since the bell is rung by the depression of either of the two knobs of the signalling key, either would serve for sending train-distinguishing signals by bell code if there were no other considerations to take into account. The particular knob to be used at any time, however,

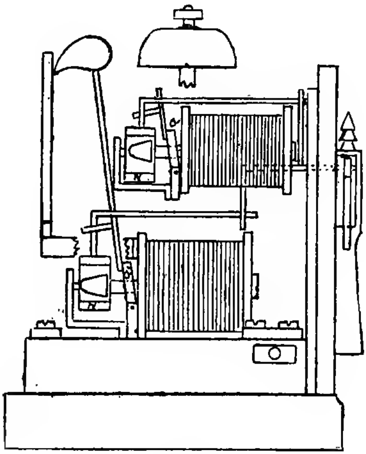


FIG. 36.

depends entirely on the indications exhibited by the instruments. Thus, suppose a train to be in the section on the "down" line, and a train is to be signalled on the "up" line. The signalman at the sending end for the "up" line must give any bell signals on the white knob, or he will lower the arms, representing the condition of the "down" line. On the other hand, the signalman at the receiving end for the "up" line must acknowledge bell signals on the black knob, or he will raise the arms representing the "up" line prematurely. If there are no trains in the section, bell signals are given and acknowledged on the black knob. The position of the arms is horizontal when trains are in the section; when no trains are

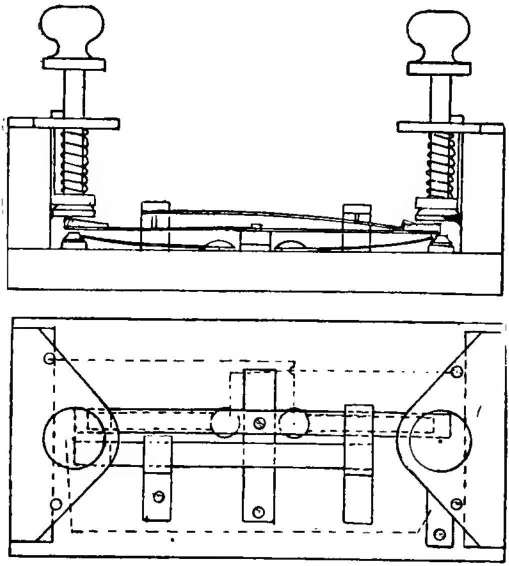


FIG. 37.—Walker's Double-Current Key.

passing the arms are lowered. There is, therefore, no indication corresponding to "Line clear" or section ready for train to enter with this form of instrument.

Preece's Block Instruments.—Another form of block instrument for use with transient currents and one line wire is shown by Fig. 38, which represents diagrammatically the connections for a block circuit using Preece's block instrument. In this form of instrument the indicator for approaching trains is of a different form to that for receding trains, in addition

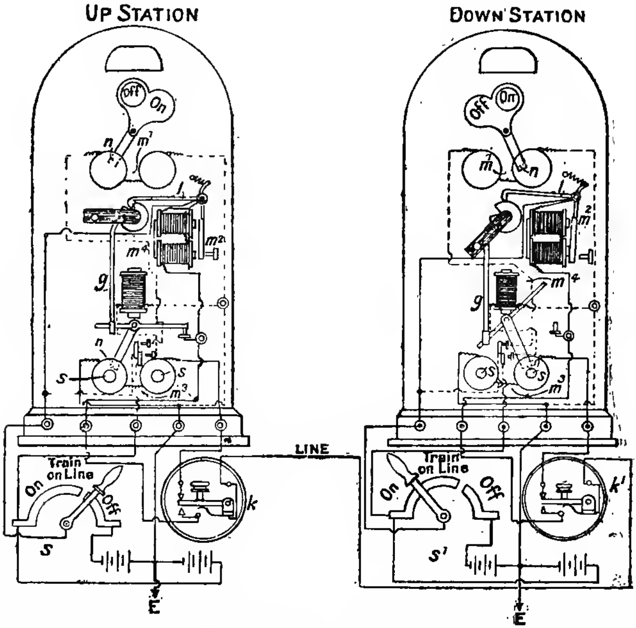


FIG. 38.—Double-Line Block Circuit—Preece's Instruments, One-Wire.

to being in a different position on the face of the instrument. The "on" "off" disc at the upper part of the instrument is the indicator for trains passing *from* that station; the semaphore arm is the indicator for trains *approaching* that station. The disc indicator at the sending station is practically a repeater for the semaphore arm at the distant station, in that its movement shows that the actions of the signalman at the distant station have been such as are calculated to lower the semaphore arm at that place. The position of the disc is "on" and the corresponding position of the semaphore indicator is horizontal, both when trains are actually passing through the section and when it is clear of trains, but the difference between these conditions is indicated, where a three-position switch is used, by the switch handle being placed in the position marked "Train on line." There are thus, practically, three different indicators in this form of instrument. Diagram Fig. 38 is drawn to show "Line clear" for a train ready to proceed from the "up" station to the "down" station. The handle of the switch, S, occupies the "off" position shown at the "up" station during the time the "Line clear" signal is being exhibited only.

The construction of the instrument presents several points of interest in the methods adopted to ensure efficiency. The disc indicator is actuated by the polarised armature of m^1, and the bell is worked by a non-polarised armature on the same electromagnet. The position of the disc depends, therefore, on the direction of the last current passed through m^1, whilst the bell is rung by all currents passing through that electromagnet. The currents passed through m^1 are from the local battery, and their direction depends upon the position of the switch, S, at that place. The semaphore arm is held in a horizontal position by the detent, *l*, attached to the non-polarised armature of

m^2, and also by the forked lever, *g*, which rests saddle-wise on the bar connected with the polarised armature of m^3. There are thus two electromagnets to actuate before the semaphore arm can be lowered, and these must be acted upon in a prearranged order. In addition to the polarised armature, *n*, m^3 actuates a non-polarised armature, which completes two local circuits each time a current passes through m^3. One local circuit is through m^4, and serves to magnetise the armature, *n*, and the cores, *s*, of m^3, the direction of magnetisation depending upon the position of the switch. The electromagnet m^2 is short-circuited when the polarised armature of m^3 occupies the position shown at the "up" station, and is not, therefore, affected by currents when the switch is in the "on" position. If the switch at the "up" station, say, is put into the "off" position, and the plunger, *k*, is depressed, a current will pass *viâ* earth m^3 at "down" station line, short-circuit of m^2 at the "up" station, and the switch lever to zinc. The current operates the two local circuits at the "down" station by the non-polarised armature of m^3. One local circuit rings the bell and the other magnetises the polarised armature of m^3, and causes the latter to take up the position shown. The forked lever, *g*, is released, but is still held in position, together with the semaphore arm, by the detent, *l*. The movement of the polarised armature of m^3 to the position shown at the "down" station breaks the short-circuit of m^2. If the plunger, *k*, at the "down" station is depressed in reply, a current is sent *viâ* m^2 at the "down" station, line, and *k*, m^3 at the "up" station, and earth to zinc at the "down" station. m^3 at the "up" station closes the local circuits and moves the disc indicator to the "off" position. The instruments are then in the position shown, which indicates "Line clear" for a train to pass from the "up" to the "down" station. When the "Train on line" signal is to be sent, the switch at the sending end is put into the appropriate position and the plunger depressed. The current being in the opposite direction to that for "Line clear," attracts the polarised armature of m^3, and through the forked lever, g, raises the semaphore arm, where it is again caught by the detent, l. The reply signal to the "Train on line" causes the disc indicator to occupy the "on" position, since the direction of the local current has been altered by placing the switch to "on."

It will be noticed from the diagram that the switches when in the "Train on line" position do not affect the currents sent from the home station in any way different from those produced when the switches are in the "on" position, and the clearing bell signals may be given and acknowledged with the switches in either of these positions. The difference between the "Line closed" and "Train on line" indications are merely shown by the position of the switch lever for the signalman's information. It will be further observed that the obviously most important signal of "Line clear" can only be exhibited by concurrent action on the part of the signalmen at the ends of the section, and unless the actions are carried out in proper sequence no such signal will be exhibited. The semaphore arm at the receiving end is lowered by the direct action of the signalman there, but only after his instrument has been prepared, so to speak, by the action of the signalman at the sending end, and the same action notifies the sending end of what has been done independently of the bell signal. On the other hand, the semaphore arm is

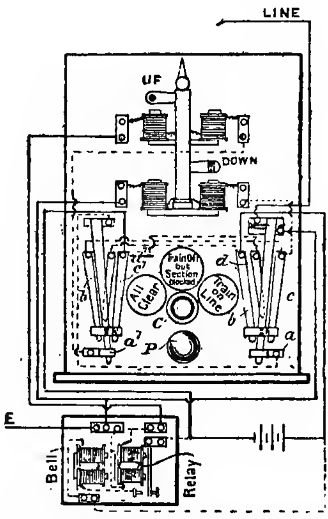


FIG. 39.—Harper's Single Plunger Block.

raised by the direct action of the signalman at the sending end when the "Train on line" signal is sent.

Harper's Block Instrument.—A further example of the single-wire block instrument is shown by the Diagram Fig. 39, which represents Harper's form of instrument. There are in this instrument two different forms of indicator; the lettered discs seen near the bottom of the instrument show what signal has last been *sent* for one line, and the semaphore arms indicate what signal has last been received for the other line. The movement of the discs into their proper position alters the direction of the current through the electromagnets at both stations. These currents are sent by the depression of the plunger at the bottom of the instrument. When the disc "All clear" is being shown, the plunger depresses the long spring on the right hand, breaking contact with *a*, making contact with *d*, and completing the circuit between *b* and *c* by the insulated cross-piece, *h*. The current passes by *b c*, and the lower electromagnet at the home station to earth, the relay, the upper electromagnets, a_1, left-hand spring, *a*, and right-hand spring, at the distant station, line, right-hand long spring, *d*, and zinc at the home station. When the disc indicator is in the position shown, or indicating "Train on line," the left-hand long spring is depressed by the plunger, and the direction of the current is reversed. Since the bell is rung by a local current, the circuit of which is closed by a non-polarised relay, it is obvious that the bell will be rung at the distant station at every depression of the plunger at the home station. Currents passing through these instruments actuate the lower electromagnets at the home station and the upper electromagnets at the distant station, and, since the position of the disc indicator controls the direction of the currents, it follows that the disc indicator at the home station must be set to the appropriate position before the signal can be given. The positions of the semaphore arms are in accordance with the signals *sent* and *received* respectively for the lower and upper semaphores, and by their position represent the character of the indication exhibited by the disc indicator at the distant station, in so far as the difference between the "All clear" and the "Train on line" or "Train blocked" signals is concerned, but do not indicate the difference between the two last-named conditions of the line. Obviously, the difference between the "Line blocked" and "Train on line" indications at any one station exercises no influence on the character of the indications at the distant station.

Fletcher's Combined Block.—Fig. 40 is a diagram showing the connections for a double-line block circuit with Fletcher's block instrument. In this form the bell-signalling apparatus is entirely distinct from the indicating apparatus, and three line wires are required. The indicators show "Line clear," "Train on line," and "Line closed" by the different positions of one indicator. The "Line clear" and "Train on line" indications are maintained by continuous currents. "Line closed" is indicated when no current is passing. All currents pass through the lower electromagnet at the home station and the upper electromagnet at the distant station. If the commutator at the "down" station, say, is turned to the left, the springs, *a* and *b*, *c* and *d*, are connected, and a current passes to earth at the home station, through the upper electromagnets at the distant station, the line, the lower electromagnets, and the springs *d* and *c*, to zinc at the home station. If the commutator is turned to the right the direction of the current is reversed, the

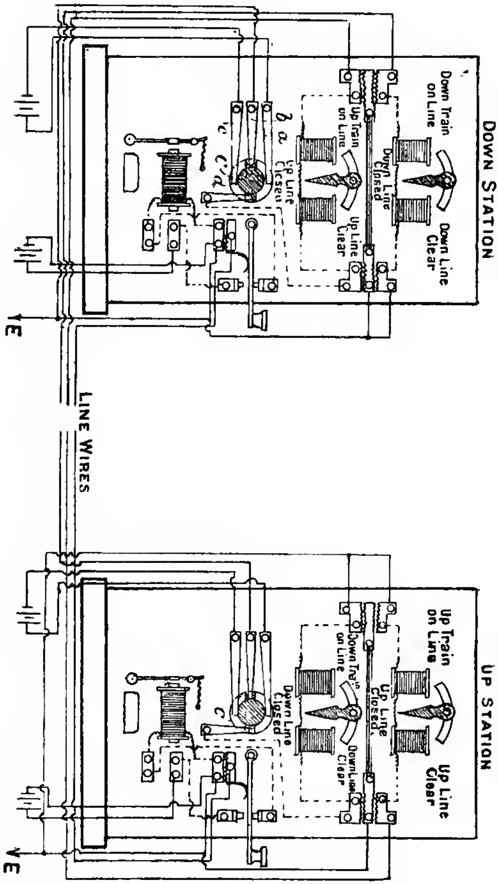


FIG. 40.—Fletcher's Combined Block, Three-Wire. Diagram of Connections for One Section.

springs *a* and *d* being connected, and also the springs *b* and *c*, and the character of the indication exhibited is altered accordingly.

Tyer's Semaphore Block Instrument.—The instrument shown in diagram, by Fig. 41, is Tyer's semaphore block. In this form of instrument the signals are sent by the plunger, P, and the direction of the currents is controlled by the position of the commutator, C, which also carries the disc indicators

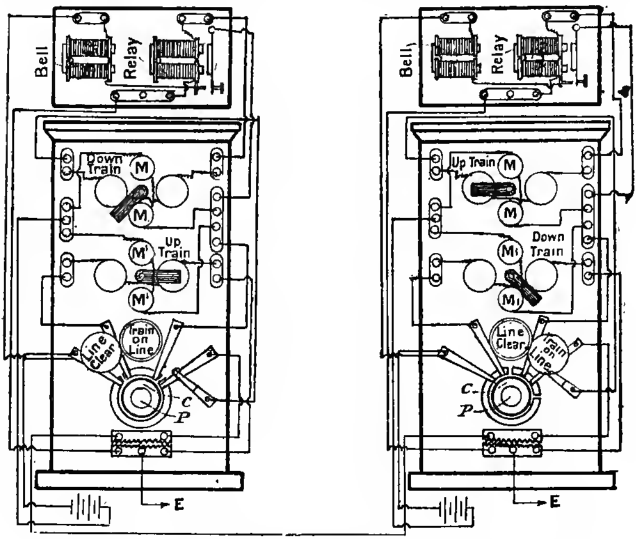


FIG. 41.—Double-Line Block Circuit—Tyer's Semaphore Block Instruments.

"Line clear" and "Train on line." Currents pass through the lower electromagnets at the home station, and the upper electromagnets at the distant station. The upper magnetising coils, M, are brought into use by the relay: the lower magnetising coils, M_1, are traversed by the currents sent from the home station.

As shown in the diagram the instrument makes no distinction between "Train on line" and "Line closed," but in later instruments this distinction is made.

Automatic Instruments.—The instruments already described are all of a non-automatic character, and depend entirely upon the action of the signalman for the exhibition of the indications corresponding to the various stages of signalling. As has already been remarked, the signalman is not infallible, and a study of the causes of accidents, which have from time to time occurred, shows the necessity for more or less control of the actions of the signalman.

One of the most important points at which attempts have been made to control the action of the signalman is the automatic locking of the block instruments in the "Train on line" position, until the train so signalled has passed a certain prearranged point in the vicinity of the receiving end of the section, thus preventing the signalman from accepting a second train before the first is clear of the section.

Such action, resulting from a lapse of memory on the part of the signalman at the receiving end of the section, was found to be the cause of a very bad accident a few years ago. An experimental attempt to neutralise the effects likely to arise in this way for a three-wire single-needle circuit is shown by Figs. 42, 43, and 44.

As will be seen from the figures, the apparatus provides for the locking of the instruments to "Train on line," after the usual distinguishing signals have passed, until the train so signalled has passed over a rail treadle, placed at a suitable point near the cabin at the receiving end of the section. The locking takes place at the receiving end of the section, and is due to concurrent action on the part of the signalmen at both ends.

The arrangement was not intended to relieve the signalman of the responsibility for seeing that the *whole* of a train, previously signalled, arrived and passed under the protection of his outdoor signals

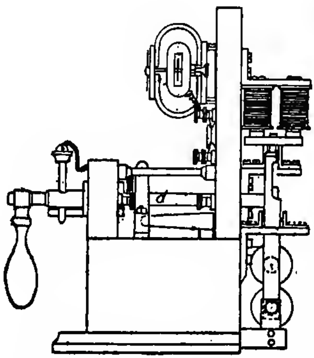


FIG. 42.—Case Removed, Instrument Locked (Right Elevation).

in accordance with the rules provided for working traffic, but was designed with a view to provide a check against any attempt he might, inadvertently, make to clear the line before the train reached a point which had previously been determined by the responsible officials to be outside the section referred to.

At the time the additional apparatus was designed, it was the rule for the signalman at the *sending* end to hold the instrument needles to "Train on line," until the signalman at the receiving end had inserted the peg as shown in Fig. 42. At the instant this was being done the batteries at both ends of the section were in use. Advantage was taken of this simultaneous use of both batteries to lock the handle of the receiving instrument in the "Train on line" position, so that if the peg was withdrawn before the proper time the instruments at both ends would

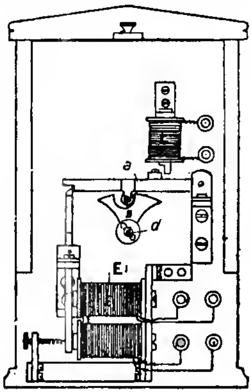


FIG. 43.—Back Elevation, Instrument Locked.

still show "Train on line," and the signalman at the receiving end would be unable to move the handle to give "Line clear," or any other signal, until the instrument was unlocked by the direct action of the train signalled on its arrival at some point where, at least a portion of the train, had passed the signal cabin.

The additional apparatus consists of the differential electromagnet, E_1, which is connected as shown in

Fig. 44, and the simple electromagnet, E, connected with the rail treadle. The commutator spindle, *d*, is prolonged through the back of the instrument, and carries the slotted sector, *s*. The rocking-bar, *a*, rides on the top of *s* when the handle of the instrument is vertical; and the armature of E_1 supports it, under the lower edge, during the time the instrument is being worked to send train-distinguishing signals, since E_1 is a differential electromagnet, and its

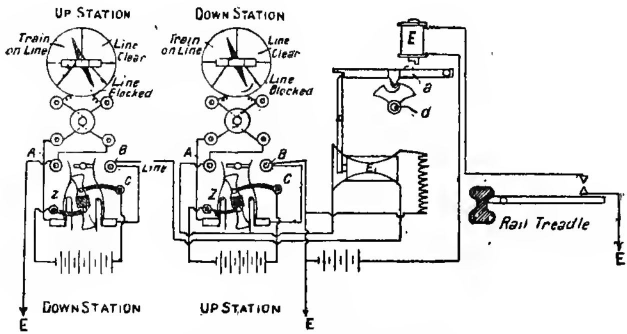


FIG. 44.—Diagram of Connections.

armature is unaffected by currents originating at the receiving end.

During the time train-distinguishing signals are being received from the sending end of the section, the armature of E_1 is affected, but the handle of the receiving instrument being then vertical, *a* is upheld by *s*. If the handle of the instrument at the receiving end is held over so that the needles indicate "Train on line," the slot in *s* comes under the friction wheel of *a*, but the latter is still held up by the armature of E_1. If, now, the handle at the sending end is also held over, the previous balance of the currents in E_1 is upset, the armature is attracted and allows *a* to fall and lock the handle of the receiving instrument in the "Train on line" position. The only legitimate means of releasing the handle after the operations described is, as will be seen, by the current set up when the circuit of E is closed by the depression of the rail.

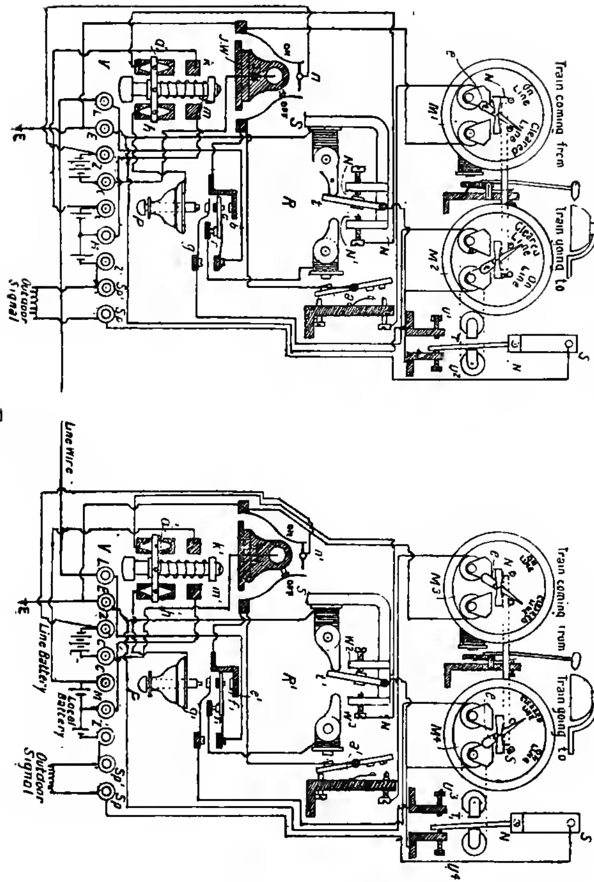
In Fig. 44 the handles of the instruments at both ends of the section are shown in the position to indicate "Train on line." It will, however, be clear from the description that the diagram represents the position of the handle at the sending station at the moment the instrument at the receiving station is being locked only. At other times the handle of the sending instrument stands vertical, as usual, and the "Train on line" indication is maintained by the position of the handle at the receiving end. As has already been said, this concurrent action of the two signalmen was the rule for working at the time the additional apparatus was designed. At present the method of working is different, but there is nothing in the requirements which is inimical to the working of the instruments as indicators.

The position of the releasing treadle requires judgment in its selection, and would probably, owing to local circumstances, be different at every place. Its position would also largely depend upon the rules in use by the particular company adopting any such method of automatic working. Some companies prohibit the acceptance of any train from the rear when the previous train is standing at the "advance" signal, although it is then protected by the "home" signal. Others prohibit the acceptance of passenger trains only under these circumstances, and allow goods or mineral trains to be brought to the "home" signal, when a similar train is standing at the "advance" signal, the "distant" being kept at danger during the approach of the second train.

Obviously, the point of release will be different in the two cases; for if the line may not be cleared until a train has passed the "advance" signal, the releasing point must be situated so that it cannot be actuated until the train has passed that signal, whilst, on the other hand, where the line is cleared when the train is within the "home" signal, the releasing point must be selected at a point near that signal.

This difference in practice is worthy of more notice. In the case where the line is not cleared until the train is passing the "advance" signal, the section obviously extends between "advance" and "advance." Where the line is cleared when the train is within the protection of the "home" signal, the section extends between the "advance" at the sending end and the "home" at the receiving end, and the part of the line between the "home" and "advance" signals is practically unblocked and worked under the observation of the signalman only.

Winter's Block Instrument.—Fig. 45 shows diagrammatically the construction of and connections for Winter's block instrument as arranged for double-line working, with one line wire and using transient



WINTER'S BLOCK INSTRUMENT

FIG. 45.

currents. All distinguishing signals are given by a bell code, and the indicators are simply used to show the condition of the line for the time being.

The apparatus provided at one station for one section consists of a plunger key, P, a reversing switch, S W, a small push, V, and the two indicator dials. The indicating pointer for approaching trains is coloured red, that for receding trains is black. The soft-iron needles, *e e*, which are attached to the same axle as the indicating pointers, behind the dials, are polarised by the bar magnet, N S, and play between the pole-pieces of M^1 and M^2. The electromagnets, M^1 and M^2, are shown partly in front view and partly in side view. M^1 actuates the bell hammer, and M^2 actuates the polarised relay tongue, T. The relay, R, is a combined polarised and non-polarised electromagnet, and is also shown partly in front view and partly in side view in order to show the various actions more clearly. All currents passing through the coils of R cause the soft-iron armature, *a*, to be attracted; the tongue, *t*, is only attracted to the stud, W^1, when the current passes in the proper direction. The switch, S W, is a commutator for reversing the line battery. The carbon is attached to the axle which carries the stud shown; the zinc is connected to the bridge, *n*. If the handle of the switch is turned from "off," as shown, to "on," the stud brings the carbon into connection with the "on" line spring, and allows the "off" line spring to make contact with the bridge, *n*, and zinc. The plunger key, P, has three contact points between *l* and *f*, between *l* and *r*, and between the plunger and *g*. When the plunger is at rest *l* is in contact with *r*, and the other contacts are broken. When the plunger is depressed, contact is made between the plunger and g and between l and f, whilst the connection between l and r is broken. The insulating piece attached to l prevents contact between l and g when the plunger is depressed. The push, V, when depressed makes two contacts—one between d and k, and the other between h and m. The two connectors bridging d and k and h and m respectively when V is depressed, are fastened together by an insulating piece. The normal position of the switch, S W, is "off," and it is only brought into use for *approaching* trains. Signals originating at the station from which a train is being dispatched are given with the switch at "off." The normal position of the indicators is to "Cleared line" when the section is not occupied. When a train is ready to proceed from the "up" station the operations to be gone through are as follows, for block working only.

UP STATION.	DOWN STATION.
Depresses P in accordance with code for "Is line clear" signal. Switch at "off."	
	Receives "Is line clear" signa on bell. Switch at "off." Puts switch to "on" and depresses P_1 in accordance with code for "Line is clear" signal.
Receives "Line is clear" signal on bell. Depresses P in accordance with "Line is clear acknowledgment" signal, and at the same time depresses V. "Train going to" indicator put to "On line."	"Train coming from" indicator put to "On line."

On the arrival of the train at the down station:

UP STATION.	DOWN STATION.
	Puts switch to "off" and depresses P_1 in accordance with "arrival" signal.

Receives "arrival" signal on bell. Depresses P in accordance with "Arrival acknowledgment" signal, and at the same time depresses V. "Train going to" indicator put to "Cleared line."

"Train coming from" indicator put to "Cleared line."

The paths of the various currents are as follows:

"Is line clear" signal.

From the line battery, C, through the axle, S W, "off" line spring *f*, *l* to the line L.

From the line L, through *r* and the coils of R_1 to earth.

From earth, through "on" line spring and bridge, *n*, to Z.

a_1 is attracted.

Local action, ringing bell (line battery):

From C through axle S W_1, "off" line spring M_3, "on" line spring and bridge, *n*, to Z.

"Line is clear" signal.

Switch at "on." From C through axle S W_1 to earth.

From earth, through coils of R, and *r* to line L.

From line L, through l_1, f_1, and "off" line spring to Z.

t is moved to W_1, but no current is established owing to the break in local circuit between *d* and *k*.

a is attracted, ringing bell.

Local action (line battery):

From C through axle S W, "off" line spring M_1, "on" line spring and bridge, *n*, to Z.

"Line is clear" acknowledgment.

Line battery.

From C through axle S W, "off" line spring *f*, and *l* to line L.

From line L, through r_1 and coils of R_1 to earth.

From earth, through "on" line spring and bridge, n, to Z.

Local battery C M Z.

From C, through K, d, W_1, u, T, and outdoor semaphore to Z.

Local battery M Z.

From M, through m, h, P, g, M_3, u, T, and outdoor semaphore to Z.

This puts "Train going to" indicator to "On line."

a_1 is attracted.

S W_1 is to "on."

From C, through axle S W_1, "on" line spring M_3, "off" line spring and bridge, n, to Z.

This puts "Train coming from" indicator to "On line."

Where the outdoor mechanical signal is interlocked with the block instrument, a slight variation in the order of the operations is made. This consists in depressing V alone, at the sending end, after the receipt of the "Line is clear" signal, and before the "Line is clear acknowledgment" signal. This completes the circuit of C M *Z* alone, and unlocks the mechanical signal. The subsequent depression of V, together with P, for the "Line is clear acknowledgment" signal moves the tongue, T, against u_1, and prevents any current being sent to the outdoor signal locking apparatus until after the "arrival" signal has been received and acknowledged.

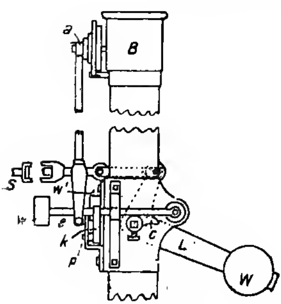
When the train, the signalling of which has been traced in the route diagrams, arrives at the down station, the switch, S W_1, is put to "off," and the plunger, P, is depressed in accordance with the "arrival" signal. This signal simply rings the bell at the up station, and puts t back to W. When the "Arrival acknowledgment" signal is sent in reply from the up station, the currents established by P and V place the indicators at both stations to "Cleared line," and the relay tongue, T, to u_2.

The paths of the currents are easily traced when it is remembered that the switch at the down station has been put to "off." The local current at a_1 (down station) is reversed, and puts the indicator at that place to "Cleared line." The indicator at the up station is placed to "Cleared line" by the action of the battery, C M, the current passing through V.

The interlocking of the starting signal with the block instrument is shown by Figs. 46, 47, and 48. The crank of the lever, L (Fig. 46), is worked by the signal lever in the cabin, but its operation differs from that of most signal levers in that it is not required to hold L up during the time the signal is "off." Fixed to the axle of L, and working with it, is the cam lever, c. Immediately above c, and in contact with it, is the straight lever, l, with its counterweight, w. At right angles to l is the counterweight, w_1, carried by a crank pivoted at p, the short arm, k, of which bears against l when the latter is horizontal. If the lever L is raised, l is also raised by the cam, c, and k, by the falling of w_1, is brought under l, and supports it when the lever L has returned to the position shown in Fig. 46. Fig. 47 is drawn to show the positions of the various parts of the apparatus at this stage. So far as the mechanical portion of the apparatus is concerned, the signal arm is free to take up the "off" position, but it is still held up by the electrical interlocking apparatus, which is contained in the box, B, at the top of the post.

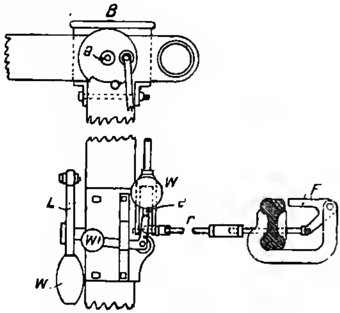
The mechanism connected with the electrical interlocking is shown separately in Fig. 48. It consists of the simple electromagnet, R_3, its armature, *i*, and three cranks, one of which carries the hammer, *f*. The axle of the signal arm is shown at *a*. The

WINTER & CRAIK'S
ELECTRICALLY INTERLOCKED SEMAPHORE



Normal position of Arm

FIG. 46.



Arm released mechanically but locked electrically.

FIG. 47.

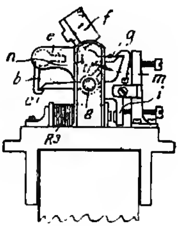


FIG. 48.

lever, *b*, and the projection, *m*, work with *a*, and under normal conditions *b* is locked by c_1. Before the releasing current passes through R_3 the lever, *g*, is locked by the armature, but when the armature is attracted *g* is released, and *f* falls upon *e* and releases *b*. If the operation of L, previously described, has been performed before the releasing current passes, or is performed after, the signal arm falls. The projection, *m*, engages with *n*, when the axle, *a*, turns and raises the hammer, *f*, and *g*, engaging with the armature, *i*, locks *f* in the position it previously occupied. When the train passes the signal, the depression of F pulls *k* from under *l*, and the weight, *w*, being free to fall, raises the arm to a horizontal position again.

The apparatus is now fully in position for a similar cycle of operations. The signalman, however, is not able to again lower the signal arm until the "arrival" signal has been received and acknowledged for the last train signalled, owing to the tongue, *t*, of the relay, R, being in contact with W_1 (Fig. 45)) during the time the "On line" indication is being exhibited.

It will be noticed from the description of the apparatus and the method of working that the principal objects aimed at in the design are concurrent action on the part of the two signalmen concerned before the section can be occupied or the signal lowered for a train to pass forward, and automatic protection of the section occupied by the raising of the signal to danger by the passage of the train over the rail treadle. The apparatus provides, indirectly, by the position of the switch, an indication similar to "Line clear" (section ready for train to enter) at the receiving end, but does not provide a similar indication at the sending end.

Saxby-Farmer.—The special apparatus for ensuring safety of working already described has been of a partial character only, and adapted to meet given circumstances. Figs. 49-61 illustrate Saxby and Farmer's union of the locking apparatus of the mechanical signals with the block signalling apparatus, and constitutes a more complete attempt to meet all the contingencies which can be foreseen. The objects aimed at in the design, besides the ordinary block signalling, are (*a*) the locking of the instrument handle at the receiving end of the section, until the train signalled has passed a prearranged point at that place; (*b*) the locking of all points and signal levers, the operation of which involves fouling of the running line, for all positions of the block instrument handles, except the normal position, when the section is unoccupied; (*c*) the locking of the "starting" or "advance" signal to danger for all positions of the block indicators except "Line clear"; (*d*) ensuring the raising of the signal to danger when it is no longer required to be "off" for the train signalled, and accepted, to proceed. The block indicator and signalling apparatus follows the usual line of design for single-wire instruments, and consists of a ringing and signalling plunger, a commutator for reversing the direction of the currents sent, the electromagnets for working the semaphore indicators, a relay, and a bell. All signals are given by the plunger, and the direction of the currents so sent is controlled by the position of the handle of the instrument. Currents pass through the electromagnets actuating the lower semaphore indicator at the home station, and through the upper electromagnets at the distant station. The non-polarised relay is actuated by all currents, and the bell is rung accordingly. In connection with the upper semaphore arm is a mercury contact switch, which makes or breaks a circuit passing to the starting signal according as the semaphore arm is down or up. A similar switch is worked in connection with the mechanism provided for locking the handle

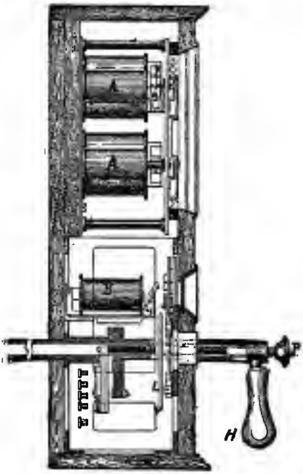


FIG. 49.

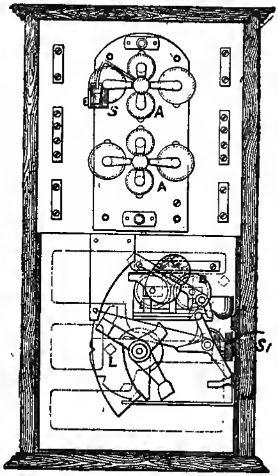


FIG. 50.

of the block instrument. This switch completes a circuit through the handle-releasing coils and a rail treadle which brings them into action, when the handle is on the "Train on line" position, and breaks the circuit when the handle occupies either the "Line clear" or "normal" (line blocked) positions. Besides these two switches there is an electromagnetic two-way mercury contact switch, in a separate case, which is used in connection with the working of the starting signal.

Fig. 49 is a side view of the instrument with the case removed, and shows the general arrangement of the indicator electromagnets, A, handle-releasing coils, B, the ringing and signalling plunger, P, the

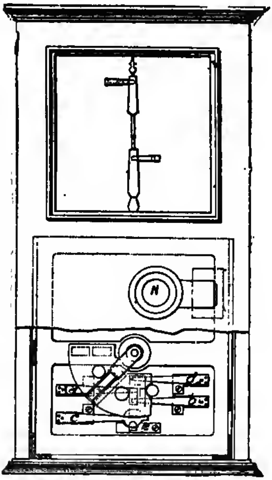


FIG. 51.

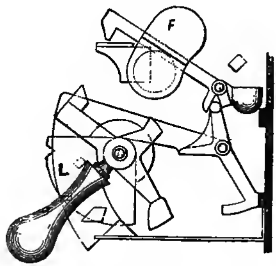


FIG. 52.

commutator, H, and the switch, S, in connection with the upper semaphore arm. Fig. 50 shows the mechanism for locking the commutator handle in the "Train on line" position after it has occupied the "Line clear" position, and also shows the mercury switch, S_1, in connection with the releasing circuit.

Figs. 52, 53, and 54 show the various positions of the handle-locking mechanism for the "normal," "Line clear," and "Train on line" positions respectively. The curved lever, L, is raised when the handle is placed to "Line clear," and a small stud, shown in dotted lines in Fig. 52, engages with the projection of the armature of the releasing coils, B (Figs. 49 and 50), and is held there until the armature is attracted, which takes place when the train passes over the rail treadle provided for

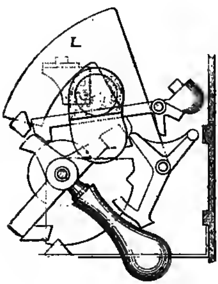


FIG. 53.

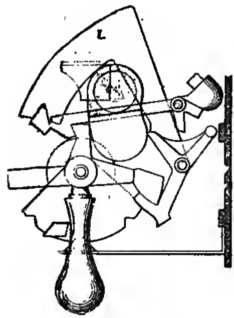


FIG. 54.

closing the circuit. The same movement causes the shaded disc, F (Fig. 52), to appear at the opening, N (Fig. 51), in the front of the instrument.

Fig. 51 shows the arrangement of the commutator. As shown, with the handle in the "Line blocked," or normal position, the depression of the plunger puts the springs *a* and *b* in contact, and also springs *c* and *d*, and at the same time breaks contact between *c* and *e*. The current so sent does not affect the indicators at either station, and the only effect is to ring the bell. When the handle of the commutator is placed to "Line clear," depression of the plunger connects springs *a* and *d* and *b* and *c*, and breaks contact between *c* and *e* as before. The direction of the current is now reversed, and the lower semaphore arm at the home station and the upper semaphore arm at the distant station are lowered,

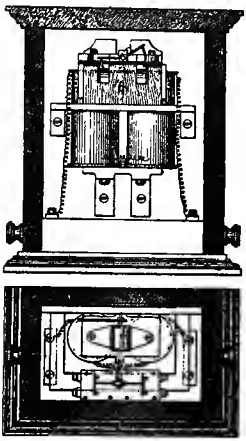


FIG. 55.—Electromagnetic Mercury Contact Switch for Controlling Outdoor Signal.

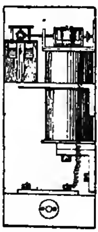


FIG. 56.

and indicate "Line clear." When the handle is in the midway, or "Train on line," position, depression of the plunger effects the same combination as when in the normal position, and the currents so sent raise the lower arm at the home station and the upper arm at the distant station to horizontal positions. Fig. 55 shows a plan and front elevation of the special mercury switch used in connection with the electrical control of the starting signal, and Fig. 56 shows a side elevation of the same. Fig. 57

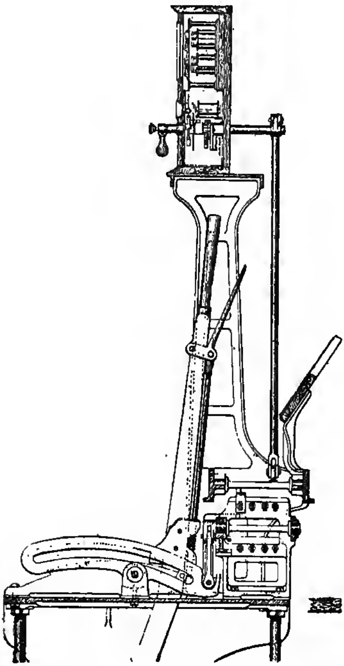


FIG. 57.—Interlocking of Block Instruments with Point Fouling Running Line.

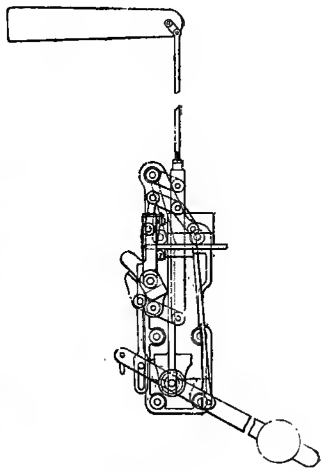


FIG. 58.

shows the method of locking the levers of fouling points, etc., with the handle of the block instrument in the "Line clear" and "Train on line" positions. Conversely, the handle of the block instrument is locked in the "Line blocked," or normal position, when these levers are being operated.

Figs. 58, 59, and 60 show the operation of the electrical control of the starting signal, and Fig. 61 is a diagram of the connections for one complete block circuit.

The operation of the instruments for signalling is

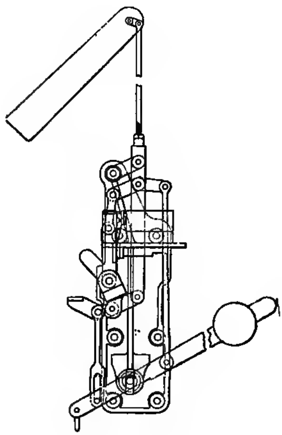


FIG. 59.

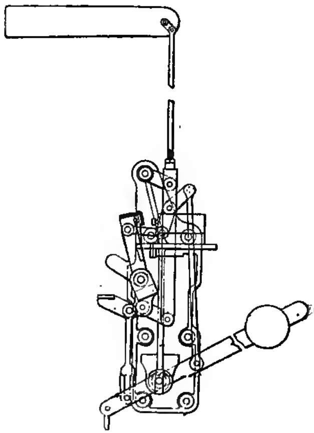


FIG. 60.

very similar to that of some of the instruments already described, and need only be referred to very briefly. The "Is line clear," or equivalent signal, is given from the sending end with the handle in the "Line blocked" position. If the signalman at the receiving end is in a position to accept this signal, he first moves the handle of his instrument to the "Line clear" position, and gives the appro-

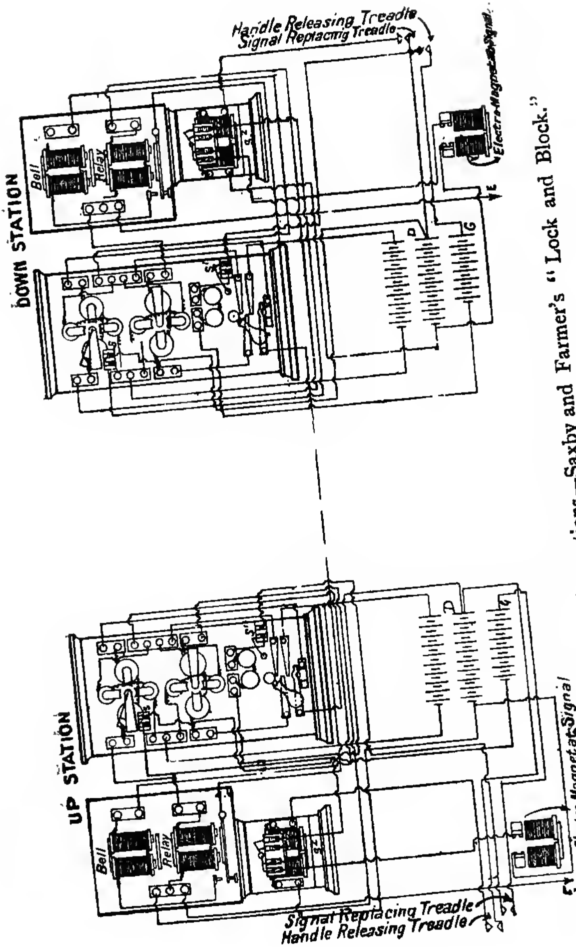


FIG. 61.—Diagram of Connections—Saxby and Farmer's "Lock and Block."

priate accepting signal. The semaphore arms are lowered at both stations, as already described, by the accepting signal, and remain in this position, indicating "Line clear," until further signals are exchanged. It will be noted that, owing to the locking of the handle of the instrument by the mechanism shown in Fig. 50, the ability to place the handle to "Line clear" is proof that the previous train has passed over the handle-releasing treadle, and owing to the interlocking of the block instrument handle with the levers controlling fouling points, the ability to move the handle from the "Line blocked" position is proof that the line is clear of shunting or similar operations. Further, the act of placing the handle to "Line clear" raises the curved lever, L, until it engages with the armature of the releasing coils. Once in this position, the locking mechanism prevents it being replaced in the "Line blocked" position until after the armature of the releasing coils has been moved. This, of course, under normal conditions, is done by the passage of the train over the treadle, but it should also be noted that the passage of a train over the treadle during the time the handle is to "Line clear" will not actuate the armature of the releasing coils, owing to the switch, S_1, being open in that position. S_1 is only closed when the handle is in the "Train on line" position. The lowering of the upper semaphore arm at the sending end causes a local current to be established, which passes from the battery, D, through the switches, S and S_2, to the controlling electromagnet on the starting signal.

Under normal conditions—*i.e.*, when the signal arm and the lever working it are both in the "on" position—the armature of the electromagnet on the signal is kept up to the poles, as shown in Fig. 58, and the continuity of the circuit is maintained in this position only. When the signal lever is put in the "off" position, this mechanical support is withdrawn, and if there is no current passing through the coils of the electromagnet the armature will fall, and the apparatus will occupy the position shown by Fig. 60. If, however, the local current through S, S_2, D has been previously established, the armature is held by the electromagnet, and the action of the balance weight on the levers and links allows the arm to assume the "off" position as in Fig. 59. If a break occurs anywhere in the local circuit during the time the signal lever is "off," and the balance weight occupies the position shown in Fig. 59, the armature is freed, and, being unsupported mechanically, falls into the position shown in Fig. 60; the relative weights of the signal arm and the central lever carrying the rod being sufficient to effect this movement. An examination of the local circuit shows that it may be broken at three points—viz., at S, S_2, and at the signal. If the upper semaphore arm is raised, the switch S will break the local circuit. This action must take place when the signalman at the receiving end acknowledges the "Train on line" signal, and it therefore follows that the signal arm cannot remain at "off" after the "Train on line" signal has been acknowledged, although the lever working the arm has been left in the "off" position. Hence we see that the signalman at the sending end is not only dependent upon the signalman at the receiving end for the release of the starting signal, but the latter will replace it if the former neglects to do so. It is, however, by no means impossible for the signalman at the sending end to obtain the "Line clear" indication for a train, and, from forgetfulness, neglect to forward the "Train on line" signal. Under such circumstances the signal would remain at "off," if no other devices than those described were in operation. A further examination of Fig. 61 will show that the electromagnet of S_2 is in connection with a second rail treadle, through the same battery as is used for the circuit S, S_2, and signal electromagnet. If this circuit is closed, the switch S_2 is reversed, and, breaking the circuit through the signal electromagnet, allows the arm to assume the "on" position. Although the closing of this circuit may be only momentary, it will be seen from Fig. 61 that the reversal of S_2 has the effect of diverting the current, previously passing through the signal electromagnet, through the electromagnet S_2, and so maintains the reversed position of the latter until the indicating semaphore arm is raised, when, the switch S being open, the circuits from the battery, D, are broken, and S_2 resumes the position shown in the diagram of connections, and is ready for another train.

From the description it will be evident that the signalman at the receiving end is master of the situation. The signalman at the sending end cannot lower the signal for a train to proceed until he has received "Line clear" from the station ahead; and if he does not himself replace this signal at the proper time it is done by the acknowledgment of the "Train on line" signal from the receiving end; or, in the event of the train being sent forward without this signal being given and acknowledged, it is done by the action of the train passing over the treadle, and the signalman is unable to again lower it until the indicating semaphore has been raised and lowered again. When the "Train on line" signal is received from the sending end of the section, the signalman at the receiving end places the handle of his instrument in the midway position, which is the only movement possible, and acknowledges the signal in accordance with the code. The movement of the handle locks it in the midway position, and it cannot now be moved in either direction. The switch S_1 is closed by the same action. On the arrival of the train at the receiving end of the section, it passes over the treadle in connection with the battery G, and a current is established through the switch S_1 and the handle-releasing coils. The armature is attracted, and allows L to drop into the position shown in Fig. 52. The handle of the instrument is now free, and may be placed in either the "Line blocked" or the "Line clear" positions. The proper position for it is, of course, the "Line blocked" position, and when this is done the "arrival" signal is given according to code.

This system is an interesting example of the possibilities of block working, and also of the difficulties to be overcome before even a moderate check can be established over those engaged on working traffic. The elaborate precautions taken to ensure the replacement of the starting signal after it has fulfilled its duty, and to ensure its not being used to send a train forward prematurely, mark the starting signal as being of the utmost importance in the estimation of the designer. There can be no doubt that the position of this signal is of great importance, but the history of railway accidents shows that its being in the "on" position has not always acted to prevent a train from passing into the section it protects, with disastrous results in some cases. The apparatus in connection with the starting signal has, obviously, been designed solely with the object of checking the action of the signalman, and provides in no way against the possibility of error on the part of that other important factor in the problem, the engine driver. Further consideration of the arrangements for unlocking the starting signal suggests the possibility of this being done through accidental contact between the line wire and another working wire along the route between the two ends of the section.

The next important point in the system is the locking of the instrument handle, at the receiving end, until the train has passed over the treadles in connection with the releasing coils. It will be noticed (Fig. 53) that the operation of locking commences when the instrument has been prepared to give the "Line is clear" signal, and is completed when the "Train on line" signal has been acknowledged. Once the handle has been moved to the

"Line clear" position it cannot, in the course of ordinary working, be replaced to "Line blocked" before the treadle is operated. An "Is line clear" signal or "Train on line" signal cannot therefore be cancelled, in the sense that all the apparatus concerned may be returned to the "Line blocked" condition without special arrangements being made for releasing the handle at the receiving end of the section. Theoretically, the "Train on line" signal should never require cancelling, but there are occasions when it may be necessary. Cancellation of the "Line clear" signal is of much more frequent occurrence, more especially in connection with junction working and at points where traffic is lifted and left. In the case of a junction, such as is shown in Fig. 21, the signalman there might offer the "Is line clear" signal, and have it accepted, from two or even the three advance cabins, in which case the three starting signals would all be unlocked electrically, and any one of them might be used. Such a case as is here supposed is by no means far-fetched. Where signalmen at junctions have to deal with a heavy mixed traffic they often have to rely upon the whistles given by the driver, and when the wind is in a contrary direction it is by no means easy to distinguish the number and length of the whistles given; and since the "Line clear" signal must be obtained before the arrival of the train at the cabin at the sending end in order to prevent delay, the cancelling signal becomes of some importance. Further examination of the handle-locking mechanism shows that it is not impossible for the signalman at the receiving end to (*a*) replace the indicating semaphore arms to "Line blocked" in the interval between his giving the "Line is clear" signal and receiving the "Train on line" signal; (*b*) give the "arrival" signal to the sending end at any time after receiving and acknowledging the "Train on line" signal, but the locking of his instrument handle would prevent him from accepting a second "Is line clear" signal. The apparatus provides indications representing "Line clear," "Train on line," and "Line blocked," at the receiving end of the section, but does not distinguish between "Line blocked," and "Train on line" at the sending end."

Sykes's Three-Wire.—Another method of locking the block instruments with the outdoor mechanical signals is shown by Figs. 62-71, which illustrate Sykes's three-wire system, familiarly known as the S.Y.X. system. As in Winter's and Saxby and Farmer's systems, the principal object aimed at is the control of the starting, or advance, signal at the sending end of the section by the signalman at the receiving end, but it is distinguished for the extreme simplicity of the electrical apparatus and for its departure from the usual design of such apparatus.

The system provides a combined locking and indicating instrument for each line of rails, each instrument being provided with a separate line wire; separate bell communication between the ends of each section by which all signals other than those indicating the condition of the line for the time being are sent; a mercury contact rail treadle placed near the starting signal to release the locking arrangements at the proper time; and an automatic signal-arm replacer, fixed on the starting signal, which is also worked in connection with the rail treadle.

The general arrangement of the block indicator is shown by Fig. 62. It consists, as will be seen, of two distinct portions. The upper part containing the small semaphore arm constitutes the block indicator for one line of the *advance* section; whilst the

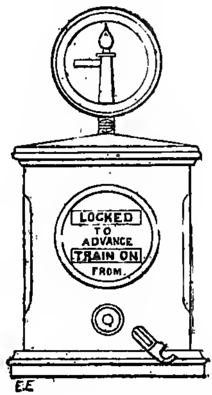


FIG. 62.—Sykes's Block Indicator.

lower part contains the mechanism for interlocking the instrument with the mechanical signal at that place, the electrical apparatus by which the mechanical signal at the *rear* cabin is released for use, and the indicators of the condition of the *rear* section of the same line. One portion of each instrument is, therefore, worked *from* the advance cabin, and the other portion is worked *to* the rear cabin, and the indications of different parts of one and the same instrument give to the signalman information of the condition of both sections so far as one set of rails is concerned.

The construction of the semaphore indicator is shown by Fig. 63. The position of the arm is horizontal when no current is passing through the coils of the instrument, and in this position the arm indicates the equivalent of "Train on line." When

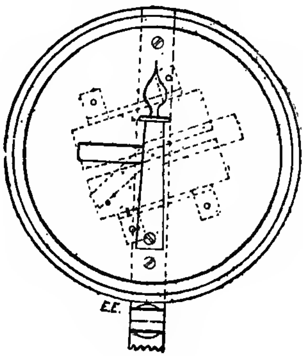


FIG. 63.

the section is clear of trains on the line of rails represented by the indicator, or of shunting operations at the receiving end of the section, the arm is held in a diagonal position by a permanent current, and indicates in this position the equivalent of "Line blocked." A reference to Fig. 71 will show that the position of the arm is controlled by the signalman at the receiving end of the section, and its indications are in no way dependent upon the actions of the man at the sending end of the section. Fig. 64 is a perspective view of the locking mechanism in the lower part of the instrument. Fig. 66 is a front

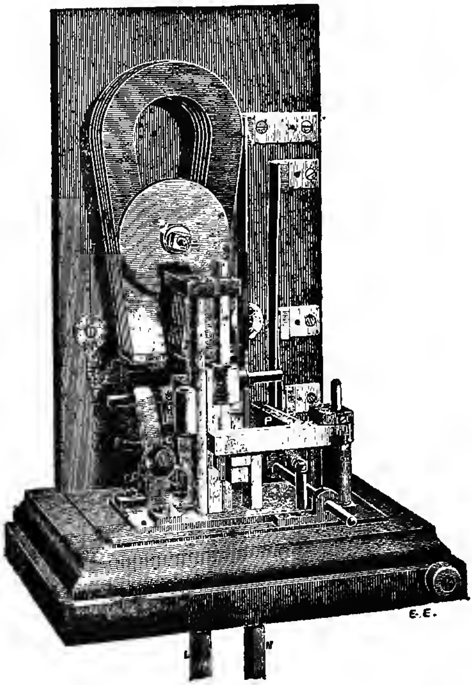


FIG. 64.

elevation, and Figs. 65 and 67 are left and right elevations of the same respectively, but the relative positions of the various parts of the apparatus are different in Fig. 67 to the positions the same parts occupy in Figs. 65 and 66. The apparatus consists of a plunger, P, actuated by the knob, R, the polarised electromagnet, H, a switch, T, the lock bars, M, *n*, O, and the rods, L and N, in connection with the starting signal mechanism. The plunger, P, at any block

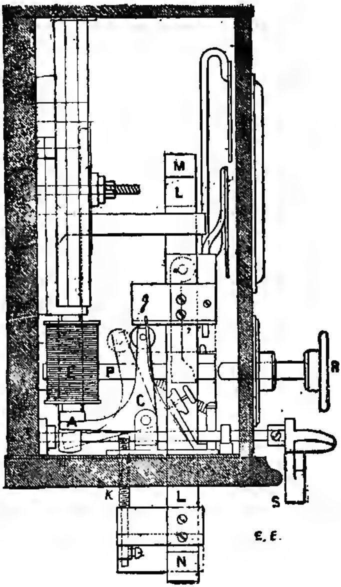


FIG. 65.

cabin makes connection between the spring, S^2, and the battery studs 1 and 2 (Figs. 66 and 71), and sends a current through the polarised electromagnet at the rear cabin in such a direction as tends to weaken the attraction of the permanent magnet upon the soft-iron armature. The armature, A (Fig. 65), is carried by one arm of a bell crank, C, the vertical arm of which carries a small friction wheel. A pin projecting from the vertical arm causes the latter to be acted upon by the strong spring, F (Fig. 66), which tends to

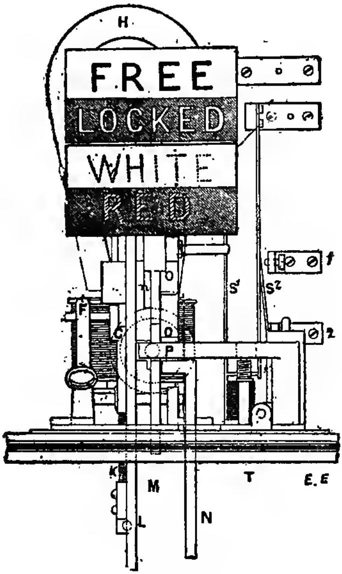


Fig. 66.

separate the armature from the poles of the electro-magnet. Under normal conditions A is held by the attraction of the polarised electromagnet, and the release is effected by passing a current of such strength and direction as will allow the spring, F, to overcome the diminished attraction of H. The switch, T, is used in connection with the one-cell battery shown in Fig. 71.

This battery is used simply to hold the semaphore indicator at the rear cabin in the "off" position when the section is clear of trains on the line of rails it represents, and no operations involving the fouling

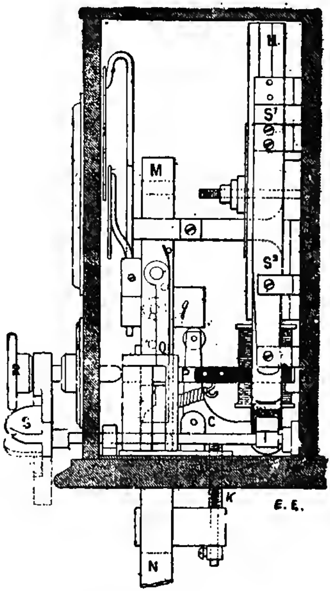


FIG. 67.

of this line are being carried out. The lever, L, is pivoted at *c* (Fig. 68), and carries at one end of the arm the lock rod, *d*, for the signal lever, and at the other end the friction wheel, *b*. The continuation of L within the case of the instrument carries a light frame, on which is painted "free," "locked" (Fig. 66). These indications appear, in their proper order, at the upper opening of the instrument case, and indicate to the signalman the condition of the starting or other signal connected with L. Within the case, L carries the projection, *g* (Figs. 65 and 67), which rests upon the friction wheel of C, as shown by the full lines in Fig. 65. Under the instrument L carries the parallel bolt, *k*, which, passing into the interior of the instru-

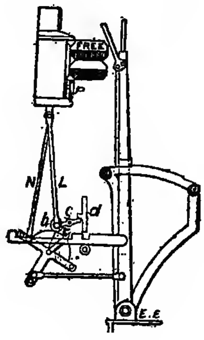


FIG. 68.

ment, engages with the horizontal arm of C and raises the armature, A, into contact with H, when the motion imparted to L by the movement of the signal lever is upward. When the projection, *g*, rests upon the friction wheel of C the weight of L is supported by the latter, and the short arm pivoted at *c* (Fig. 68) is in such a position as to lock the signal lever in the "on" position. If the armature, A, is released L is lowered until the friction wheel, *b* (Fig. 68), rests upon the semi-circular rim of the double bell crank, and by doing so lifts the lock rod, *d*, into the position shown by Fig. 68 and releases the lever. At the same time the word "locked" disappears, and "free" takes its place at the upper opening of the instrument, indicating to the signalman that the lever is free to be placed in the "off" position. The tongue, *t* (Fig. 68), working on the same centre as the double bell crank, is loose, and works in a V groove on the vertical face of the crank. When the lever is placed in the "off" position *t* passes under the friction wheel, *b*, and raises L, and, in consequence, the armature, A, is raised into contact

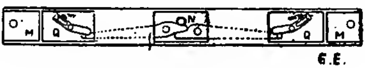


FIG. 69.

with the poles of H by *k* and held there. The word "free" disappears and "locked" takes its place at the upper opening of the instrument, indicating, in conjunction with the position of the signal lever, that the latter is locked in the "off" position. Consideration of Fig. 68 will show that this is really the case, and the signal lever cannot be fully replaced in the "on" position until the armature, A, has again been released. This release takes place when the train passes over the rail treadle near the signal actuated, and the word "free" again replaces "locked" at the opening in the instrument case. In replacing the lever in the "on" position, *t* again raises L and the armature. The latter is retained by H, and the former by projection, *g*, resting on the friction wheel of C, and, so far as the electrical control of the signal is concerned, the apparatus is ready for a similar cycle of operations. The word "locked" again appearing at the opening,

FIG. 70.

indicates the locking of the signal lever in the "on" position. The slotted lock bar, M, carries on one side the swinging lever, O (Figs. 65, 66, and 67), and on the other side a second slotted bar, *n* (Fig. 66). As seen in Figs. 65 and 66, O is resting on the top of the rod, N, which is in the position it occupies when the signal lever is in the "on" position. If the plunger, P, is depressed under these conditions, the lever, O, is pressed back until it clears N, and the lock bars, M, *n*, O, drop into the position shown by Figs. 64 and 67 when the plunger is released. The mechanical result of this operation is to exhibit "Train on" at the lower opening of the instrument, and to place the slots of the lock bar, M *n*, in such positions, relatively to the plunger, that the latter cannot be again depressed until certain operations have been performed. The electrical results following the depression of the plunger are the breaking of the one-cell battery circuit by the fall of M (up-line instrument at "C," Fig. 71), and the consequent raising of the semaphore arm at the rear cabin to the horizontal position (up-line instrument at "B," Fig. 71), and the unlocking of the armature, A, at the rear cabin, by the current established by the contact of the spring, S^2, with the battery studs 1 and 2 (Fig. 71). A glance at Fig. 68 will show that when the signal lever is pulled into the "off" position, the rod, N, is drawn downward, and if the plunger has been previously depressed N will slide over the sloping face of O (Fig. 67), pressing it back meanwhile, until it reaches its lowest point, when O being free of N, again takes up a position immediately over the latter. In replacing the signal lever in the "on" position, the upward movement of N raises M, *n*, and O into the positions shown in Figs. 65 and 66, when the plunger is available for use again. If it should be required to place the signal lever in the "off" position, without previous

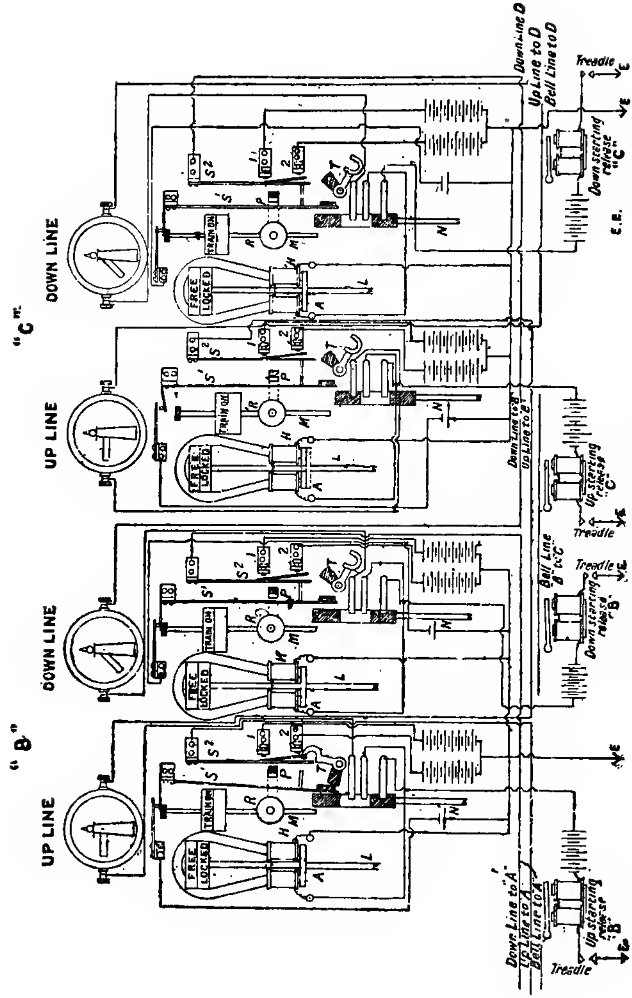


FIG. 71.—Sykes's Lock and Block.

use of the plunger, as would be the case for a train issuing from a relief siding, such as is shown by Fig. 20, the lowering of N simply lowers M, *n*, and O into the position previously described, when, as before, the signalman is unable to depress the plunger in order to allow a train to leave the rear end of the section. It is evident therefore that a necessary condition of the use of the plunger is that the signal lever controlling entrance to the advance section shall be in the "on" position.

In addition to the operations described, the placing of the signal lever in the "off" position breaks the connection of the locking electromagnet with the line wire to the advance cabin, and connects it with the special circuit and battery to the rail treadle (up-line instrument at "C," Fig. 71). Remembering that the apparatus locks the signal lever in the "off," as well as in the "on" position, and that "locked" appears at the upper opening at this stage of the operations, it will be seen that it is impossible to release the armature, A, by a current from the advance cabin quite irrespective of the locking of the plunger at that place consequent upon its use to release the armature in the first instance. In addition to the apparatus described, the system includes a mercury contact rail treadle (Fig. 69), in which the contacts are made by the tilting of the vessels containing the mercury, consequent upon the depression of the rail acting through a plunger on the short ends of two levers, to the longer arms of which the vessels containing the mercury are connected. There is also an automatic arrangement for replacing the signal arm in the "on" position by the passage of the train over the treadle, irrespective of the position of the lever operating the signal under normal conditions.

The automatic signal replacer is shown by Fig. 70. The rod actuating the signal is attached directly to the upper part of the box containing the apparatus, and the slide bar, *f*, is worked by the lever from the cabin. The normal position of the sloped upper end of *f* is under the lever *l*, in which case the slot on the upper surface of *l* engages with the slot on the lower surface of *p*, the latter being pulled into a vertical position by the spring, *s*. Under these conditions the box and the apparatus it contains work with the movement of the signal lever, the upward movement being transmitted from *f* through the levers, *l* and *p*, to the case and the rod working the arm, and the downward movement by the greater weight of the box and rod as compared with that of the signal arm outside the centre on which it turns. If the electromagnet is energised, the hammer, *h*, is released and falls upon the rod, *i*, and disconnecting the two slotted levers, *l* and *p*, allows the box to fall and place the arm at danger. The wheel, *w*, is pressed outwards by the sloping end of *f*, and causes *p* to turn on its centre. The Λ-shaped projection of *p* engages with the wheel, w_1, on *h*, and causes the latter to assume its original position. When the signal lever is placed in the "on" position, the slide, *f*, is lowered, and *l* engages with *p*. The apparatus is then ready for further use.

Consideration of the illustrations, and description of the functions of the various pieces of apparatus forming the system, will show that the objects aimed at in the design do not differ materially from those of other systems, but the arrangement of the apparatus is novel, and the electrical devices are of the simplest possible character. Fig. 71 is a diagram of the connections for a simple block section such as is shown by Fig. 19; but the block bell connections are omitted, as they differ in no way from those described in connection with the three-wire single-needle system, and are entirely independent of the block indicators and locking apparatus. The paths of the currents will be easily traced from Fig. 71, which is drawn to represent the positions of the apparatus on the assumption that a train is passing through the section from "B" to "C" on the up line. This train has been accepted by D as shown by the horizontal position of the semaphore arm of the up-line instrument working from D; and the change in the connections of the electromagnets shows that the starting signal at "C" is "off," whilst the position of the armature and the "locked" indication exhibited show that the signal lever is locked in the "off" position. The indication "Train on" at "C" shows that the plunger has been used to liberate "B's" signal, and is itself now locked. The position of "B's" electromagnet connections and the "locked" indication exhibited show that the train has passed over the treadle at "B," and that the signal lever has been placed in the "on" position; whilst the position of the switch, T, at "B" indicates that the train has not been cleared back to "A," or that "B" has undertaken shunting operations involving the fouling of the running line inside the starting signal. The switch, T, in the position shown at "B's" up-line instrument would embrace the plunger rod and prevent it being used inadvertently.

The novel arrangement of the battery used in operating the plunger is intended to minimise the chance of inconvenience being caused by failure of the battery or its connections. The batteries act in parallel when in use, and the connection to the battery terminals in the instrument are duplicated. Of course the chance of failure with two batteries, each capable of doing the work, is much less than with one battery alone. As shown in Fig. 71, however, failure of the battery earth would render both batteries inoperative, and it would therefore be necessary to carry the duplication of connections to the fullest extent in order to secure all the advantages accruing from the use of duplicate batteries.

Fig. 71, as stated, represents the arrangements for working the simplest possible block section only. For junction working the arrangements have necessarily to be more complex. For such a junction as Fig. 21 represents, releasing treadles are required for each of the *diverging* lines, and each treadle must be capable of working the same instrument. For the lines *converging* at the junction the plunger used to liberate the signal at the rear cabin of any one of the converging sections is arranged to be free for use only when the points have been set for a train coming from that direction. This, of course, with the usual signal and points interlocking, would mean the control of each plunger by the "home" signal for that section, and would ensure all other signals for lines converging there being at danger. Only one treadle would be required for trains coming from any of the converging lines. The arrangements for special cases like junction working, will, however, depend greatly upon local conditions, and it is not possible to give more than the barest outline of the arrangements for such cases.

Circumstances will, however, sometimes arise in apparently simple cases which would seem to indicate the necessity for more elaborate arrangements than are shown by Fig. 71. Fig. 20 is a very simple block station, but if we assume the arrival of a train at that place with a bare time margin in front of a more important train, the necessity for shunting the first will arise. If the releasing treadle is placed at or in advance of the "advance" signal, and there is only one treadle, the train which is to be shunted will require to actuate the treadle—in which case it may actually be in the advance section—before the starting signal (which is assumed to have been lowered) can be replaced. If the starting signal has not been lowered, the signalman knowing the train will require shunting, then some further arrangement will be required to release the plunger in order to use it to enable the second train to advance when the first has been safely shunted. Further consideration of the same case would suggest the possibility, with only the arrangements described, of the shunted train being afterwards allowed to proceed to the "advance" signal, and of a second train being brought into its rear from the rear cabin, since the starting signal being "on" the plunger would not be *absolutely* locked. Of course, the case cited would be readily met by establishing control of the instrument with the siding points levers, or even control of the switch-handle, T, with the same lever, but the case is given simply to show that in apparently simple cases the arrangements for complete safety against the results of carelessness or neglect must be more elaborate than would seem necessary at first sight. Further consideration of the apparatus suggests the possibility of the starting signal being unlocked by contact of the block instrument line wire with another working wire on the same route, and this, in combination with other circumstances not altogether unknown in railway work, might result in two trains being in the section on one line of rails together.

This, of course, is by no means peculiar to the instrument just described, but is common to all classes of instrument in which the movements resulting in the release of locking apparatus or the setting of the indicators in their more important positions, are due to one person only. Of the various classes of instrument already described, only two, Preece's and Winter's—two instruments which have much in common—take notice of the effect likely to be produced in this way. Whilst the danger of serious results from such causes is very much less now than a few years ago, owing to improved construction of lines and greater vigilance in maintaining them in an efficient condition, yet line contacts are not entirely things of the past, and, as has already been remarked, the history of railway accidents is full of instances of curious combinations of circumstances, which would appear as most improbable of simultaneous occurrence. In this system, as in others of a similar kind, cancellation of a signal which has resulted in the preparation of the line for the passage of an approaching train can only be done by special means, which may or may not be immediately available for use by the signalman, and the use of which is an infringement of the automatic character of the apparatus. In some cases cancellation is directly prohibited, and the replacement of the apparatus in its normal position is made by the next train in that direction, it being worked through the section at "caution," in consequence of the defect in the apparatus. Probably such a regulation would do much to promote care in the dispatch of signals asking for the clearance of apparatus for an approaching train, seeing that every lapse and the consequent delay would have to be fully explained.

This system, like others, whilst providing for the automatic clearing of the section by the passage of the train itself, makes no provision for automatic notification of the *entrance* of the train into the section at either of the cabins controlling it. Yet, surely, if it is undesirable for the signalman at the receiving end of the section to trust entirely to his observation for guidance in clearing a section, it must be equally undesirable for him to trust to the signalman at the sending end for notification of the entrance of a train; and circumstances might easily arise where such independent notification would be of the utmost value to the signalman at the receiving end of the section in the event of an unauthorised train entering a section through the prevalence of fog or other similar cause.

Swingbridge Arrangements.—Fig. 72 represents a portion of the main line of one of the through routes to the North. Two important lines from the north and east converge upon a swingbridge crossing

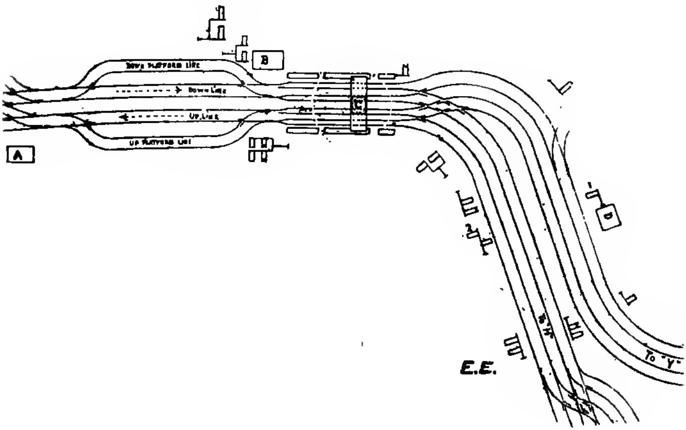


FIG. 72.

a navigable river. All four sets of rails are carried over the swingbridge, but the two "up lines" and the two "down lines" are "bunched," and the bridge is little wider than would be required for the ordinary double line of rails. At the south end of the bridge the lines widen again owing to the station platform lines being distinct from the running lines. Consideration of Fig. 72 will show the necessity for extra precautions in working this section of the line, owing to the possibility of accident resulting from the fouling of the lines at the north end of the bridge, and from the presence of the bridge itself.

This portion of line is divided into two block sections, A B and B D (Fig. 72); C is a cabin on the swing portion of the bridge in which is installed the control of the hydraulic machinery for operating the bridge for the passage of river traffic, but although it is provided with electrical apparatus, connected with B, by which the operation of the bridge is controlled, it is entirely dissociated from the block working of the section, B D, in which it is situated. The signalman at B is in this case the person controlling the operation of all traffic on to the bridge from either direction; and he also controls indirectly the river traffic by means of the apparatus by which the bridge is locked in the position for the passage of railway traffic.

The line is worked by three-wire single-needle block instruments, to which is added an adaptation of Sykes's lock and block to the indicators for the two up lines between D and B. The operation of the bridge is controlled by Sykes's instruments also, and the handles of the two down-line instruments are connected with the signal locking at B.

Fig. 73 is a diagram showing the wires used for signalling and locking between A and B, B and D, and B and C. The construction of the up-line block instruments at B, working to D, is shown by Fig. 74, and the additional apparatus to the corresponding instruments at D is shown by Fig. 75. So far as the block instruments themselves are concerned, they differ in no way from others previously shown, and the novelty of the arrangement consists in the addition

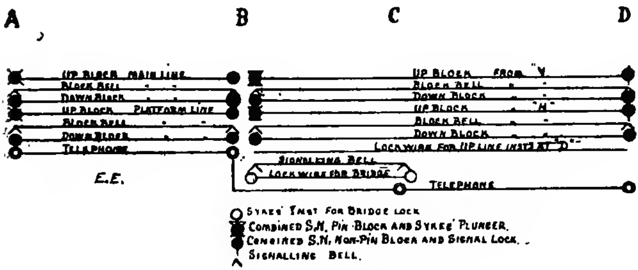


FIG. 73.

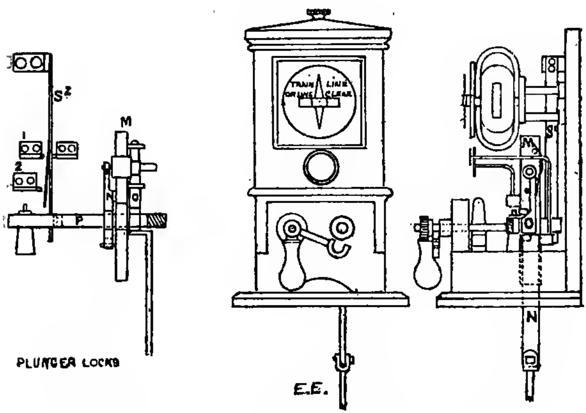


FIG. 74.—S N Instrument with Sykes's Plungers.

of the lock bars M *n* O, the continuation of the lever L, and the plunger P (Figs. 65, 66, 67), for specific purposes. Practically, the apparatus shown by Fig. 64

is split into its two component parts, the plunger and its locking apparatus being added to the "up" line

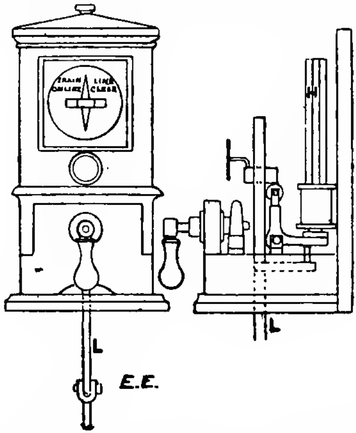


FIG. 75.—S N Instrument with Sykes's Signal-Locking Apparatus.

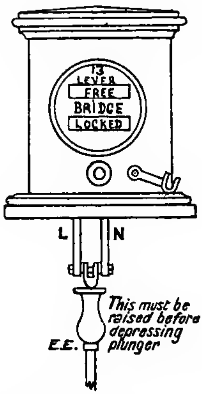


FIG. 76. Bridge-Locking Apparatus.

instrument at B, and the signal locking, or receiving portion of the complete instrument, consisting of the polarised electromagnet, armature, etc., being added to the corresponding instrument at D. The special bridge-locking apparatus is shown by Fig. 76, the arrangements of apparatus at C being identical with those at B. The apparatus is practically the same as is shown by Fig. 64, with the exception that S^1 and the other connections for the semaphore indicator are omitted as the latter is not used. The handle of the switch, T (Figs. 65 and 67), is retained, but it is merely mechanical in the present arrangement. The general arrangement of the instruments at B relatively to the signal levers working the signals, points, clearance bars, and inter-cabin control, is shown by Fig. 77, together with the interlocking of the "down" line instruments to A with the lever locking. Fig. 78 shows the electrical connections for the locking apparatus between B and C and B and D. The connections of the block instruments are not given, for reasons already adduced. It will be observed that the locking and indicating apparatus of the additions to the up-line block instruments at B and D are operated by one lever instead of by two, as in the ordinary arrangement of Sykes's instruments for block working, and this of course follows from the separation of the different parts. The levers, N, operating the plunger locks at B are connected together, as shown diagrammatically in Fig. 77, so that only one plunger can be used at once. The plunger of either instrument can only be depressed *after* the lever operating the rod, N, of that instrument has been moved into position for a train to approach on that line, and as this lever is interlocked mechanically with other levers necessary to that particular line, it follows that the road must be completely set at B before either of

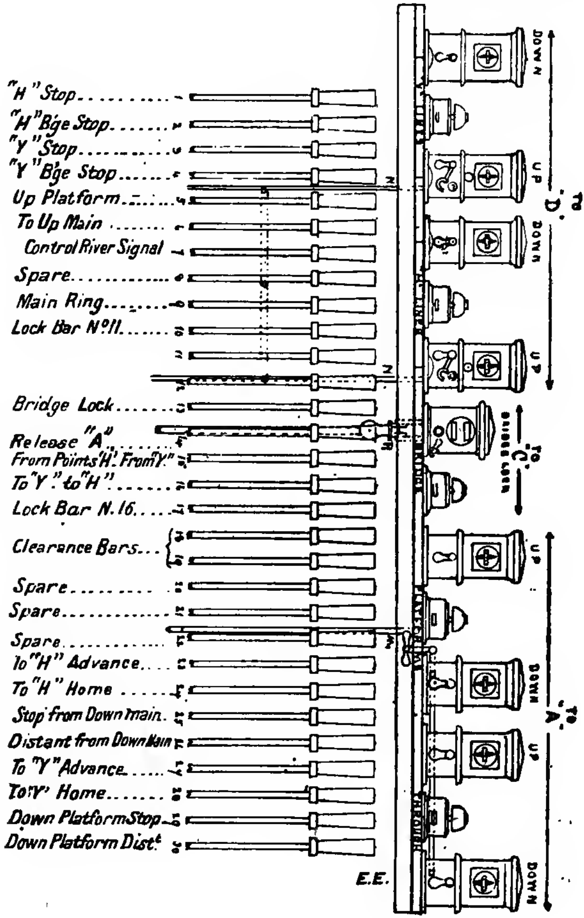


FIG. 77.

the electrical locks at D can be released, and even then only the lock controlling the signal for one particular line can be released.

The signals 1 2 (Fig. 72) at D are those which are under electrical control from B. The levers, at D, working these signals are also connected, so that

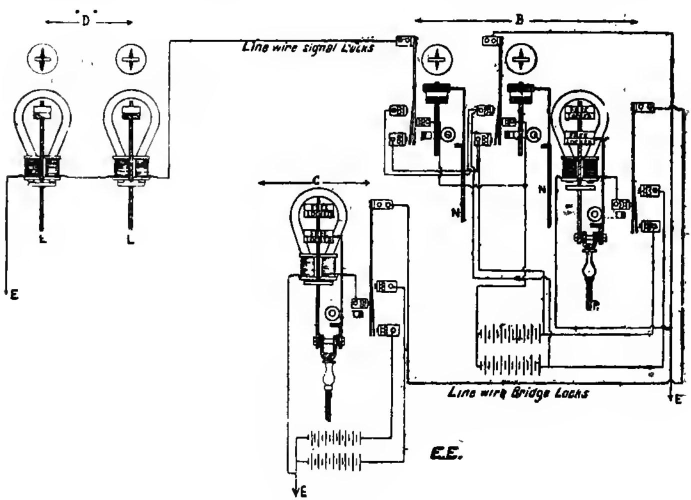


FIG. 78.

the operation of the lever for one of them locks the rod, L, of the other instrument, so that it cannot be released by a current from B, however sent. This is an additional check against fouling at the north end of the bridge, and is quite independent of the action of the plunger locks and the connection existing between the two rods, N, at B.

As will be seen, B effectually controls the approach of trains from D, and so long as the apparatus is in order and the mechanical signals are obeyed it is impossible for trains to foul each other at the north end of the bridge. Fouling between a train passing from B on the "H" line and a train approaching B on the "Y" line is provided against by the mechanical interlocking of the signal and point levers.

In addition to the provisions described for ordinary working over the "bunched" part of the block section, B D, provision has to be made for blocking all four lines from both directions during the time the bridge is open for river traffic. The up lines from D to B have been described. B controls the down-line signals at A by lever 15 (Fig. 77), and this lever is interlocked with the handle, M_1, which, when placed vertical, causes the down-line instruments at A and B to indicate "Train on line." Hence, *so long as the mechanical signals are obeyed*, the bridge is protected against the approach of trains from A on the "down" line.

When it is necessary for the bridge to be opened for river traffic, C notifies B by the code arranged for use with the separate bell circuit. When the latter is ready, after performing the operations indicated for the protection of the down line, etc., he operates the bridge lock lever (13, Fig. 77) and raises the lever P_1 by hand, and by depressing the plunger unlocks the instrument at C, enabling him to make the preliminary arrangements for opening the bridge. C then raises the rod, P_1, of his own instrument, and by depressing the plunger locks the lever 13 at B in the open position, and thus prevents it being inadvertently put back. Under these conditions C is master of the situation, and B is unable to undertake any operation involving the approach of trains from either A or D. When the bridge is again ready for railway traffic the operations are reversed, and C becomes dependent again upon B for permission to operate the bridge on the succeeding occasion.

Blakey and O'Donnell. — Fig. 79 represents, diagrammatically, Blakey and O'Donnell's method of interlocking and automatic signalling as adapted for use with single-needle instruments. As will be seen, the design requires the use of an additional line wire between the treadle at A and B.

The hammer, *h*, of the signal replacer, G (Fig. 79), is held off by the rod *i* (Fig. 70) when a current passes through the coils of the replacer only. The arm, therefore, normally stands at danger through the rod *f* not engaging with *p*, and the latter with *e*. Consideration of Fig. 79 will show that the "Line clear" current from B passes through the coils of R, and, in consequence, the armature of the latter makes contact at *l*. If the signal lever is now pulled into the "off" position, the replacer circuit is completed at K, and the battery B_3 sets up a current through G, which holds the hammer, *h* (Fig. 70) in position, and allows *f* to gear with the mechanism, and to lower the signal.

When the train passes over the treadle at A, the battery B_4 at B energises the relay, R, the treadle at B forming a closed circuit normally. The armature of R_1 is attracted, breaks the circuit of the

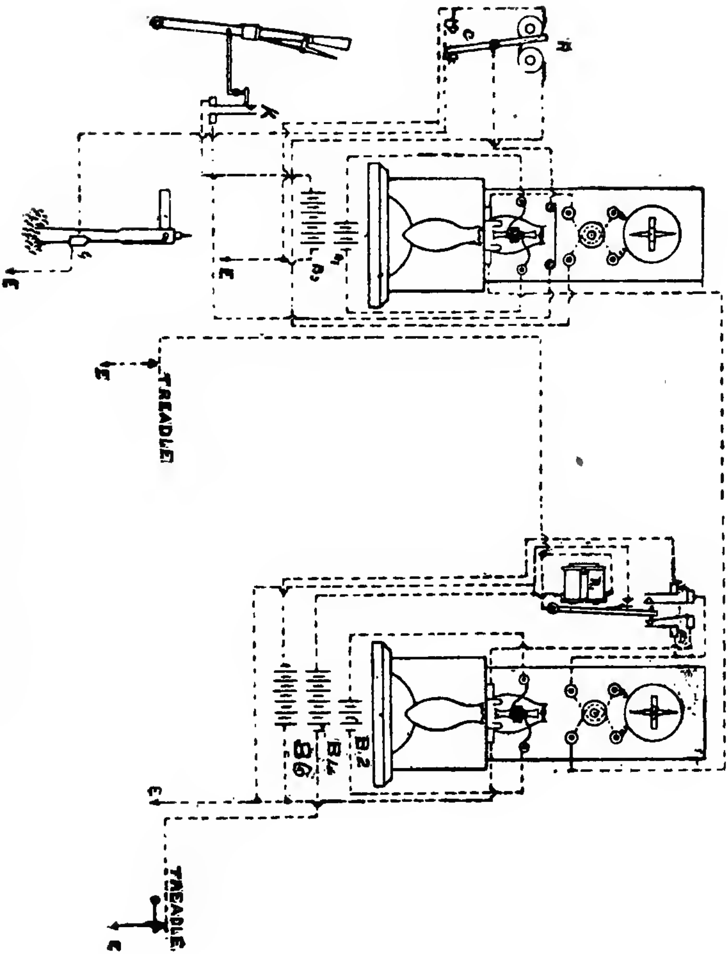


FIG. 79.—Blakey and O'Donnell's Interlocking.

instrument battery, B_2, and at the same time completes the circuit of B_6 through the instruments at B and A, and through the coils of R at the latter place.

The needles now indicate "Train entering section," and the armature of R breaks the contact at *c*. The signal replacer circuit being broken, the hammer, *h* (Fig. 70) being no longer held up, falls upon *i*, and puts the signal to danger.

The current sent by the depression of the treadle at A continues only during the period of such depression. An examination of the connections at B will show that the movement of the armature of R, under the action of the treadle current, completes a second circuit through R_1, the armature, and the treadle at B, which maintains the armature in position for indicating "Train entering section."

On the arrival of the train at B, depression of the treadle there *breaks* the circuit, B_4, treadle, and R_1, and the armature of the latter returns to the position shown by Fig. 79. The movement of the armature of R_1 breaks the circuit of the battery B_6, and completes that of the battery B_2.

It will be noticed that the signalmen at B and A are not actively engaged on the operations necessary to indicate "Train entering section," since the operations are performed automatically by the action of the train passing over the treadle at A. The instrument handle at B may stand in any of the three positions without affecting the indications during the time the train is in the section.

Should the signalman neglect to unpeg the handle from the "Line clear" position, it will be seen on consideration that when the train passes over the treadle at B the instruments will at once indicate "Line clear" at both stations, and the signalman at A will be in a position to pull off the signal controlling entrance to the section without having *asked* permission previous to doing so.

The design affords an intimation to the signalman at the receiving end of the section of the entrance of the train into the section he controls independently of what may be done by the signalman at the sending end of the section, and this is a point of considerable importance. Another point of some importance is that neither of the signalmen is in a position to alter the "Train entering section" indication. Other points are the control of the starting or advance signal at A by the signalman at B, and the automatic release of the circuit by the arrival of the train at a certain point at the receiving end.

A similar development of the principle of automatic signalling is shown by Fig. 80, which represents Sykes and O'Donnell's system as applied to single-needle instruments, and which is at present on trial on the Great Northern Railway at Finsbury Park and elsewhere.

The additional apparatus consists mainly of the polarised relay, R, and the differentially-wound electromagnets, R_1 and R_2, the contact, K, controlled by the position of the lever of the signal controlling entrance to the section, the treadles, and the Sykes signal replacer, G. The spring contacts, *a* at A, and

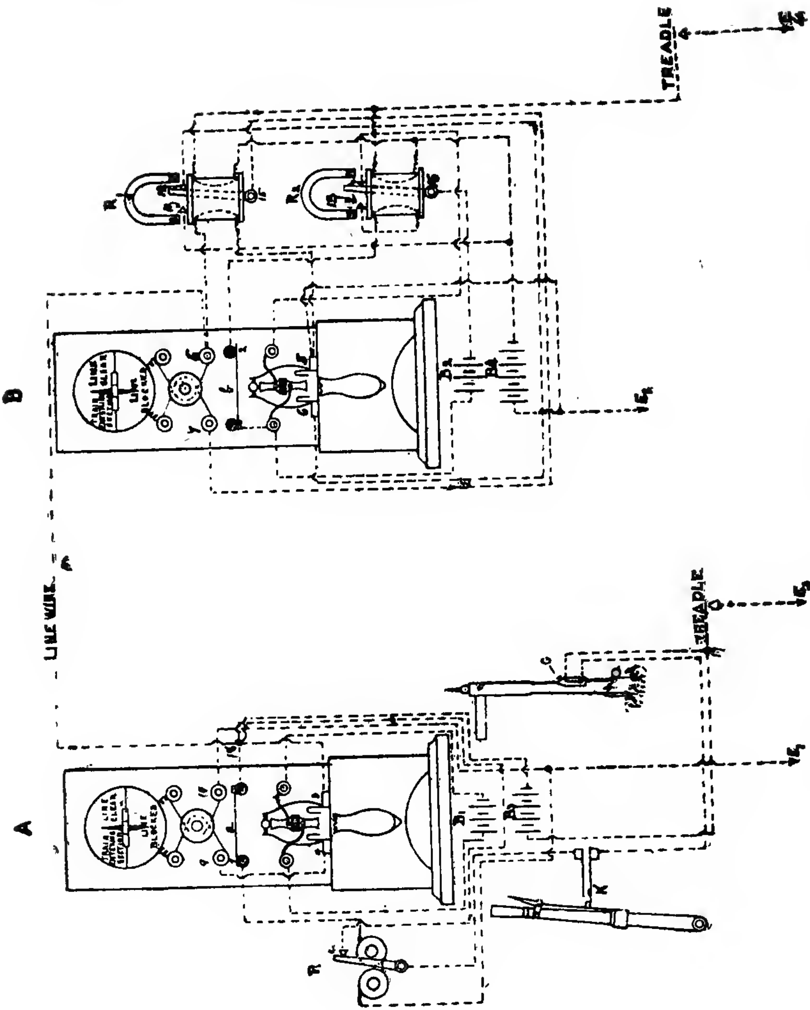


FIG. 80.—Sykes and O'Donnell's Interlocking for S N Instruments.

b at B, are shown in the positions they occupy when the needles are indicating "Line blocked," as in Fig. 79. If the handle at B is pegged to "Line clear" the spring *b* is caused to break contact at 2, and if the handle at A is moved from its normal position the spring *a* breaks contact at 1. The movement of the spring *a* is necessary in order to prevent currents originating at A from having the same effect upon the relay, R, as similar currents originating at B are required to have. The movement of *b* is necessary to ensure against premature replacement of the armature of R_2 to the contact 14 in the event of the signalman having neglected to unpeg the handle from "Line clear" after the receipt of the "Train entering section" signal.

The contacts made by the armatures of R, R_1, and R_2 are as shown when the needles are indicating "Line blocked." A portion of the current originating at B when the instruments are indicating "Line clear" causes the contact *c* of the armature of R, at A, to be broken. The remainder of the portion of this current which reaches A is used to deflect the needle of the instrument. Another portion of the current set up in pegging the handle at B to "Line clear" passes through one of the coils of R_1 at B, but strengthens the contact between the armature and 12. The paths of the "Line clear" indicating current are shown diagrammatically by Fig. 81, from which it will be seen that the relay R and the S N instruments are in parallel at A, and that both these form a shunt on the coil of R_1 at B.

When the "Train entering section" *signal* is sent on the bell, the signalman at B should peg the needles to that position. If he does not, however, the passage of the train over the treadle at A sets up a current from the battery B_3, which, dividing at E_3, passes partly by E_1 and partly by E_2. The part passing by E_1 divides again, one portion passing through R replaces the armature against *c* and completes the signal replacer circuit through 17, G, K (the signal lever being pulled into the "off" position), *c*, 1, *a* to 18. The other part passing by E_1 passes to 10, the

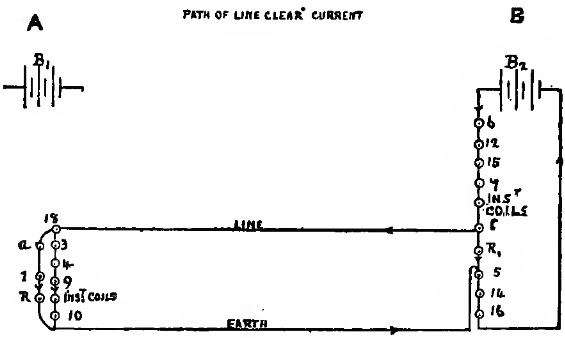


FIG. 81.

S N instrument coils (deflecting the needle to "Train entering section"), 9, 4, 3, and 18. These two portions join at 18 and return to *Z* of B_3.

The part of the current originating at B_3 on the depression of the treadle at A, which passes to E_2, passes further to 5 at B, thence through one coil of R_1 (reversing the position of the armature to contact 11), thence to 8, line wire, 18, and *Z* of B_3.

It will be noticed that the reversal of the armature of R_1 breaks down the circuit of the battery B_2, which has hitherto been maintaining the "Line clear" indication, and completes the circuit of the battery B_4.

The current set up at B_3 by the depression of the treadle at A lasts only during the period of depression. During the time the train is passing over the treadle at A both batteries, B_3 and B_4, are in operation. After the train has passed completely into the section the work of maintaining the indications and other necessary operations is performed by B_4 alone.

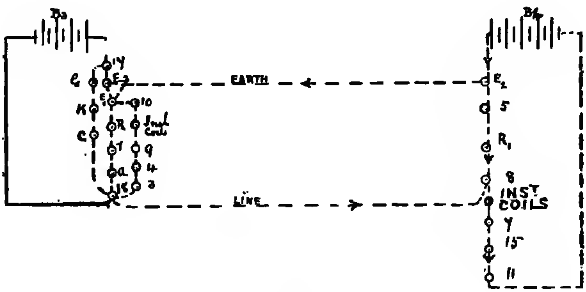


FIG. 82.

Fig. 82 is a diagrammatic representation of the path of the current originating at B_4 during the time the latter is acting alone. As will be noticed, the direction of this current through the various pieces of apparatus is the opposite of that of the "Line clear" current. Further, the replacer circuit at A is also traversed by a portion of the "Train entering section" indication current.

On the arrival of the train at the treadle at B, a fresh current is set up from B_4 by the depression of the treadle. This current divides, part passing through one coil of R_2 and part through one coil of R_1. The result is to replace the armature of R to contact 12, and to place the armature of R_2 to contact 13. The result of these two operations is to remake the circuit of B_2 at 12 and to complete a local circuit under certain conditions through C of B_2, *b*, R_2, 13, 16, *Z* of B_2. The condition to be observed for the completion of this local circuit is that the handle of the instrument at B shall be in such a position as to complete the contact between *b* and 2—that is to say, the handle must not be in the "Line clear" position. The current thus set up through R_2 replaces the armature of the latter to contact 14, and sets the apparatus in position for use for further traffic.

Besides the operations described, the apparatus acts in a most ingenious way to prevent the signal controlling entrance to the section from being lowered when either the "Train entering section" or the "Line blocked" indications are being exhibited.

The form of replacer is shown by Fig. 70. As already explained, the arm is lowered by the rod *f* engaging with *p*, and being locked by the lever, *l*, the hammer, *h*, when no current is passing through the electromagnet, engaging with the lever attached to the armature, and being held by it. Returning to Fig. 80, we find that the "Line clear" current from B breaks the replacer circuit at *c*, and, consequently, no current can pass through G, even when the contact, K, is made by the lever being pulled into the "off" position. On the train passing over the treadle at A, the contact at *c* is made by the currents set up from B_3 and B_4, and a current passes from B_3 through G, K, *c*, and 18, which operates the replacer and puts the signal to danger. If the signal lever is replaced in the "on" position *completely*, the current through G will be broken by the opening of the circuit at K. The rod *f* (Fig. 70) will then be in its lowest position, and under normal circumstances the replacer would be geared for lowering the signal at any future time. It will, however, be noticed that K is operated, not by the mere replacement of the lever, but by the lowering of the catch of the lever. The circuit through G is therefore complete until the lever is fully in position and the armature of the replacer does not retain the hammer, *h*, and the rod *f* cannot engage with *p*. Further consideration will show that any attempt to lower the signal by subsequent movements of the lever will be ineffective owing to the closing of the contact K by the lifting of the catch of the lever setting up a current which energises the electromagnet of the replacer during the whole time the contact, *c*, is maintained. Further consideration will show that if the lever of the signal is replaced in the "on" position during the time the train is in the section, it will be necessary to pull it into the "off" position before the mechanism of the replacer will engage so as to allow the signal to be lowered.

Summary of Objects.—The objects aimed at in the designs shown by Figs. 79 and 80 are obviously identical, and may be summarised as on the next page:

(*a*) Effective control of the signal controlling the entrance to the section by the signalman at the advance station.

(*b*) Automatic intimation of the actual entrance of a train into the section.

(*c*) Automatic clearance of the section.

Whilst these are the chief objects of both designs, they differ considerably in the means by which they are obtained, and slightly in the degree of perfection attained by the apparatus.

Fig. 79 may be called a five-wire system since that is the number of line wires required to operate the apparatus in its proper sequence for a double line of rails. Fig. 80 accomplishes the work with three line wires, and four batteries as against five batteries required by Fig. 79. Fig. 79 is, moreover, defective and inferior in that it does not necessitate independent operations for the exhibition of "Line clear" for successive trains.

Both systems aim at obtaining changes in the indications of the instruments without the intervention of the signalmen at either end. Whether this is desirable is a question upon which opinions may differ considerably, and opens a wide field for argument on the functions which should, or should not, be performed by the signalman. Whether the signalman is to be divested of responsibility, and work as an automaton under the control of the apparatus, or whether he himself is to be the controller of the apparatus, with such restrictions against the chance of error on his part as experience suggests and circumstances allow, are points which it is impossible to settle off-hand. It does not, however, appear desirable to the author to carry the automatic working to the extent shown by Figs. 79 and 80, in so far as the clearing of the line on the passing of the train out of the section. Consider what is meant by the "Train out of section" *signal* as given under the ordinary conditions of working. Clearly it is an intimation from one signalman to the other that the former has satisfied himself that the *whole* of a train previously signalled between them has passed out of the section, and the *subsequent indication*, "Line blocked," is a permanent reminder of this. In such a case both signalmen are concerned in the operations necessary before the "Train on line" indication is changed to "Line blocked."

On the other hand, if the signalman at the receiving end relies upon the indication exhibited in consequence of the passage of the train over the treadle before giving the "Train out of section" *signal*, he may come to rely upon it too implicitly, and, since the first vehicle actuates the treadle, he may on occasion find that the line has been cleared by an incomplete train. It is true that the signalman is not relieved from responsibility in seeing that the *whole* of the train passes, but the treadle operates to exhibit "Line blocked" whether this is the case or no.

The signalman at the sending end has no means of distinguishing the indication exhibited in consequence of the actuation of the treadle at B, from that due to failure of the line wire or the batteries operating the "Train entering section" indication. It is true that the *indication* "Line blocked" may be followed by the "Train out of section" signal, but that is not its proper order.

To the author it appears that the only legitimate use of automatic apparatus is such as will prevent the signalman from performing such operations as indicate changes of condition before the time arrives for doing so. Anything which tends to lessen the sense of personal responsibility on the part of the persons charged with the working of traffic is to be deprecated. By all means the signalman should be checked in his actions by the trains he operates, but these trains should take no part in performing the operations pertaining to the signalling itself.

Single-Line Working.—The principles under which single-line block working is carried on differ in no way from those adopted for ordinary double-line work, the section limit being imposed upon trains passing between any two adjoining cabins. Inasmuch, however, as trains passing in either direction have necessarily to pass over the same line of rails, it is obvious that some other precaution than that afforded by the ordinary form of block is necessary to ensure that two trains shall not, through negligence in any way, enter the section from opposite ends at the same time. This is generally accomplished by the "staff," or "staff and ticket," system of working single lines, to which block working is often merely supplementary.

In single-line working the line is divided into a convenient number of parts, at the junctions between which passing places are provided for trains proceeding in opposite directions; and the driver of any train passing through any such section, as B C

(Fig. 83), must obtain from the signalman at the entrance to the section some visible authority other than, and supplementary to, that given by the usual

FIG. 83.—Staff Sections, B-C, C-D.

mechanical outdoor signals, and must deliver the same to the signalman at the exit end on his arrival there. In the case of the simpler single lines this

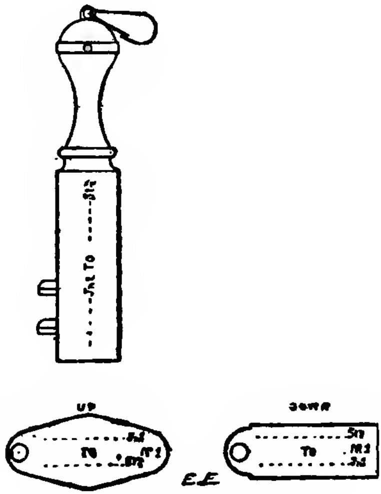


FIG. 84.—Staff and Tickets.

authority to proceed is given by the signalman handing the train staff (Fig. 84) to the driver of the train about to enter the section. As there is only one staff to each section, and as no train may enter a section without the staff accompanying it, the driver, on receiving the staff, knows that no train will be sent from the opposite end, and he may therefore proceed as far as the next staff station. It will be noticed that the signalmen at intermediate staff stations will have two staffs to deal with, whilst the signalmen at the ends of the single line will have only one to handle. In order to prevent interchange of staffs, each is, in some way, made distinct from the others, either by difference in form or colour, or by being appropriately lettered.

Trains on single lines worked by "staff" alone are liable to considerable delay, more especially where the line is fed with traffic at one or more points, such as at C (Fig. 83). If a train is sent from B to C, say, and takes the staff, no train can pass between these points in the same direction until the staff has been returned to B. This may be done by a train passing from C to B in the ordinary course, or a special engine may be sent with the staff to B; or, in the event of an engine not being available, the staff may be sent by a messenger on foot, or horseback, if the circumstances are sufficiently urgent. In any case, considerable delay to traffic results from any deviation from the ordinary or prearranged working of the line, and special traffic must be carefully arranged to fit in with the ordinary, and special advice of additional trains must be given to the officials concerned in the working of the line, or that portion affected.

In order that trains may pass over any staff section in the same direction in succession, the modification known as the "staff and ticket" is introduced, the "ticket" being a supplementary authority for the driver to proceed, which is understood to be available for use *only* when the staff for the section to be entered is in the possession of the signalman at the *entrance* to the section.

The staff usually takes the form of a cylinder of brass or hard wood of distinctive shape, and has engraved upon its surface the names of the points constituting the staff section for which it is available. The "ticket" is usually a flat iron plate of oval or rectangular form (Fig. 84), and is similarly lettered. In addition, the very necessary information respecting the direction in which it is to be used—*i.e.*, for "up" or "down" journeys—and its number are marked upon it. By these means the "ticket" affords a check upon the signalman, and ensures the use of the proper ticket, and also affords information to the driver, by its number, of the condition of the line through which he is to proceed. Each cabin is provided with a small lock-up box, in which a certain number of "tickets" are kept for use as required. The key for this box forms part of the staff, and the ticket-box, therefore, can only be opened by the signalman who has possession of the staff. If a train is to be sent away from the staff station, and it is certain that another will require to follow it before the staff could be returned under ordinary working conditions, a "ticket" is given to the driver, and the staff is retained by the signalman until such time as it becomes necessary for the staff to be sent to be available for trains in the opposite direction, tickets, in their proper numerical order, being delivered to drivers of all successive trains except the last, to whom the staff is given. This method constitutes a great advance on simple staff working and enables traffic to be handled with much greater facility. Even with this modification, however, the schedule of arrangements of trains must be closely adhered to, and if any deviation from it is made, or trains are sent unexpectedly, it is a mere matter of chance if delay does not ensue.

Fig. 83 shows a single line divided into staff stations with passing places for trains proceeding in opposite directions. The number of staff sections for any line will depend upon its length, the amount of traffic passing over it, and the number of points at which traffic is lifted or delivered. For busy lines it is, of course, of advantage for the staff sections to be short, in order to lessen the delay to trains waiting for others to clear the section. On the other hand, cutting the line into numerous staff sections involves expense in providing passing places, staff cabins, and signalmen; and delays to through traffic in consequence of the frequent slackening of speed to exchange staffs or "tickets."

Where the "staff and ticket" system is in use, and trains proceeding in the same direction may follow each other, a combination of the block system with the staff is found to be advantageous. In Fig. 85 a portion of the staff section, B-C, is shown as split into three block sections, B-M, M-M^1, and M^1-C. Block apparatus of any suitable kind is provided in B, M, M¹, and C, and the usual complement of mechanical signals is provided at each place. A train leaving B, say, with a ticket for C would be signalled on the block instrument in the usual way, and would be cleared back to B when it passed M and was proceeding to M¹. A second train might then be sent away from B in the same direction either with a second ticket, or the staff, as might be desirable. Between B and C the trains are worked under block rules only, and they are not required to stop or slow down for the exchange of staffs at M or M¹, but may run straight through,

FIG. 85.—Staff Section B-C with Intermediate Block Sections, B-M, M-M¹, M¹-C.

so long as the proper mechanical signals are exhibited. At the same time there is nothing to prevent the ordinary work of lifting or leaving traffic being performed at either M or M¹. In this way, as will be evident, a glut of traffic passing in one direction can be much more readily dealt with than by the simple staff, or staff and ticket, systems alone. Although the fact that between B and C there may be three trains would seem a violation of the principle underlying the staff system, yet, on closer examination, it will be evident that the primary object of the staff is to prevent trains entering a section from opposite ends at or about the same time, and the trains in the case considered are all passing in the same direction. Further examination will show that the staff section space has been replaced by a shorter block section space, and so long as no irregularities occur the system is perfectly safe.

There is nothing special in the instruments used for single-line block working where nothing more than the mere indication of the condition of the line is required. Any form of instrument in use on double lines may be easily adapted to single lines. The single-needle instruments described in connection with double-line working only require to be provided with a pin at each end for pegging the needle, instead of at one end only, there being, of course, only one indicator for each section, and only two wires required. Winter's block instrument (Fig. 45) simply requires *Z* of the line battery to be connected to the terminal, Sp, to enable it to be used for single lines. In this case one instrument serves for the two sections which are controlled from the cabin. Block instruments, in the design of which some attempt has been made to secure a degree of automatic control, have some claim to be considered as capable of being used on single lines without the aid of the staff system, but such adaptations have made no progress in this country. Other instruments, such as Walker's, Harper's, Fletcher's, and the single-needle instruments can only be used to facilitate traffic over the lines, and are subordinate to the staff as a *safety* appliance.

The want of flexibility in the staff system, and the delay consequent upon any deviation from the ordinary or prearranged working, has led to modifications, and instruments have been devised by means of which safety is ensured, and much of the delay to the traffic is obviated. The principal alteration consists in the

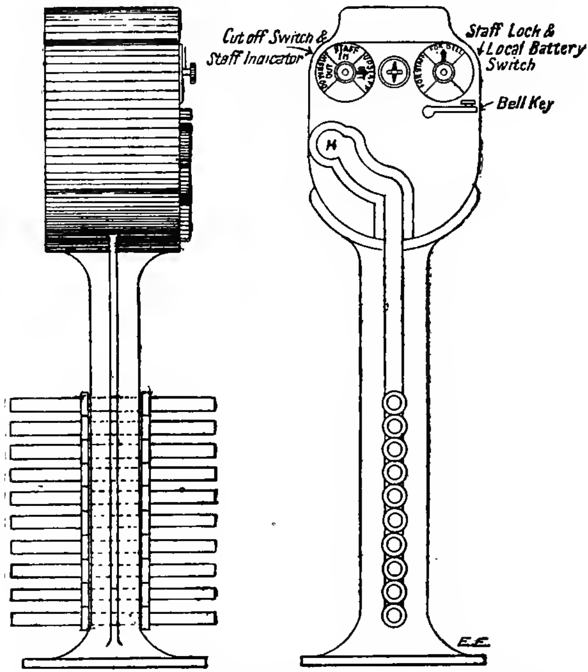


FIG. 86.—Webb and Thompson's Electrical Train Staff Instrument.

abolition of the single staff governing the passage of traffic in both directions, and the substitution of a number of staffs at each end of the section. The staffs for any one section are all similar, and are of equal value; and these are contained in instruments, placed in the cabins, which are so constructed that only one staff can be withdrawn from the instrument for any section at a time. Whilst such an arrangement enables traffic to be more readily handled, and releases the rigidity of the simpler system, it is obvious that the precautions to be observed in such a method

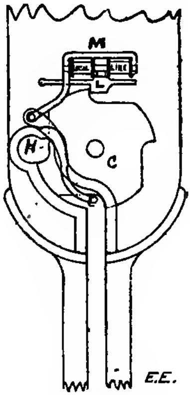


FIG. 87.

are necessarily more elaborate, and the control of the instruments containing the staffs must be absolute.

An interesting instrument, from an electrical point of view, for this purpose, is Webb and Thompson's electrical train staff instrument, which is shown by Figs. 86-88.

Fig. 86 shows front and side views of the exterior of the instrument with a number of staffs in position, together with the two switches, indicator, and bell key. Staffs can only be inserted or withdrawn from the instrument at the opening, H. Staffs may be *inserted* at any time, but can only be *withdrawn* under prearranged conditions.

Fig. 87 represents the arrangement by which the staffs are locked in the staff pillar. The cam-wheel, C, turns on its centre. When a staff is raised with the object of withdrawing it, it must lift the bent lever, *l*, before entering the passage to H. The compound electromagnet, M, is lifted by the movement of *l*, and if it is energised *properly* it lifts the lock, L, with it. Otherwise L remains in the position shown. If L is raised with M, the motion of the staff, under the movements of the signalman, towards H causes the cam-wheel, C, to turn, and allows the staff to pass to H, and be withdrawn there. In the event of M not being properly energised, L will remain as shown, and the cam-wheel being locked against turning in the necessary direction, it will be impossible to withdraw the staff under the conditions. Obviously, therefore, the withdrawal of a staff depends upon the excitation of the magnet, M, whilst a glance at Fig. 87 will show that staffs may be put into the pillar at any time.

The instrument is provided with a switchboard (Fig. 88) of five switches, four of which are two-way switches, whilst the fifth has only one contact. The switches marked No. 1 and No. 2 are actuated by the movement of the cam-wheel (C, Fig. 87), and change the positions of contact every quarter revolution of C.

The switch marked "bell key" is actuated by the depression of the lever similarly lettered in Fig. 86. Normally the bell key (Fig. 88) makes contact at "23"; when the lever is depressed, contact is made at "33." The "local battery key" and "staff lock

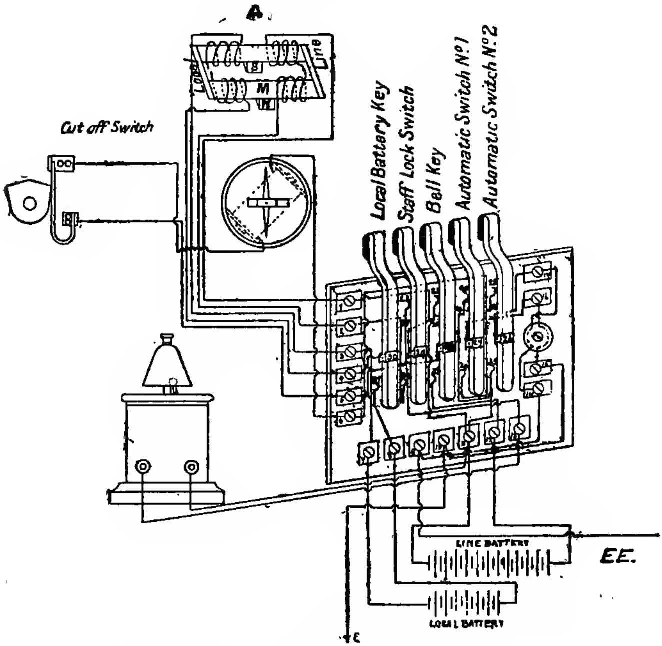


FIG. 88.—Webb and Thompson's Electrical Train Staff Diagram of Connections for One Section of Single Line.

switch" bars (Fig. 88) are operated by the switch on the right hand of Fig. 86. When the handle is as shown by Fig. 86, the "staff lock" bar makes contact at "22" and the "local battery" bar is disconnected. When the handle is placed to "For staff" the "staff lock" bar makes contact at "32" and the "local battery" bar at 31. The cut-off switch (Fig. 88) is operated by the left-hand switch, shown in Fig. 86. When the indicator attached to the handle is in the position shown it does not affect the "cut off" switch, shown in Fig. 88, but when held *hard* down in the position shown the spring is displaced from the upper stud, and the circuit broken. The indications "Staff in," "Up staff out," "Down staff out," of the left-hand switch do not depend in any way upon the actual conditions being similar to the indication exhibited. They are merely reminders which the signalman may or may not place in accordance with the actual state of affairs, without affecting the working of the apparatus. The staff lock electromagnet, M (Fig. 87), is shown diagrammatically in Fig. 88, and the construction of the indicating magnetic needle is shown in the same figure.

All train distinguishing and other signals passing between the signalmen at opposite ends of the staff section, are given by a bell code; the bell being rung by depressing the key shown on the front of instrument in Fig. 86.

Bell Code.—The bell code in use does not differ materially from that in use for double-line working in cases where all distinguishing signals are by bell, and need not be further referred to.

The operation of withdrawing a staff at either cabin is very simple, and can only be done by the joint action of the two signalmen at opposite ends of the section. (The connections being identical at each end only one station is shown in the diagram.) Assuming that a staff is to be withdrawn at "A" under the conditions of the apparatus as shown by Fig. 88, and that the preliminary notification signals have been given and accepted, the operation is as follows: "A" places the right-hand switch to "for staff," "B" depresses bell key and keeps it down, "A" withdraws staff, and then turns the left-hand switch to "up staff out," turning the switch *hard down* before releasing it. This latter action notifies "B" that the staff is out, and he releases the bell key. This completes the operation, the right-hand switch at "A" being replaced automatically to "for bell" during the operation of withdrawing the staff.

Remembering that the "local battery" bar is making contact at "31," and the "staff lock" bar at "32," at "A," and that the "bell key" at "B" is making contact at "33," it will be seen that two currents are passing around the staff lock electro-magnet, M, at "A"; and following the directions of the currents through the windings of the "local" and "line" coils respectively, it will be found that the resultant magnetic effect is to produce poles at "N" and "S" (Fig. 88). Under these circumstances the lock, L, will be raised, with the electromagnet, M, by the movement of the lever, *l*, when the staff is being withdrawn from the pillar towards H (Figs. 86 and 87). The paths of these currents, in the positions occupied by the automatic switches Nos. 1 and 2, at "A" and "B," is as follows.

"A."	"B."
	From carbon of line battery to 12, 33, 28, 5, cut-off switch and galvanometer, 6, 18, 25, 26, 17, 14, 9, and line wire to
9, 14, 17, 26, 25, 18, 6, cut-off switch and galvanometer, 5, 28, 23, 20, 29, 32, 2, line coils, 1, 11, 19, 24, 27, 16, 15, 10 to earth and	10, 15, 16, 27, 24, 19, 11 to zinc of line battery.
Local battery.	
From carbon to 8, 31, 30, 4, local coils, 3, 7, to zinc.	

These currents excite the electromagnet, M, and it will be noted that not only are two currents necessary, but their directions must be in accordance in order to do this. Since the electromagnet is provided with a complete magnetic circuit, either of the two currents would fail to excite it, effectively, for the purpose it is intended for alone; and if the direction of either current is reversed, the effect upon the lock pawl, L, will be nil. The method of obviating the disadvantages of an air-gap by making the lock pawl, L, the armature for the consequent poles developed is also worthy of notice.

The movement of the cam-wheel changes the points of contact of the switch bars Nos. 1 and 2 from "24" and "25" to "34" and "35." The breaking of the contacts of these bars with "24" and "25" breaks the path of the current from "B," and releases L from M; this path being immediately replaced by another through "34" and "35." If the new path is traced it will be found that the current from B has been reversed in direction through the line coils at "A," and consequently poles are not formed at "N" and "S" as before, and the lock pawl will be unaffected by any subsequent movement of M whilst these conditions obtain. Not only is this the case, but if the operations described are gone through with the object of liberating a staff at "B" it will be found that the direction of the currents through the line coils at "B" is such as, in conjunction with the fixed direction of the current through the local coils, is ineffective for the purpose of raising L in order to allow the cam-wheel to turn.

The instruments are said to be "out of phase" when the switch bars Nos. 1 and 2 make different contacts at the two ends of the section, and they can only be made operative again by putting them "in phase." This may be done by replacing the staff in either A's or B's pillar. In the first case the switch bars Nos. 1 and 2 at "A" return to the top contacts "24" and "25"; in the second case the switch bars at "B" are caused to make contact with the bottom springs "34" and "35," and thus make contact at the same points as the similar bars do at "A." Shortly, if the paths of the currents are traced, under the various conditions necessary, it will be found that staffs may be withdrawn at either place when the switch bars Nos. 1 and 2 make similar contacts only.

It will be noticed from the path of the line current that it passes through the galvanometer at each cabin, and, therefore, during the time the bell key at "B" is depressed, to enable a staff to be withdrawn at "A," the galvanometer needles are deflected. Some means of notifying "B" of the completion of the operation of withdrawal is necessary, and this is effected by breaking the circuit at the cut-off switch by pressing it hard over, as already observed. Both galvanometer needles assume a vertical position, and the signalman at "B" accepts this as an indication of the completion of the operation.

The right-hand switch is automatically replaced to "for bell" by the turning of the cam-wheel, and a study of the connections will show that at the moment of replacement the current will pass through the bell at "A." No notice of the one blow on the bell, resulting from the change of connection, is taken, and it is of no significance whatever, since the man engaged in withdrawing the staff requires no signal to tell him when he has got it out.

Such an instrument as that just described is obviously a great advance on the simple single staff and ticket system, in so far as facilitating the working of traffic and immunity from danger of accident is concerned. Under ordinary circumstances there need be no delay, as in the single-staff system, owing to the staff being away; and the lock, L, being contained in a strong lock-up iron case, if the batteries and connecting wires are protected against being tampered with it is not possible to, even burglariously, take a second staff out of either pillar. This, of course, is the premier object of the design, without which it would be worthless as an instrument for single lines. A minor point in connection with the design of the instrument may be noticed. It is that, although both men are actively engaged during the whole time occupied in withdrawing a staff at either end of the section, only one of them is concerned with its replacement. Under these circumstances it will be observed that it is not *essential* for the signalman at the sending end of the staff section to remain in his cabin until the last train through the section at night, say, has been signalled

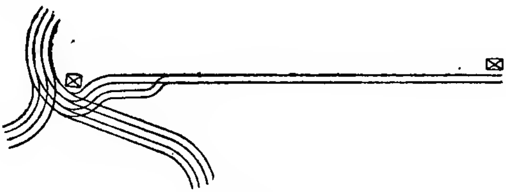


FIG. 89.

out. The staff can be placed in the pillar at the opposite end, and the two instruments put in "phase," without the assistance of the man at the point from which the train started. An understanding between the signalmen would, of course, have to exist before this could be done.

Single lines differ considerably in character. Some, as Fig. 89, end as single lines; others, again, form a connecting link between two double lines, as Fig. 90, and feed both; with such a line as Fig. 89 the traffic is bound to balance—*i.e.*, the same number of trains must emerge at the junction as enter it—and the number of staffs kept at each staff cabin will remain fairly constant. In such a case as is shown by Fig. 90 this may not occur, especially where the single line is fed from a number of points in its length, and there exists a number of staff stations between the extreme points of the single line. A number of trains may enter at one junction and leave by the other, and there would thus be an accumulation of staffs at some point and a corresponding denudation at another point, dependent upon the preponderating direction

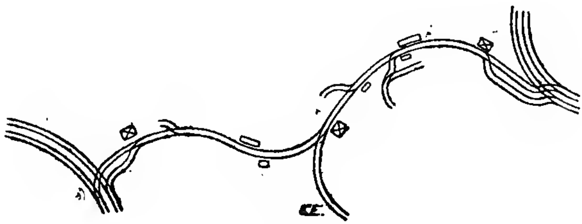


FIG. 90.

of traffic. In such cases, for instruments such as Webb and Thompson's, and others of similar design, special means have to be taken to restore the balance of staffs, or the line would ultimately be in the same condition as with a single-staff system. This is usually done by giving to the telegraph lineman for the district, a key which will open the case of the instrument and enable him to lift the lock, L, by hand, until a sufficient number of staffs has been removed from the pillar having a surplus, for conveyance to the point where a deficiency exists. Of course, this is only done under the supervision of the more responsible officials of the locality; and the person removing staffs in this way must give and take receipts for them, and it must only be done at such time as no staff is in ordinary use. In this connection it will be noticed that an *even* number of staffs must be removed for conveyance to the opposite end of the section, in order that the instruments may be left in "phase" for ordinary work during the time occupied in conveying the staffs from one point to the other. If the lineman conveys his bundle of staffs by a train passing in that direction, the driver must be furnished with a separate one, in order to leave the instruments out of "phase" during the passage of the train through the section.

On single lines where the traffic is light at night provision is made for switching out an intermediate staff station, staff working being carried on between the two cabins on each side. In such cases the instruments for working the longer section are distinct from those working to the intermediate station, and the staffs are of such form and size as to prevent them from being worked in conjunction with any instrument but the right one. The switching operation is somewhat elaborate, and a good idea will be more readily formed from the instructions given for its performance:

"As soon as the train next before the time specified in the working time-table for switching out has passed B and has arrived at C or A, as the case may be, and train out of section......... has been received for it at B, the signalman at B must ascertain by single needle or telephone, as the case may be, that all the staves at A and C are in their respective staff pillars. Having ascertained that such is the case he must give ('closing cabin signal') on bell........., which signal must be acknowledged. B must then peg down the bell key of each of his staff instruments by means of the pin provided for the purpose, and A and C must each of them hold down the bell key of the instrument working to B, which will be shown at B by the deflection of the needles. This action electrically unlocks the switch at B and permits that station to switch out, which he must do by depressing the lever on his switch instrument and turning the pointer from 'Switched in' to 'Switched out.' Having done this, he must send to A and C on the single needle, A A A......... which signal must be repeated to show that it has been understood, which will call the attention of these stations to the fact that the action of closing B has been accomplished (or where single needles do not exist the communication must be made on the telephone). On the receipt of this signal on the single needle, or the notification by telephone, A and C may cease to hold down their keys. All the instruments at the three stations have thus become disconnected, and the staves, both local and through, locked up in them. In order to bring the through staff instruments into operation, A and C must then turn the pointer of their battery switches from intermediate station to through section, which act will connect the through instrument at A with the through instrument at C. Stations A and C must then exchange the test signal with each other, and having done so must intimate to B that their through instruments are in circuit by sending him, by the single needle or telephone, the word 'through.' B is thus made aware that A and C are working on the through circuit, and after switching out his cabin-to-cabin single needle or telephone in the usual manner, if he is supplied with one, and unpegging the bell key on each of his staff instruments, he may close his cabin and leave."

"The rules for opening B are as follows: On the arrival of the signalman at B he must first switch in the cabin-to-cabin single-needle instruments if they exist (but if the telephone is in use without a single needle then a verbal communication must be made on that circuit), and then send fifteen beats on the needle, thus (five to the left, five to the right, and five to the left) to A and C. If there is no staff out of the pillars, A and C must each return the code of fifteen beats, and then hold down their bell keys on the through staff instruments, which will unlock the switch at B. B must then depress the lever of his switch instrument and turn the pointer from 'Switched out' to 'Switched in,' and having done so he must move the handle of the single-needle cabin-to-cabin instrument to and fro three times—thus, N, N, N—which will call the attention of those stations to the fact that the action of opening B has been accomplished, and those stations must turn the pointer of their battery switches to intermediate station. A and C must then each of them exchange with B the test signal on the bell, and working by local staff can then be commenced."

Arrangement of Circuits.—Fig. 91 represents

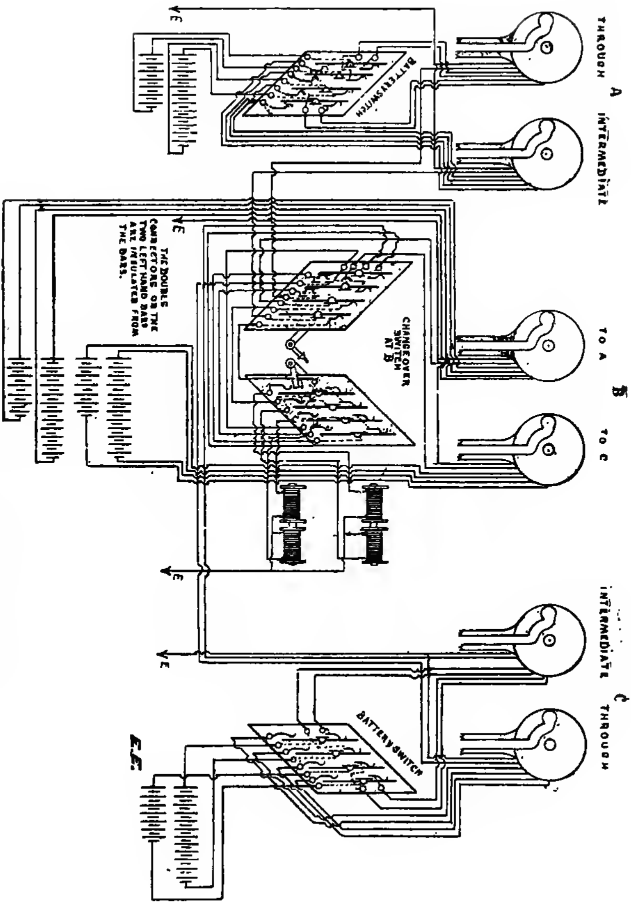


FIG. 91.—Webb and Thompson's Switching Apparatus.

diagrammatically the arrangement of circuits where switching from "intermediate" to "through" sections is in operation. As will be seen, an additional line wire is provided for the "through" section instruments at A and C, and switches are provided at these places by which the batteries may be used for either the "intermediate" or "through" instruments. The main switch by which the change over is effected is situated at B. It consists of two distinct sets of switches of four each; one set being operated by depressing the tapper key, the other set being operated by the arrow-shaped handle. The four switches shown in connection with the key are in their normal position, and change of position of the contact points can only be *maintained* by keeping the key depressed. The four switches on the left will maintain upper and lower contacts according to the position of the handle by which they are operated. The operation of the left-hand contacts from top to bottom, or *vice versâ*, is controlled by locks which are released by the action of two electromagnets of similar construction to that used in connection with the staff lock and shown in Figs. 87 and 88. When the bell keys of the intermediate instruments at A and C are held down, and the similar keys of the two instruments at B are pegged down, depression of the tapper key on the switch causes currents to pass, from A and B, through the coils of one electromagnet, and currents from B and C through the coils of the other. If these currents are in "phase" with each other the electromagnets are energised, but not otherwise, and the handle of the left-hand set of switches may be turned. Assuming that the left-hand switches occupied the positions shown by Fig. 91 before the operation commenced, the movements indicated will, if traced, be found to have disconnected the line wires of the "intermediate" instruments, situated at A, B, and C, at B's switch, and to have joined the "through" section line wire through at the same place. By altering the positions of the battery switches at A and C, the batteries previously used for the "intermediate" instruments are connected to the "through" instruments. Further consideration of the connections will show that the switches on the right of the change-over switch are simply used for the purpose of directing the currents set up by the depression of the keys of the instruments at A, B, and C, through the releasing electromagnet coils, and their use is temporary only. The actual change of connections is made by the left-hand switches. Further consideration of the diagram will show that the movement of the left-hand switches breaks the circuits from A, B, and C, through the lock coils and releases the locks and thus prevents the left-hand switch handle from being replaced in the position from which it has just been moved without the whole operation being repeated on the other instruments.

The operations just described constitute the change from "day" to "night" or "intermediate" to "through" instruments. The reversal from "through" to "intermediate" is similarly made, but as B has no instruments on the "through" circuit the pegging of the instruments at B is not a feature of this operation. Consideration of the conditions obtaining in switching from "through" to "intermediate" will show that only one of the releasing electromagnets (the lowest in Fig. 91) will be in use for this operation, the currents from A and C passing through different coils of the same electromagnet which operates on the one lock in this position.

Consideration of the system as a whole will show how absolute the control of the staffs and the switching out of intermediate stations actually is. In all cases of switching the three men at A, B, and C are all actively engaged, and the operation cannot be performed by any two of them alone. Not only is this the case, but owing to the fact that the switching currents must be in "phase" the possibility of error from attempting to switch when a staff is out of any one of the six pillars is prevented. Indeed, so highly is the system approved by Board of Trade officials that they allow fixed mechanical signals to be dispensed with at stations, situated between the staff stations, at which trains are required to stop.

Another feature connected with the switching out of intermediate stations during the times when traffic is known to be slack, other than the saving of wages, etc., is the possibility of using one set of instruments when, from any such cause as a line fault, the set in use has failed. This is an advantage which is not to be despised where traffic is heavy.

Consideration of the instructions issued for switching show clearly that the instruments must be supplemented by some other means of communication in order that the various stages of the operation may be arranged and its completion reported. Where such means of communication do not exist it must of course be provided, and constitutes an additional expense, but there are few places now which are not provided either with a telegraph instrument or a telephone, and there will be less in the future.

Tyer's Tablet Instrument. — Another form of instrument in extensive use for single line work is Tyer's tablet instrument, three varieties of which are shown by Figs. 92-95. The electrical connections for

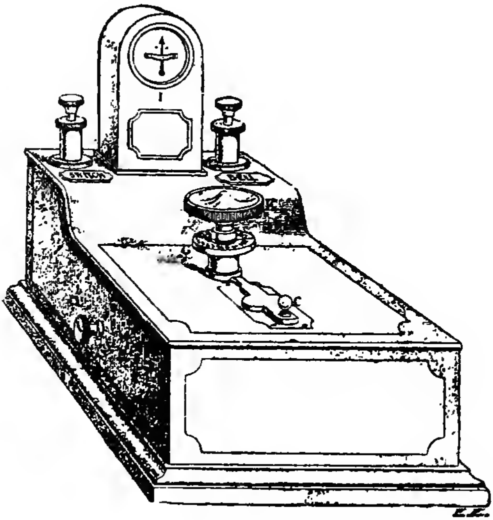


FIG. 92.

the respective instruments are shown by the diagrams Figs. 92A, 93A, and 95A.

The "tablet," which constitutes the authority to proceed through the section, is usually an annulus of metal appropriately numbered and lettered in accordance with the section it is intended to represent. The

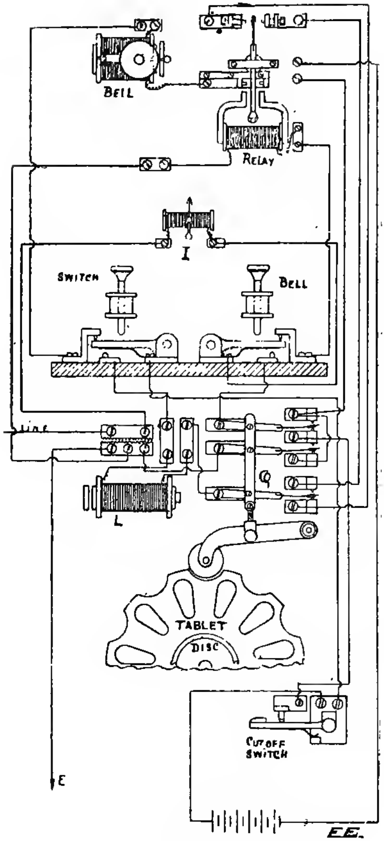


FIG. 92A.

tablets are placed in suitable receptacles in the body of the instrument, and the arrangement of the mechanism is such that only one tablet can be out at one time, and this removal can only be made after certain conditions have been complied with.

In the instrument shown by Figs. 92 and 92A the tablets are inserted in radial slots cut in a rotating disc, the motion of which is controlled by a pawl and ratchet wheel, the pawl in turn being operated by the locking electromagnet. The rotation of the tablet disc is effected by turning the knob, K, and movement of the disc actuates the commutator, Q, shown in Fig. 92A. The instrument is also provided with an indicator, I, a bell plunger, a switch plunger, a bell, a relay, and a small cut-off switch shown at the bottom of the diagram. Tablets are inserted or withdrawn at the opening covered by the cap, C (Fig. 92). The operation of withdrawing a staff, at A say, is carried out as follows, after the usual bell signals have been exchanged. A grasps the knob, K, and turns it as far as possible from left to right, and depresses the switch plunger, S. At the same time B depresses his bell plunger. Under these combined operations A's instrument is unlocked, and by turning the knob, K, from right to left he is able to bring a tablet into position under the cap, C. It is then only necessary to raise the latter in order to remove the tablet. The lifting of the cap, C, mechanically locks the rotating disc, so that only one tablet can be removed at a time, and this lock is only removed by placing C in its original position, when, of course, the instrument is again locked by the pawl and ratchet wheel.

Consideration of the diagram of connections will show that the depression of S, at A, during the operation of unlocking the instrument at that place, simply provides a path for the local current set in action by the upper tongue of the relay making the proper contact for the completion of the local current through the locking magnet, L. As shown in Fig. 92, the proper point of contact is on the left relay. The current from the distant station, B, due to the depression of the bell plunger at that place, simply passes through the indicator and relay, but the actuation of the latter for the purpose of unlocking L, in conjunction with the simultaneous depression of S, depends upon the direction of the current sent from B. The direction of this current is controlled by the commutator, Q, and a glance at Fig. 92A will show that the release of either instrument depends upon the commutator occupying similar positions at both places.

Provision is made for disconnecting the local battery whenever a tablet is immediately under the cap, C. This is done by the tablet, when in position in the rotating disc, depressing the cut-off switch shown at the bottom of Fig. 92A. No signals can be sent under these circumstances, and for this reason it is necessary to turn the knob, K, from left to right after a tablet has been inserted before the clearing line or arrival signal can be sent to the rear station.

With this form of tablet instrument a tablet may be returned to the instrument from which it was taken, and a tablet may therefore be withdrawn for local shunting purposes, involving use of part of the staff section only, without the necessity existing of conveying it to the opposite end of the section. One feature of this form of the tablet instrument is the absence of any indication of the condition of the line.

Figs. 93, 94, and 93A show another form of the tablet instrument. In this form tablets are inserted by raising the cap, C (Figs. 93 and 94), and with-

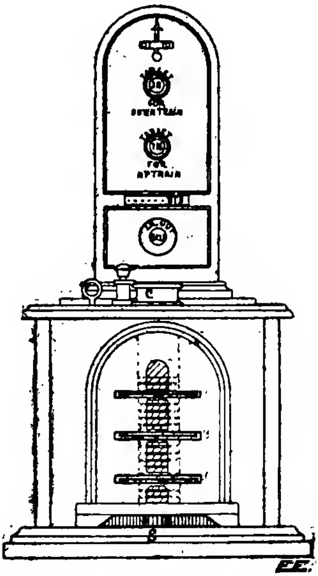


FIG. 93.

drawn by pulling out the slide, S, at the bottom of the instrument. The tablets are contained in a hollow column above the slide, the lowest tablet fitting into a recess in the slide, and having its upper surface flush with that of the slide. A number of auxiliary slides, *s*, are provided to assist in supporting the tablets, which are lowered into the bottom slide as necessity arises. The positions of the tablets

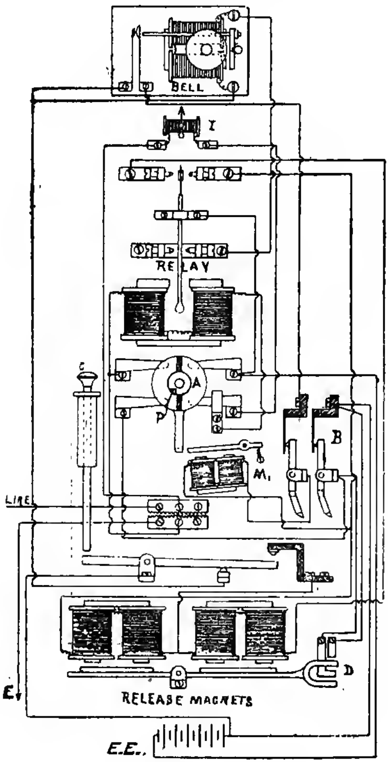


FIG. 93A.

are visible from the front of the instrument, so that the approximate number available for use at any time may be observable, in order that any transference of tablets, rendered necessary by unbalanced traffic, may be made in time to prevent delay. The bottom slide cannot be withdrawn from the instrument unless it contains a tablet.

The means used for preventing a tablet for one section being put into the instrument for another

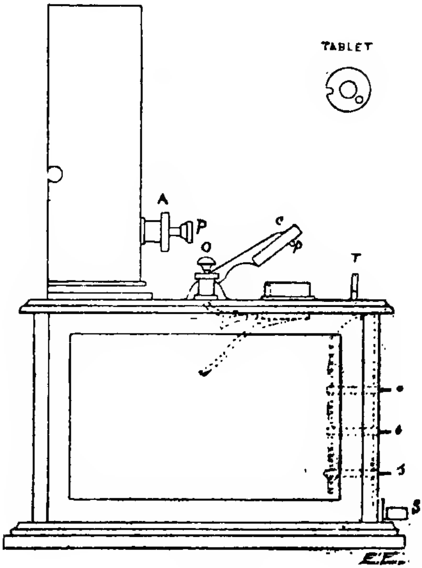


FIG. 94.

section are shown in Fig. 94, in which the cap, C, is shown raised for the insertion of a tablet. A radial slot is cut in the tablet, which, when the latter is put in the receiver, fits into a projection for it, and necessitates the tablet being placed in one particular position when in the receiver. In addition to the slot, a small hole is formed in the tablet into which the pin, *p*, shown on the cap, projects. This pin must pass through the hole in the tablet before the cap can be placed down, which must be done before the lower plate on which the tablet rests can be released. By forming the hole in the tablet at different points relatively to the slot, and fixing the pin, *p*, on the cap in positions to suit, any tablet other than one intended for that instrument will prevent the cap from being placed in the position necessary to release the lower plate or receiver. When the cap is in its position for releasing the receiver the weight of the tablet depresses the lower plate, and the tablet falls off it and falls into the column shown by the dotted lines in Fig. 94. The locking shown between the cap, C, and the receiver plate is diagrammatic only.

The electrical part of the instrument is shown by the diagram Fig. 93A. It consists of a two-part commutator, bell plunger, relay, indicator, bell (which also acts as a relay), unlocking plunger, electro-magnetic commutator lock, slide-releasing magnets. The operation of releasing a tablet is very similar to that described in connection with the instrument shown by Fig. 92. The switch, O, is depressed at the station at which the tablet is required, and the bell plunger is depressed at the distant station. The current from the distant station simply actuates the relay and indicator, and the former, in conjunction with the unlocking switch, provides a path for a local current through one or other of the releasing coils. A second local current is set up by the plunger attached to the bell armature, which passes through the electromagnet controlling the commutator. The withdrawal of the slide breaks the two spring contacts at B, and these remain broken during the whole time the slide is out. One of these contacts breaks the circuit through the commutator electromagnet, M_1, and the other contact breaks the battery circuit to the commutator and the bell plunger. An auxiliary circuit, however, is provided at D for the latter, and is closed by the armature of the releasing electro-magnets. The lower indication "in" "out" is actuated mechanically by the turning of the commutator at that place; the upper indication is operated by the current, sent from the distant station, through the relay, after the commutator has been turned from its normal position.

The construction of this instrument is such as to prevent a tablet being returned to the instrument from which it has been taken. The tablet must be taken to the opposite end of the section. It cannot, therefore, be used for local purposes only.

The latest form of the tablet instrument is shown by Fig. 95, and the electrical connections, in diagram, by Fig. 95A. In this form the electrical portion is confined to the unlocking of the commutator. Tablets are inserted and withdrawn by means of the slide shown at the bottom of the instrument. The operation of unlocking the instrument is performed by the distant station depressing the bell plunger for a specified time, during which the commutator is turned. A considera-tion of the diagram will show that, as in the other instruments described, the action of the current from the distant station is confined to the operation of the relay, and that the actions resulting in the release of the apparatus are due to the local current. It will,

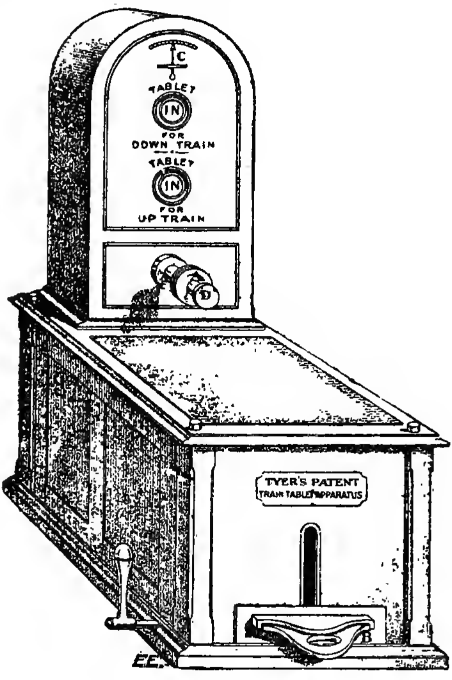


FIG. 95.

however, be noted that this instrument differs from the others in that the signalman at the station which requires a staff is not called upon to contribute in any way towards the completion of the path of the local releasing current. At the same time he is actively engaged in the operation at the same time as the signalman at the distant station, since he must complete his portion of the work during the time the bell plunger is being depressed at the distant station.

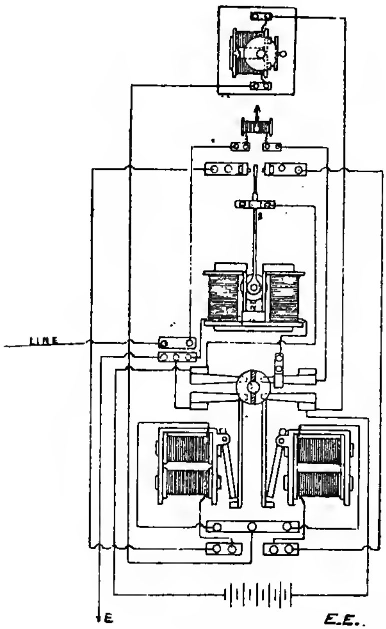


FIG. 95A.

It is of considerable importance in tracing the action of these instruments that the movements required to release or insert staffs and their order be clearly understood. For this reason the following extracts describing the movements in their proper order are taken from official instructions:

"If a train or engine is at station A, and requires to proceed to station B, the signalman at A must give the proper 'Is line clear' signal to B, the signalman at B having ascertained that the line is clear for the train to run upon, must repeat the signal; if not prepared to accept the train he must give one beat of the bell or gong. The signalman at A, after receiving the proper acknowledgment for accepting the train, must then give five rings: thus, 4—1, signifying 'Release tablet.' B must, provided the previous train has passed his box and there is no obstruction on the line upon which the approaching train is to run, repeat the signal back to A. The signalman at A must, if the old pattern of instrument is in use, press down the bell plunger and keep it down till the galvanometer needle rises to its normal position, which shows that the signalman at B is turning his lower disc; the signalman at A must then immediately release the bell plunger and press down the switch plunger, and keep it down till the upper disc is turned red, showing the word 'out,' then release the switch plunger, lift up the check, draw out the tablet slide, give one beat of the bell or gong, then give tablet to driver. The signalman at B must, after receiving the tablet from the driver, deposit it in the instrument, lettered side downwards; then give the 'Train arrived' signal to A and immediately turn the lower disc to white, showing the word 'in'; then press down bell plunger, holding same down for three seconds. The signalman at A must, after receiving the 'Train arrived' signal from

B, press down the switch plunger, holding down the same till the upper disc is turned to white showing the word 'in.' Both instruments will then be in their normal condition." The instrument referred to in the above extract is shown by Figs. 93, 93A, and 94.

"If the new-pattern instruments are in use, the signalman at B, if prepared to accept the train, must, after acknowledging the signal, press down the bell plunger for three seconds; if not prepared to accept the train, he must give one beat of bell or gong. The signalman at A, after receiving the proper acknowledgment for accepting the train, must turn his lower disc commutator from right to left, showing the word 'out,' then draw out the tablet slide, give one beat of the bell or gong, then give the tablet to the driver. The signalman at B must, after receiving the train tablet from the driver, withdraw his tablet slide empty, insert the tablet, lettered side downwards, push the slide home, raise and lower the switch lever on left-hand side of the instrument, then give acknowledgment of arrival signal. This will have the effect of reversing the upper disc at B from 'out' to 'in.' B will give one beat in reply, which will have the effect of reversing the lower disc at A. Both instruments will then be in their normal position." The instrument referred to in this extract is shown by Figs. 95 and 95A.

Consideration of the design of these instruments will show that the objects aimed at are precisely the same as those aimed at in the construction of the train staff instruments already described, although the means by which these objects are attained are, of course, entirely different in the two forms of instrument. The ultimate object is, of course, the conversion of the line between any two stations forming a section into an up or a down line as necessity requires and circumstances allow. Both forms of instrument are, in so far as their application is concerned, simply developments of the simpler single staff system which they have replaced, and rely for their advantages over the original system on the greater number of the symbols of authority to proceed which their design enables them to control effectively. No deviation from the fundamental principle of the original system is made; the only difference is that the authority to proceed through the section is available at either end as circumstances require. This, of course, is often a matter of great importance in reducing the delay to traffic to a minimum, but the rigid adherence to the original principle of staff working makes instruments such as the train staff or tablet unsuitable for working in conjunction with intermediate block sections, which, as has already been remarked, is of considerable use for facilitating the passage of traffic in one direction, where the single staff and ticket system is in use. With such systems as those described, block working as a safety device is unnecessary, owing to the absolute control established by the instruments over the staff or tablet used; indeed, such instruments themselves constitute a form of absolute block in that they rigidly impose a space limit between trains passing through the section they protect. At the same time the staff section constitutes the minimum length of block section, and the length of these determines the facility with which traffic can be handled under certain conditions.

It is questionable whether the rigid adherence to the principle of the simple staff shown by the design of the instruments described is really so necessary as it would appear to be. It will be noted that the line is converted into an up or a down section, as the case may be, *at the moment* the staff, tablet, or other recognised authority to proceed, *is withdrawn from the instrument.* Further, the design of the majority of the instruments is such that it is not *necessary* for the symbol to be conveyed to the opposite end of the section in order that the line may be made neutral, as is shown by the arrangements for supplying staffs or tablets for local shunting purposes, such staffs or tablets being returned to the instruments from which they were taken. The handing of the symbol to the driver for conveyance to the other end of the staff section is a relic of the requirements imposed by the original single staff system, in which the staff was absolutely necessary to the conversion of the line from a neutral state to an up or a down section, as the case may be. With such instruments as those under consideration the conveyance of the symbol and its insertion in the other instrument is only necessary in consequence of their designs being modelled upon the requirements of the original staff system, and is really a serious disadvantage in that it leads, where the traffic does not balance, to the necessity for special transference of symbols from one point to another in order to allow of continuous working. In so far as possession of the staff or tablet constitutes the driver's authority to proceed, the use of the "ticket" in the single staff system shows that any subsidiary authority will suffice for his purpose so long as it is recognised. This is, of course, leaving out of consideration the fact that entrance to the section is controlled by the fixed mechanical signals in addition to the staff or its equivalent.

Further consideration on the lines indicated would show that, with proper precautions, a "staff and ticket" system, with one staff only at each end, in which the *staff* would never leave the station at which it is placed, and would be used only as a means to liberate a subsidiary authority of a similar nature to the ordinary "ticket," would appear to have many advantages. With such a system the line could be converted into "up" or "down" at will, and ordinary block working could be carried on in conjunction in order to facilitate the passage of a number of trains in the same direction, the number of trains proceeding in the same direction in any one *staff* section being determined by the number of intermediate block sections, these latter being in accordance with experience of the traffic on the line. Such a system as here outlined would not be difficult to devise, and would involve nothing extraordinary in the way of apparatus, whilst it would appear to meet all the requirements of single lines.

Permissive Block Working.—In certain cases absolute block working is not necessary in consequence of the character of the traffic dealt with, and is undesirable on account of its volume and the necessity for dealing with it in comparatively large batches. Such cases have to be dealt with in a different way. In many cases block working is dispensed with altogether, and the various trains signalled by bell only. In other instances a modified form of signalling, known generally as the permissive block, is made use of. Practically speaking, it is not entitled to the name, since no attempt is made to preserve the space limit between successive trains, which is the essential feature of the absolute block system. Probably two or three instances of actual use of this system, with the advantages obtained, will do more towards showing the necessity for, and the benefit accruing from, this method of working than anything else.

Three examples of lines on which permissive block working is in use are shown by Figs. 96, 98, 100. In Fig. 96, the passenger station, H, is the virtual junction for trains from T, P B, Y, W, and L. Trains arriving at H from P, Y, P B, and W proceed no further, and passengers travelling by these trains, *en route* for T or L, are transferred to other trains at H. It frequently occurs that a train from T is at the up platform when trains from P, Y, and P B which require to connect with it arrive. Hence these trains must pull up at the same platform, in order that passengers who desire to change for L may do so, the bays being too short and not sufficiently numerous to accommodate the later trains. Similarly, trains from W arrive on the down line with passengers to connect with a train already at the platform ready to proceed to T, Y, P, or P B.

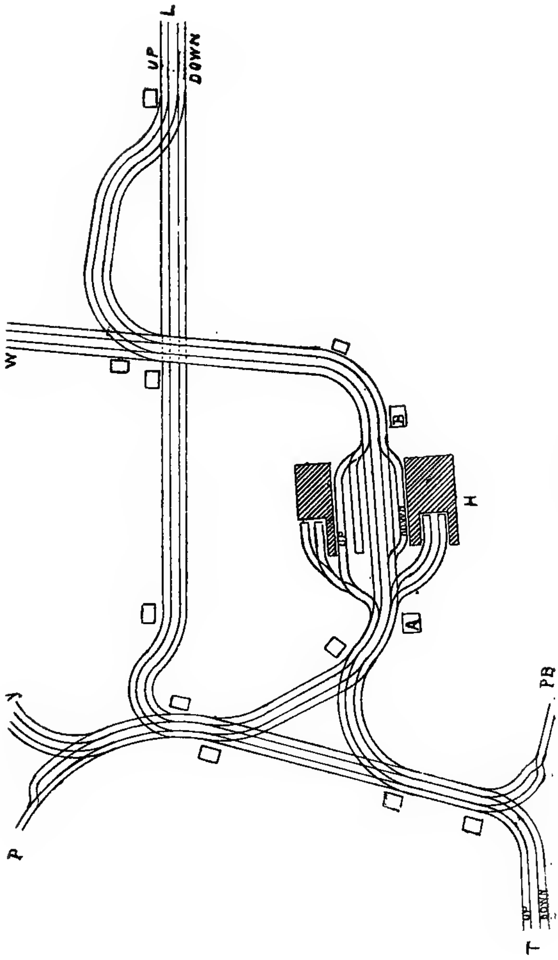


FIG. 96.

Hence block signalling, as commonly understood, cannot be carried on between A and B (Fig. 96).

If bell signals only are used in such a section, considerable responsibility rests upon the signalmen, and great care has to be exercised in order to ensure that trains shall not enter the section from either end at too high a speed in the event of the line being already occupied. Under such circumstances the signalmen have no reminder of the condition of the

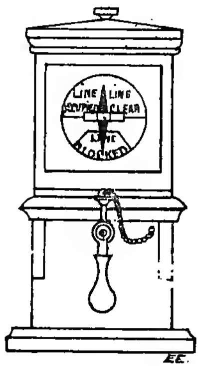


FIG. 97.

lines other than that afforded by the bookings in their train-books, and the danger of sending trains into the section is further enhanced if a curve exists on the line, or fog prevents the whole of the section being visible to the men at each end.

The instrument shown by Fig. 97 is used as an indicator of the state of the lines in the section A B at H. It is simply an ordinary S N block instrument, such as is used for absolute block working in other places, but differs in the lettering of the dial, and in provision being made to peg the handle in a *vertical* position as shown, in addition to the two ordinary positions on either side of the vertical. The dial is lettered on the upper left-hand quadrant "Line occupied," and on the upper right-hand quadrant "Line clear." The lower half is lettered "Line blocked." Signals are given between A and B by means of separate bell communication in exactly the same manner as for absolute block working. If A transmits the "Is line clear" or "Be ready" signal to B on the bell, the response of the latter will depend upon the actual condition of the line. If the line is clear of trains, B will reply as per code, and peg the needles to "Line clear." If the line is already occupied, B replies to the bell signal as before, but pegs the needle to "Line occupied." These are the preliminary signals, corresponding to the "Line clear" signal in absolute block working, which are given on the approach of a train to A, and upon the answer given by B to this signal depends the action taken by A in forwarding the train into the section. If the needles are pegged to "Line clear," the signalman at A will lower the home signal, and allow the train to pass in the usual way. If the needles are pegged to "Line occupied," the train must be sent forward at caution, the home signal being kept at danger, and the train being brought forward by hand or other special signals. On the train entering the section A B, the usual "Train on line" signal is sent by A, and B, in response, unpegs the needles from "Line clear" or "Line occupied," as the case may be, and pegs the handle of his instrument in its vertical position, when, the needles at B and A being vertical also, the indication exhibited at both cabins is "Line blocked." As successive trains pass out of the section the "Train out of section" signal is given for each, as in the absolute system, the handle being pegged in the vertical position at the receiving end afterwards for all trains except the last one of any group of trains.

When the last of any group leaves the section, it being then clear, the handle is unpegged, but the indication shown by the needles is unchanged and remains at "Line blocked." The difference of the indications, section clear of trains, and section occupied, at the receiving end of the section, consists in the position of the peg for the handle, except during the time "Line occupied" or "Line clear" is being exhibited. In the first case the peg is inserted, as shown by Fig. 97; in the second case it hangs in front of the instrument by the chain to which it is attached. The right and left indications of the needle simply show that permission has been given for a train to enter the section; in the first case it may run straight in without stopping; in the second case it is to be sent in at caution, it being an additional train.

In many cases it is often difficult for the signalman to communicate a hand signal to the driver of a train standing at the home signal. Obstructions to such signals being seen may arise from another train, standing on the opposite line, being between the driver of the train signalled and the signalman, and in this case the use of a hand signal, especially at night, is liable to be accepted by some other train than the one it is intended for. In such cases, subsidiary mechanical signal arms, or "calling on" signals, are fixed to the same post as the home signal, and are used as a signal to proceed at caution. These signals are, of course, used on the occasions when the "Line occupied" signal is exhibited, the ordinary home signal being used when "Line clear" is shown on the indicators.

It will be observed that this instrument has no provision for showing the number of trains signalled into or accepted in the section, and the signalman at the receiving end must, when conditions exist which prevent his seeing the whole of the section, rely upon his train-book for the information upon which depends his answer to any "Is line clear" or "Be ready" signal that may be offered for his acceptance.

Fig. 98 represents a section of line which, between the points A B, is worked partly by absolute and partly by the permissive system. The sidings shown constitute an important goods and mineral traffic distributing point. The lines between A and B are five in number, two of which constitute the main line, and are worked under absolute block rules; two are up and down independents, and are worked under permissive block rules, whilst the fifth line is a connecting link between the distributing sidings at A and a goods centre at B, and is not worked under any block rules. The construction of the distributing sidings is not such as to afford room for the shunting of more than one train at a time, and it is, therefore,

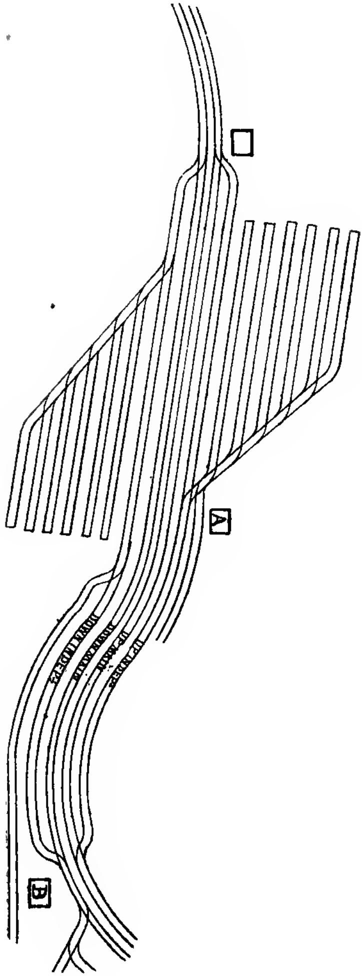


FIG. 98.

of some importance to get completed trains out of the way as quickly as possible. Such trains are sent to B on the up independent lines, and, being worked under permissive rules, the traffic is dealt with in a much quicker and more effective fashion, since the departure of completed trains from the neighbourhood of the shunting ground is not dependent upon the absence of traffic on the main line, as it would be if the independent line did not exist, and the trains emerged direct on to the main line at A. The arrangement is such as to make B the virtual junction for the distributing sidings on the up side, with the further advantage that such trains complete a portion of their journey at the same time as traffic, which would otherwise delay them, is being carried on on the main line. Trains emerging on to the main line at B come under absolute block rules during their further progress. In a similar way, trains on the down line enter the down independent at B, and run direct to the distributing sidings at A, without further interference with the main line. The use of permissive block rules for the independents is obviously of more use for clearing the main line of a number of trains, at such junctions as A and B, for more important traffic, than if the independents were worked under absolute block rules, since a number of trains may be put on the independent, instead of waiting till the line was clear of the previous train.

The form of instrument used at the receiving end of the section between A and B (Fig. 98) is shown by Fig. 99. This is Tyer's form of permissive block instrument. Its chief point of difference from the previous form of block instrument consists in the provision of means for advising the signalman of the number of trains in the section at any time. The commutator carries, inside the instrument, a small disc, around the circumference of which is painted "Line closed," "Line clear," "Train on line," "2," "3," "4," "5," "6." These indications are exhibited at the lower opening in turn, and in the order just given. These indications are mechanical, and are

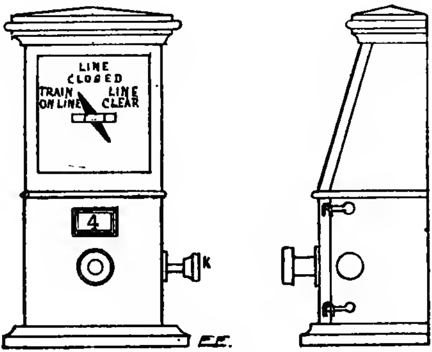


FIG. 99.

shown by turning the commutator handle, and they are in addition to the indications given by the needle. It will be observed that only when two or more trains occupy the section at the same time does the lower indication differ from that of the needle. The commutator is locked automatically in either of the eight positions it can occupy, and can only be turned forward or backward *during* depression of the small knob, K, on the right of the instrument. Hence, the movement of the commutator must be made deliberately, and it cannot be moved without special intention to do so. The ultimate capacity of a line on which such an instrument is in use would be six trains—*i.e.*, six trains might all be between the two block cabins, A and B, on one pair of rails at the same time. The instrument used at the sending end of the section is similar in appearance to Fig. 99, but it has no commutator or indicator of the number of trains in the section, and the signalman is not called upon to work it in any way.

Another example of the conditions under which working of traffic under permissive block rules may

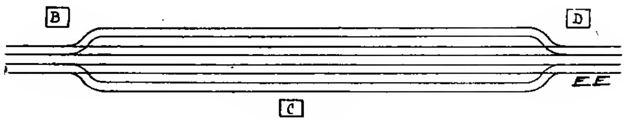


FIG. 100.

be of advantage in facilitating traffic over crowded lines is shown by Fig. 100. On this line there is a large amount of fast passenger and other important traffic between two large and important towns, one of which is a seaport of some magnitude. In addition to this traffic there is a large amount of various kinds, but of less importance, in so far as time for delivery is concerned. Such traffic has therefore to give precedence to the more important. Under the absolute rules considerable delay would occur, and therefore, in order to cope with the various classes of traffic, the lines have been doubled for several miles. The original main line is worked under absolute rules, whilst the up and down independent lines are worked under permissive rules. Trains arriving at one of these junctions, with a small time margin in front of more important traffic, may be run upon the independent line alongside the train for which they have been diverted from the main line, and may be ready to continue the journey the moment they arrive at the exit junction. Practically no delay occurs to either class of train under these circumstances. Not only is this the case, but the main line may be rapidly cleared of a *number* of trains, since the permissive rules allow of a certain number of trains being in each section at the same time.

The form of instrument used on the section of line shown by Fig. 100 for the independent lines is given by Fig. 101. This represents Hampson's form of permissive block instrument. The apparatus for both lines is enclosed in one case. As in Tyer's form of instrument, indications of the number of trains in the section are exhibited at the lower opening, in addition to the dial indications; the dial signals are operated by the signalman at the receiving end only; the commutator and rear section recorder are locked in any one of the positions it can occupy; and the instrument is not adapted to transmit descriptive signals of any kind. As in Tyer's form, all signals, other than the mere indication of the condition of the line, are made by a separate bell communication. The instrument is operated by the withdrawal of the slide, S, which makes the usual simple commutator changes necessary to show "Line clear" and "Train on line" on the dials, and also imparts movement to a sector, passing behind the lower opening, which is lettered "Line closed," "Line clear," "Train on line," "1," "2" "3," "4," in order given. Movement of the slide from one position to the next in order, backward or forward, can only be made *after* depressing and releasing the knob, K, shown on the right of the

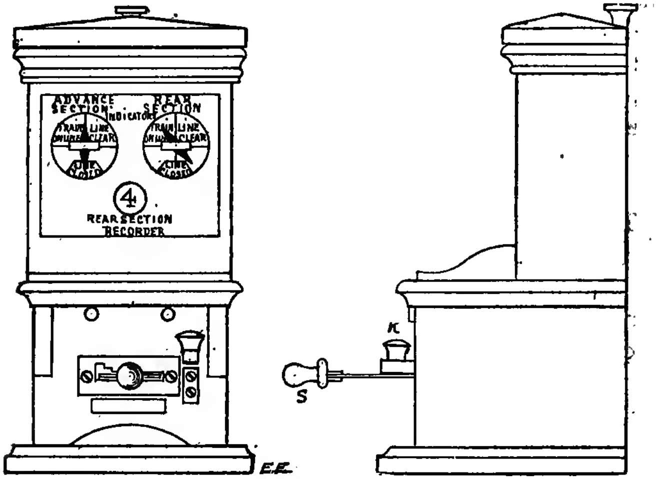


FIG. 101.

commutator handle. In this respect Hampson's instrument differs from Tyer's. In Tyer's form the commutator must be turned during the time the knob, K (Fig. 99), is depressed, and it may, under these conditions, be placed in any of its positions. In Hampson's instrument the commutator slide can only be moved after the knob, K (Fig. 101), has been depressed and released, and it can then only be moved into the *next* position, forward or backward, as the case may be. At the same time there is nothing to prevent the releasing key of Hampson's instrument from being depressed any required number of times. The essential difference between Tyer's and Hampson's instruments is, that with the former it would be easy for a signalman to inadvertently turn the commutator through two positions instead of one; with the latter, the recorder can only be made to travel through two positions by two distinct operations of the releasing key, and must therefore be deliberately made.

It will be observed that the method of working with Tyer's and Hampson's instruments is slightly different to that described in connection with the instrument shown by Fig. 97. The difference consists in the double character of the preliminary signal in use with the latter form of instrument. The two former move more nearly on the lines of the absolute block, in so far as the indications exhibited are concerned: the latter form labours under the disadvantage of having two forms of indicator, the needle and the peg, one of which, the needle, exhibits the same signal whether the line is occupied by or clear of trains. In addition to this, it has the defect of not providing any record of the number of trains in the section at any time at either end. Tyer's and Hampson's instruments do provide such indications, up to a prearranged limit depending upon the instrument, but they only do so at the receiving end of the section. It is sometimes contended that it is unnecessary to provide such indications at the sending end of the section, as the signalman there has the dial indication to guide him, and, moreover, cannot send a train forward until the "Be ready," or equivalent preliminary signal, is accepted by the man at the receiving end. This contention would be unanswerable if there was anything of an automatic character in the indications, or if they depended in any way upon the trains themselves to act as a check. This, however, is not the case. The indications of the instrument are merely records of the movements of the signalman, and the construction of the locks is not such as will prevent a signalman from moving a commutator in such a way as will indicate a less number of trains than is in the section. If the number of trains in the section is two, say, and a third is sent in from the other end, there is nothing to prevent the signalman from inadvertently moving the commutator to indicate "Train on line," or "1," instead of moving it so that it indicates "3." The instrument at the sending end would still indicate "Train on line," as it does whatever number of trains may be in the section, and there is thus no control or check other than vigilance in comparing the "Train out of section" signals with the bookings in the train-book. The exhibition of numbers, indicating the trains in the section, at the sending end, worked synchronously with those at the receiving end, and from that end, would provide a check against error on the part of the signalman at the receiving end, which, under certain circumstances, might be of great value.

Another feature of instruments of the class of which Tyer's and Hampson's are representative, is an inevitable difference between the indications exhibited by the instruments, and the actual condition of the line at a certain stage in the operation of signalling. The "Line clear" indication is, as already explained, preparatory, and indicates an intermediate stage between line occupied and line clear of trains. Practically, it indicates the conversion of the line from a neutral condition to a state of preparation for the reception of a train which is known to be approaching. An examination of the methods of working will show that there is no such intermediate stage in the conversion of the line from the occupied to the unoccupied state. But in instruments of this class, where the indications for the exit of the last of a group of trains must be made in the exact reverse order to those for the entry of the first of the group, there must necessarily be a "Line clear" indication exhibited between "Train on line" and "Line closed." This, of course, is contrary to the actual conditions obtaining at the time. The "Line clear" indication so shown is, of course, exhibited for a short time only, and is considered of no significance. Such an indication, however, does not appear on any form of absolute block instrument. In this respect, Tyer's form of lock allows of more speedy movement from "Train on line" to "Line closed," since by keeping the knob, K (Fig. 99) depressed, the commutator may be moved at once over the two positions, the needle giving a mere kick to "Line clear" during the operation. In Hampson's instrument, the needles must stand at "Line clear" until the knob, K (Fig. 101), has been depressed and released a second time, and the slide pushed home.

CHAPTER V.

MISCELLANEOUS APPARATUS.

Gate Crossings. — It frequently happens that a highway crossing is situated between two block cabins. Such crossings are, of course, provided with a gatekeeper, but if the crossing is situated on a sharp curve, or during foggy weather, the gatekeeper has some difficulty in assuring himself that no danger exists in opening the gates for vehicles, foot-passengers, or, worst of all, cattle passing along the road. Matters were improved by providing the gatekeeper with an intermediate bell connected in the block bell circuit, which reproduced all the bell signals exchanged between the cabins on each side of the crossing. This method was imperfect, in that the gatekeeper had to distinguish the different classes of signals from each other, to rely on his memory after the signals had passed, and was unable to distinguish between signals for "up" and "down" trains.

The apparatus now provided on one line is shown by Fig. 102. The small needle indicators are inserted in the "up" and "down" block indicator circuits, and the bell is inserted in the block bell circuit as before. The gatekeeper has no control over the instruments, and is not called upon to do any work in connection with them, but by the aid of the indicators he is able to see, at any time, whether a train is approaching from either direction, and from the character of the indication, "Train on line" or "Line clear," is able to judge its approximate distance.

Signal Repeaters.—When signals are not visible from the cabin from which they are worked, some means of indicating the position of the arm becomes necessary. At one time it was customary to fix a small subsidiary signal in a position where the signalman could see it, and arrange it to be worked from the same wire as the signal it was intended to represent. Such mechanical repetition had many

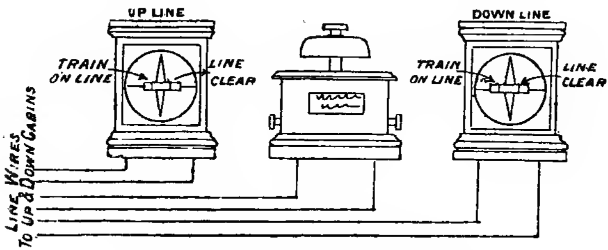
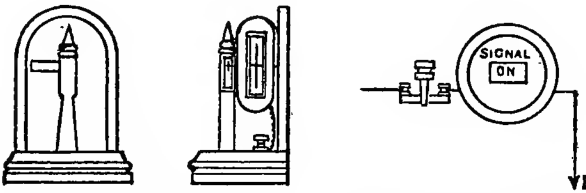


FIG. 102.—Gate Crossing Equipment.

defects, and was unreliable, and electrical methods of repeating signals were early brought into use.

The forms that signal repeaters have taken at various times, and in various hands, have been numerous. Some have been miniatures of the signal and arm, others have the indications lettered on dials, and the position of the arm is shown by the relative positions of the pointer, or the indications exhibited. Some repeaters show "off" and "on" only. Others have been made to show "on," "caution," and "off," whilst still others show "on," "out of order," and "off." Some forms of repeaters require two wires, but the majority only require one; some forms require continuous currents to maintain the "on" positions, others to maintain the "off" position, whilst still others require continuous currents for both "on" and "off." The disc indicator, shown in Fig. 103, requires continuous currents for both "on" and "off"; the semaphore form shown in the same figure requires a continuous current to maintain the "on" position, whilst the needle form of indicator shown by Fig. 106

FIG. 103.



Semaphore Distant Indicator. Disc Indicator with Plug Switch.

requires continuous currents for the "off" and "out of order" positions.

The construction of the contact boxes at the signal for providing the necessary indications is naturally governed by the character of the indications decided upon as desirable. An earlier form of contact box and the method of fixing is shown in Fig. 104, where the movement is obtained from the rod at a point between the counterweight and the arm. In this method the indicator shows two positions only—"on" and "off," the "on" position being the normal indication when no current was passing, and the "off" being maintained by a continuous current.

Consideration of the conditions of working shows that such an arrangement lacks the reliability so important a piece of apparatus should have. In the first place, the point indicated is not that of the arm itself; in the second place, the apparatus is self-

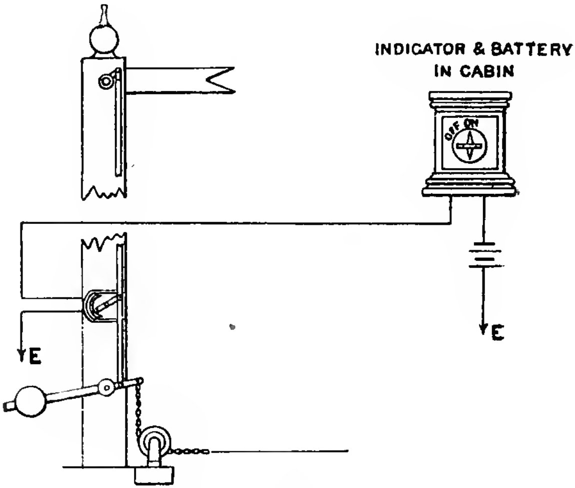


FIG. 104.

testing in one position only. If the rod working the signal arm broke between the contact box and the arm, or if the key fixing the arm to the spindle slipped out, the arm would indicate "off" whilst the electrical repeater would be showing "on."

Further consideration shows that the relative positions of the signal lever, signal arm, and electrical repeater are of great importance, and that there exists a great necessity for the repeating apparatus being self-testing in the "on" position. If the signal arm is "on" when the signalman expects it is "off" no accident is likely to occur, and slight delay to traffic is the only probable consequence. If, however, the signal is "off" when the signalman

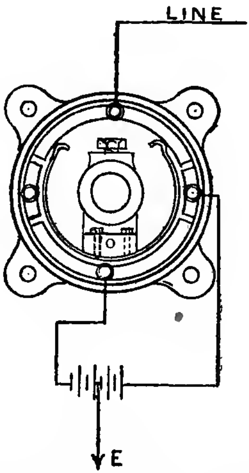


FIG. 105.—Signal Indicator Contact Maker.

expects that it is "on" the consequences may be very different, since it is the signal arm which ultimately controls the passage of traffic, and all other apparatus, mechanical or electrical, are merely accessories used to ensure the exhibition of the proper outside signals for the time being.

The forms of contact box shown by Figs. 105 and

106 are fixed concentrically with the spindle of the signal arm, and obtain the motion from the movement of the spindle. They are used in connection with the needle form of repeater shown in Fig. 106. With this form of repeater three positions are shown—"on," "out of order," and "off"; and Fig. 106 is drawn to show the "out of order" position. This indication, as will be seen, is an intermediate one

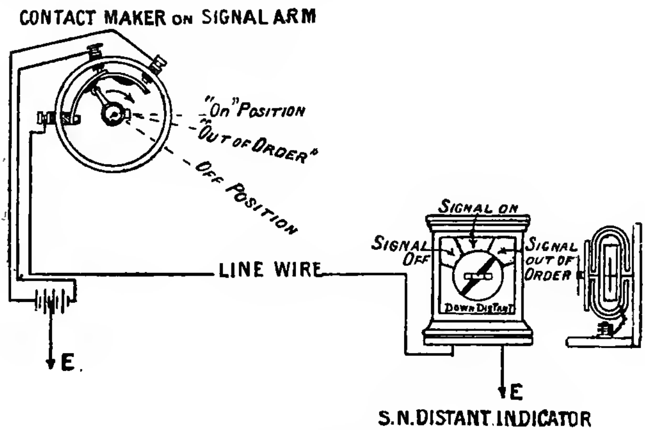


FIG. 106.

between the "on" and "off" positions of the arm, and must be passed over each time the arm passes from "on" to "off," and *vice versâ*. The chief use of this indication is to show that the signal arm is *fully* "on" or "off." An "out of order" signal would be shown on the electrical repeater instead of an "off" signal in one case, or an "on" signal in another case, if the wire working the signal has become slack or tight from expansion or contraction respectively, and such an indication would be interpreted by the signalman as indicative of the necessity for regulating the wire working the mechanical signal.

It will be noticed that the movement indicated is not that of the arm but that of the spindle; and that the removal of the key fastening the arm to the spindle would allow the signal arm to fall, without effecting a corresponding change of position of the electrical repeater. It is true that the position the arm would take up under these circumstances would, if noticed by a driver, be regarded with suspicion, but it should not be forgotten that it is the signalman for whom the repeater is provided, and he would have no notification of the position of the arm being other than that corresponding to the position of the lever working it.

The "out of order" indication of the form of electrical repeater shown in Fig. 106 is of some interest when its significance is understood, and the limitations imposed by the form of instrument and the method of using are considered. As has been stated, the "out of order" indicates a discrepancy between the relative positions of the signal arm and the lever, and so far it is a true "out of order" indication. Whilst this is so, it will be observed that, owing to the repeating apparatus not being self-testing in the "on" position, conditions may easily arise where the indication of the electrical repeater may differ from the actual position of the arm, and the latter differ from the position of the lever. Further, a defect in the repeating apparatus, if it occurs when the signal is "on," affords no indication of its existence to the signalman.

To the writer it seems unsound to treat the signal and the repeating apparatus as different pieces of apparatus. Rather, it seems, that they should be considered as one, and the "out of order" signal should be such as not only indicates a discrepancy between the positions of the arm and lever, but also a defect in the repeating apparatus. In short, an efficient repeating apparatus should do, for a signal

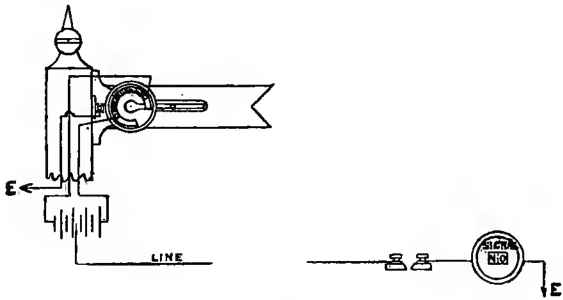


FIG. 107.

which is out of sight, all that a signalman can do for himself in connection with a signal within sight.

Another form of contact-maker, and the method of attaching to the signal, is shown by Fig. 107. It is used in conjunction with the disc indicator shown in Fig. 103. The "on" and "off" positions are both maintained by continuous currents: if from any cause the circuits are broken, the indicator takes up an intermediate position as shown in Fig. 107. This form would appear to possess considerable advantages over the forms shown by Figs. 104, 105, and 106, in that the movement indicated is that of the arm itself, and the apparatus is self-testing in any position. The intermediate position shown by Fig. 107 is a true "out of order" signal, and is shown not only when the arm occupies a different position to that of the lever, but also when a defect occurs in the electrical repeating apparatus. A small peg switch is provided by which the circuit may be disconnected during such times as the signal is not being used, in order to prevent the batteries being run down unnecessarily. As the Board of Trade inspectors require signal indicators to be fixed in plain sight, and immediately opposite the lever working the signal, there is not much danger of the absence of the peg being unnoticed when the apparatus is being brought into use. At the same time, combinations of circumstances may arise in which the absence of the usual indication would be undesirable.

Signal Light Indicators.—During darkness, the arm of a signal post is replaced as a signal to drivers by a light, which is invariably red for "danger," and is green, or white, when the line is clear for an oncoming train. Where signals are at a distance from the cabin, and the back lights are not visible, the existence of the light is indicated.

The apparatus employed for this purpose is of a simple character, and is shown by Fig. 108. It consists of an expansion bar, *a*, formed of an iron rod passing through a copper tube which is fixed above the flame of the lamp. The difference in the coefficients of expansion of iron and copper cause the former to exert a pull on the short end of the lever, *b*, and separates the contact points. The expansion bar is connected to a small make and break bell and battery, placed in the cabin, by a special wire. If the light goes out from any cause, the expansion bar cools, and the bar, *b*, is brought into contact with the terminal base, and the bell begins to ring and will continue to do so until the light is re-established. A small peg switch is

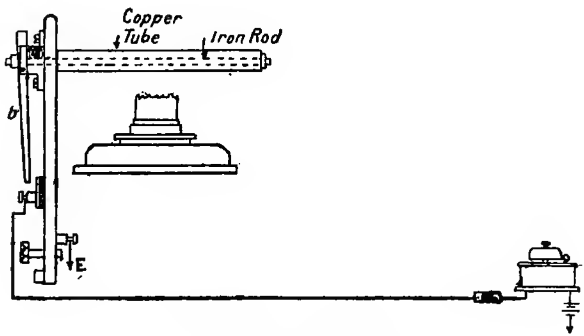


FIG. 108.—Light Indicator.

provided, so that the circuit may be disconnected during the time the lamp is not required to be alight.

In other cases the bell is supplemented by an indicator showing "Light in" and "Light out." The "Light in" signal is maintained by a continuous current, and the indicator circuit is arranged as a shunt on the bell connections, as shown in Fig. 109. In this way the bell is rendered silent during the time the indicator shows "Light in"; but should the light go out or anything occur to interrupt the circuit, the continuous ringing of the bell draws the signalman's attention to the new position of the indicator.

"Distant" Signal Lights. — The form of the arm of a "distant" signal is slightly different to that of "home" or "advance" signals in being cut at the outer end, as shown in Fig. 104. This difference in form is made in order that the difference

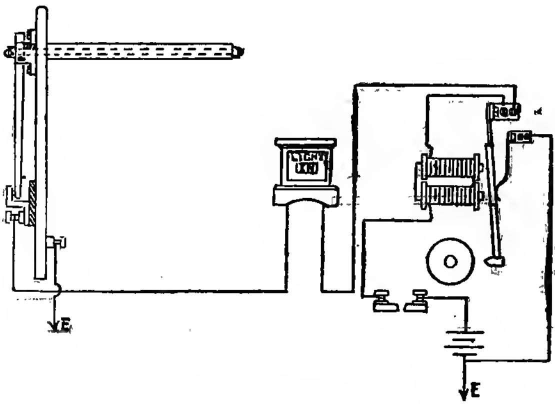


FIG. 109.—Diagram of Connections for Continuous-Current Light Indicator.

in the signals may be more easily identified, and to accentuate the difference existing in the character of these signals. "Distant" signals are passed whether "off" or "on"; "home" or "advance" signals must not be passed under ordinary circumstances when "on." The two latter signals are essentially "stop" signals; the former is not.

In order that a similar distinction may exist between the lights of "distant" and other signals, the apparatus shown by Fig. 110 is being introduced by Messrs. Stevens and Sons, the railway signal engineers, for the purpose of changing the fixed light now in use to one of a "flashing" character. The lamp is of the usual construction, but in front of the light is

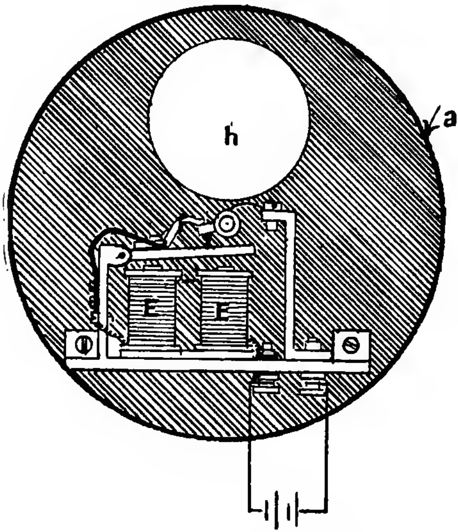


FIG. 110.—Distant-Signal Flash-Light Mechanism.

placed a circular disc, *a*, to which an oscillatory movement is imparted by the motion of the armature of the electromagnet, E. The apparatus is of a simple make and break character, the interruption of the circuit taking place between *f* and *g*. A circular hole is cut in the disc, *a*, at *h*, and this is placed on a level with the flame of the lamp. The movement of the disc causes the light to be alternately covered and uncovered, the return motion being obtained by the aid of the greater weight of the lower portion of the disc.

As already intimated, the apparatus is as yet only in the experimental stage, and it is therefore too

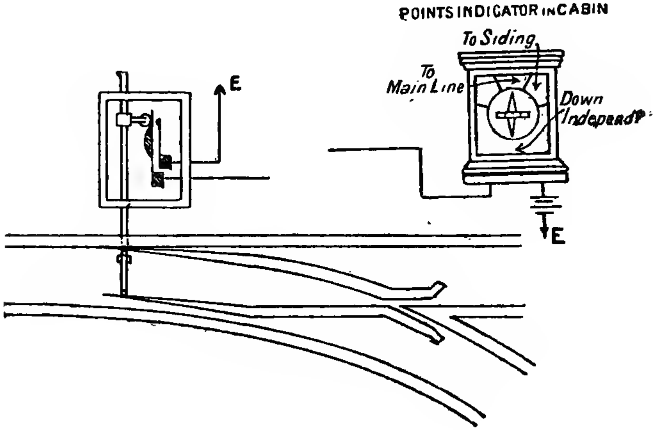


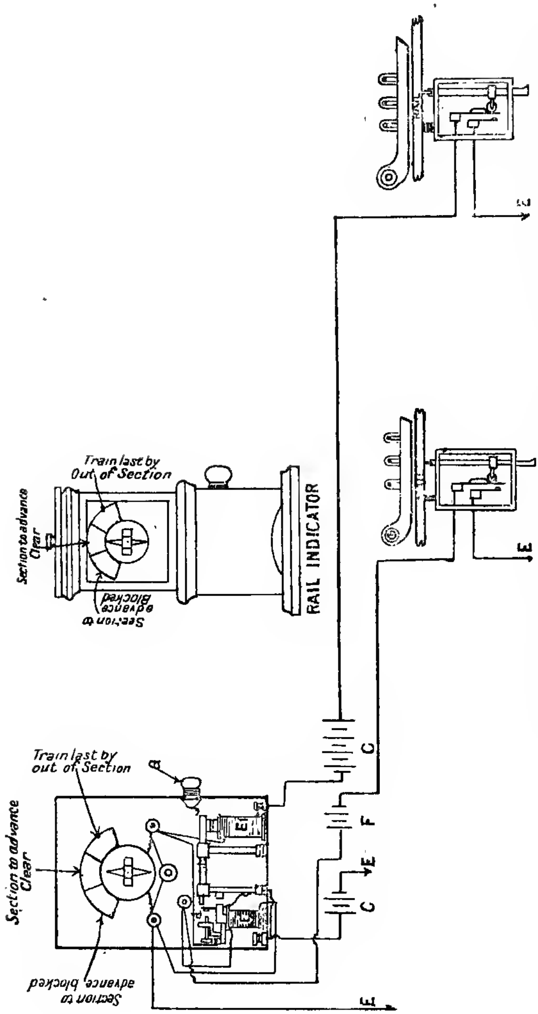
FIG. 111.

early to discuss its suitability or otherwise. At the same time it may be said that signals fitted with such an apparatus, as at present constructed, would require to have the "flashing" indicated in the cabin, in addition to the indicating of the existence of the light. Moreover, the "flashing" would require indicating for signals which under ordinary circumstances are in plain sight, for the reason that the apparatus does not "flash" the back light, which is the only part the signalman can see.

Points' Indicators.—It sometimes happens that "points" are placed in positions where they cannot be seen by the signalman. In such cases the apparatus shown by Fig. 111 is sometimes used.

Indicating the Section between Cabin and "Advance" Signal.—It frequently happens that whilst the arm of an "advance" signal is visible from the signal cabin, owing to its being placed on a comparatively high post, the base, and a part of the line cannot be seen on account of some object, such as a bridge crossing the line, intervening. In such cases there is a possibility of a short train, standing at the "advance," being forgotten, and another train being sent into its rear. The apparatus shown by Fig. 112 is intended to minimise the danger arising in this way by indicating a section of the line, which commences somewhere near the cabin, and terminates at a point a little beyond the "advance" signal.

The apparatus consists of two rail contacts fixed at selected points, and an indicator. Line wires are run to each rail contact. When a train passes over the first rail contact the parallel bar is displaced by the flange of the wheel, and the magnet, E, is energised by current from the battery, F. The armature of E is attracted, and the rocking bar, *b*, falls, locking the armature, and thus maintaining the local circuit through the battery C, *d*, and the indicator coils, and displaying the signal, "Section to 'advance' blocked." When the train passes over



Contact Blocking Section to Advance. Contact Clearing Section to Advance.

FIG. 112.

the second rail contact the electromagnet, E, is energised by the current from the battery G, the rocking bar is raised and the armature of E released, the local circuit of the battery C is broken and the needle of the indicator points to "Train passing out of section," which indication is maintained until the last vehicle, *in motion*, has passed over the rail contact. The normal position of the needle, when no current is passing, is "Section to 'advance' clear." The knob, *a*, at the side of the instrument is provided for the mechanical release of the rocking bar, *b*, from the position indicating "Section to 'advance' blocked" for cases where a train, having passed over the first rail contact, has shunted into a siding without having passed over the second. This last arrangement detracts somewhat from the value of the apparatus as an automatic arrangement. It will be noticed that there are three batteries to provide two deflections only. The work of the local battery, C, might, with a slight rearrangement of the connections, be performed by the battery F.

Rail Contacts.—Rail contacts are not as yet so important a feature of railway signalling as they are probably destined to be, when the apparatus used assumes a more automatic character than it possesses at present. One form of rail contact is shown by Fig. 111, in which the flanges of the wheels of a passing train are made to impart a horizontal movement to a bar laid parallel with and close to the rail, the return motion being obtained by a massive spring acting against the motion imparted by the train. Most rail contacts, however, are made to take advantage of the deflection of the rail by the weight of a passing train, in order to obtain the movement necessary for an intermittent connection. Several forms of rail contact suggested and used for various purposes are shown by Figs. 113, 114, 115, 116, 117, and 118.

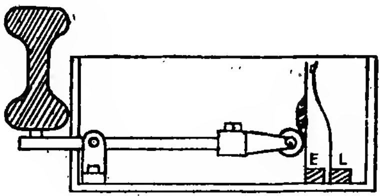


FIG. 113.

Rail contacts differ slightly in accordance with the character of the signal they are intended to provide for. Some forms only make contact during the time the rail is sufficiently depressed; others make contact

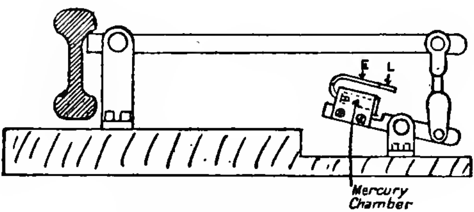


FIG. 114.—Circuit Broken.

for a longer period. Figs. 113 and 114 are examples of the first division. In the form shown by Fig. 114 the two connecting wires are sealed into one end of small chamber containing mercury, and the link work is arranged so that the mercury covers the ends exposed inside the chamber when the rail is pressed down. In this form a deflection of the rail of $\frac{1}{8}$in. is sufficient to make the necessary contact. Owing to the small deflection required, the outer lever is practically steady during the passage of a train.

Fig. 115 is an example of the form of rail contact, by which a more prolonged contact is obtained. The contact-making apparatus consists of two mercury-

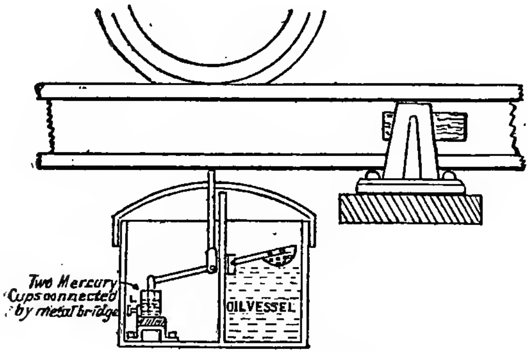


FIG. 115.—Circuit Closed.

cups to which the wires are connected. When the rail is depressed, a metallic bridge-piece dips into the mercury-cups, and completes the circuit. The lever arm carrying the metallic bridge is pivoted at or near its centre, and carries at the opposite end a semi-circular, perforated bowl, which under normal conditions dips into a vessel containing paraffin oil. When the rail is depressed the bowl is raised into the position shown, and is emptied of oil at the same time. When the train has passed over and left the plunger free the bowl slowly fills with oil and sinks, and by raising the metallic bridge out of the mercury-cups breaks the circuit. By proportioning the number and size of the perforations, a contact for any desired length of time may be obtained.

Another form of mercury contact-maker, shown by Figs. 116 and 117, is that used by Messrs. Saxby and Farmer in connection with their system of interlocking the mechanical "advance" or "starting" signal with

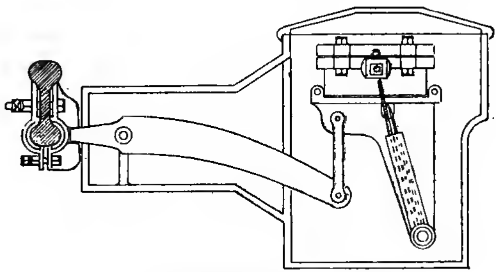


FIG. 116.—Buck's Patent Rail Contact.

the block instrument. In this form the vertical motion of the rail is made to impart a horizontal motion of the mercury-cup, and the alteration of the level of the mercury brings it into contact with the curved metallic bridge seen in Fig. 117. The lever worked direct from the rail is locked with it, as will be seen from Fig. 116, and the return motion is also imparted by the rail.

Siemens's form of rail contact, shown by Fig. 118, is capable of giving a more or less prolonged contact by the depression of the rail. In this form mercury is also used to make the contact, and it is pumped, by the deflection of the rail, to a slightly higher level than the normal, in order to bring it into contact with the projected connection to which the line wire is connected. The spring-plate, *b*, is flexible, and on the deflection of the rail the mercury is forced up the tube, *h*, and into the small chamber, *c*. When the

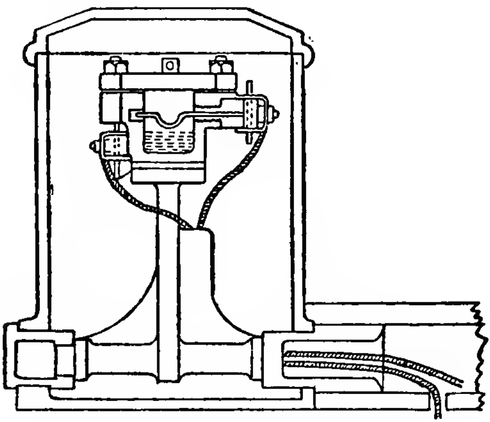


FIG. 117.—Buck's Patent Rail Contact.

rail is released, the mercury runs through the hole, *s*, into the larger chamber and breaks the circuit. The difference in the levels of the mercury in the large chamber, and under the spring-plate, *b*, ensures the latter keeping the plunger, P, in contact with the under side of the rail, when the latter is not depressed. An indiarubber ring, *a*, is placed under the rail in order to exclude dust or grit which might impede the free working of the plunger. The apparatus is shown attached to a flat-bottomed rail, but it would equally be as easily fixed to one of the ordinary double-headed form.

Considering the forms of rail contact shown, and some of the duties they have, or may have in the future, to perform, it will be seen that they are, as has often been pointed out, defective, in that the first vehicle passing over the contact performs the duty which should be done by the last. "Last

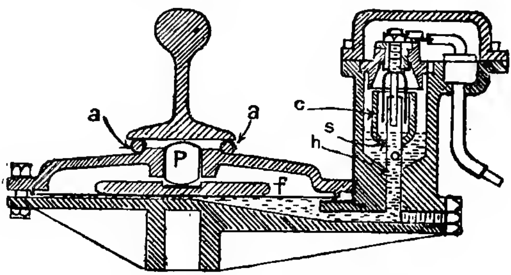


FIG. 118.—Siemens's Rail Contact.

vehicle," in this case, implies something more than the last which passes a certain point, since it is quite possible for a train to divide and one portion to be left standing in such a position as constitutes it a danger to a succeeding train.

Consider, by way of example, the case for which the instrument and arrangement of rail contacts shown by Fig. 112 is intended, and assume that a short train is standing at an "advance" on a sharp curve, and out of sight of the signalman. So long as no part of the train has passed over the second contact, the indicator will remind the signalman of the presence of the train; but if only a part of the train passes over the contact, the indicator will ultimately show "Section to advance clear." Under these circumstances the signalman would be justified in sending a succeeding train forward. It is true that the driver of the train is supposed to see that he has got the whole of his train with him, and it is also true that the guard on seeing a part of the train proceed forward should take steps to protect the part left standing; yet it is undeniable that most curious and, apparently, improbable combinations of circumstances are constantly arising. In any such event as that outlined, the indicator would be showing an incorrect signal.

It is, of course, a comparatively easy task to pick out defects in any form of apparatus intended for a specific purpose under varying conditions. These remarks, however, are only intended to show that the apparatus in use on railways for certain purposes is, in some cases, still in the evolutionary stage. Where rail contacts, of the forms shown in Figs. 69 and 112-120, are intended to actuate apparatus which gives indications of the nature of "Line clear," they would appear to be ineffective, in that they are unable to differentiate between the last vehicle of a train and any of the preceding vehicles.

In order to ensure the fullest possible protection to trains from apparatus, such as is shown in Fig. 112, or other apparatus indicating "Line clear," the last vehicle of every train should be capable of performing some duty that cannot be done by any other vehicle of that train. This, of course, involves the last vehicles being of a distinctive character to the others, or provided with an attachment which shall be capable of performing for the indicating instruments the same function the tail lamp, or other "Last vehicle" signal, does for the signalman.

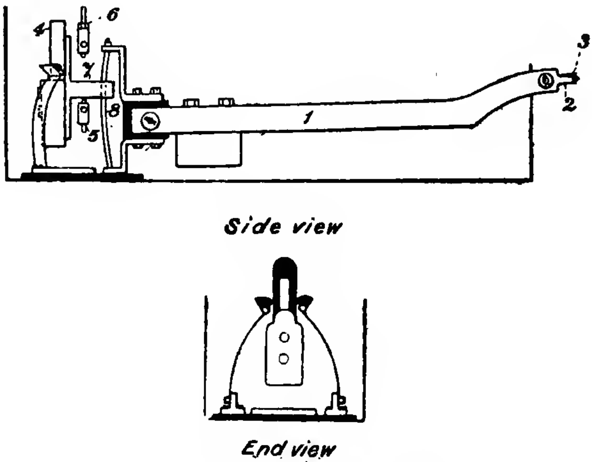


FIG. 119.—Hollins's Rail Contact.

Sykes's form of rail contact is shown by Fig. 69, and it is characteristic of the thoroughness of the arrangements made to obviate failure by Mr. Sykes in all apparatus of his devising. The contact is made by the tilting of two mercury-cups, by the depression of the rail; the object aimed at in the use of two contacts being to secure immunity from total failure in the event of one of them being defective, in the same way that two independent batteries are provided for the operation of his block instruments, as shown by Fig. 71.

Another form of contact maker, described by Mr. F. T. Hollins, of the Great Eastern Railway, in a paper read at a recent meeting of the Institution of Electrical Engineers, is shown by Fig. 119, which gives a side view of the apparatus, and also an end view of the contact maker. The tail-piece, 2, fits into a hole in the web of the rail, and is keyed by

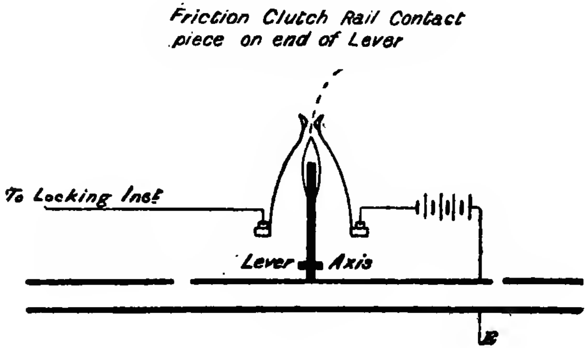


FIG. 120.

the adjustable steel key, 3. The contact is made by 4, which is carried by a friction clutch, 7, which, again, slides on the steel bar, 8. The motion of the contact maker and friction clutch is limited by the stops, 5 and 6. The position of the contact maker on the steel rod, 8, is therefore capable of being automatically adjusted to suit the condition of the road, by the passage of trains over the rail to which the treadle is attached.

In order to prevent premature action of the rail contact, Mr. Hollins insulates a rail at the point at which the treadle is fixed, and arranges the circuit

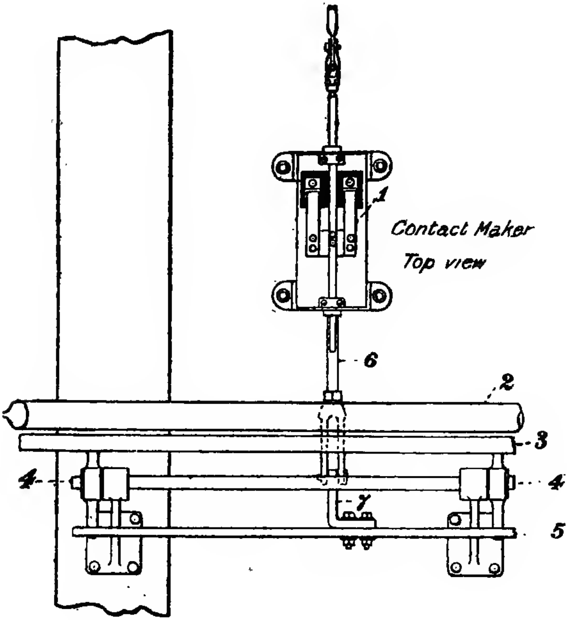


FIG. 121.

of the unlocking current so that it is completed only when the insulated rail (Fig. 120) is joined to the opposite one, which, of course, occurs when any vehicle passes over that portion of the line.

Figs. 121 and 122 show Sykes's electric fouling bar, which is used to ensure that no portion of a train, which has been shunted into a siding, is in such a position as is likely to entail danger to a train which may arrive on the line with which the siding is connected. Where trains are shunted into a siding instead of passing over the releasing treadle near the advance or starting signal, a second or more treadles are required in proportion to the number of points at which trains may be turned from the main line. Under such conditions the

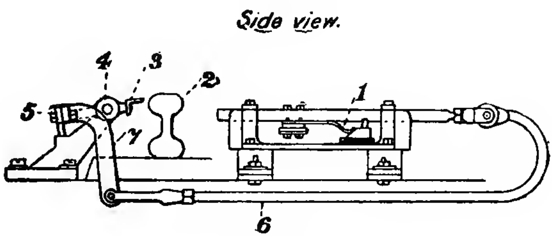


FIG. 122.

second treadle must be placed at some point in the siding, and the point at which release is to take place is not easy of selection, under ordinary conditions, owing to the great difference in the length of trains. Fig. 121 is a plan of the electric fouling bar, and Fig. 122 is a longitudinal section. The bar, 3, is depressed by the flange of the wheel of any vehicle, and this motion is imparted to the rod, 6, and causes the contact, 1, to be broken. The circuit of the treadle (which may be placed anywhere further in the siding) is completed through the contact, 1, and depression of the treadle can only release the lock of the instrument when the contact, 1, is complete. The bar, 3, is sufficiently long to ensure its being depressed by at least one wheel of any vehicle, and thus prevents the contact, 1, from

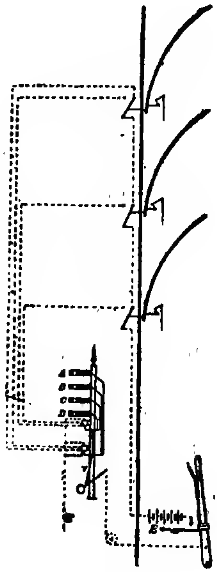


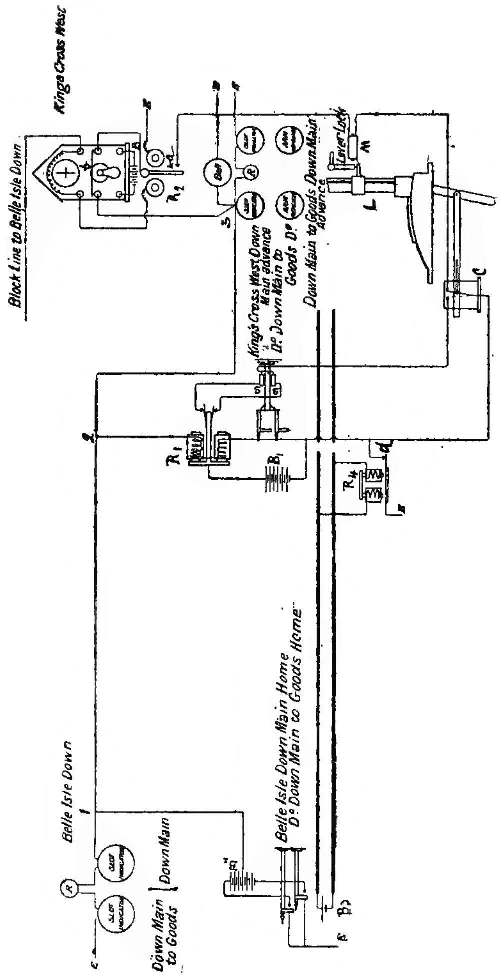
FIG. 123.

being closed until the last vehicle entering the siding has cleared the fouling bar.

Another piece of apparatus described in the paper by Mr. Hollins, already referred to, is Sykes's signal selector, which is shown by Fig. 123. The apparatus is intended for use where a number of signals are fixed upon one post, and provides for the working of any one of the signals by one lever, the signal arm lowered on any occasion being dependent upon the position of the *points*. As will be seen from the diagram of connections (Fig. 123) a line wire is run from each set of points to the signal post, and a battery wire to all the points contact boxes, the latter being in series. When all the points are as shown, the circuit is completed through the most distant point box, and operates the signal for the straight road. If the most distant points are set for a train to pass to that branch, the circuit for that signal arm is closed, and so on for any other points connected with the arrangement.

The movement of the lever in the cabin raises the rod, *r*, on the post. This rod is connected to the middle of as many horizontal levers as there are arms to be operated. One end of each horizontal lever is attached to the rod which operates the particular signal arm it is intended for. The other end of each horizontal lever is connected with the selector, and when the circuit from any pair of points is closed, and a current established, the selector fixes the end of the corresponding horizontal arm. Subsequent movement of the rod, *r*, causes the end of this horizontal lever, to which the rod operating the arm is connected, to move upwards and lower the arm.

The operation of any of the arms depends upon the points being properly closed for the line which is controlled by the arm which it is intended to



Block Line to Belle Isle Down
Kings Cross West
King's Cross West Down Main advance
Do Down Main to Goods Do
Down Main to Goods Down Main Advance
Lever Lock
Belle Isle Down
Down Main
Down Main to Goods
Belle Isle Down Main Home
Do Down Main to Goods Home

FIG. 124.

lower, and the apparatus thus becomes a points' indicator. Apart from this, however, it forms no part of a *safety* device, since, as will be observed from the diagram of connections, it, obviously, depends upon the mechanical interlocking between the different points' levers to prevent more than one road being set at a time.

A novel and interesting application of electrical interlocking, also described by Mr. Hollins, is in use on the Great Northern Railway near King's Cross Station. The arrangement is shown diagrammatically by Fig. 124.

R_1 and R_2 are polarised relays, R_4 is a non-polarised electromagnet connected across the rails through the tunnel, which constitute a section insulated, electrically, from the rails at either end of the section. B_3 is a battery of low electromotive force connected permanently with the insulated section of rails as shown. B_2 is a battery, the middle point of which is connected with the slot indicators at Belle Isle, and, by a line wire passing through the tunnel, with the relay R_1, the slot indicators, bell, and the armature of R_2 at King's Cross West.

When Belle Isle pegs the block instrument needles to "Line clear," the current passes through the coils of R_2, and closes the contact *a*. Belle Isle next lowers one or other of the two signals "Belle Isle Down Main Home," "Belle Isle Down Main to Goods Home," as may be required. The movement of the arm completes the circuit of one of the sections of the battery, B_3, the current from which divides at 1, again at 2, and again at 3. At 1, part of the current goes through the slot indicators at Belle Isle, and the remainder to King's Cross West by the line wire. At 2, part of the current passes through the relay, R_2, to earth through the contact *d*, the remainder passing to 3. From 3 the current branches through the bell and slot indicators in parallel direct to earth, and through *b*, *a*, M, and C to earth at *d*. The action of the latter portion of the current releases the lever lock by energising M and releases the signal lever, L, which may then be pulled into the "off" position.

Movement of L reverses the position of the double contact, C, and the circuit from 3 through *b*, *a*, and M being broken, the lever lock is replaced in position for engaging with L when the latter is returned into the "on" position.

The current passing through R_1 sets up a current from B_1 which passes through one or other of the Sykes signal replacers, S S, according to the direction of the current through the coils of R_1, and passing by C, after L is moved into the "off" position, lowers the signal arm by the action of the replacer.

When the block indicators are indicating "Train on line" the contact *a* is broken by the reversal of the armature of R_2, and the lever lock is not affected by M even if the lever, L, is in the "on" position.

When the engine or train previously signalled enters upon the insulated section of line at the King's Cross end, the battery B_3 is short-circuited through the wheels and axles of the vehicles, and the armature of R_4 being no longer held, breaks the contact *d*. This breaks the current set up from B_2 by the lowering of the arm at Belle Isle, which has been passing through

R_1, and consequently breaks the current through the signal replacer, S, affected, which then places the signal to danger behind the train. Hence, as long as a train occupies any portion of the insulated section of rail the circuit of R_1 is broken, and the signal replacer, S, cannot be actuated, since no current can

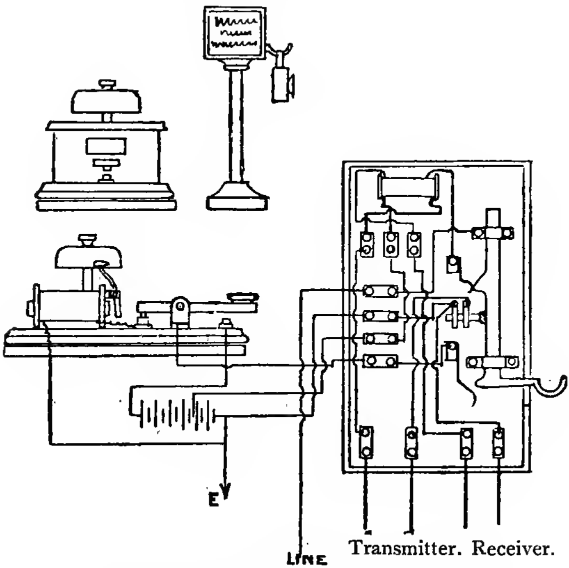


FIG. 125.—Block Bell and Telephone Circuit.

be passed through R_1, even under such conditions as obtain when the block indicators are exhibiting "Line clear," and, the lever lock being released by M, the lever, L, is pulled into the "off" position.

It will be noticed that the lever, L, operates either of the signals, and that it can only be pulled into the "off" position after the receiving signalman has given permission for an approaching train to enter the section.

It will also be noticed that the signalman at Belle Isle really controls and decides which of the two signals at King's Cross West shall be operated by the movement of the lever, L, at the latter place, whilst the battery B_3 can only maintain the circuit by which the signal arms are actually brought into active operation during the time the insulated section of the line is unoccupied.

Telephones on Block Circuits.—The extensive use of telephones on railways has led to the trial of combined circuits for telephones and block bells, the latter being selected because the currents used for bell signalling are transient only. A form of switch used for this purpose is shown by Fig. 125. The arrangement, of course, admits of being used between two successive cabins only. The block bell is used as a means of call to the telephone.

CHAPTER VI.

General Conditions.

It may be useful to recapitulate some of the chief conditions which experience, and the general trend of development, indicate as necessary, and it may also be of some interest to see in what degree the most modern apparatus is calculated, if adopted generally, to secure immunity from errors of a similar character to those which are known to have been the direct cause of some of the more recent accidents. It is only by the study of the combinations which make for or against the object aimed at that the knowledge usually denominated "practical" is obtained, and it is commonly acknowledged that the experience acquired from failure is most completely assimilated.

The chief causes contributing to accident have already been referred to. They may here be briefly summarised as follows: (1) acceptance of a train into a section which is already occupied; (2) sending a train into a section already occupied; (3) failure to notice the positions of the fixed mechanical signals. These deviations from the rules under which block working is carried on, have all at one time or another been the first cause of accident.

The three causes enumerated cover the possibility of error on the part of the three responsible persons engaged in the working of any train through a block section worked under absolute rules—viz.: (1) the signalman at the receiving end; (2) the signalman at the sending end; (3) the driver of the train passing into or out of the section. Of these three persons the first is usually considered as holding the most responsible position, since it is he who, under the ordinary working conditions, accepts or declines to allow trains to enter the section at the opposite end, according to the condition of the line at the time. There is no doubt that when working strictly to regulations, the signalman at the receiving end is in a position of great responsibility, since, before accepting any train, he must assure himself that the *whole* of the preceding train has cleared the section, and that no obstruction exists, at his own station, which involves possible impediment to the approaching train throughout the *whole* length of the section it has entered, or is about to enter. A failure in observing this most elementary rule of block working led to a most disastrous accident on one of the leading railways about four years ago, and resulted in considerable loss of life under most lamentable conditions, and in great destruction of property.

During the time that work is carried on in accordance with the rules of the service, the sending signalman's responsibilities are confined to the exhibition of the proper mechanical outdoor signals for the information of the driver of any train which may approach, and generally acting in accordance with instructions received from the other end of the section. If, however, any deviation from the usual method of working occurs, either from negligence or inadvertence, it is just as likely to originate at the sending end as at the receiving end, and the results may be equally disastrous. There is no lack of instances where trains have been sent forward under the impression that the indication of the block instrument refers to that train, and the lowering of the signal at the proper time has been neglected. In other instances trains have been sent forward without any of the usual block signals being exchanged, and the signalman at the receiving end has had no intimation of the train until it came under his personal observation.

In so far as the *acceptance* of a second train into an absolute block section is concerned, apparatus of a similar nature to that shown by Fig. 44, Saxby and Farmer's (Figs. 49-61), or Sykes's (Figs. 62-71), in which the receiving instrument is locked to "Train on line" until the train signalled has passed a certain point, or one of a number of points at relief sidings or junctions, would appear sufficient. To be consistent, however, the arrangements should be completely automatic, and this, of course, involves the use of releasing treadles at each of the points at which a train may clear the section, and other means of cancellation than exist at present.

In so far as the *sending* of a second train into a section is concerned, such arrangements as are shown by Fig. 45-48 (Winter's), Figs. 58-60 (Saxby and Farmer's), or Fig. 70 (Sykes's), in which the signal controlling the advance section is locked until the "Train on line" or "Line clear" signal is accepted, and is automatically replaced to "danger" by the passage of the train into the section, are a great advance on the usual method of working, and should be sufficient to prevent such errors. These methods have the further advantage of not interfering with the usual method of working traffic, or requiring the line to be cleared for a greater time than ordinary for an approaching train. This, of course, is a matter of considerable importance in the working of busy junctions.

In cases of non-automatic working, a point of some importance arises on further consideration of the two probable causes of error just referred to. In one case, the *acceptance* of a second train may be made under the impression that it has been forgotten to clear the line for the last train. On the other hand, as has been shown, a train may be sent into a section under a similar misapprehension. In neither case does the ordinary form of instrument afford any indication of the deviation from the regular methods of working, and any attempt to avert the consequences arising, must depend upon the signalman remembering the conditions actually existing, and, recognising his error, taking such steps as are possible under the circumstances. Certainly, some such intimation might be of the greatest possible utility to the signalman at the receiving end of the section; and it is quite conceivable that, under certain circumstances, prompt action on the part of the receiving signalman, as a consequence of an automatic indication of the presence of two trains in the section, might enable him to avert the consequences of the error, by allowing the first train to draw within the protection of one of the stop signals. Such apparatus need be of the simplest possible construction, but, owing to its casual use, would require to be carefully maintained in working order.

If the third contributory cause of error—failure to notice the position of the fixed mechanical signals—is considered, it will be observed that there is not anything like the number of devices in use, or suggested, to protect the driver from possibility of error. With some exceptions the driver is the only person of the three concerned who has, practically, been left to depend upon himself. Whilst this is the case, neither of the signalmen are in such a position of responsibility as the driver. Errors on the part of either of the signalmen may be minimised and accident averted by vigilance and promptitude on the part of the driver, and have been on many occasions. If, however, the driver errs and runs past the signals, the signalmen have no control over his actions whatever, and are powerless to avert the consequences. It cannot be too strongly insisted upon that block signalling is only a means to an end, and that end is the exhibition of the proper signals for the guidance of the drivers of trains. If the necessity for automatic control of the means of signalling to the driver is felt, and the general line of progress is sufficient to prove this, how much more important is it that special means should be provided to ensure that the person, for whose guidance the whole system of signalling is devised, is really made aware of the conditions under which he is running at any and every point where signals are exhibited.

A big smash on one of the leading lines a few years ago, was directly traceable to failure on the part of the drivers of the train to observe the positions of the mechanical signals at the entrance to the section in which the collision occurred, owing to the prevalence of fog. One of the two drivers of the train which ran past the signals paid for the error with his life, and the other with the loss of a limb. It is true, of course, that railway companies have elaborated arrangements for replacing the usual visual signal by aural equivalents in the event of a fog, or other similar cause, preventing the former from being available. For the period of the introduction of fog signalling, it was no doubt eminently suitable, but for the present period it leaves something to be desired. In the first place, the indication to the driver that the line is clear, and signals, which he cannot see, are off for his advance, is of a negative character only. The absence of an explosion, due to the engine passing over one or more fog signals, is taken as an indication that the line is clear to proceed. Under this condition the driver has no real assurance that fog signalling has been commenced.

Again, the fog signals have, in the ordinary form of working, to be placed in position by men stationed at the signals, and these men must take the position of the arm as a guide to their own actions in placing the fog signals to be exploded, or removing them, according as the signal arm is "on" or "off." The control of the section of line protected by the signal is dual, and therefore, whilst there *may* be two possible checks against error, there are undoubtedly two points at which error may arise. Further, the calling out of the fogmen for their special work depends under the present system, in many instances, upon the signalman, and he must exercise his judgment upon the necessity, or otherwise, for calling out these men as occasion may require. Some time may elapse between the decision to commence fogging and the actual commencement, more especially during the night. During this interval the necessity for the fogmen may increase, or it may cease altogether. In the first case the signalman may think he has delayed calling out the men too long, and in the other case he would think his action was premature. In either case his position is not a comfortable one.

Many attempts have been made to provide automatic, or semi-automatic, means to warn the driver of the positions of signals he is approaching or passing, under conditions which prevent their being seen; and railway companies are by no means backward in giving a trial to apparatus which possesses any of the elements necessary to success. Some forms of apparatus for this purpose are adaptations of the ordinary fog signal to use, at any time, by the aid of mechanical means, by the signalman working the signal. Usually a number of fog signals are kept in a special case near the signal, and the signalman, by the use of a special lever in the cabin, communicating with the box by a wire, is able to place a fog signal near the rail, on a specially prepared base, for explosion by the depression of a rod over which the train passes. The ability to commence using the fog signal at any time is a great advantage.

Unless, however, the apparatus is duplicated, only one fog signal can be put in position at once, and in the event of its not being exploded, from any cause, the results may be serious. Moreover, the adjustment of the fog signal in position for explosion is somewhat fine for operation, at such a distance as "distant" signals are usually placed, by the aid of a wire which is subject to alterations of length with varying temperatures.

Electrical methods have also been suggested for this purpose. Some of these involved the use of a bell fixed on the engine in any convenient position. This bell was to be operated by a battery, also carried on the engine, the circuit being closed by an obstruction placed by the side of the line, which was operated by simple means in conjunction with the signal to be indicated. This arrangement was not reliable on account of the difficulty experienced in maintaining batteries in a state of efficiency under the conditions of their use, and also on account of the vibrations and shocks to which the apparatus was subject. Other arrangements involved the use of a large bell, fixed in proximity to the line at a suitable height, which was intended to ring continuously whilst the signal was "on," and which could be put out of operation when not required by the use of a small peg switch. Such arrangements are of little use for the purpose intended; the difficulty of conveying sounds from the outside, to the inside of the cab of an engine in rapid motion, are immense, and can only be appreciated after experience.

Suggestions have also been made for repeating the position of the signal arm directly on the engine by mechanical means, worked in conjunction with the signal. One of these methods, suggested by the author about four years ago, is shown by Figs. 126 and 127. The apparatus on the engine for indicating the position of signals consisted of a small fac-simile

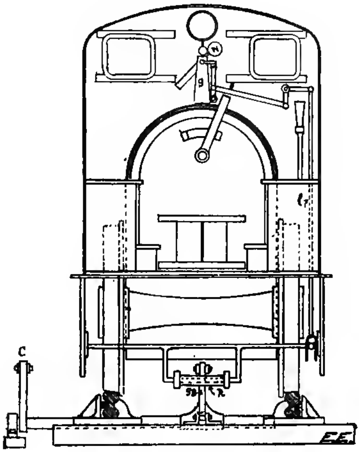


FIG. 126.

of the ordinary outdoor signals. This was fixed on the cab of the engine, as shown. A counterbalance, W, was fixed to the arm, so that when not otherwise supported the latter took up the "on" position. To the frame of the engine was pivoted a metallic rectangle, R, arranged to turn on its upper side as an axis. A rod, bifurcated at its lower end to engage with pins, *p*, on the rectangle, R, passed then to *s*, and supported the arm in the "off" position under normal conditions. Movement of the rectangle in either direction caused the support to be withdrawn from the arm of *s*, and it at once took up the "on" position by the action of the counterbalance. As will be noticed from Fig. 126, the arm could only be replaced in the "off" position by the direct action of the driver.

The great difficulty in connection with the design of apparatus for this purpose, is the violent shock experienced when used on trains travelling at a high

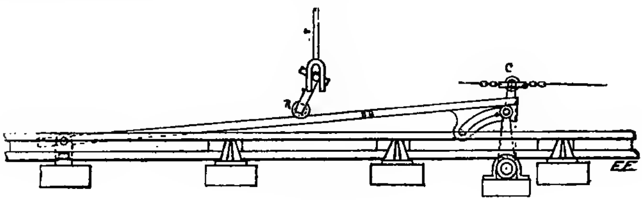


FIG. 127.

rate of speed. In order to minimise the shock, the swinging rectangle, R, was operated by sliding over the inclined bar, B (Fig. 127), which was fixed in the centre of the four-foot way, and one end of which was raised, or lowered, as the signal was "on" or "off." When the signal arm was "off" it was, of course, intended that the bar, B, should be in such a position as would prevent its operating upon the swinging rectangle, R.

The fixing of such a means of operating an indicator on the engine requires considerable care if placed in the four-foot way, on account of the small amount of space available. The bar, B, when inclined for use, must project above the rail level; since the space between the rail is often filled up at level crossings, the swinging rectangle must necessarily be set high enough to miss all such points. On the other hand, the bar must not be of such a height as to come in contact with the engine firebox, or any of the mechanism. Of course, it is possible to place such apparatus on the outside of the rails, but as engines do not always run engine first, it would be necessary to provide bars on both sides of each line of rail, or as an alternative provide attachments on each side of the engine.

A similar apparatus, patented by Messrs. Raven and Baister, of Darlington, is at present under trial on the North-Eastern Railway Company's lines. This arrangement is shown by Figs. 128 and 129. The main principle is the operation of a special alarm on the engine, when the latter is approaching or passing a signal at danger. In this form, however, the alarm takes the form of a special whistle, which may be operated by steam or compressed air. The valve controlling admission of steam or air to the whistle is operated by the movement of the pendulum levers, *b*, when the latter come in contact with the raised obstructions. The lever, L, which is connected to the pendulum levers, carries a pin which works in the straight slot, c^1, formed on the lower end of the rod, *c*, and also works in the curved slot formed on the fixed plate, *g*. Movement of the pendulum, *b*, causes the pin to rise in the fixed curved slot, and raises c^1 and c, and opens the valve. It will be interesting to note the progress made in this development of automatic signalling, as, from the remarks made, the necessity for some such method is

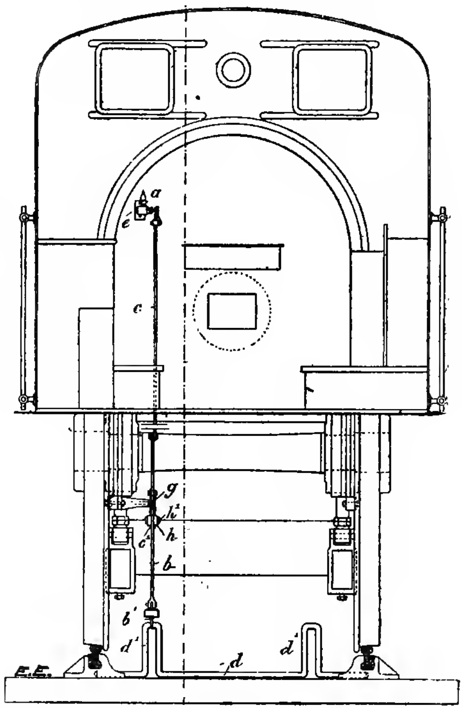


FIG. 128.

increasing. One of the greatest advantages arising from the use of such methods as those just described is due to the fact that they are in continual use, and, therefore, require no special arrangements to be made, and involve no additional operations on the part of any person concerned, to contribute towards the results desired.

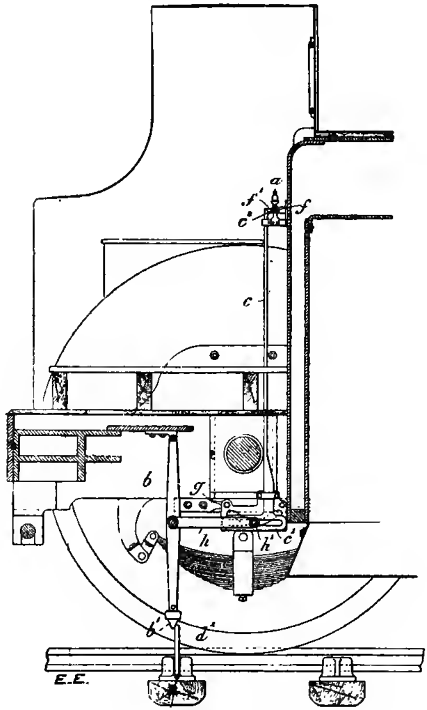


FIG. 129.

Such methods of signalling as are indicated by Figs. 126-129 are capable of much more general use than as mere substitutes for another form during exceptional circumstances. Whilst the general adoption of such substitutes for the present outdoor mechanical signals would constitute a revolution in the method of signalling to drivers of trains, it would, in the author's opinion, be a considerable advance towards complete efficiency, and could not fail to be more economical than the present methods of signalling.

Closely connected with this part of the subject is the question of repeating the positions of the mechanical signals in the cabins from which they are operated. The relative importance of the "on" and "off" indications has already been referred to. It only remains to point out that confining repetition to "distant" signals which are out of sight of the signalman is not consistent. The general rule is to repeat a signal which, even under normal conditions, is not visible to the signalman; and as "distant" signals are more frequently out of sight than any other, repetition is confined almost solely to this class of signal. Bearing in mind the real reason for repetition, it follows that any signal which may, under any circumstances, be out of sight of the signalman should be similarly treated. Very slight consideration is necessary to show the advisability of repeating all signals; during fog or snowstorms, distant signals, which under normal conditions are in plain sight, are quite invisible, as also are "advance" and "home" signals in particularly bad cases. As fogmen depend entirely upon the position of the signal arm for their guidance, it becomes of double importance that the signalman should have an accurate knowledge of their positions under these circumstances. For these and similar reasons, the increased use of repeaters of the positions of the mechanical signal arms seems desirable; and, as already pointed out, the repetition should be that of the arm itself, and not that of some point on apparatus more or less intimately connected with the arm.

Another point of great importance may be shortly referred to. This is the need for an uniform system. At present nearly every railway company's system differs from those of other companies, in either the regulations, or the apparatus employed, or both. For this diversity of method, or apparatus, no really valid reasons can be alleged. The handling of railway traffic is practically the same wherever carried on, and the fact that block working, wherever used, is, in its essential characteristic—the enforcement of a space limit—uniform, is proof that uniformity of means to the end is merely a matter of arrangement. The end in view in all cases is exactly the same, and there is no reason to suppose that, generally, any one of the ways taken is speedier or smoother than the others. On the other hand, the advantages accruing from uniformity of code and apparatus would be considerable, and would put into the hands of railway companies powers which, under certain conditions, would be of the greatest importance, but which they do not yet appear to appreciate. Unfortunately, the amount of capital already invested in existing apparatus precludes the idea of a speedy reformation in this respect.

It may be thought that in giving so much attention to non-electrical methods, such as traffic arrangements and the mechanical signalling of trains, the writer has, to use a familiar colloquialism, "got off the rails." The term "block system" is too frequently used to indicate the electrical portion of the apparatus only. It cannot, however, be too strongly emphasised that the signalling which acts in *notification* of the movements of the trains, and only indirectly controls those movements, and that through another medium, is not the *whole* of the "block system." The term "block system," as the writer understands it, has a much broader significance, and consists in the preservation of a space limit between the successive trains; the means used to effect this desirable end being of importance only in proportion to the degree of perfection attained in producing that effect. The recognition of the necessity for a space limit is as old as railways themselves, and the methods of the present period are simply developments, rendered necessary by continual increase of traffic, along a line which has been rigidly marked out by a continual process of trial and error. In just the same way that the weakest link must be taken into account in gauging the strength of a chain, the whole of the apparatus connected with the working of traffic must be passed under review, before its combined efficiency can be fully estimated. No part can stand alone, Careful traffic arrangement is necessary to ensure that smooth and speedy working which is the first essential of all successful work. Electrical signalling is necessary for the preliminary arrangements required to marshal traffic in the order of its importance, to facilitate its passage with safety, and to notify its progress. Mechanical signalling is the executive of both.

CHAPTER VII.

Mr. Alexander Siemens's Automatic Block Signalling System.

From "Engineering."

In this system the trains automatically make electrical contact at certain points along the line, and the apparatus used by Mr. Siemens for this purpose is shown by Figs. 130-135. In this system powerful currents of electricity are necessary. In the case of electric railways, the current would be taken direct from the main conductor, and in other cases either a special dynamo would be put down or the current taken from the mains of an electric supply company.

The signals are so arranged that they are set by the passage of trains over certain portions of the line, and sets of such signals, applied to successive block sections of the line, constitute an automatic system requiring no attendants for working them. For this purpose, at or near each end of a block section of the line, a signalling apparatus is provided of the following description.

On a horizontal axis is fixed a semaphore arm or a set of coloured glasses, or both, these being counterweighted by a heavy arm on the axis, so that when the axis is free the signals are moved by the counterweight to the position signalling "danger." The heavy arm is a bar of iron bent to the form of a circular arc, and arranged so that it can enter a solenoid coil. When this solenoid is excited by a current of electricity the bar is attracted into it, and the axis is turned, moving the signal arm to the position indicating "line clear."

The signal arm axis carries another arm which in each of its two positions makes a contact, and in one of the positions, corresponding to the "line clear" position of the arm, this arm is held by a catch on the armature of an electromagnet. The coils of this electromagnet are connected with the contact maker, Fig. 134, arranged at a certain part of the line at the entrance to a block section, so that when a train passes over the contact maker or rail treadle a current of electricity is transmitted to the electromagnet, and the core being thus excited attracts its armature, withdrawing the catch from the arm of the signal axis, whereupon the signal, in obedience to the counterweight, assumes the "danger" position. At the same time the arm, released from the catch, moves away, breaking the contact for the electromagnet, and making a contact whereby a current is transmitted to the next signalling apparatus behind, and this current exciting the solenoid there, causes the signal to take the "line clear" position. On the train reaching the next contact apparatus a like action is repeated, the train thus automatically blocking each section that it enters, and not unblocking it until it enters the next section in advance.

From the description it is apparent that the signal at the entrance to any one section cannot be made to indicate "line clear" unless the signal at the entrance to the next section in advance has previously been put into the "danger" position.

Although the control of one signal by another is only described for the simplest case, it is obvious that the electrical connections of three or more signals can be so combined that each signal can only be set to show "line clear" when certain other signals are at "danger."

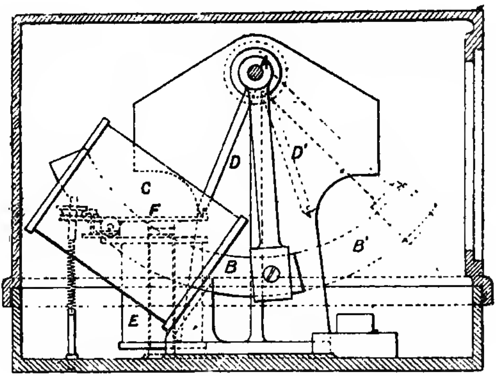


FIG. 130.

Figs. 130 and 131 are vertical sections on planes at right angles to each other of Mr. Siemens's signalling apparatus. A is the axis on which is fixed the semaphore arm or pair of coloured glasses, counterweighted by the bent iron bar, B, which enters the heart of the solenoid, C, and is of sufficient weight to hold the signal arm in the "danger" position. E is the electromagnet, the spring armature, F, of which terminates in a catch which holds an arm, D, fixed on the axis A. The arm D, or it might be another arm fixed on the axis A, is arranged to act as a switch making and breaking contacts for the conductors to the solenoid and the electromagnet in the following manner:

Assuming that a train is running along a section of line from X station to Y station, that the signal at X is at "danger," blocking the section against

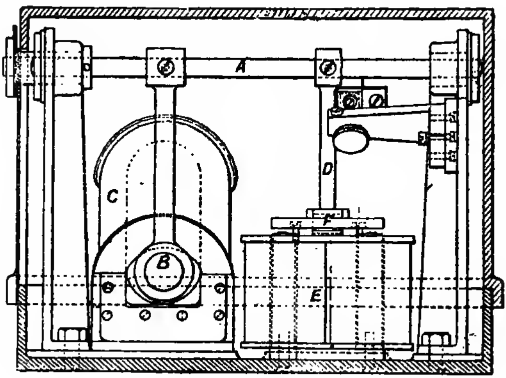


FIG. 131.

the entrance of another train, and that the signal at Y is at "line clear," showing that the train may enter the next section from Y to *Z*, in that case the apparatus at X has its bar, B, and arm, D, in the position indicated by the dotted lines B^1 and D^1, Fig. 130, but the apparatus at Y has the bar B within the solenoid and the arm D held by the catch of F. As the train leaves the section X to Y and enters the section Y to *Z*, it, by acting upon the rail treadle, causes the current to pass through the coil of the electromagnet, E, at station Y. The armature, F, being thus attracted, the catch holding D is withdrawn, and the bar B assumes the dotted position B^1, the signal at Y being thus set to "danger," blocking the section Y to *Z*. At the same time D, in moving to the position D^1, breaks the contact for the electro-magnet, E, and makes another contact whereby a current is transmitted to the solenoid C at station X. The solenoid then attracts the bar B, setting the signal arm to "line clear," indicating that the section X to Y is clear, and the signal at X is retained at "line clear" by the catch F holding D until it is released by a succeeding train entering the section X to Y.

It is obvious that two or more signals as above described may be combined in such manner that two or more signals require to be brought into the "danger" position before another signal can be brought into the "line clear" position.

Such combination of signals is effected by the employment of an auxiliary signal apparatus or relay constructed and operating as follows: Referring to Fig. 132 two solenoids are arranged in combination with one iron core in such manner that when a current passes through one solenoid so as to attract the core, the latter remains in this position even after the solenoid ceases to be excited, until the second solenoid is excited, when the core will be moved thereby into a second position, in which it at the same time breaks the circuit of such second solenoid.

In the first-named position of the core it effects the closing of a local circuit, which starts from a contact made by a train when about to enter the section protected by the signal, thence passes through certain other conflicting signals, provided they are in the "danger" position in which they make the requisite contacts, then through the second above-mentioned solenoid and into the signal of this apparatus, effecting the lowering of the same to "line clear."

The effect of employing the auxiliary signal apparatus or relay is therefore that the signal in connection with it is only lowered when the train is about to enter the section, and when all conflicting signals are at "danger."

When applying this apparatus at a junction the "entering" contact is not actuated by the train depressing a rail, but several such contacts are provided, each corresponding with one of the lines of rails diverging at a junction, the one or other of which is actuated by suitable means, according to the destination of the approaching train. The contacts may, for instance, be effected by permanent projections on the engines when each engine has always to go to the same destination, or they may be effected by levers under the control of the engine driver, so that he can select the line of the junction along which he wishes to run his train by effecting the particular contact by means of the corresponding lever.

The signals at a junction may be worked in conjunction with the levers moving the points, so that the electric current is made to move over the points before the signal is lowered, or, in cases where the levers are worked by hand, the electric signals may be interlocked with them in any well-known manner.

Fig. 132 is a section of the casing containing an auxiliary signalling apparatus or relay, shown partly

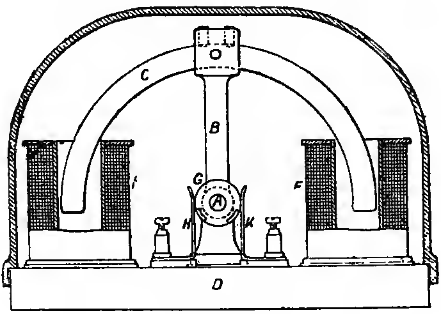


FIG. 132.

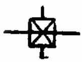
in section. On an axis, A, is pivoted an arm, B, carrying a semicircular bar, C, of soft iron. On the base, D, are fixed the two solenoids, E and F, into the hollow interiors of which the ends of the bar, C, enter, and in which they can freely move. On the axis, A, is fixed a rotary switch or commutator, G, against which bear springs, H K, the periphery against which they bear being partly of conducting material and partly of non-conducting material, so that contacts with the springs are made or broken according to the position of the bar C. On the axis, A, there may be several sets of commutators, G, and springs, such as H K, according to the conditions of the signalling circuits to which the relay is applied.

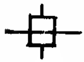
When one of the solenoids, E for instance, is excited by an electric current passing through its coil, the one end of the bar, C, is attracted as a core into it, and as in this movement its centre of gravity passes the vertical line of its axis, it remains, like a trembling weight, in the position to which it is attracted after the solenoid, E, ceases to be excited. But when the other solenoid, F, is excited, the other end of the bar, C, is attracted into it, and the bar tumbles to the other side, and remains there after F ceases to be excited, until E is excited again.

The current of each of the two solenoids, E and F, is arranged in connection with the commutator, G, and springs, H K, in such a manner that when the bar, C, is made to tumble over to either side, the circuit of the solenoid which it attracted is opened, and the circuit of the other solenoid is closed, ready to act when a current is transmitted through it.

Fig. 133 shows diagrammatically the signals, contacts, and connections at a junction, J, where S_1, S_2, etc., are signals, as shown in Figs. 130 and 131, and R_1 and R_2 are relays, as shown in Fig. 132. In the diagram the following conventional signs are used:

 Contact made by signal being put to "danger."

 Contact made by signal being put to "line clear."

 This contact sets the signal in question to "danger."

 This contact on post puts the signal to "line clear."

 Contact on rail to set signal behind train to "danger."

 Contact on rail to lower signal in front of train, on condition that relay circuit has been closed and all conflicting signals are at danger.

The following examples may help to make the diagram clear. Consider an "Up" main train to make contact e_5. This sets the signal, S_1, to "danger," and puts the signal further behind to "line clear." The train now passes on to contact f_1, and this will set the signal, S_1, to "line clear" if two conditions are fulfilled. (1) That a previous "up" main or branch train has passed over contact e_6, thereby pulling over the relay R_1, thus closing contacts 2 and 3, and breaking contact 1. (2) That the conflicting signal S_4 is at "danger." If either of these conditions is not fulfilled the train cannot lower the signal S_2, and the driver must pull up and wait on contact f_2 until the relay contacts 2 and 3 are closed, and the signal S_4 is put to "danger." This ensures that a previous "up" train must have passed the contact e_6, for the signal S_4 can only be put to "danger" by a train making contact e_7, and the

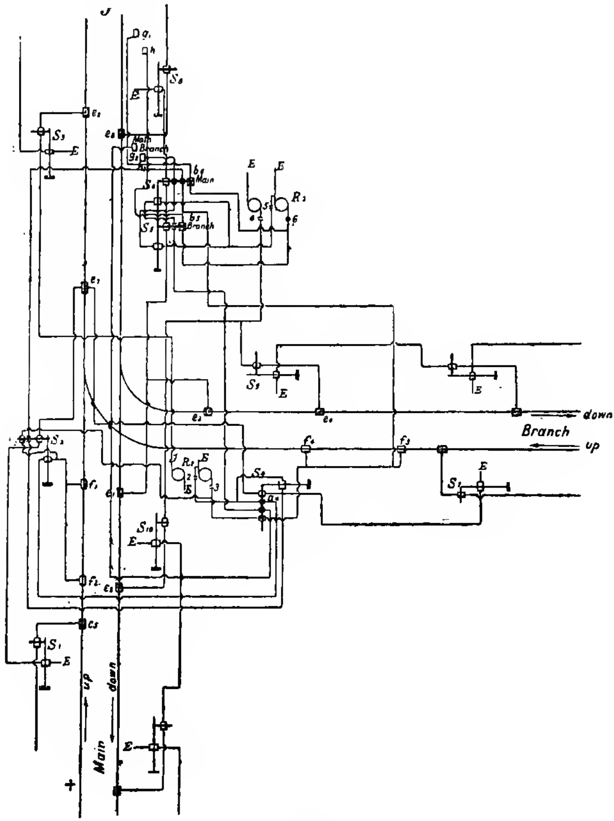


FIG. 133.

relay R_1 can only be pulled over by the same train making e_6. Under these conditions a current can flow from f_2 through S_2 (lowering same), through contact a_4 on S_4, through contact 2 on relay R_1 to common return. As soon as S_2 is lowered the contact b_2 is made, and the current then passes through contact 3 of relay R_1, through solenoid to common return, thus making 1 and breaking 2 and 3 of the relay. Having lowered S_2, the train can now pass on to e_7, the making of which has the effect of pulling S_2 to "danger," and S_1 to "line clear." Passing on further, the contact e_6 is made, and the signal S_3 is put to "danger," also the relay R_1 is pulled over, breaking contact 1 and making 2 and 3. Everything is now ready for the next main or branch "up" train that comes along. If it is a branch "up" train a similar series of contacts are made. For, on making f_3, a current can pass through S_6 if it is at "danger," through S_2 if at "danger," through S_4 (lowering same), through 2 of relay R_1 to common return. This ensures that no main "up" train can get past f_2, that no main "down" train can get past S_6, also the previous "up" train has passed e_6. Passing on to e_7, the signal S_4 is put to "danger," and S_7 is put to "line clear."

Next consider a "down" main train leaving the junction, J, having made contact g_1, by a lever or other device, on the locomotive. This will lower S_6 on condition that the signals S_4 and S_5 are at "danger," and that the relay R_2 has been pulled over (thus closing contacts 5 and 6) by either a previous "down" main train having passed over e_2, or a previous "down" branch train having made e_4. If these conditions are not fulfilled the train must wait on g_2 until the preceding train, if it was a "down" branch train, has passed e_3, putting S_5 to "danger" and S_8 to "line clear," and has further passed e_4, pulling over relay R_2, thereby making contacts 5 and 6, and at the same time putting S_9 to "danger"; or until the preceding train, if it was a "down" main train, has passed e_1, pulling S_6 to "danger" and S_8 to "line clear," and has passed e_2, putting S_{10} to "danger," and at the same time pulling over relay R_2, making contacts 5 and 6. Under these conditions a current can pass from g_2, through S_4, through S_5, through S_6, thereby lowering same, through contact 5 of relay R_2 to common return. The lowering of S_6 makes the contact b_6, thereby allowing the current to pass through contact 6 and round solenoid of R_2 to common return, thereby pulling over core of R_2, making contact 4, and breaking contacts 5 and 6 ready for the same train, when it passes e_2, to send a current through 4 of R_2, round solenoid to common return, making 5 and 6 and breaking 4.

If the next train leaving the junction, J, is a branch train, a similar series of contacts are made. For on making h_1, if all is safe to proceed—that is, if S_6 has been put to "danger" and the contacts 5 and 6 of relay R_2 have been made—a current can pass from h_1 or h_2 through S_6, through S_5, lowering same, and through 5 of R_2 to common return. On lowering S_5 contact b_5 is made, and the current passes through 6 of R_2, through solenoid to common return, thus pulling over core of R_2, making contact 4, and breaking 5 and 6 ready for the same train, when it has reached e_4, to pull back the core of R_2, making contacts 5 and 6, and breaking 4. On passing e_3, the signal, S_5, is put to "danger."

In the foregoing description the automatic actuation of the points by the trains themselves has not been mentioned. It only remains to show how the trains automatically change over the points in order to complete the description of this system. Fig. 134 shows an arrangement of an electric motor and connections for actuating the points, and Fig. 135 is a diagram which shows how the contacts of Fig. 134 are connected to the system itself.

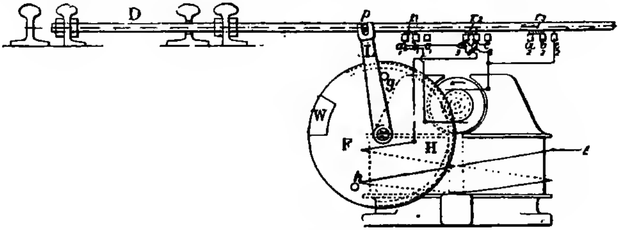


FIG. 134.

Referring now to Fig. 134, the movable rails or points are fixed to a rod, D, which extends beyond the rails and has fixed into it a pin, *p*, which engages with a lever, L, pivoted at *x*. An iron disc, F, turns about *x* as centre, and has fixed near its edge a weight, W, and the two pins, *g* and *h*, which are long enough to strike the lever, L, when F is turned round. A spur wheel, H, on the other side of F turns about *x* as centre, is in gear with a pinion on the motor shaft, and carries a pin which is capable of engaging two projections on the disc, F. Insulated from the rod, D, and moving with it are three metal strips, r_1, r_2, r_3, which, when the rod, D, is in its extreme position on the one side, connect contact pieces, a_1 b_1, a_2 b_2, a_3 b_3, respectively, and in the other extreme position of the rod connect b_1 c_1, b_2 c_2, b_3 c_3, respectively. The contacts a_3, b_3, c_3, are for reversing the current through the motor armature, at the same time keeping the direction of the current in the field-magnet coils the same. The contacts, a_1 b_1 c_1, a_2 b_2 c_2, a_3 b_3 c_3, are shown in Fig. 135 in connection with the relay R_2 and signals, and will be referred to presently. Suppose the rails to be in the position shown in the figure—that is, a_1 b_1, a_2 b_2, a_3 b_3, are respectively connected. If a current flows to b_1 from an outside source, it passes *viâ* the strip r_1 to the contact a_1, from thence through the armature of the motor, through a_3, *viâ* r_3 to b_3, through the electromagnet winding to the common return. This causes the armature to turn in the direction of the arrow, and the spur wheel, H, is turned until its pin comes in contact with the projection on the disc, F, thereby turning the latter round and raising the weight, W. As soon as W gets past the vertical position it falls, and the pin, *h*, striking against L carries it with it, thus moving over the points, and making contacts b_1 c_1, b_2 c_2, b_3 c_3. At the same time the current through the motor is broken.

If a current flows from an outside source to b_2, when the rails are in such position that b_1 c_1, b_2 c_2,

b_8 c_8 are connected, the current through the armature of the motor is in a reverse direction, and the rails are automatically put over to the other side.

In Fig. 135 actual connections, contacts, etc., are

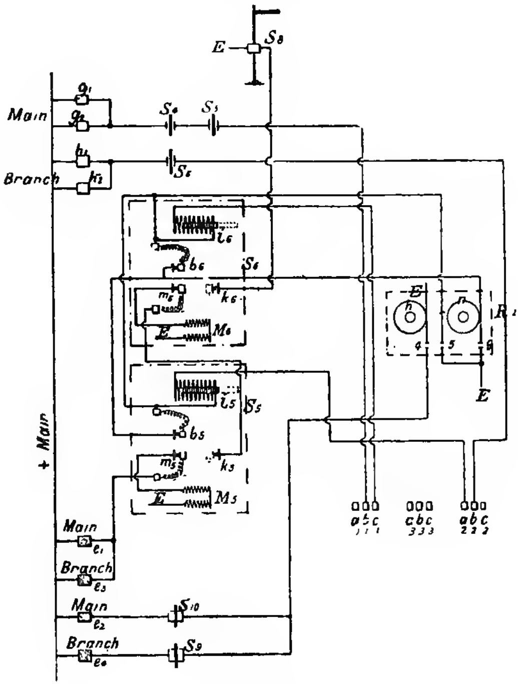


FIG. 135.

given in the case of signals S_5 and S_6. Reference is made to Fig. 133 for the relative positions of the rails themselves with respect to the signals, rail treadles, etc., shown in Fig. 135. The following explanation is given in order to show how the points are automatically changed over by the train itself, and the subsequent operation of the signal in question.

Consider a main "down" train (Fig. 133) having made g_1 or g_2. If the signals S_4 and S_5 are at "danger," a current can pass to b_1. If the points are not yet right, contact is made between b_1 a_1, b_2 a_2, and b_3 a_3 respectively, and the current passes through the motor, causing it to put over the points, as already described. Contacts b_1 c_1, b_2 c_2, b_3 c_3 are now made, and the current is thereby diverted, and now passes *viâ* C through the solenoid i_6 of the signal S_6, thereby lowering the same on condition that the previous "down" main train has passed over e_4, putting S_{10} to "danger," and also closed contact 5 of relay R_2; or a previous branch "down" train has passed over e_4, putting S_9 to "danger," and also closed contact 5 of relay R_2. Having lowered S_6 the driver can proceed, knowing that his points are right, that S_4 and S_5 are at danger, and that the previous "down" main or branch trains have passed e_2 and e_4 respectively. On lowering S_6 the contact b_6 is made, and the current finally passes through the solenoid, n, and the contact 6 of R_2, breaking contacts 5 and 6, and making contact 4. On arriving at e_1, a current passes through contact K_5 of S_5, for it is at "danger"; through m_6 and electromagnet, M_6, of signal S_6, thereby putting the same to "danger," and the current passing through contact 4 and solenoid, p, of relay R_2, puts over same, making contacts 5 and 6, and breaking contact 4.

If the train is a "down" branch train, a similar series of contacts are made. For on making h_1 and h_2, if S_6 is at "danger," a current can pass to b_2, and will change over the points, as already described, thus automatically making a_2 b_2. It is then diverted and passes *viâ* a_2 through solenoid, i_5, of S_5, lowering same on condition that a previous "down" main train has passed over e_2, putting S_{10} to "danger," and also closed contact 5 of relay R_2; or a previous branch "down" train has passed over e_4, putting S_9 to "danger," and also closed contact 5 of R_2. Having lowered S_5, the driver can proceed, knowing that his points are right, that S_6 is at "danger," and that the previous "down" main or branch trains have passed e_2 and e_4 respectively. On lowering S_5 the contact b_5 is made, and the current finally passes through the solenoid, n, and contact 6 of R_2, breaking contacts 5 and 6, and making contact 4.

On arriving at e_3 a current passes through contact m_5 of S_5, for it is at the "line clear" position, through electromagnet, M_5, putting S_5 to "danger," and having thus made K_5, it passes *viâ* K_6 to signal S_8, and lowers same. It is now impossible for another branch "down" train to lower S_5 until the train in question has passed e_4; and this it cannot do until the train in front of it has lowered S_9, thereby opening the section. On arriving at e_4, signal S_9 is put to "danger," and the current passing through contact 4 of R_2 puts over same, making contacts 5 and 6 and breaking contact 4.

TIMMIS'S AUTOMATIC SIGNALLING SYSTEM, LIVERPOOL OVERHEAD RAILWAY.

One of the most interesting applications of electrical traction is that of the Liverpool Overhead Electric Railway, the success of which is gratifying evidence of the applicability of electricity to railway working under suitable conditions. Not the least interesting part of the enterprise is the electrical signalling, which is automatic throughout the line. The arrangements for this purpose are all to the design of Mr. J. A. Timmis, to whom the author is indebted for the following description and illustrations.

As is well known, the line is used for passenger traffic only, and the arrangements are of a correspondingly simple character; the deviations from purely straight running lines consisting of one cross-over road at each intermediate station, and two at each terminal station.

The total length of the railway is nearly seven miles, and it is now being extended. There are thirteen stations, numbered from two to fourteen, and as the distance between successive stations constitutes the block section, there are in all twelve block sections.

The signal arrangements at intermediate stations consist of a "home" signal, which stands at a distance of about one hundred feet from the platform end, behind the train standing there, and a "starting" signal at a short distance in advance of the platform. The latter signal, as will be seen later, acts also as a "distant" signal for the station in advance. At the terminal stations of the line an "advance starter" is added to the signals already described. All these signals are operated electrically by means of suitably-placed contacts, which in certain cases complete, and

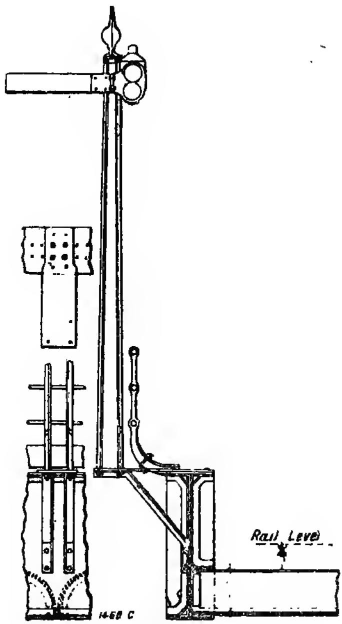


FIG. 136.

in other places break, circuits operating the signals as may be required.

The form of signal used is shown by Fig. 136. The contacts made or broken, as the case may be, by the passage of trains are each operated by a long arm standing by the side of the rails, which projects into the path of a bar carried on the last vehicle of each train. The arm is moved through an angle of forty-five degrees, and held there during the time taken by the train operating it to move through a distance of twenty-four feet. The contact surfaces are long, and move over each other with considerable friction in order that they may be kept perfectly clean.

The signal arms are worked by electromagnets specially designed by Mr. Timmis for the work. An electromagnet measuring seven inches by five inches in diameter will raise a weight of fifty-six pounds from a distance of two inches when a current of five amperes is passed through the coil. When used to operate a signal the load is much less than this, and when the signal has been lowered the current required to maintain it in that position is, of course, much less than that required for the initial effort. For this reason the operation of lowering the signal arm is made to bring into the circuit a considerable resistance which reduces the current from five amperes to about one quarter ampere. Even this current is large for the maintenance of the signal arm in the "off" position, since one-tenth of an ampere has been found experimentally to be quite sufficient. A very large margin is thus allowed over the actual requirements.

All signals are fitted with a switch working in connection with the electromagnet operating the signal arm. In the "off" position of the signal arm the switch makes such contacts as passes a "holding down" current from the battery at the local station; when the arm is in the "on" position the switch is in such a position as to pass a "lowering" current through the coils of the electromagnet from the advance station, the resistance being cut out.

Separate line wires are run for each line of rails. These line wires commence at the "starter" signal at one station and run to the "starter" signal at the next station in advance, connecting with the intermediate "home" signal *en route.*

The "starter" signals at intermediate stations are fitted with mercury contacts by which the line wire for that section may be completed or broken in accordance with the position of the arm. Two plates, which form the connections, are fixed within a vessel containing mercury, which is attached to the arm of the signal. When the arm is in the "on" position, the mercury connects the two plates and completes the circuit of the line wire; when in the "off" position, the mercury flows away from the plates and leaves them insulated from each other, and thus breaks the circuit of the line wire. It should be noted that the connection between the plates is never broken by the mercury flowing away from them when a current is passing.

All "home" signals are fitted with a mechanical lock, which is maintained in its inoperative position by a key which is hung upon it. At one time this key was used to unlock the lever of the cross-over road points. Its removal from the mechanical lock set that "home" signal to "danger" irrespective of the action of the electromagnet, and without interference with the latter. This arrangement has now been superseded by a device by which the cross-over road lever is locked in position by two bolts which are themselves held in the locking position by an electro-magnet actuated by the "holding down" currents of the "up" and "down" "home" signals respectively.

Fig. 137 represents diagrammatically the connections making and breaking contacts, signal operating electromagnets, and two-way switch in connection with the resistance, the "starter" signal mercury contacts, "down" platform switches, mechanical locks and batteries, etc., for normal working at three stations at each end of the line. If we assume that a train is about to travel on the "up" line between No. 2 and No. 3 stations and follow its course, the arrangements for ensuring safety will became apparent. If we further assume that no train is in the section between No. 2 and No. 3 station all signals will be "off."

Contacts A, B, and D (Fig. 137) are *breaking* contacts, E is a *making* contact. "The "advance starter" signal at No. 2 station is maintained in the "off" position by the contact A, the electromagnet, resistance, and contact 2 of the switch. The "home" and "starter" signals at No. 3 station are maintained in the same position by similar currents passing through B and D respectively from the battery at No. 3 station. Another circuit is formed at No. 3 station from the battery through E, the mercury contact on the "starter," and by the line wire to the "home" signal at No. 3, and the "advance starter" at No. 2. This circuit is broken at two points—viz., at E, which is a making contact, and at the mercury

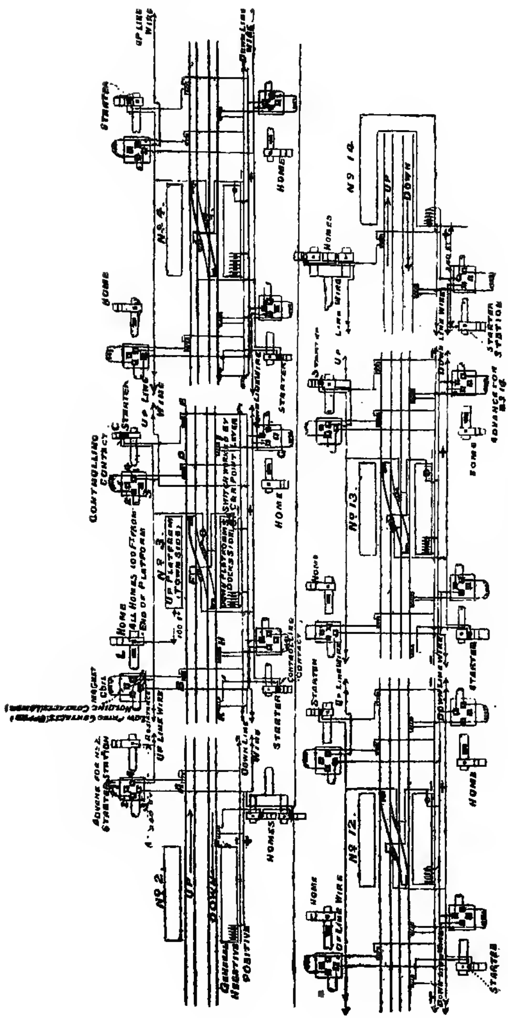

Nº 2.
UP
DOWN
GENERAL NEGATIVE
POSITIVE
HOMES
Nº 3.
UP PLATFORM (TOWN SIDE)
ALL HOMES 100 FT FROM END OF PLATFORM
HOME
STARTER
CONTROLLING CONTACT
UP LINE WIRE
DOWN LINE WIRE
Nº 4.
Nº 12.
Nº 13.
Nº 14

FIG. 137.

contacts on the arm of the "starter" signal at No. 3 station.

Referring to Fig. 137, we find that the passage of the train past A breaks the circuit at that point, and cuts off the "holding down" current during the time the train actuates A. The "advance starter," therefore, goes to "danger," and this operation involves change of the switch on the signal such that contact points 2 and 4 become connected. The contact A is remade as soon as the train passes that point, but the "advance starter" signal arm is not lowered, since the circuit previously existing from the battery at No. 2 station is broken by the fresh position taken up by the switch. In any case the current set up by the battery at No. 2 station is not sufficiently strong to give the requisite pull to *lower* the signal, as it necessarily passes through the resistance.

Following the train on its passage to No. 3 station, we find that on approaching the "home" signal for that station, which is "off," the contact B is broken and the signal put to "danger," whilst the switch contacts are rearranged precisely as described in connection with the "advance starter" at No. 2 station. In order to ensure the "home" signal being put to "danger" by the train, the contact B is double, and operation of either will release the signal arm. If one contact fails there is still another to be relied upon, and it is extremely unlikely that both would fail together. It will be noticed that there are two signals now standing at "danger" behind the train, the progress of which has, so far, been traced.

After stopping at the platform, the train proceeds towards No. 4 station. The "starter" of No. 3 is still "off," but, on the train passing the contact D, this signal is put to "danger" in precisely the same way, and with the same effect upon the switch working in connection with the electromagnet, as in previous cases. Moreover, the putting of the "starter" of No. 3 to "danger," closes the circuit of the "up" line wire through the mercury contact on the arm of the signal. There are now three signals at "danger" behind the train.

When the train passes forward to E, it operates the *making* contact at that point, and the "starter" signal arm of No. 3 station being at "danger," a current passes from the battery of No. 3, through the mercury contacts of the starter, along the "up" line wire to the "home" signal of No. 3, where it divides, part passing through the "home" signal circuit, and part passing to the circuit through the "advance starter" at No. 2. Remembering that the signal switches of these two signals are connecting contacts 2 and 4, we see that the current set up by the making of the contact E will be of sufficient strength to *lower* the signal arms, since it does not pass through the resistance in connection with the switch of either signal. The result is to place the "home" at No. 3 station and the "advance starter" at No. 2 station in the "off" position, and to replace the switches of these signals in their original position. The current set up by the closing of E lasts for a comparatively short time only, but a glance at the diagram will show that the work of maintaining the two signals in the "off" position is taken up by the battery at No. 2 for the "advance starter" there, and through another circuit from the battery at No. 3 for the "home" signal at that station.

It will be noticed that the "starter" signal of No. 3 station is still at "danger"; and, further, by the arrangement of the mercury contact with the line wire circuit and contact E, it is absolutely necessary for this signal arm to be in that position before the passage of the train past E can operate to replace the two signals in the rear.

If we follow the train during its further passage in the same direction, we find that the "starter" at No. 3 station is maintained in the "danger" position, until the "starter" at No. 4 station is placed in that position by the operation of the *making* contact, corresponding to E at No. 3 station, at that place; the operation of the "home" signal at No. 4 station, meanwhile, being precisely as described for No. 3 station.

Hence, we see that a train starting from any station is protected by one signal being at "danger" until it reaches the "home" signal at the advance station; whilst standing at the platform of any intermediate station it is protected by two signals; and for the short distance between the contacts D and E it is protected by three signals standing at "danger." It will be noticed that placing the third signal to "danger" behind the train is not intended as an *additional* protection for the train, but is necessary to ensure that that signal is protecting the train, *before* the other signals in the rear are lowered for the passage of a succeeding train.

The operations at all the intermediate stations are precisely the same, and it is not therefore necessary to follow the passage of the train further. The arrangement ensures, so long as the signals exhibited are observed, that the space between successive trains is that between successive "starters" so long as we consider the continuous passage of trains in one direction from one terminal station to the other.

One point in connection with the design of the apparatus may be here noted. The signal arms are held in the "off" position by a continuous current only; their position when not under constraint is at "on." Hence any failure of the circuits which causes interruption of the current acting upon the signal arm has an effect which stops the passage of traffic, and therefore tends to safety. This is a most important point, and is, of course, the practice on all railways; the temptation to reverse the practice where the signals are operated by electrical apparatus is, however, much greater than where mechanical appliances are in use, on the ground that, as is the case at Liverpool, the normal, and therefore the most prolonged position, if maintained *actively* will be more costly than if maintained passively or by gravity.

The exigencies of railway working, however, demand more than the simple straightaway running already described, even for so favourable a case as the Liverpool Overhead Railway. Trains may require to shunt from the "up" line to the "down" line, or *vice versâ*, in consequence of a breakdown in one of the sections; and, as has already been stated, cross-over roads are provided at each station for this purpose, although their use is exceptional.

Suppose the train, the progress of which has been traced between Nos. 2 and 4 stations, required, on its arrival at No. 3, to return to No. 2, instead of passing to No. 4. It will be remembered that the "advance starter" at No. 2, and the "home" at No. 3, are both at "danger" when the train is standing at No. 3 station platform. The train will draw forward to clear the cross-over road points; but in doing so will not actuate the contact D or E, the distance between the points and D being sufficiently great to allow of any train standing between them without operating the latter. Hence, the "up starter" at No. 3 station is not placed to "danger," and the "up" line is protected by two signals in that position in the rear of the train.

Assuming that the arrangement for effecting the shunt are the keys by which the lever of the cross-over road points are released, we find that removal of the keys sets the "up" and "down" "home" signals at "danger," and provides that they shall not be operated in the usual way during the time the keys are in use. The levers are thus blocked, and there is no danger that the "home" signals will be lowered during the time occupied by the shunt.

When the points' lever is released the cross-over road is set by hand, and the movement of the lever results in the switch, S, forming the local battery with the two contacts F and G.

The passage of the train over G sets up a current which passes to the "up" line wire, and thence through the electromagnets at the "home" signal at No. 3 and the "advance starter" at No. 2. The latter signal is placed in the "off" position; the electromagnet of the former is operated and the switch changed, but the arm is not lowered owing to the action of the mechanical lock.

Hence, the "up" line is still protected by the "home" signal standing at "danger."

The passage of the train over F does not affect that contact, since F and G are only actuated by trains passing from the "down" to the "up," and from the "up" to the "down" line respectively.

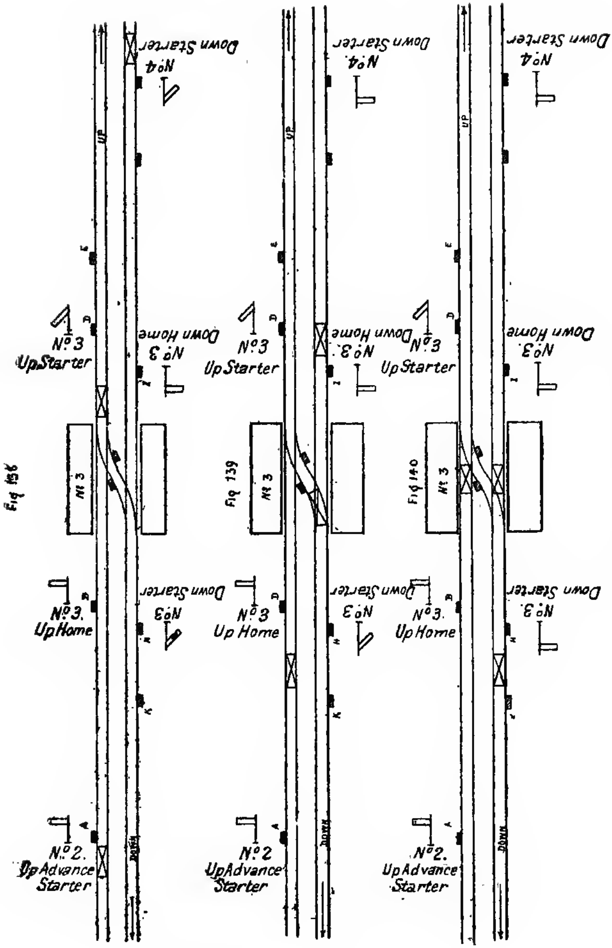
The further passage of the train over H places the "down" line starter to "danger." If the keys are now replaced upon the "home" signals, the latter will be replaced to "off," but the train will be protected by the "starter." The passage of the train over the contact P at No. 2 station places the starter at No. 3 in the "off" position. This completes the cycle of operations required to work a train through any of the cross-over roads provided at intermediate stations.

If we carefully consider the arrangements described and the effects produced in their proper order, we shall be able to estimate more accurately the degree of safety secured by the use of the apparatus as shown by Fig. 137, and thus be in a position to contrast it with that secured under the usual conditions of signalling, both as regards the running between stations, and for shunting operations such as have just been considered.

The train arrives at the point from which he set back is to be made with two signals at "danger" behind it—viz., the "advance starter" at No. 2 station, and the "home" at No. 3. The "starter" at No. 3 remains "off," since the train does not require to actuate the breaking treadle, D, in order to allow the cross-over road to be set for the train to pass to the "down" line. Removing the key for the points' lock from the "up" "home" signal brings into play a further protective device, which prevents that signal arm being placed to "danger" by the usual means, although the movements which usually have this result may be made.

Turning to the "down" line, the signals for trains approaching No. 3 from No. 4 have to be considered before the operation of shunting is actually commenced. A little consideration will show that the "home" signal, under normal circumstances, is only at "danger" for the time the line between the contacts I and K is occupied. Under such circumstances, the shunt from the "up" to the "down" line could not be made. Assume, then, that the three signals—"down starter" at No. 4, "home" and "down starter" at No. 3—are all in the "off" position. The removal of the key from the "down" "home" signal at No. 3, puts the arm to "danger." The condition of the signals, etc., at this point in the operations is shown by Fig. 138.

The passage of the shunting train over G leaves the cross-over road protected by the "home" signal of No. 3, and a train from No. 2, on the "up" line, may proceed to that point. The "down starter" at No. 4 station is "off" also, and a train may proceed



FIGS. 138, 139, AND 140.

on the "down" line to the "down" "home" signal at No. 3. Neither of these trains will interfere with the operation of the cross-over road. The condition of the signals at this stage is shown by Fig. 139.

The passage of the shunting train past H puts the "down starter" at No. 3 to "danger" behind it. The replacement of the key on the "down" "home" lowers that signal and allows the train standing there to advance to the platform, the "home" signal being put to "danger" by the operation of the contact I. The passage of the shunting train past the contact K will lower the "down starter" at No. 4, and the "down home" at No. 3. Hence, in order to ensure protection for the train, which we have considered as standing at the "down home" of No. 3, when it arrives at the platform, its passage over the contact I should not be made until the shunting train has passed K. Unless this condition is complied with, the passage of the shunting train over K would lower both the "home" at No. 3 and the "starter" at No. 4, if the latter is in the "on" position, and the train standing at the platform (Fig. 140) will not be protected by any signals.

In so far as the train, which has been assumed to be standing at the "up" "home" signal during part of the operation of shunting (Fig. 139), is concerned, the replacement of the points' lock key will lower the arm and allow the train to proceed to the platform (Fig. 140), the "home" signal being placed to "danger" by the passage of the train over B. Its further passage over D and E will result in the "up starter" at No. 3 being put to "danger," and the "up advance starter" at No. 2 and the "up home" at No. 3 being lowered respectively.

As already stated, the arrangement by which the cross-over road lever was unlocked by a key kept on the "home" signal has been superseded by another device, which is as follows:

The cross-over road lever is locked in its normal position by two plugs. These plugs are themselves locked in position by an electromagnet, actuated by the holding currents of the "up" and "down" "home" signals respectively. Thus, with both "homes" at "off," both plugs are locked. On the "up" "home," say, being put to "danger" by a train passing over the contact B into the station, the corresponding plug is pulled out, which breaks the line-wire circuit to that "home" and the "starter" in the rear. A similar movement is gone through for the "down" road, and the "down" line wire to the local "home" and the rear "starter" is broken. The lever is then free to be worked on the train clearing the cross-over road, and the roads are both blocked in the rear. The key may be done away with, or used in the case of an emergency.

On the shunting being completed the lever is put back, but both roads are blocked. As this shunting is in the nature of an exceptional circumstance, the first train from either direction has to run "against signals," which is provided for by a pilot or special code on the station bells when normal working is resumed.

The arrangement of the terminal station No. 2 is shown by Fig. 140, and the terminal No. 14 by Fig. 141.

At each of these stations there are two cross-over roads. At No. 2 station a small cabin, containing a five-lever frame, is situated on the "down" platform; and at No. 14 station a similar cabin, with a four-lever frame, is provided on the "up" platform. Sykes's bars are used at three stations to control the signals and points. The following table refers to station No. 2, the connections for which are shown by Fig. 140.

TABLE I.—Arrangements at No. 2 Station.

Train on bar No. 1	No. 9 signal up.
,, ,, ,, No. 2	,, 7 ,, ,,
,, ,, ,, No. 3	,, 4 ,, ,,
,, off bar No. 3	,, 4 ,, down and No. 5 up.
Train off bar No. 3, and points 6 closed for cross-overs	No. 5 signal down and Nos. 4 and 7 signals up
Train off bar No. 1	No. 9 signal down and No. 10 up.
Train off bar No. 1, and points 8 closed for cross-over	No. 10 signal down and No. 9 up.
Train off bar No. 2	No. 7 signal down.
Train off bar No. 2, and points 6 closed for cross-over	No. 7 signal up.

The corresponding arrangements for No. 14 station are given below.

TABLE II.—Arrangements at No. 14 Station.

Train on bar No. 1	No. 6 signal up.
,, ,, ,, No. 2	,, 7 ,, ,,
,, ,, ,, No. 3	Nos. 8 and 9 signals up.
,, off bar No. 3	No. 8 signal down and No. 9 up.
Train off bar No. 3, and points 5 closed for cross-over	No. 8 signal up and No. 9 down.
Train off bar No. 2, and points 4 closed for cross-over	No. 7 signal down and No. 6 up.
Train off bar No. 1	No. 6 signal down and No. 7 up.

The estimate of the cost of the electrical energy expended in working the signals is remarkably small.

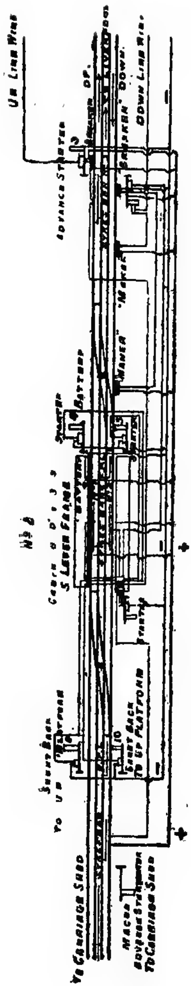


FIG. 141.

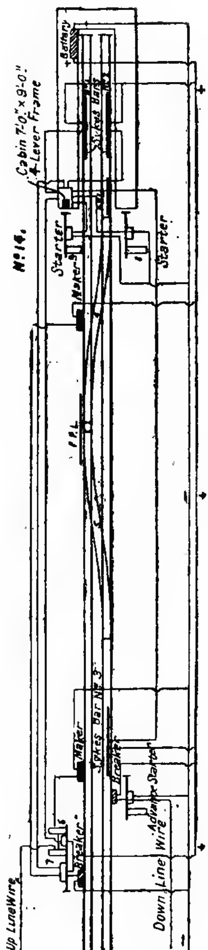


FIG. 142.

Each station is provided with four signals, which, with a three minutes' service of trains, will each be lowered four hundred times during a working day of twenty hours. If the *lowering* current of five amperes is on for one second, the quantity used during the working day is

$$\frac{400 \times 1 \times 5}{3{,}600} = \cdot 55 \text{ ampere-hours.}$$

The electromotive force is forty volts, and the expenditure of electrical energy per signal per day for lowering purposes is, therefore, twenty-two watt-hours, and for each station eighty-eight watt-hours.

This, however, does not include the *holding-down* current. Assuming each signal to be down one and a-half minutes, for each of the foregoing four hundred movements it will be down six hundred minutes per day. The current being one quarter ampere, the quantity will be

$$\frac{150}{60} = 2\cdot 5 \text{ ampere-hours.}$$

The expenditure of electrical energy for maintaining the signals, at one station, "off," will be four hundred watt-hours, and the total for both purposes will be

488 watt-hours per station per day.

Taking this as the average for all thirteen stations, the total expenditure of energy for the whole railway works out

6·344 kilowatts per day;

which, at 8d. per kilowatt,

$$= 4s.\ 2\tfrac{3}{4}d.$$

As evidence of the reliability of the electrical apparatus for actuating signals, it may be said that, on the Liverpool Overhead Railway, there has been no failure of a signal to go to "danger" at the proper time for over eighteen months, or no failure in nine millions of workings.

Timmis's Electrical Apparatus, Earl's Court.

Mr. Timmis's work on the Liverpool Overhead Railway is more particularly related to the actuation of the outdoor signals exhibited for the guidance of drivers than for signalling the passage of trains from one point to the next in order on the line. Another example of this gentleman's work in this direction is shown by diagrams (Figs. 143-147), which represent the arrangements in use at Earl's Court Station.

The apparatus includes electrical methods of actuating points and locking bars and bolts, semaphore signals, and ground discs, and provides for the electrical interlocking of the levers by which these operations are, initially, brought about.

Fig. 143 is a diagram of the section of the line where the apparatus is in use, and shows the signals and points. Fig. 144 is a diagram of the wiring of the installation, and shows the electric switches by which the points, signals, and ground discs are operated, the detectors, lock magnets, and lock switches for carrying out the system. Fig. 145 shows details of the points actuating apparatus.

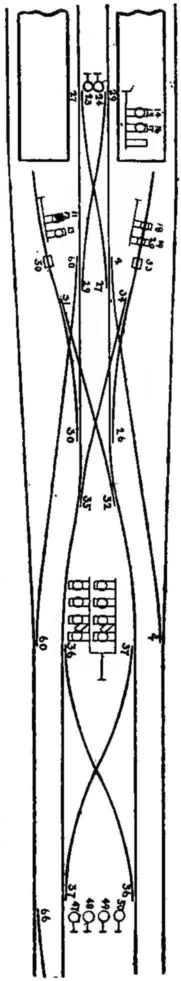
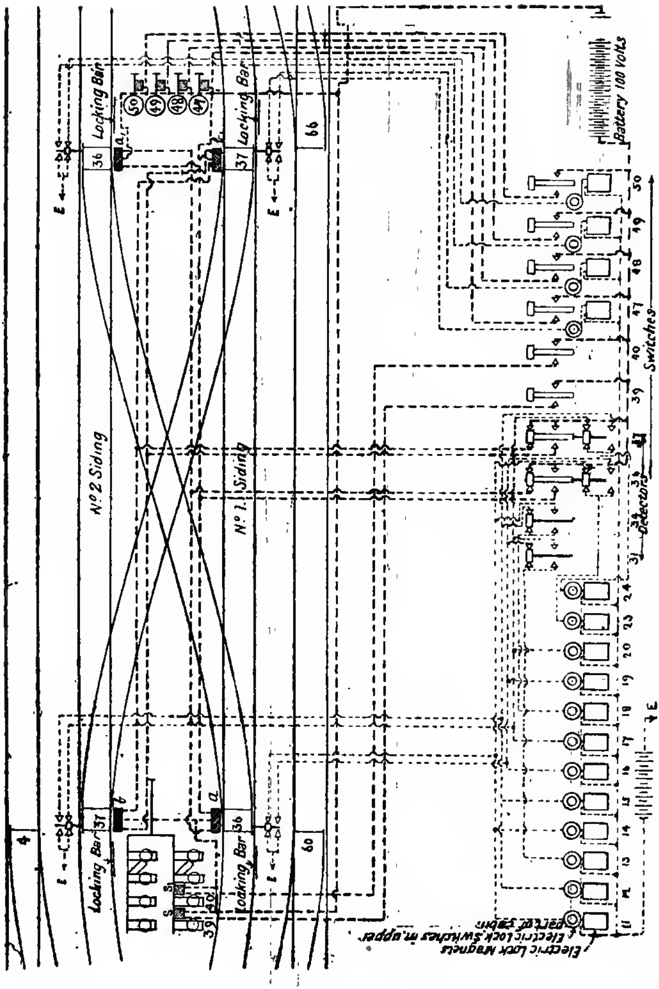


FIG. 143.

FIG. 144.—Timmis's Electric Signals, Earl's Court Station (East Cabin). Wiring Diagram.



Thick dotted lines denote connections of actuating circuits; thin dotted lines detector circuits. Repeater wires not shown.—One wire each from the east and west ends of 36 and 37 respectively to cabin—or four in all. Earth used for return.

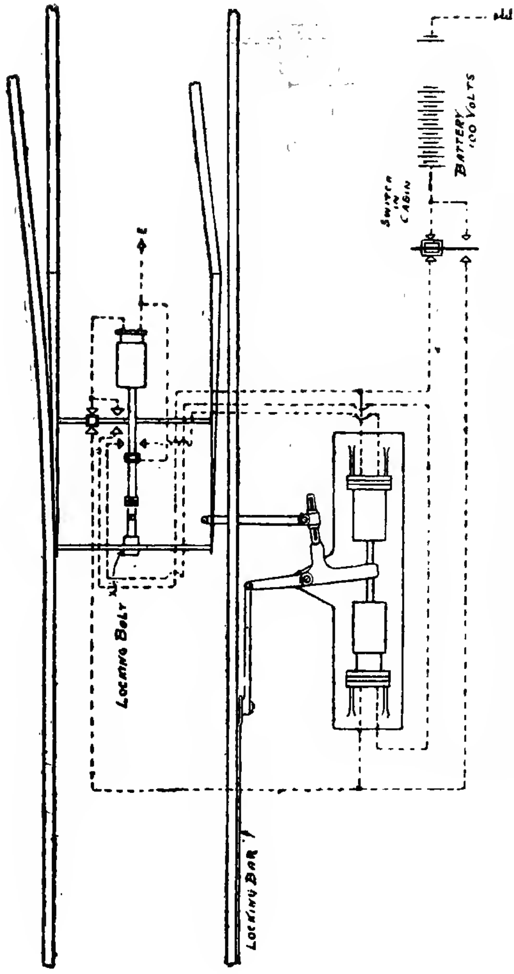


FIG. 145.—Point and Point—Lock Magnets. Wiring diagram.

Fig. 146 shows details of the electric lock switch, and Fig. 147 shows the arrangement for actuating the signals and ground discs.

As will be noted from Fig. 144, the points actuated by electrical means are those for the double cross-over roads, marked 36 36 and 37 37; the apparatus

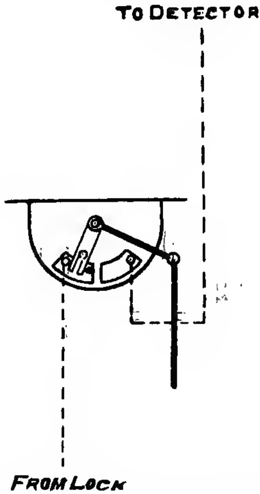


FIG. 146.—Connections for Electric Lock Switches, 11-20, 23, 24, 47-50.

shown by Fig. 145 being represented in Fig. 144, diagrammatically, by *a a*, *b b*. These points, it will be seen, are operated in pairs, and an examination of Fig. 145 will show that the current is only used during the operation of changing the position of the points.

The semaphore signals 39 and 40, and the ground discs 47-50, are actuated electrically, and are held in the "off" position by a continuous current, as on the Liverpool Overhead Railway; the strength of the current being reduced, after the initial effort of lowering the signal arm, by the interpolation of a resistance in the circuit, as shown by Fig. 147.

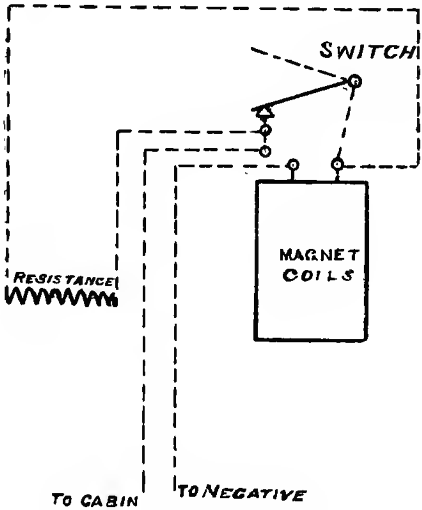


FIG. 147.—Connections for Signals and Ground Discs, 39, 40, 47-50.

The points 36-37 are actuated by the levers having the same numbers; and the signals 39 and 40, and the ground discs 47-50, are each operated by the similarly numbered lever. The operation of the levers 11-24, controlling similarly numbered signals (Fig. 143), depends upon the position of the detectors.

The levers are locked in the frame in the ordinary way, in addition to the electrical control, and it is thus impossible for a signal or ground disc to be operated unless the points which it controls are properly set and locked.

The cost of working such a system is said to be remarkably low. Assuming that each pair of electrically-actuated points is operated two hundred and forty times per day, or once every six minutes, the cost of the electrical energy used is put as less than one farthing per pair of points per day. The cost of operating the signals is stated to be less than one halfpenny per signal per day.

Over and above the low cost of operating, the advantages claimed for the system are its capability of working signals, etc., safely at any distance from the point of operation, and the possibility of dispensing, in many cases, with intermediate cabins; the signals at such places as those at which intermediate cabins would otherwise be necessary, being operated from the advance or rear cabins as might be desirable, the positions of the signals, etc., being at all times repeated in those cabins.

The actuation of points and signals by electrical means, as done by Mr. Timmis in the instances given, and as suggested by Mr. Siemens, would appear to open up a wide field for the employment of electrical apparatus, and, combined with electrical interlocking of the means of operation, would undoubtedly tend to the benefit of the service by decreasing the manual labour necessary for operating the apparatus, and by economising space; and would also, no doubt, decrease the initial cost of fitting up the cabins.

There is, of course, no novelty in the suggestion to interlock the means of operating signals, etc., by electrical methods in preference to the mechanical means now employed for the purpose, and which have given such excellent results. Such methods are of old standing—as suggestions—but have never passed much beyond the experimental stage, probably owing to the fact that electrical apparatus was, until recent years, constructed with a view to the electrical effects intended, and without sufficient consideration to the conditions under which it would have to be used to produce mechanical effects of any appreciable magnitude. The present time, when it has been recognised that mechanical effort is not efficiently transmitted through paper, paraffin, wax, or silk, and is not assisted by the most liberal use of varnish or lacquer, would seem to be opportune for a revival of the efforts to actuate points, signals, and other apparatus, situated at a distance from the point of operation, by electrical means, and to interlock the means of operation by the same agency.

INDEX.

A.

B.

C.

S.

BIGGS & CO.S BOOK-LIST.

Electrical Engineers' Series.

Practical Electrical Engineering. A complete treatise on the Construction and Managemeut of Electrical Apparatus as used in Electric Lighting and the Electric Transmission of Power. 2 Vols. Imp. Quarto. By Various Authors. With many Hundreds of Illustrations. Price £2. 2s.

The Principles of Alternate-Current Working. By ALFRED HAY, B.Sc., Lecturer on Electrotechnics, University College, Liverpool. Illustrated. Crown 8vo. 5s. This book is intended to be used as a text-book on the subject for students entering upon its study. The great importance of alternate-current working in lighting and in power transmission makes a systematic study necessary.

Electric Light and Power: Giving the Results of Practical Experience in Central-Station Work. By ARTHUR F. GUY, A.M.I.C.E. Illustrated. Price 5s.

Central-Station Directory. The Electrical Engineers' Central-Station Directory, with various tables and the Board of Trade Regulations. Demy 8vo. Price 3s. 6d.

First Principles of Mechanical Engineering. By JOHN IMRAY, with additions by C. H. W. BIGGS. Illustrated. Price 3s. 6d.

First Principles of Building: Being a Practical Handbook for Technical Students. By ALEX. BLACK, C.E. Illustrated. Price 3s. 6d.

First Principles of Electricity and Magnetism By C. H. W. BIGGS, M.I.E.E., Editor of *The Electrical Engineer*. Illustrated. Price 3s. 6d. This book has been prepared more especially to assist students for the elementary examinations for the City and Guilds Institute.

Physical Units. By MAGNUS MACLEAN, M.A., D Sc., F.R.S.E. Illustrated. Price 2s. 6d. This little book discusses the present state of the subject under the following headings: Fundamental Units—Geometrical and Kinematical Units—Dynamical Units—Electrostatic System of Units—Magnetic Units—Electromagnetic System of Units—Practical Electrical Units.

Portative Electricity. By J. T. NIBLETT, author of "Secondary Batteries." Illustrated. Price 2s. 6d.