Rapier on Railway Signals.

ON THE

FIXED SIGNALS OF RAILWAYS.

BY

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WITH AN ABSTRACT OF THE DISCUSSION UPON THE PAPER.

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RAILWAY SIGNALS.

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THOS. E. HARRISON, President,
in the Chair.

No. 1,393.—"On the Fixed Signals of Railways."[1] By RICHARD CHRISTOPHER RAPIER, Assoc. Inst. C.E.

IT is a trite axiom, that two solid bodies cannot occupy the same space at the same time. The duty of the railway signalling engineer may be said to be to endeavour to prevent two bodies, which are moving at high velocities, from seeking to violate this law of nature.

Wherever the possibility exists of one train coming into collision with another—as, for instance, when a goods train has to come out of a siding about the time an express train is due, timely notice should be given by signal as to which of these operations should be first performed. From this necessity the present systems of Fixed Signals on Railways, and the interlocking of switches and signals, have been gradually developed.

The demand for increased signalling facilities is not confined to this country, but has arisen in other European countries also; and distant colonies are now inquiring for, and purchasing, the most finished appliances for these purposes.

In endeavouring to trace the progress of fixed signals, it must necessarily be that many varieties of arrangement and many inventions may escape the attention of the Author; but his purpose is to describe the actual steps which have contributed to present results, and in so doing he hopes to demonstrate that the systems which now appear to be indispensable are not fanciful complications, but are really simple in character, and form a complete series of safeguards, to provide against almost every variety of error on the part of the persons in charge of the switches and signals.

Against error on the part of those in charge of the trains, the only safeguard is to be found in the complete adoption of the

[1] The discussion upon this Paper extended over portions of four evenings, but an abstract of the whole is given consecutively.

absolute block system, and of means for enabling the drivers to observe signals well in advance.

The absolute block system consists in dividing the line of railway into longer or shorter lengths, and by means of telegraphic and fixed signals allowing only one train at a time to be on the same length. This method of working railways was proposed in the year 1842 by Mr. (now Sir William) Cooke, Assoc. Inst. C.E.; and during the thirty years which have succeeded, various modifications of Sir William Cooke's plans have been tried on different railways, with the result of finding that nothing short of the absolute block system, then recommended by him, will meet the present requirements of English railways.

Under the "absolute" block the signalman at station A is not permitted to send a second train to station B until he has received a signal from B that the first train has arrived there. When a train starts from A to B, the signalman at A telegraphs to B, "Train on line," and B acknowledges the signal, and virtually replies, "Yes, train on line; keep your signal at danger until I tell you." This is called the "absolute" block.

Under the "permissive" block system it is simply permitted to signalman B to block signalman A in the event of anything occurring at B which may render that course desirable. If, however, a train has just left A, of course the message comes too late to enable A to prevent the train running into the obstruction at B.

The permissive block has been well tried on the principal railways, and is preferred by some because it enables the trains to be sent one after another with greater rapidity; but it affords very little protection, and it is now generally agreed that intermediate signal stations must be erected on all lines of constant traffic, so as to make shorter lengths, rather than allow several trains to be on a long length at the same time.

When the distance between any two stations is so great as to cause the line to be blocked for too long a time, the best plan is to interpose one or more intermediate signal stations. The distance apart of the signal stations seldom exceeds 4 miles, and is often only $\frac{1}{4}$ mile, the average being $1\frac{1}{2}$ mile.

In 1863, a Paper by Mr. W. H. Preece, M. Inst. C.E., on "Railway Telegraphs," gave an account of the methods of signalling by telegraph from one station to another.[1]

The Author now proposes to describe the Fixed Signals on railways by which the signalmen are enabled to communicate

[1] *Vide* Minutes of Proceedings, Inst. C.E., vol. xxii. p. 167.

with the drivers of the trains, also the apparatus for controlling the movements of signals and switches, and the facilities at present for allowing fast trains to pass slower trains.

The subject naturally divides itself into the following heads:—

1. Early railways opened without signals.
2. The early types of signals, and their intended indications.
3. The semaphore signal, which is now becoming the universal type.
4. The use of distant signals.
5. At a later stage signals alone were found insufficient without the concerted action between switches and signals ensured by interlocking apparatus.
6. The various stages of interlocking apparatus.
7. The necessity of protecting facing switches against movement during the passing of a train.
8. The facilities now afforded, by complete signalling and locking apparatus, for working passing-places for enabling slow traffic to get out of the way of faster traffic.
9. Various matters connected with railway signalling which are not yet established axioms, but some of which seem likely to become so.

The Stockton and Darlington, the Newcastle and Carlisle, the Liverpool and Manchester, and other early railways, were opened without any fixed signals.

About the year 1834 an approach to fixed signals was in use on the Liverpool and Manchester railway. On the top of a post, the height of an ordinary lamp post, was placed, by means of a ladder, a red or white light. This signal was for night use only. Mr. Edward Woods, M. Inst. C.E., designed a more permanent arrangement, substantially as in Figs. 1 and 2; but without the vanes for day use. So little attention was, however, then given to the subject of signals, that no practical steps were taken until the opening of the Grand Junction railway in 1838, which was furnished with the signals shown in Fig. 3, similar ones were erected on the Liverpool and Manchester. This signal consisted of a circular, or D-shaped board, fixed on a spindle with a handle to turn it through an arc of 90°; a lamp for night was fixed either on the same spindle, or on the post which formed the support of the moving spindle. The disc towards the driver indicated "danger," and when turned on edge "safety."

Mr. Woods' signal, Fig. 1, became adopted in Scotland, and many are still in use in that country.

In 1838 Sir John Hawkshaw, Past-President Inst. C.E., designed the movable rails with disc signal, Figs. 4, 5, 6, 7, and 8, for the Manchester and Bolton railway. The disc signal was connected to the movable rails, and, with them, was set in motion by the handle and balance-weight acting upon the bevel-wheels and eccentric, so that when the switches were open to the siding the disc was presented "full on," whereas if the switches were open to the main line, the edge only of the disc was seen. If any train came out of the branch whilst the switches were set for the main line, the wheels were elevated by an inclined rail, and were thrust laterally by the high guard-rail, Figs. 7 and 8, so as to push the carriages on to the main line and prevent them getting off the rails entirely.

On the Newcastle and Carlisle railway, in 1840, red disc signals (Fig. 9) were put up. The disc, 4 feet in diameter, was fixed on a revolving pole with a handle to turn it, and the exhibition of the signal was considered to block both lines; the early practice on that line being, that if a train were standing in the station on one line, any train arriving from the opposite direction had to wait outside the station until the first train left.

In Fig. 10 a type of signal is shown which the Author believes was peculiar to the Stockton and Darlington railway.

On the Stockton and Hartlepool the first signal consisted simply of a candle placed in a window of the station to indicate that the driver was to stop to take up passengers, and the absence of the candle implied that he might proceed without stopping. When the Stockton and Hartlepool was opened in 1842, the three junctions, Fig. 11, were deemed to be sufficiently protected by a pointsman's box, and a pole 30 feet high, fitted with a pulley at the top and a rope, by which a wooden disc or a red lamp was hauled up, as a signal that trains might pass round the curve which joined the Stockton and Hartlepool lines, and that trains to or from Ferryhill might not pass. When the disc was down, the trains might pass from Stockton or Hartlepool to or from Ferryhill, but not round the curve. This signal was constructed by Mr. John Fowler, Past-President Inst. C.E., then resident engineer and manager of that line. No fixed signal was provided to cover the contingency of two trains arriving at the junction for Ferryhill at the same time; this was considered sufficiently simple to be within the personal direction of the pointsman.

On the Great Western railway a ball signal, Fig. 12, was introduced about 1837. The ball drawn up to the top of the post, after the manner of a high-water signal, indicated "safety," and a common stable lantern was hooked on at night instead of the ball. The kite signal, Fig. 13, was made about the year 1838. It consisted of a light iron frame, fixed on the top of a post, and covered with canvas mounted on rings on the top bar of the frame. A double string served to spread out the canvas on either side to indicate "danger" or "caution," or to reef it entirely to indicate "safety." These signals, though favourites with Mr. Brunel, gave place in 1843 to the forms shown in Figs. 14 to 21.

In Fig. 14 the signal consists of a cross-bar 8 feet long, and 1 foot wide, and a disc, 4 feet diameter, fixed at right angles to the cross-bar. The presentation of the cross-bar to the driver indicates "danger," and the disc (15) "safety." It is worthy of note that, whilst the Great Western introduced the disc as a "safety" signal, other companies adopted it as a "danger" signal. At junctions, double arms and double discs were used to govern the branch line, Figs. 16 and 17.

In 1847 a distinction was made on the Great Western between signals for "up" and for "down" lines. The plain cross-bar, Fig. 14, was appropriated to the up line, and for the down line the cross-bar was fitted with end pieces or horns pointing downwards, Figs. 18 and 19. A signal, Figs. 20 and 21, to block both up and down lines was made with end pieces pointing up and down.

About the same time the caution signal, Fig. 22, was adopted; the arrow painted red and pointing to the rails indicated "danger," and the green side of the arrow, Fig. 23, pointing from the rails, "caution," or "go slowly." These arrows referred only to the line next to which they were placed. The practice used to be to keep the danger signal on for five minutes, then turn the arrow to caution for five minutes more, and finally the main signal, Fig. 15, to safety. Lamps for night were not at first used upon all signals on the Great Western, but were introduced gradually.

For some years the semaphore signal has been in course of application on the Great Western, and in a short time the signals above described will have become quite extinct on that railway. They are, however, still preferred to the semaphore on the Bristol and Exeter railway.

When the London and South-Western was opened to Southampton, say in 1840, the form of signal, Fig. 24, was introduced by the late Mr. Albinus Martin. It consisted of a light iron framework, 5 feet diameter, covered with canvas or tin, but with a semicircular aperture in it extending to within 6 inches of the outer edge. This disc was mounted on a central pivot fixed on a post. The periphery of the disc was grooved for the reception of a cord. A double cord was attached to the frame of the disc, and brought down round an adjustable pulley, near the ground, so as to be within convenient reach of the operator, like an ordinary window-blind cord, but on a larger scale. This signal was much used as a cover to shunting operations, as follows:—If the closed part were turned to the left as in Fig. 24, it indicated that the left-hand road only was blocked; if the closed part were to the right, as in Fig. 26, it indicated that the right-hand road was blocked. If the closed part were turned to the top, as in Fig. 27, it indicated that both lines were blocked, and if the disc were turned bodily, with its edge to the driver, it indicated that both lines were clear.

The evolutions above described were only of use during the day: for night use two lamps with red and green glasses on each were fixed on spindles on either side of the post, to enable the shunters to show danger to either or both lines of way. This movable disc was a favourite shunting signal for nearly thirty years, but is now giving place to the semaphore.

The form of signal shown in Fig. 28 was also introduced about the same time, as a signal for one road only; and it was for a long time the standard type of distant signal on the London and South-Western railway. The disc has an aperture on one side and a lamp is fixed under the disc and on the same spindle. The presentation of the disc with the closed part to the left hand shows danger to an approaching train; and when the edge of the disc is presented, safety is indicated. A driver coming from the opposite direction sees the *open* side of the disc to *his* left hand, and so is informed that the signal does not concern him. On this line, as on the Great Western railway, double discs were used for branch lines.

About 1840, on the London and Brighton, the Lancashire and Yorkshire, and other lines, the signal shown in Fig. 29 was generally used.

Another variety is shown in Figs. 30, 31, in which the discs are mounted on a horizontal axis, carried in bearings fixed on the top of a post. This has been used since 1846 as a distant signal in distinction from the semaphore type which was at first introduced on some lines for a "home" signal only.

Figs. 32, 33, 34, represent the "danger," "caution," and "clear" signals respectively used on the Caledonian.

The above may be said to include all the types of early signals, although many varieties have been made, with slight and even fanciful differences. All these early signals, often puzzling and sometimes conflicting, are now fast giving way to the simpler and more definite semaphore signal.

Semaphore Signals.

About the year 1841, Mr. C. H. Gregory, Past-President Inst. C.E., designed and erected at New Cross the semaphore signal, Figs. 35, 36. This was an adaptation of the old form of semaphore used for telegraphing to short distances; and has proved to be, perhaps, *the* most important step in the development of railway signals.

The drawing is a sketch of the first signal erected, except that one arm only is shown in the drawing for the sake of greater clearness. At first the lamps, with red, green, and white lenses, were worked by a separate handle; but soon a pair of bevel-wheels were added, so that one handle worked both the blade and the lamp; also levers connected by rods were substituted for pulleys connected by wire ropes, and counterweights were added to make the signal self-acting to the position of danger.

The left-hand arm when in a horizontal position indicated "danger" to an approaching train; the left-hand arm at an angle of 45° proceed with "caution;" and the arm altogether lowered "line clear." It now appears remarkable that this great improvement in signalling was not at once generally adopted. The old disc signals of various sorts still continued to be erected, and the introduction of the improved semaphore signal was comparatively slow.

On most British railways, the three signals "danger," "caution," and "clear" (Fig. 37), are still used at intermediate stations, and "stop" and "caution" at junctions. On some, as the Great Western, Brighton, Great Eastern, Metropolitan, and South-Western, only "stop" and "go on" (Fig. 38), and other companies seem inclined to adopt two signals only. This the Author conceives to be right, for wherever the block system is in use the "caution" signal means precisely the same as the "clear" signal, viz., "go on to the next signal-post;" and if not, then no amount of caution will afford sufficient security. There is another reason for the abolition of the caution signal, and the adoption of the 45° signal (or still better 60°, as on the Great Western), viz., when the arm is completely down, the signal is positively *absent*, thus in a measure reverting to the system (now found to be insufficient) that absence of signal means safety. On the other hand, the horizontal arm for "stop" and the arm lowered 60° can always be seen. An arc of 60° is preferable to 45°, as it is less unfavourably influenced by variations in the length of the signal wires, caused by changes of temperature.

Now that so many arms are fixed on one post, or on posts near together, it is more than ever desirable that all signal arms should at all times be distinctly in view, so as to diminish the likelihood of one being mistaken for another.

A signal is said to be "on" when it is at danger, and "off" when at caution or clear.

Although distant signals were not generally used until long after the introduction of the semaphore, disc signals continued to be put up for distant signals, and the introduction of the semaphore was for a long time limited to the junction or station signals; and hence arose a special and limited use of the word "semaphore," as meaning "home signal"—a limited use of the word which continues to this day, even although all the signals may be of semaphore type.

Figs. 39, 40, represent the present ordinary semaphore signal, with lamp and glasses for night use. Sometimes the lamps are fitted with internal coloured glasses, movable either in a vertical or a revolving direction; but the usual plan is to have a fixed lamp, and movable external coloured spectacles. By using red and green lights only, if a coloured glass falls out the light is shown white, and thus a driver is able to warn a signalman of the defect; whereas, if red, green, and white are used, the falling out of a red glass would not be detected, because the driver would consider the light given as white (by reason of the failure of the coloured glass) as a genuine "clear" signal. Fig. 41 shows the light and elegant posts of Messrs. Stevens and Sons, of lattice iron; Fig. 42, the iron posts made by the Ribbon Post Company.

In fixing signals it is frequently necessary to make them very high, in order to obtain a sky background. On the North London, where the lines are much enclosed by houses, the signal-posts are sometimes upwards of 60 feet high, and it then becomes necessary to fix duplicate arms low down on the post. In Fig. 43, the high arm is seen against the sky from a distance; and as the driver approaches the post, and the high arm is less distinguishable, the lower arm becomes more so. The two arms, and of course the glasses of the lights also, are moved together by the same mechanism.

It is often convenient to put several arms relating to as many roads on one post. For some time junction signals were frequently so arranged, but this has now been given up for the following reason:—In Fig. 44, if the signal-post planted in the fork carried all the four signals—up and down main, up and down branch—as the rule is for a driver to stop *at* a signal-post, one driver might come along the line x as far as the post, and in doing so have 'fouled' the branch line, when a train arriving from y would cut the first in two. This led to the plan of putting the down signals on one post in front of the switches, and the up signals in the fork (or *vice versâ*, as the case may be), and thus a driver arriving from the direction x would stop at the signal-post A, and one arriving from y would stop at the signal-post B.

A still better plan at junctions is to have a separate signal-post for each line.

Fig. 45 shows a case in which it is necessary in a station-yard to exhibit several signals on one post to provide for as many roads.

Until recently it was usual, though the practice was not universal, to put the main-line signal at the top, and then in rotation, the main platform, the goods, and the through crossing or other subordinate line.

Another plan is to make the top signal refer to the road farthest to the left hand, the next signal to the next road, and so on.

The first method has the advantage that the driver of an express train always knows that the top signal is the one for him, regardless of what station it may be, and of the arrangement of the lines. On the new plan the driver has to remember not only where he is, but also the arrangement of the roads at that place, and then he has to pick out his signal accordingly, which may be the first at one place, and the second, third, or fourth at others.

Another modification of several signals on one post is shown in dotted lines in Fig. 46, in which the signal farthest to the left hand also refers to the road farthest to the left. Although not long introduced, it is already found necessary to give some preferential distinction to the main line. This is done by making the main-line signal the highest, the platform signal the next, and so on. Thus a driver on the main line after all knows his signal not by its position with reference to the right or the left hand, but from its being the highest. There seems therefore to be no compensating advantage for the great amount of top weight and consequent instability incurred by the new arrangement.

The London and North-Western Company make the following distinctions of signal-blades, Fig. 47.

Top blade plain is for the main line.

Second blade, with an annular plate 15 inches diameter, fixed flat on the blade and near the end of it, is for the auxiliary line.

A blade with a plate in the form of an S refers to a siding.

On the Brighton railway, distant signal-blades are sometimes cut, Fig. 48, for the sake of distinction where signals are numerous.

Several companies paint the names of the different signals on the blades.

The semaphore signal is now rapidly superseding all other types of main and branch line signals, and will soon be universal as a means of guiding trains on their journey. The only other type likely to be of continued service is the disc, as a signal to trains which have to trespass on the main line in the course of shunting operations.

Figs. 49, 50, represent a ground indicator in general use; sometimes to show the position of switches for shunting purposes, but when worked by a separate lever in a locking frame, it forms a good signal for leaving a siding or for going through a cross-over road. The advantage of this signal for these purposes is that it is low down on the ground, and is usually seen only by the persons whom it concerns.

It consists of a lamp with red and green lenses and corresponding discs fixed on the lamp; the lamp is carried by an internal spindle having a short arm keyed on to it, and a rod or wire turns the lamp through an arc of 90°. Its normal position is with the red lens towards the siding, and the green lens being turned towards the siding by the signalman gives permission to come out of it.

Another disc for these purposes, on the Brighton line, is similar in construction and indication to that shown in Figs. 30, 31, excepting that one disc only is used 15 inches in diameter, and the post is only about 4 feet or 5 feet high.

A signal for leaving a siding (Fig. 51) has been lately designed by Mr. Blackall of the Great Western. It consists of a small semaphore arm, and a pair of red and white lenses fixed at an angle of 45°, so as to throw the light upwards. This signal can easily be made so as to be visible only from the siding and not from a distance on the main line.

Another useful purpose to which a small disc signal (Fig. 52) may be applied can be seen at the Victoria Station. The platforms are all furnished with departure signals of the semaphore type, and in addition to these there is a small disc signal appertaining to each platform, fitted on the opposite side of the post. The discs are used to show that carriages standing there may be shunted across the main lines to the carriage sidings about $\frac{1}{4}$ mile off. These small discs (like the semaphores) are moved solely by levers in the locking apparatus, and can only be "given" after all necessary switches have been set to suit the operation about to be performed. The advantage of these discs for this purpose is, that each post already carries two semaphore arms relating to two platforms; and distinct signals being required for the carriage shunting, inasmuch as the carriage shunting crosses the main lines, the distinct type of signal has an advantage in being less likely to be mistaken.

Semaphore blades of a smaller size are sometimes used for the same purpose.

Distant Signals.

Signals placed at a distance in advance of the point of danger were first introduced in Scotland, after the opening of the junction of the Hawick branch with the main line from Edinburgh to Berwick in 1846. Two board signals, similar to Fig. 1, were erected, one for the protection of the up line, and the other for the down line. These were placed about 50 yards on either side of the pointsman's box, in front of which the switch handles were concentrated. The pointsman, having to walk to and fro to these signals many times in a day, arranged a wire, with a few chairs as a back balance-weight, so that he could from his box pull either signal to "safety." This was found to be such a convenience that a distance signal was put up at St. Margarets, near Edinburgh, 250 yards in advance of the point of danger; and after this distant signals became general. Their indications and working are just the same as the ordinary signals, with the simple difference that instead of being worked by a handle at the post, they are worked by a lever at a distance pulling on a wire to bring the signal to "safety" (Fig. 53), and a balance-weight and lever fixed on the post restore the signal to danger upon the wire being relaxed. If from any accident the wire should be broken the signal goes to the "stop" position.

The Great Northern railway was, at its construction in 1852, completely fitted with distant signals of the semaphore type, and this was, the Author believes, the first instance of the kind.

In practice distant signals are used in two ways:—

1. Where the distant signal is lowered first, and acts only as an

intermediate signal, the driver being expected to be prepared to pull up at the home or station signal. This is the practice at all stations on the Metropolitan, but not at junctions.

2. Where the distant signal is lowered only *after* the home signal has been set to "go on." In this case a driver finding a distant signal against him draws within it slowly, whistles to the signal-man, and prepares to pull up at the home signal, if it should still be against him. If, on the other hand, the distant signal is at "go on," the driver expects to find the home or junction signal the same, and ordinarily does not pull up.

In order to secure completely this safe plan, it is desirable to have the distant and the home signals to interlock with each other, so that the distant signal cannot be given until after the home signal; for it has happened that a signalman has given the distant signal whilst the junction was still foul, expecting to get it clear before the arrival of the train, which the event showed he was not able to do.

Separate distant signals should also be fixed for each road, because, if not, there is nothing to show the driver whether the right road is prepared for him or not.

If only one distant signal be used, then it ought to be locked, so that it cannot be given if a branch road, goods road, or siding, is open; and for these the driver should creep within the distant signal until he could see the junction signals. The giving of a distant signal ought to imply a clear road for the main line; and if it be desired to indicate a clear road for the branch also, it can only be done satisfactorily by a *separate arm* on the distant signal post, as shown at *x*, in Fig. 44.

Sometimes when the signal is round a curve, or in a cutting, double distant signals are used; *e.g.*, one signal is fixed at about 1,000 yards, and one at about 400 yards. A driver finding the first one against him draws inside it, and goes at reduced speed to the second—by that time the second may be in his favour, but if not he draws very slowly within it. The second signal has also this advantage: the first may be out of sight of the signalman but the second in sight, and he can thus see that the signals are working properly.

Distant signals are sometimes fixed at 1,500 yards, but beyond 800 yards their action is always more or less uncertain, and should be checked by a repeater. Where the signal-post is round a curve, or is in any way obscured from view, such a repeater should also be fitted.

An electric repeater is a miniature arm beside the signalman, controlled by an electro-magnet, the circuit of which is completed or interrupted by a contact maker fixed on the signal-post, and thus the movements of the signal are repeated on the miniature.

A mechanical repeater is a small disc or signal-arm beside the signal lever, worked by a return wire from the signal; thus, when the repeating disc or arm moves in consonance with the expectation of the operator, it shows that the distant signal has also been moved as intended. Mechanical repeaters are in use for all distant signals on the Metropolitan railway.

Where the distant signal of one signal-box is near the home signal of another signal-box, Fig. 146, a useful contrivance is the "slotted" signal, by which one signal does duty for both purposes. In Fig. 146 the same signal-blade C acts as home signal for signal-box A, and as distant for signal-box B. The rod R (Fig. 54) which actuates the signal has a slot in it, and is loaded by two weighted levers, the one being controlled by signalman A, and the other by B, either weight being sufficient to put the signal "on." Thus either man can keep the signal "on," but it requires the consent of both to take it "off." This signal is extensively used.

Stop signals are sometimes placed between a distant signal and a home signal of a busy station, to allow trains to stop under cover of them in readiness to enter the station as soon as opportunity offers.

Similarly, advance signals are placed a little beyond the exit of a station to allow the station to be cleared of departing trains. A train may go as far as the advance signal, and wait until informed by it that the line is clear to the next station.

INDICATORS.

The Author believes that the semaphore and disc signals are the only kinds likely to continue in use, but before the systematic introduction of locking apparatus several forms of switch indicator did good service; the type most used being Stevens's, Figs. 55, 56. It consisted of a signal-arm mounted in a V-shaped frame, actuated by a rod which received its motion from the switches. The blade laid to the right or left indicated which way the switches were standing. Below the arm was an arrangement of coloured glasses and lamp for night use. Various forms of lamp close to the ground have also been tried for showing the position of any particular set of switches.

The Great Western indicator is shown in Figs. 57, 58.

Deas and Rapier's post indicator in Figs. 59, 60. The signal-blade and the spectacle-frame are united and hang on a pivot, the spectacle-frame being heavier than the blade. Upon a stud a short distance from the central pivot hangs a rod, and when the weight of this rod is on the stud it causes the blade to overbalance the spectacle-frame, and so brings the blade down and the glasses up to safety; the other end of this rod is connected to the balance-weight of the switches, so that an amount of movement not sufficient to be dangerous to the switches would yet lift the rod far enough to allow the signal to go fully to the "stop" position.

These indicators, as also the types shown in Figs. 61, 62, 63, are extensively used in Russia, Australia, South America, and other countries; but for crowded traffic they are altogether insufficient, and they are now superseded by more secure contrivances, to be hereafter described.

Self-acting Signals—Giving an Interval of Time.

During the last thirty years numerous inventions have been tried on railways, for the purpose of showing the length of time which had elapsed since the last train passed. Mr. Curtis on the Great Western, Mr. Gibson on the North-Eastern, Mr. Baronowski on the North London, have all made practical contributions in this direction. Mr. Baronowski's invention consisted of a mercurial column, which was filled by the motion of a lever (Fig. 64) actuated by the wheels of a passing train. The mercury passed freely into the column through a large valve in the piston, and dripped slowly out of it through a small aperture. The descent of the mercury in the column actuated a signal which could be seen by the driver of a passing train.

Self-acting Signals—Giving an Interval of Space.

Various attempts have also been made to render the signals of railways self-acting, so as to give an interval of space instead of, or in addition to, an interval of time.

Sometimes the small aperture in Baronowski's apparatus was controlled by a cock, which was opened by a wire actuated by means of the gear at the next signal station.

In 1864 Mr. Funnell made a series of signals (Fig. 65) for the Brighton railway. These were fixed between Brighton, Shoreham and Lancing. Their action was as follows:—Suppose an engine started from A, by means of a treadle it put the signal at A to danger. When the engine arrived at B it put a signal to danger at B, and the same motion by means of a contact spring completed an electric circuit, which passed a current of electricity through an electro-magnet fixed at A, and thus released the A signal. Similarly when the train arrived at C, the C signal was put to danger and the B signal to safety. These signals were in use for some time, but were finally abandoned as the wires were constantly either purposely or accidentally broken.

On the North London, the Lancashire and Yorkshire, the Brighton, the South-Eastern, and other lines, a lever has been used for restoring signals to the "stop" position, by the wheels of a passing train. This arrangement sometimes did good service when the signals were worked by the porters of the stations, and they omitted to restore the signals to "stop" with sufficient promptitude. Now, however, these levers have all been taken out.

Another scheme has lately been brought forward for working the points and signals of a junction by levers which the engine driver could present from the under side of the engine to gear fixed between the rails; but, supposing a perfect system of self-acting signals to be devised capable of working as a self-acting block system without the expense of a signalman, it would still be necessary to overlook each set every day to see that they were in proper working order. Again, such self-acting system would only be applicable to long stretches of road free from stations or junctions, because at stations and junctions there must be some intelligent control of the signals, their use at such places being of a character too varied to be reducible to an automatic mechanism. Such long stretches of road are so rarely to be found in this country, that it would not be worth while to introduce an exceptional system even if it were perfect.

Audible Signals.

Thus far visible signals only have been treated of; in foggy weather it is necessary to supplement the visible signals by a signal which shall appeal to the ear. In the year 1841 Mr. E. A. Cowper, M. Inst. C.E., designed the detonating fog-signal now universally used on the railways of this country. It consists of a thin metal case, 2 inches in diameter and ½ inch deep, furnished with two leaden ears which can be readily bent down, so as to embrace the head of the rail, and prevent it falling off. (Fig. 66.) A small quantity of gunpowder is placed in the case, and is exploded by the compression of one or two matches as the wheel of the engine passes over the case. The matches are of the kind formerly called "Promethean matches;" they are made with a small glass bulb of sulphuric acid inclosed in a little chlorate of potash and sugar, or other combustible wrapped in paper, and are very certain in their action. Recently, detonating powder has been substituted in some cases. In the first instance, Mr. C. H. Gregory, Past-President Inst. C.E., allowed trials to be made on the Croydon railway, where the efficiency of the new signal was so thoroughly demonstrated that it was adopted shortly afterwards. In the following year it was introduced on the London and Birmingham, and soon after on railways generally. Not only are all stations furnished with a supply, but guards, signalmen, and gangers are required to have constantly at hand a certain number of these fog-signals.

Each plate-layer has his appointed place at some signal-post, and being furnished with a supply of fog-signals, he uses them as follows:—Whenever a signal-arm is at stop he places a fog-signal on the line served by that signal; whenever the signal is put to safety he takes the fog-signal off the line again.

Contrivances have been proposed for putting fog-signals on the rail by mechanical means, so that, whenever a danger-signal was exhibited, a fog-signal should be presented to the rail. Other contrivances have also been proposed to signal to the driver by means of a bell or whistle on the engine without the use of a detonating signal. One system of this kind is in use on the Northern Railway of France, but it is substantially the same as that fixed in 1865 on the North British railway (Figs. 67 and 68), at the suggestion of Mr. John Anderson, Secretary of the Callander and Oban railway. On the engine, tender, or guard's van was fixed a gong, bell, or whistle, to be actuated by the movement of a lever hanging down from the under side of the engine or break-van, this lever reached within a few inches of the ground, and its terminal end carried a pulley or roller.

When any signal was put to danger, a corresponding inclined plane, P, was slid into a central position between the rails, so that if an engine should pass it, the roller of the lever would touch the inclined plane, and the lever would thereby be elevated to the position shown in dotted lines, and the signal apparatus on the engine or break-van put in motion. When the danger-signal was taken off, the wedge-shaped block was slid laterally about 6 inches, so as to clear the lever hanging down from the engine. This apparatus was fully tested during eight months, when it was approved. Anderson's apparatus was also useful in case of repair of the line; the plate-layers being furnished with a wedge-shaped block of wood, had only to spike it to two sleepers ½ mile in advance, to ensure a driver receiving timely warning that repairs were going on.

Railway signalling has afforded many striking illustrations of the truism that "invention repeats itself;" and in the type of signal now under consideration this has been especially exemplified. Mr. Ager has, during the last three years, fixed several signals on the London, Chatham and Dover railway, the same as Mr. Anderson's except that, instead of sliding a solid inclined plane in a lateral direction to meet the depending lever from the engine, he adopts a steel spring about 6 feet long (Figs. 69, 70), mounted on a bar which turns on journals at each end, so that when the bar is caused to perform one quarter of a revolution the spring is laid flat, as shown in dotted lines in Fig. 70, and is thus taken out of the way of the gear on the engine. If an engine comes up when the signal is at danger, it would find the spring in the vertical direction, and the lever or rod (furnished with a roller) hanging down from the engine (Fig. 69) strikes the spring and thus receives motion sufficient to open the whistle on the engine.

The apparatus on the Northern Railway of France is identical with Mr. Anderson's, with the exception that, instead of a lever under the engine, there is a metallic brush, which, coming in contact with the inclined plane, completes an electric circuit. This causes an electro-magnet on the engine to open a small steam-whistle which continues sounding until the driver stops it, thus arresting his attention—*provided* all goes well with the apparatus. If audible signals were adopted in addition to visible signals, there would be a tendency to cease to look out for visible signals, and too great dependence would be placed on the audible signals. A driver, so long as he heard no signal, would presume that all was in his favour. Now, quite apart from possible failures of the apparatus, this would be setting up the principle that absence of signal implies permission.

All plans of audible signals revert to the old idea of "*giving danger signals*," a system inadequate to the requirements of English railways.

Another form of audible signal, free from the objection above stated, has been contrived by Mr. R. Burn, jun. This is illustrated in Figs. 71, 72. If the signalman should deem it advisable to give an audible signal in addition to the ordinary signal, he moves an additional or supplementary lever (Fig. 71), which causes a catch to take into the ratchet-wheel carrying the signal wire, which is slackened sufficiently to allow the treadle to rise above rail level and present an inclined plane to the lever or other gear fixed on the engine to receive the signal. This audible signal has the advantage of not always sounding the whistle as a matter of course when the semaphore is at danger.

Of Switches and their Connections.

In the early days of railways, switches consisted only of two pointed rails about a yard long, pivoted at the heel ends, and without any rods or gear. In entering facing switches, it was the duty of the fireman to descend and adjust the facing point, and as the wagons travelled slowly along, he, from time to time, gave the tongue a hitch to close it, in the interval between the passing of one wheel and another, an operation requiring both a quick eye for wheels and a quick hand at the switch tongue. The man who first fitted a pair of these primitive points with a rod and a lever was considered to have made an important invention.

When railways began to be constructed for passenger traffic, it was soon established that there should be as few "facing" switches as possible.

There is not so much danger with backing-out or trailing switches, for if accidentally left open to the siding, the flanges of the wheels of the engine and vehicles, pressing against the inside of the closed tongue, move it in the required direction.

The importance of the facing switch can be best appreciated by supposing a heavy mineral train travelling along a main line of railway (Fig. 44), and an express train being nearly due, it is desirable that the coal train should go into a siding and leave the main line clear for the fast train. Now this can be done either by means of a backing-out switch as at D, Fig. 44, or by means of a facing switch, as at F. To leave the line by the backing-out switch, the train, often a very long one, must go ahead its full length till the tail of the train clears the points. The train must then be brought to a stand, and next be put in motion again in a backward direction until the whole of the train is inside of the siding. It is obvious that this is an operation requiring much time, frequently ten minutes.

On the other hand, the "facing" switch allows the heavy train to clear the main line whilst it is still on the move, and without stopping until it is safely out of harm's way.

Now a main line of railway cannot be interfered with for ten minutes, unless protected by signal, and no protection by signal can be considered complete except by interlocking the switches with such signal.