Rapier
on
Railway Signals.

R21

F. Ransome with the Author's kind regards.

ON THE

FIXED SIGNALS OF RAILWAYS.

BY

RICHARD CHRISTOPHER RAPIER, Assoc. Inst. C.E.

WITH AN ABSTRACT OF THE DISCUSSION UPON THE PAPER.

EDITED BY

JAMES FORREST, Assoc. Inst. C.E.,

SECRETARY.

By permission of the Council.
Excerpt Minutes of Proceedings of The Institution of Civil Engineers,
Vol. xxxviii. Session 1873-74.

LONDON: PRINTED BY WILLIAM CLOWES AND SONS,
STAMFORD STREET AND CHARING CROSS.
1874.

ADVERTISEMENT.

THE Institution is not, as a body, responsible for the facts and opinions advanced in the following pages.

RAILWAY SIGNALS.

TABLE OF CONTENTS OF MR. RAPIER'S PAPER.

THE INSTITUTION OF CIVIL ENGINEERS.

March 31st, 1874.
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 ¼ mile, the average being 1½ 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 ¼ 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 signalman, 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.

Interlocking Apparatus.

As the number of junctions increased, it soon became apparent that not only must distinct signals be given for distinct lines, but that some kind of concerted action must be secured between signals and switches, as they might be conflicting. An important step was taken in this direction by Mr. Gregory, who, in 1843, at the Bricklayers' Arms Junction, gathered together chains from all the signals into a stirrup frame (Fig. 73); and a sort of parallel motion was fixed to the frame, between the stirrups, in such manner that the depression of any stirrup pushed the parallel motion so as to block one or more of the other stirrups, and thus it was impossible to give two signals which conflicted with one another at the same time. The switch levers were fixed on the same platform with the stirrup apparatus, but were not interlocked therewith. The switchman, while working the switches with his hands, worked the signals with his feet.

After this it was an easy step to make the switches lock also. The first idea was to couple together any set of switches with its own proper signal, so that the signals and points should move together *pari passu.* This soon appeared to be insufficient, because sometimes the signal moved and the points did not, or *vice versâ*, and thus it was found that the mere *connection* of signals and switches did not fully meet the case. Switches and signals are said to be *connected* when they are simply coupled together and have a *pari passu* motion; they are said to be interlocked when the movement of a signal to safety cannot be *commenced* until after the necessary movement of the switches has been *completed*, and also the movement of switches cannot be commenced until after all the signals concerned by them have first been set *fully* to danger.

The first interlocking of switches and signals took place at East Retford Junction, in the year 1852. Though the contrivance was simple in the extreme, it contained the germ which has developed into the systems of interlocking now in use.

A signal had been given for a train to start whilst a pair of facing points in front of the train were still open. As the points happened to be close to the signal-post, a flat bar was brought from the near switch tongue close past the foot of the post (Fig. 74), and the vertical rod which moved the signal was continued down the post to meet the flat bar. The flat bar travelled with the switches, and when the latter were in the right position for the main line, a hole in the bar opposite the signal-rod allowed it to pass through, and the signal could be set to safety. After the signal was lowered, the points could not be altered, because the signal-rod passing through the bar, as shown by the dotted lines, prevented any alteration of its position. If the points were in the opposite direction, the solid part of the bar was opposite the signal-rod, and the signal could not be moved.

This simple kind of locking has been extensively used as a signal-post lock, and in the form known as the goose-neck lock (Figs. 75, 76), and the notch lock (Fig. 77, 78).

The wire which moves the signal has interposed in it a square bar, with a long pointed piece forged on and parallel to it, in such manner that the square part moves in guides, and the round limb parallel to it comes opposite to a prolongation of the switch rod, which also moves in guides. A hole is made in the prolonged switch rod so that, when the switches are in their right position, the bolt of the goose neck can pass through, and the wire be pulled and the signal given; but with the switches in a wrong position, the solid part of the rod is opposite to the point of the goose-neck bolt, and prevents the signal-wire being pulled. Similarly, when a signal has been given, the bolt of the goose neck passing through the switch-rod prevents the switches being moved until after the signal is restored to danger and the goose-neck bolt thereby withdrawn. Sometimes the same signal-wire is coupled to goose-neck locks appertaining to several sets of switches concerned by that signal.

The more complete development of the interlocking system, by the use of apparatus, in which all the movements of switches and signals are rendered harmonious, is illustrated in Fig. 44. This is a ground plan of an ordinary double junction, and for its working nine levers are required, viz.:—

Up switch lever.
Down switch lever.
Up main distant signal.
Up main junction signal.
Up branch distant signal.
Up branch junction signal.
Down main junction signal.
Down branch junction signal.
Down distant signal.

Instead, however, of having only one down distant signal, it is better to have a down main distant and a down branch distant, thus increasing the number to ten levers, and if a lock-lever be added for the facing points, to eleven levers.

The switches are coupled to their respective levers by rods working in guiding rollers, mounted in small cast-iron frames. Sometimes these frames are made with a lid for protection from the weather (Figs. 79, 80). The rods are usually gas pipe of 1 inch internal diameter. If the lengths are joined by screwing, a solid plug should be inserted and riveted into each end of the tubes as an extra safeguard. When the switch-rods exceed 30 yards long, an expansion lever (Fig. 81) should be placed midway between the switches and the signal-house, and then any expansion of the rods in one direction is compensated by the like expansion in the other —without such levers the varying length of the rods prevents the correct working of the switches. The levers, bell-cranks, pedestals, and screw couplings should all be made of wrought iron. The signals are coupled to their respective levers by similar connections of ½-inch gas pipe for short distances, and by wires for long distances. The greatest distance at which switches are so coupled is 410 yards on the Great Western at Moulsford, but this distance is found to be excessive for traffic, though not for mechanical, reasons. Signals are worked at distances of 1,400 to 1,500 yards, but any distance beyond 800 yards is troublesome.

Besides the signals and switches of junctions—level crossing gates, canal bridges, and even turntables are sometimes interlocked; in short, whenever any one operation interferes with the performing of another, the interlocking system ought to be applied.

The normal position of switches at a junction should be as in Fig. 44, so that the points are open to the outermost roads respectively. Thus a down train accidentally overrunning the points would go along the branch, and would not run foul of a train which might be coming along the up branch line.

The principle of all interlocking systems is, that the signals can only be given in harmony with the setting of the switches, and *vice versâ.* For example, suppose an up branch train is expected, the up switches must first be set for the branch, and this movement of the switch lever ought to lock the up main signals and the down main signals, and unlock the branch up signals: the branch up home signal should then be lowered or "given," and then the up branch distant.

Much on the same plan as Mr. Gregory's concerted signal frame, Mr. Chambers, some years later, extended the locking (previously confined to signals only) to the switches, but not to the distant signals. A frame on this plan, believed to be the first of the kind, was put up at Willesden Junction in 1859.

The frame was built by Messrs. Stevens and Sons; the interlocking was suggested by Colonel Yolland, and a race ensued between Mr. Chambers and Messrs. Stevens to prepare the necessary fittings.

Figs. 83 to 87 show Mr. Chambers' junction apparatus.

The up switches actuated by the lever U are open to the main line.

The down switches actuated by the lever D are open to the branch line. The upper stopping plate U works with the up switch lever. The lower stopping plate D works with the down switch lever.

When the up points are open to the main line as in Fig. 44, the up main signal can be given, because in that position of the plate U, there is a hole in the plate opposite the leg of the stirrup, which allows it to pass through. But the up branch signal could not be given, because there is no hole in the plate U opposite the leg of the stirrup which moves the up branch signal. Also as long as the up main stirrup is pressed down to give the signal, the up points U cannot be altered, because the leg of the stirrup locks the plate U.

But suppose the stirrup allowed to go up to danger, then the lever U can be brought over to open the up points to the branch line; and, in so doing, the plate U is thrust forward, so that its solid part comes under the up main stirrup, which is thereby locked; but the part under the up-branch stirrup now has the hole under the up branch stirrup, which is able to pass through.

By thus providing all switch levers with plates passing under the signal stirrups which concern them, making holes in the plates so as to allow the signals to be free, and no holes where the signals ought to be stopped, the complete interlocking of switches and signals was obtained.

In another variety of Mr. Chambers' apparatus, Fig. 86, a handle was used for signals with a prong bent in the arc of a circle, which prong was locked by the switch plates in the same way as the stirrups before described.

This arrangement was efficient so long as any signal had to be locked by only one or two sets of switches, but if a signal had to interlock with several sets of switches, say for example, ten or twelve, as in Figs. 86, 87, and that the first ten happened to be free to the signal, and the last one not free, a considerable movement of the signal might take place before it was checked by the last plate.

The switches and signals are now all worked by levers arranged in a row; and the levers are usually sorted, so as to have the signal levers at the ends of the frame, and the switch levers at the centre. Sometimes the switch levers are arranged adjacent to the signal levers to which they relate; and, in a long frame, this plan is more convenient to the operator, as all the signal and switch levers which have to be moved for any one operation are close together. Fig. 115 is an example of this arrangement, being a drawing taken from a photograph of a frame of eighty levers, made for the level crossing of the Great Northern with the Manchester, Sheffield, and Lincolnshire railway at Lincoln Station. It will be observed that in this frame there are no less than twelve directions for the arrival and departure of trains, and that in each case the levers required for any one train are close together.

At the Waterloo Station Messrs. Stevens and Sons arranged the levers in two rows, and lately, at the new City Station of the Great Eastern Railway, Messrs. McKenzie, Clunes, and Holland have arranged them in four parts.

Shortly after the completion of Mr. Chambers' apparatus a great step was made by Messrs. Stevens and Sons. Horizontal bars having hooks or claws on them, Figs. 88 and 89, were arranged in guides, so that the hooks engaged on to the levers. A spiral spring pressed the bars to the left, and they were moved to the right by the pressure of the lever against a short inclined piece mounted on the bar. In the normal position, Fig. 88, the bars are thus kept to the right and the hooks lock some of the levers. When any lever is moved into the secondary position, as soon as the pressure of the lever is withdrawn, Fig. 89, the spiral spring pushes its bar into the secondary position, and so unlocks the levers which were locked, and locks those that were unlocked. The back-locking of the switch levers by their respective signal levers was performed by subsidiary catches fixed on the levers, about halfway down their length.

In Messrs. Saxby and Farmer's apparatus, Figs. 90, 91, and 92, the switch and signal levers are arranged in a row, and have about half their length above, and the other half below, the floor of the signal-house. Under the floor are, in a horizontal plane, short locking levers between the switch and signal levers, each locking lever moving on a pivot *p* at the inner end, the outer end being articulated to a locking bar *b*, moving in guides, and having locks, L, L, L, attached to it in positions corresponding with the requirements of the various levers. The edges of the active locking levers are slanted cam fashion, so that when the motion of the switch lever comes in contact with the locking lever the latter was operated sufficiently to cause the passive locks L, L, Fig. 91, to engage the levers C, D, but not sufficiently to unlock the lever X. The middle part of the movement of the switch lever does not affect the locking lever, but the latter part completes the movement of the locking lever, thus still further securing the levers C, D, by the locks, and releasing the locks of the lever X, Fig. 92.

If, for example, a main-line signal be given, by the lever X being drawn over, this movement of the lever backlocks or secures the switch lever A in the right position for the main line. Of course any one lever may require to be locked by any one or more other levers; this is done by successive tiers of locking levers, similar to the one tier shown in the figures.

Many varieties of similar apparatus were subsequently designed, the general principle of all being, that locking bars moved in *horizontal* planes should interlock the levers moving in *vertical* planes; the chief point of difference being the method of causing the levers to impart the necessary motion to the locking bars.

One of these, made for the late Mr. Michael Lane, M. Inst. C.E., is shown in Figs. 93, 94, and 95. The necessary motion was obtained by a rack attached to the switch lever, which caused a pinion to revolve. This pinion was fixed on the axis of a screw, which being thereby made to revolve in a fixed nut, travelled in a horizontal direction, thus obtaining the necessary change of position of the locking bars or plates. This method was not so good as those before described, as the locking was obtained only by what may be called a *pari passu* motion, whereas the other plans secured the locks comparatively earlier in the stroke of the lever and released them comparatively later.

Messrs. Skinner, Baines, I'Anson, and others, likewise produced different modifications.

Another kind, Fig. 96, made by Mr. Francis Brady, M. Inst. C.E., was of a stronger construction and less likely to be deranged by the application of excessive exertion at the handle. The switch and signal levers are in a row. Under the floor horizontal shafts appertain to, and are actuated by, the different switch levers; on these shafts are fixed cam pieces opposite to such signal levers as are concerned by those switches; from each signal lever a pair of long connecting links proceed in a direction at right angles to the shafts, and articulated to these links are concave arms moving on pivots fixed on the bed plate. The concave arms worked by the signal levers are opposite the cams which are worked by the switch levers in such manner that any signal lever can only be moved when all the switch cams are turned away from the concave arms worked by that signal lever. If any switch cam be turned towards any signal concave arm as at B, that signal lever is thereby locked. Also, when any signal lever has been moved, the concave arms fit against the cams on the shaft worked by the switch levers, as shown by the black dotted lines at A, Fig. 96, and so prevent the latter from being altered. This apparatus is extensively used on the South-Eastern railway. It consists of many parts, but it is strong, and the various parts are fac-similes of each other.

A decidedly different apparatus was brought out by Messrs. Livesey and Edwards (Fig. 97). Above each lever was a short arm mounted on a pivot at one end, and finished at the other end in the form of an eyelet. The short arms were actuated so that when any handle was moved which required the locking of the signal lever A for example, the mechanism pulled down the short arm so that the eyelet embraced the end of the signal lever and securely locked it. This method had the great advantage that the locking was all in sight: but it had the great disadvantage of requiring another plan of back locking, *i.e.*, securing the switch lever in its new position by the subsequent movement of the signal lever.

After the various locking apparatus above described had been in use a few years, and the wear and tear of actual working began to have its effect, two points arose requiring attention—

1st. The locks, with the exception of Mr. Livesey's, had hitherto been all under the floor, and so far down the length of the lever, that the signalman had considerable leverage over them and the pins and studs on which they were pivoted, and as a good deal of force was often applied, it frequently happened that some part of the apparatus was damaged.

2ndly. Wear and tear resulted in considerable clearance between the locks and the levers, so that levers were frequently imperfectly locked.

Recent Interlocking Apparatus.

The next decided step was to perform the locking and interlocking by means of the spring catch rods used for securing the levers in their places.

Figs. 98 and 99 show Mr. Easterbrook's method of effecting this. Each catch rod has a prolongation extending some distance below the floor. On the outer side of this rod are notches ½ inch wide, and 1 inch pitch. Adjacent to these, horizontal bars, also notched, are so placed in guides that the teeth of the bars engage into the teeth of the catch rods to prevent their movement. When the bars are slid along so that a notch comes opposite to a catch rod, then that rod can be moved.

The horizontal bars have motion imparted to them by the catch handle of the lever to which they belong. This movement is imparted simply enough when the levers are in their vertical position; but in order to obtain it after the lever has been moved into its new position, Fig. 99, a sector lever has to be provided, so as to permit of the catch rod travelling along the sector. When the transit of the lever is completed, the depression of the catch rod depresses the sector lever, which in its turn moves the sliding bar into its new position.

This method of locking has the advantage that the man's hand has not much leverage over the locks, and so cannot strain them; and also the advantage that the locking of the signal levers that ought to be locked is completed before the switch lever begins to move, and the unlocking is not accomplished until after the movement of the switches has been fully completed. The complication, however, is great, and the number of pieces in the gear considerable.

Similar apparatus was made by Messrs. Saxby and Farmer. Recently, however, a much improved machine has been produced by that firm, Figs. 100 and 101.

The levers are arranged in a row as usual, and 6 inches apart. Between the levers are sector plates mounted on pivots 6 inches above the floor. Each catch rod terminates in a substantial end piece, which carries a stud projecting laterally so as to engage the slot of the sector. When the lever is in its forward position, the catch rod depresses the sector into the position shown in black line. On the top of the sector, and formed in the same piece with it, is a lever rising perpendicularly for 16 inches, and terminating in an eye; coupled to this eye is a locking bar, which is thrust out in a horizontal and forward direction. Now it will be seen, that if the handle be pressed against the lever, the catch rod will be elevated and with it the sector, thus causing a movement of the eye of the sector lever, and consequently a movement of the locking bar. In this position of the sector the arc of the slot is true to the pivot on which the lever moves: consequently as the lever is drawn over no movement of the sector takes place. When the movement of the lever is completed, the depression of the catch rod and stud depresses the sector, and the sector lever draws the locking bar still farther out. Each signal lever has a locking bar with notches cut in it, moving in a to-and-fro direction.

In the frame in the rear of the levers are arranged bars moving in a longitudinal direction, and each switch lever has one of these longitudinal bars belonging to it. These longitudinal bars are so near to the transverse locking bars of the signal levers, that locking pieces mounted on the switch bars may engage into the notches of the signal bars. Given the signal bar with as many notches in it as there are switch bars, it is clear that locking pieces may be mounted on any switch bar so as to lock any signal bar in any desired manner.

The switch levers have also sectors, but their thrusting bars, instead of being notched, are furnished with a male wedge piece, Fig. 101, engaging into a dove-tailed wedge piece fixed on the longitudinal bar belonging to that set of switches, so that the reciprocating motion of the bar in a to-and-fro direction draws the longitudinal bar in a longitudinal direction. For economy of space some of the longitudinal bars are placed above, and some below, the transverse bars, as shown in Fig. 100.

If it be proposed to move any signal lever, the depression of the catch handle at once shows whether the signal lever is locked or not. If it be not locked, the depression of the catch handle draws out the locking bar $\frac{1}{2}$ inch and thus opposes the solid parts of the bar to the locks on the switch bars, and consequently no contradictory switch could be moved.

This apparatus is so strong in principle, that it is made almost entirely of cast iron, and all similar parts are cast from the same patterns.

In Messrs. Stevens and Sons' new frame, each lever has one or more thrusting bars attached to it. These thrusting bars pass through guiding bars fixed in the frame, and running in a longitudinal direction. Between the guiding bars there are sliding blocks which abut against one or other of the thrusting bars of any two conflicting levers, Figs. 102, 103.

If lever No. 7 be moved, the bar *a* would thrust the block *b* against the thrusting bar of lever No. 8, which would be thereby locked.

If any lever (say No. 5) has to lock a lever, No. 7, at a distance from it, their respective sliding blocks are connected by links L, L, shown in dotted lines. When the levers are well sorted, so as to lock adjacent ones, comparatively few of these links are required.

A new locking frame is also made by Messrs. McKenzie, Clunes and Holland, of which there is a good example at the new Liverpool Street Station of the Great Eastern railway.

In Mr Poole's gear the usual detents and spring catch handles for securing the levers in position are dispensed with, and the levers are pressed by springs into recessed notches in the top plate of the apparatus. Before the operator can pull any handle towards him, he must first move it in a lateral direction to get it out of the notch, and this preliminary movement performs the locking. It will be seen from Fig. 104, that if the switch lever be pressed laterally so as to release it from the notch, the lower part of the lever (Fig. 105) will move the sliding bar to the right, and this, by means of the bell-cranks, the locks L, L, so that their projections will come in front of the levers for the main home and main distant signals and prevent those levers being moved laterally out of the notches in the upper catch plate. There are also detents for preventing the sliding bars being accidentally disturbed, but the above is the principle of the locking. Each switch lever and each distant signal lever requires a set of locks, and the successive sets are arranged in tiers.

Mr. Buck's apparatus is on the principle of having one substantial lock to each lever mounted on pivots formed as a continuation of one edge of the lock, Fig. 107, so that when left to itself the lock falls clear of the lever, Fig. 106; part of the axis of the lock is square, and from the vertical side of this square a plate P hangs vertically. This plate is for the purpose of extending over several longitudinal sliding bars A, B, &c., Fig. 108, running the whole length of the frame. These sliding bars are appropriated to and actuated by such switch levers or signal levers as require them; and on them brackets are fixed (Fig. 106) to engage the vertical plate of any lock, or locks, which it may be desired to move into the locked position.

When a lever is required to interlock with several others, it is fixed only once by its one lock; but this can be moved by any of the levers concerned, and any number of successive levers being moved do not interpose successive locks, but they simply lock a lever, if this is not already effected.

An examination of the various complications of locking apparatus led the Author to consider whether some simpler construction could not be devised, for there are thousands of parts in a single machine.

In attempting simplification, the Author determined to disregard all previous systems, and to commence, as it were, *de novo*. The subject was successfully reasoned out as follows: As a first principle it may be predicated, that it is quite easy to lock a number of levers in their normal position by shooting bolts through them, or over them, as in Messrs. Stevens's first apparatus. When, however, any lever is moved into its secondary position, it can no longer be locked or unlocked by the same bolts, because the lever has moved away and is no longer near the said bolts; therefore the locking and unlocking in the secondary position must be accomplished by other locking bolts or bars. The Author conceived the idea of making each lever with a sector forged on it (Figs. 109, 110), so arranged that there should always be some part or other of the sector adjacent to all the locking bars, and thus the same locking bars could perform both the primary locking and the "backlocking." In this he succeeded so well as to lock and backlock all the levers of a ten-lever junction, by means of only six moving pieces, and the whole of the levers of an eighty-lever frame (Fig. 115), for the Great Northern railway, by only twenty-seven moving pieces.

In Fig. 110, lever No. 3 actuates the down points. As the frame stands, the down points have just been opened to the main line, and the locking bar X has been moved to the left, and is in the position shown in Fig. 111.

The sectors have notches cut in them wherever the locking bars ought to pass through, and are left solid where the bars ought not to pass. X is the locking bar belonging to lever No. 3, and Y to another switch lever. These bars are moved by flanges forged on the sectors, working in finger pieces fixed to the bars, Fig. 114.

The bars are shown in plan with the levers in section, Fig. 111, 112, and 113. It will be seen that when lever No. 3 is down the main-line signals are movable, and the branch-line signals are locked. If the switch lever, No. 3, be put up so as to set the switches in favour of the branch, the first part of the motion causes the flange of the sector to move the locking bar into the position shown in Fig. 112, by which it will be seen that all signals are locked, and after the motion of the lever is completed the bar is put into the position Fig 113, thus still farther locking the main-line signals and unlocking only the branch-line signals. Now if a branch-line signal, No. 2, be given, the solid part of the sector of No. 2 comes into the notch in the bar, and thus renders its motion impossible, and by consequence the switch lever to which it belongs, so long as the signal is given. To move any switch lever it is necessary that all the signal levers which concern it be restored to danger or stop.

The possibility of thus making a locking apparatus being thus established, the next inquiry should be as to its efficiency.

1st, as to locking early in the travel of the lever; the amount of movement required to effectually lock all levers is only $\frac{1}{2}$ inch at the man's hand, and $\frac{1}{16}$th inch at the short end of the lever to which the switches are connected, an amount far less than the slack or spring of the gear; and thus the locking is secured before the switches begin to move.

2nd, as to strength of the locking mechanism; this is satisfactory, inasmuch as the locking is obtained simply by the interlocking of two notched bars, without the intervention of pins or articulated parts; these bars are $\frac{1}{2}$ inch thick, and the man's hand has only a leverage of 2 to 1 over them, an amount quite insufficient to enable him to injure either of them.

3rd, wear and tear may reasonably be taken as diminished in proportion to the diminished number of pieces, and further by the circumstance of their being almost all of wrought iron and machine cut.

4th, all the apparatus is in sight, and can be readily examined or taken out for any necessary additions or alterations.

The majority of engineers shrink from the effort to follow the complex arrangements of a large locking machine. The apparatus under notice demonstrates that complete interlocking can be accomplished without any complexity of parts. The whole of the switch levers and distant-signal levers are interlocked by the addition of only one moving piece to each lever, and all other signal levers are interlocked without any additional parts whatever, simply by making the levers themselves of the right shape.

Level crossings.—A detail, which appears to have some advantage in dealing with level crossings, is to have a separate locking bar or lever so that in one position all the signals of one road are entirely locked, and in the other position all the signals of the other road are locked. This plan has the advantage of giving the operator something special to do, in such exceptional cases, as changing his attention from one line to another which crosses it. In Fig. 115 is shown a locking-up bar worked by a lever for determining which railway is open and which is locked. When the lever is in its normal position the Great Northern line is free and the Manchester, Sheffield, and Lincolnshire line is locked. If the lever be brought down the locking-up bar would be slid to the left and the Great Northern signals would be locked, and the Manchester, Sheffield, and Lincolnshire signals would be free. This plan is also adopted for locking canal bridges, turn-tables, street gates, &c., which are all level crossings of less degree, but similar in character to the crossing of one railway by another.

SWITCH LOCKS.

From the confidence engendered by the interlocking system a new danger soon arose.

It frequently happened that a signalman reversed the switches before the whole of the train had passed over them, and thus caused part of the train to change lines, or to go off the line altogether. In 1867 Messrs. Livesey and Edwards made a switch lock to prevent this sort of accident. It consisted of a bar 12 feet long laid close to the rail, either inside or outside, and articulated on fulcra somewhat after the fashion of a parallel ruler (Figs. 116, 117). In the completed position of the switches either way, this bar lies so that its upper surface is just below the wheels. In order to produce any movement of the switches, the bar must be elevated; and the bar cannot be elevated if any wheel of a vehicle is resting upon it (Fig. 118). At first this bar was actuated by the same lever which moved the switches; but in 1869 Messrs. Saxby and Farmer made the important improvement of actuating this lock by a separate lever. This has been further improved by the addition of a locking bolt acting upon a bar connected with the switches in such a way, that if the switches were not fully home to one side or the other, the bolt would not enter either of the holes provided for that purpose (Figs. 119 and 120).

On this plan any set of facing switches is controlled by two levers in the locking frame. If it be desired to move a particular set of switches, the lever which locks them must first be drawn over so as to withdraw the bolt. As this lever acts at the same time on the long bar, the locking bar cannot be lifted if any portion of a train is still passing over it, and consequently in that case the switches could not even be unlocked, much less moved. After the switches are unlocked, their position can be changed, and then the locking lever must be restored to its place before a signal can be given, for the signals are interlocked by the locking lever so that no signal can be given, whilst the locking lever is in the unlocked position, and when it is in the locked position signals can only be given in accordance with the position of the switch lever.

This invention provides against the most dangerous class of accident. The locking bolt ascertains whether the switches are fully set in one position or the other, but not if the switches have moved, or remained stationary. For example, the rod leading from the signal box to the switches might be broken, and the locking bolt would not in the ordinary course ascertain the fact, because it locks up just the same for either completed position of the points.

In some switch-locks now being manufactured for the Great Northern railway, the Author has supplied this desideratum.

Fig. 121 shows the position of the locking bolt when the points are locked for the main line; Fig. 123 when locked for branch line; and Fig. 122 when unlocked. The switch *bar* has a T-shaped aperture, Fig. 121. The locking bolt has one end $4\frac{1}{2}$ inches broad on the horizontal line and 1 inch thick, the middle part is 1 inch square, and the other end is 3 inches broad on the vertical line and 1 inch thick. Now in the mid-position of the lever, the lock, Fig. 122, is in mid-position also, and the switches can be moved either way. If the switches be moved in favour of the branch, then the locking lever can only be got home by bringing it down in favour of the branch also, and *vice versâ*, because the horizontal limb would not enter the vertical hole. This plan ascertains whether the switches have moved in the direction intended or not. It covers the contingency of the fracture of the rod which ought to move the switches; for if a signalman found that the lock lever would not come home in favour of the branch, he would be thereby informed that the switches were not home for the branch, and, of course, all the signals would remain locked.

Varieties of the locking bar, but without the lock-up lever, have been made by Mr. Brady, of the South-Eastern railway, Fig. 124; Mr. Buck, of the Brighton railway, Fig. 125; Messrs. Stevens and Sons; Mr. Bell, of the North British railway; and Mr. Luke, of the Great Western railway. All these are similar in principle, and differ only in detail.

Messrs. Stevens and Sons' switch lock consists of a long bar in advance of the switch, like a movable checkrail. In its normal position a balance-weight causes it to touch the running edge of the main rail (Fig. 127). This bar is moved away from the running edge by the gear which lowers either signal, by means of the cranks *c* or *d* engaging into the slotted bar *b*; at the same time a goose-neck bolt (Fig. 128) is shot into the switch rod *r*, taking into the hole provided for the main line or the branch line according as the points may be set. Thus as long as the lock-bar is open the switches are locked, and the bar cannot be shut as long as any vehicles are passing because the flanges of the wheels are interposed between the bar and the rail.

The use of the slotted bar *b* enables the signalman to restore the signal to "stop" before the train has fully entered the points; in that case the bar is simply kept open by the flanges of the wheels, and after they have all passed it is closed by the balance-weight and chain P. This gear is complete, with the exception that it does not discover whether the switches have moved in the direction intended or not; the goose neck locks up the same way both for main line and branch.

Mr. James Bell Junr.'s switch lock has a bar like Messrs. Stevens's, but coupled to and working with the switches, and the main and branch signal wires are locked with the switches on a similar plan; except that the locks are so arranged that only the right signal can be given, corresponding with the actual position of the points, and an erroneous position *would* be discovered.

The varied movements of the switch locking bar in a vertical direction by Messrs. Livesey and Edwards, in a lateral direction by Messrs. Stevens and by Mr. Bell, in an arc by Mr. Buck and by Mr. Brady, are further supplemented by Mr. Luke of the signal department of the Great Western railway. Mr. Luke moves the bar in a longitudinal direction. It is placed (Fig. 126) just so that the flanges of the wheels touch it, and as it were tend to kick it away in the contrary direction to that in which the train is moving. In order to unlock the points, the bar has to be moved in the same direction as the train is travelling, which cannot be done whilst the flanges of the wheels are tending to push it the other way.

Another type of switch lock has been introduced by Mr. Harrison, President, on the North-Eastern system of railways. This lock has for its principal object the securing of the switch tongues *at* the point by means of iron wedges, which are pushed home by the apparatus after the movement of the switches has been completed (vide Figs. 129, 130 and 131). The tongues are actuated by a plate with a cam-shaped groove in it (Fig. 130), and moving in guides; at the first part of the motion it will be seen that no movement of the tongues takes place whilst the straight part of the groove is passing the actuating stud, but during that part of the travel the wedges are withdrawn; then the angular part of the groove presses against the stud and moves the tongues, and finally during the travel of the remaining straight part, the wedges are slid into place again to hold the tongues in the contrary position, the closed tongue being held tightly against the stockrail, and the open tongue being also secured by being held in a slot formed in the body of the wedge for that purpose, Fig. 130.

The switches are thus well secured against accidental displacement by the train itself; they are also secured against being inadvertently moved by the signalman, by the addition of any of the long locking bars above described.

In a lock for securing switches at the extreme point by Messrs. McKenzie, Clunes and Holland, Fig. 132, the locks L and M are moved by the same mechanism as the signals of their respective roads. When both signals are at danger, both tongues are unlocked. Now if it be desired to give a signal for a train to go along the main line, the same gear which moves the signal also pulls the lock L into the position shown in the figure, and this lock presses the tongue close to the stockrail. If any attempt were made to move the branch-line signal, its lock M would strike against the end of the open tongue, and the signalman would thus be informed that the switches were not in favour of the branch.

These locks prevent the switches being moved until after the signals have been restored to "stop," but they do not prevent the switches being disturbed whilst a train is passing if the signals have been quickly restored to the stop position.

Mr. Price Williams's switches, Figs. 133 to 136, are intended to give a continuous road, and are in course of trial at Crewe.

Another kind of apparatus for a similar purpose, but specially adapted for India, was made by Mr. John Brunton, M. Inst. C.E. (Figs. 137, 138, 139, 140, 141.) The first part of the motion of the handle A turns "on" a signal disc (Fig. 138), and at the same time elevates the tongue rail of the switch, which cannot be done with a train on (Figs. 139, 140). The further motion of the handle causes the tongues to move laterally into their other position, by means of the worm on the revolving shaft acting on the rollers fixed on the switch rod. The concluding part of the motion allows the closed tongue to descend, and to become locked by the block locks, and also reverses the signal arrow, which always points to the side on which the road is open (Fig. 137).

The principal object Mr. Brunton had in view was the provision of mechanism, adapted for manipulation by native pointsmen. Hence the desire to accomplish the several operations of moving the switch, locking the switch, and showing the signal by means of one handle only. After preliminary trials in England and Scotland, two sets of this apparatus were made for the Great Indian Peninsula railway, and sent to Bombay, but there has not been time yet to have news of their performance in working. For India and similar countries, where the places to be protected are chiefly the entrances from the single line of way to the stations, Mr. Brunton's apparatus has the advantage of being less costly than a complete locking frame, and perhaps better adapted for native use.

Having thus shown that facing switches may, by the use of proper appliances, be rendered as safe as backing-out switches, the Author will now proceed to describe some of the conveniences of facing switches—conveniences which cannot be had without their use. This is perhaps the most suitable place to refer to the circumstance, that, for many years, facing switches were used on the London and North-Western line, about a mile out of Euston Station, for receiving an assistant locomotive from the front of the train. Heavy trains leaving Euston require two engines to get them up the steep gradient to Camden. After the train was well started, the front engine was disengaged by a slip coupling, and then ran on a few yards in front of the train. A pointsman, standing all ready, opened the switches to receive the first engine into the siding, and immediately reversed them to allow the second engine and train to proceed on the main line. These points were not worked from a signal box, which would have been unsafe, but by a man on the ground. The distance was too short to cover the operation by signal of any kind, and it was entirely a matter of careful handling. These points were so used for fifteen years, many times every day, without any accident occurring. Their use was discontinued five years ago, when the train arrangements were changed, so as to allow all trains to stop at Willesden. Since then the auxiliary engines have been unhooked at Willesden. This is a remarkable testimony that facing points, well looked after, are not necessarily dangerous.

Facilities now afforded for getting the Fast Traffic Clear of the Slow Traffic by means of Facing Switches.

The absolute block system enables the greatest possible number of trains to travel over one pair of rails in a given time, and the various contrivances of complete signals, interlocking apparatus, and facing switch locks tend to insure the safety of the traffic—indeed without all these mechanical adjuncts it would be impossible to work the block system satisfactorily.

Already the numbers of trains on several railways are far beyond what would be possible without the block system. For instance, on the North London railway, at Liverpool Street, 250 trains pass over the same rails in a day of nineteen hours, giving an average of only four minutes between the trains, and frequently the interval is only two minutes. Without the certainty afforded by the block system that that interval of time represented a real interval of controlled space, it would be far too short.

On the Metropolitan railway 193 trains per day traverse the same metals, and 400 trains could with safety be passed, inasmuch as 20 of them pass in one hour; but here the trains all travel at the same speed. On the North London railway nearly the same conditions obtain as on the Metropolitan, as to identity of speed of the trains following each other.

The Metropolitan railway between King's Cross and Moorgate Street is laid with four lines of rails, two lines being reserved for the use of

The Metropolitan,
The Metropolitan District, and
The Great Western Companies,

and the other two lines called the "Widened lines" being set apart for the traffic of

The Midland,
The Great Northern, and
The London, Chatham, and Dover Companies.

The following extracts from the Company's working Time Tables, show the intervals at which the trains run during the busy period of the day, viz., 9·0 to 10·0 A.M.

EXTRACT No. 1.—MAIN LINE.

NOTE.	Description.	Arrive at Moorgate Street.
		A.M.
	G. W. and D. K.	9·0
G. W. and D. K. signifies joint Great Western and District trains	D.	9·5
	H.	9·10
	D.	9·15
	H.	9·20
D. signifies District	D.	9·25
	G. W. and D. K.	9·30
	D.	9·35
Metropolitan Co.'s trains. { H. signifies Hammersmith; M. " Main line }	G. W. P.	9·38
	H.	9·41
	M.	9·45
	H.	9·50
G. W. P. signifies Great Western Main line	M.	9·55
	G. W. P.	9·58
	G. W. and D. K.	10·1

EXTRACT No. 2.—WIDENED LINES.

NOTE.	Description.	Arrive at Moorgate Street.
		A.M.
Mid. signifies Midland train	Mid. T.	9·2
	G. N. P. T.	..
	L. C. and D. M.	9·7
	G. N. P. T.	9·11
	L. C. & D., C. P.	9·14
	G. N. P. T.	9·16
	Mid. T.	9·18
G. N. „ Great Northern train	L. C. & D. M.	9·21
	G. N. P. T.	9·24
	L. C. & D. T.	..
	G. N. P. T.	9·28
	L. C. & D. M.	9·30
L. C. D. „ London, Chatham, and Dover trains	Mid. T.	9·32
	G. N. P. T.	9·34
	G. N. P. T.	9·38
	Mid. T.	9·43
	L. C. & D. M.	9·45
	G. N. P. T.	9·45
	L. C. & D., C. P.	9·51
	G. N. P. T.	9·53
	Mid. T.	9·55
	L. C. & D. M.	9·58

The total number of trains using the Moorgate Street Station daily is as follows:—

MAIN LINE.

Description of train.	Up.	Down.	Total.
Metropolitan	116	116	232
District	38	38	76
Addison Road (G. W. and D. Joint)	32	32	64
Great Western, Main line	7	7	14
Total	193	193	386

WIDENED LINES.

Description of train.	Up.	Down.	Total.
Midland	49	49	98
Great Northern.	62	62	124
L. C. and D.	80	80	160
Total	191	191	382

Total number of trains 768 per day.

As each arriving and departing train requires a separate movement of the engine, for changing from one end of the station to the other, this gives a total of 1,536 movements of engines, on the four lines of way in nineteen hours, and every movement has to be distinctly and separately signalled. This of course could not be done without the aid of electric instruments, to enable the signalmen to communicate with each other, and to have a constant record on the face of the instruments to show what is being done at the time even by themselves.

On the Great Eastern railway 220 trains and engines per day pass on the same metals between Bethnal Green Junction and Stratford. The trains at that part of the line all travel at nearly the same speed.

Where there is a mixture of fast passenger trains with slower goods traffic, and with suburban traffic, new elements come into play. It may be premised that there is a great difference between the number of trains which can be started from a terminus on the same metals and the number which can arrive on the same metals, for the simple reason that trains may be started with almost absolute punctuality, and so preserve their intended distances from each other; whereas, in arriving, the fast trains will overtake the slower ones, and the punctuality is less certain, and so the same regularity cannot be secured: consequently, several railways are furnished with a third line of rails for trains arriving in London. On the Brighton line, for instance, there is a third line for arriving trains from Balham Junction to Victoria Station, Fig. 142. The third line enables the fast traffic to clear five stations in the last 6 miles of the journey, and as many suburban trains *en route*. During the day of twenty-four hours, 34 trains pass along this third line, and 88 trains on the slow line. All the trains, from Clapham Junction to Balham Junction, 127 in number, are despatched by one line.

A further step in this part of the subject is illustrated by the Great Northern and the London and North-Western railways, both of which have a fast passenger service and also a large coal traffic. It is obvious that this is quite different from the stereotyped traffic and speed of such railways as the Metropolitan or North London, and on both the Great Northern and the London and North-Western liberal arrangements are made for separating —not so much the goods traffic from the passenger traffic, as for separating the fast trains from the slow ones.

On the Great Northern, Fig. 143, passing places are provided from Hitchin to Stevenage, 3½ miles, from Hatfield to Potter's Bar, 5 miles, and from Wood Green to Caledonian Junction, 5 miles—all on parts of the line free from tunnels or other expensive works. In the diagram the passing places or slow lines, and also the branch rails, are shown by a full line, and the main rails by dotted lines. When a coal train arrives at one of these passing places, if the main line is clear and no fast train is expected, the coal or goods train is allowed to go by the main line; but if any fast train is expected, the coal train is directed by the signalman through the facing points on to the side line. When the slow train arrives at the south end of any passing place, it is allowed by the signalman to rejoin the main line, under the protection of the block telegraph. At Hitchin and at Hatfield such long passing places are provided only on the up-line, the up-traffic being most in need of them, inasmuch as the coal trains are heavy on the up-journey and empty on the down; and also punctuality is less certain in the arriving than in the departing trains. On the line between Holloway and Finsbury Park, 56 trains per day are passed over the down main line, and 78 trains per day over the down side line—total 134; and 67 trains over the up main, and 74 trains over the up side—total 141; exclusive in both cases of specials and light engines. This shows a moderate number of trains over each line; but the mere numerical reduction of the number of trains does not represent the whole benefit. The greatest advantage is gained by sorting the trains, so that the trains on the same line are more nearly of the same speed, and consequently preserve more nearly their intended intervals of time and space. At Holloway the accommodation is still further increased by the addition of more lines, and thus along 2 miles of the up through line there are only 25 trains per day, chiefly the express trains from York and Manchester. The fast traffic is thus released from obstruction by goods or coal trains: these latter wait in the Holloway sidings, until such time as convenient intervals between passenger trains admit of their being passed through the tunnel to the goods yard. The junctions at Edgware, Highbury, and Enfield are specially worthy of notice, as they are arranged so as to avoid an up branch line crossing a down main, or a down branch crossing an up main line. At Highbury Junction the line to Highbury leaves the up slow line on the level, and the line from Highbury descends, and passes under the main line at Holloway, curves round and joins the down slow line. At Edgware Junction the down branch line strikes off from the down slow line to the left on the level; the up branch line, which must cross the down main line, does not cross it on the level, but is carried up an incline and crosses over the

main lines by a bridge, it then descends and sweeps round into the up slow line. At Enfield Junction the up branch line approaches the up slow line on the level, and the down branch leaves the down slow line by a curve, and ascends an incline and crosses the main lines by a bridge. At each of these junctions the level crossing usual at ordinary junctions is avoided, and the effect is to release the 141 up trains and 56 down trains from having to run the gauntlet of about 60 trains of the Highbury and Enfield branches, and to release the 134 down main trains and 25 up main trains from having to be crossed by about 30 up trains from Barnet. Many other junctions on the Great Northern, London and Brighton, and other railways, are arranged on the same plan.

On the London and North-Western an additional up line, Fig. 144, has been for some years in operation from Bletchley to King's Langley and from Watford to Willesden, the only interruption being caused by the Watford Tunnel, through which there are but two lines. An additional tunnel has now been made, and very shortly the third line will be complete from Bletchley to Willesden. The fast passenger traffic goes by the main line, and the slow passenger traffic and most of the goods and coal trains by the up slow line, but some express goods trains go by the main up line. The total number of down trains is now 91 on the same metals, exclusive of specials and light engines; on the up main line there are 31 passenger and 8 goods trains, and the on up slow line 57 goods and 11 passenger trains; but these relative numbers are variable, because the station-masters have a discretionary power to send any train by either line as circumstances may require. When the new fourth line, now making from Willesden to Bletchley, 43 miles, is finished, the intention is to work them as shown on Fig. 145. All through passenger trains, and some through goods, will go by the fast lines. The slower trains of all kinds will go by the slow lines. This sub-division of the traffic will increase the carrying power of the railway in a much greater ratio than the increased number of lines, for the reasons before referred to. Probably two pairs of rails would carry four times as much traffic as one pair would do with the same minimum intervals between them. It is intended to have all goods yards as far as possible on the east, or slow side of the railway, so as to keep shunting operations as much as possible out of the way of the fast lines. It is proposed shortly to complete the four lines of way to Euston Station on the south, and to Roade on the north. A duplicate tunnel has already been made side by side with the Kensal Green Tunnel; and, indeed, the four lines are completed as far as the face of Primrose Hill Tunnel. An additional up line is in use from Nuneaton to Rugby, 14 miles. Additional up and down lines are in use from Huyton to Edge Hill, and in course of construction from Stafford to Crewe. In all these cases two lines will be appropriated to fast traffic and two lines to slow traffic. Between Stafford and Crewe the fast lines will be to the east and the slow lines to the west, as the existing goods accommodation is chiefly on the west side.

By the kindness of Mr. Johnson, M. Inst. C.E., Chief Engineer of the Great Northern railway, the author is enabled to give some particulars as to the cost of the passing places on that line:—

GREAT NORTHERN RAILWAY.

Miles.		
	Cost of additional up and down lines between Copenhagen Tunnel and Wood Green, including alterations of stations	£208,734
*3½	Ditto of up line between Hitchin and Stevenage	11,406
	Per mile	3,258
*5	Ditto of up line between Hatfield and Potter's Bar	20,291
	Per mile	4,058
	Ditto of down line between Hatfield and Welwyn Junction for Luton traffic	6,069
		£246,500
32	Probable cost to complete four lines, King's Cross to Hitchin	£1,000,000
	Per mile	31,275

The items marked with an asterisk (*) are strictly speaking passing places for fast and slow traffic. The sites were selected as being free from tunnels or other expensive works. The cost of the land is not included, as it was already in the possession of the company, but even so £4000 per mile must be considered a moderate sum. To make four complete lines from Hitchin to King's Cross would be very costly, owing to the large proportion of tunnel work.

Mr. Baker, M. Inst. C.E., Chief Engineer of the London and North Western railway, has obligingly communicated the cost of the third line from Bletchley to Willesden, 43 miles, as being £350,000, or about £8000 per mile. This is also a moderate sum, for in making long passing places there is not the same opportunity of choice of site as in making short ones, and some expensive works must be incurred. The estimate for completing four lines, from Camden to Bletchley is £980,000.

Separate Goods Yards.

The general adoption of separate goods yards, away from the main line, and communicating only with it at the ends, is likely to do a great deal in the direction of taking goods traffic out of the way of the passenger traffic. A good example of this improvement, as carried out at Lincoln by the Great Northern Railway Company, is shown in Fig. 146. The lines marked "old main line" were, until June, 1873, the main lines for all traffic. On each side of the main lines were sidings for making up goods trains, with the usual cross-over and through roads, and of course there was a great deal of shunting going on on the main lines. In the early part of the year 1873, new roads were made for the main line outside of the goods sidings, and with a wide space of ground between the sidings and the main line, which will probably be ample for their extension for some time to come. The traffic from the north arrives at A. Passenger trains go along the new lines to the Lincoln station. Goods trains go into the old lines (small dotted) and are there disposed of by the shunting staff: goods trains ready to go south or north are let out by the signalmen, with due reference to the block system of working. Wherever this improvement of confining the goods traffic to a site on one side of the line only is carried out, the main lines are relieved of a great deal of the cross shunting, now a principal source of delay and danger.

Fig. 147 shows a similar arrangement for the accommodation of coal traffic on the Great Eastern railway at Temple Mills near Stratford. Many similar alterations have recently been carried out by the principal railway companies.

Conclusion.

The advantages of the block and interlocking system scarcely require further proof, than the mention, that the chief railways in England have already adopted it on the busiest parts of their lines, from experience of its necessity.

It secures not only a controlled interval of space, but when distant signals sufficiently far off are used, it secures virtually two intervals of controlled space; and in many cases, even if a driver fails to observe one signal, observance of the next would still preserve him from accident.

As points of detail, attention should be directed to :—

Identity of type of signal for trains on their journey.

Identity of type of signal for shunting purposes in station yards.

Identity of meaning of signals, viz., "stop" and "go on."

Identity of arrangement of adjacent signals, the high speed or main line to be the highest signal.

As a rule signals should be placed to "safety" (if the line is clear) before an expected train comes in sight. The practice of keeping signals at "danger" until they are "whistled off" by the drivers is apt to lead drivers to be too venturesome, in running up to signals without sufficiently reducing the speed of their trains.

The protection of all switches, whether facing or trailing, by interlocking apparatus of few parts and simple construction.

The protection of all facing switches by locking bars.

The use of detector bolts to ascertain that the switches are fully set as intended.

Distant signals sufficiently in advance of the point of danger, and, where necessary, furnished with repeaters.

Separate distant signal arms for each home signal.

The use of "stop" and "advance" signals for the relief of station yards, by enabling trains to stand outside the station under protection of signals.

Free use of loop lines to enable fast and slow traffic to clear each other.

Wherever possible, separate goods yards for shunting purposes should be provided.

At remote stations the use of the fixed signals is sometimes omitted altogether; and then when required they are apt to be unobserved.

Also the taking out of locks from the interlocking apparatus at such times as races and fairs should be not only prohibited but prevented.

At places of light work the hours of signalmen should be sufficiently long to make a day's work.

At places of constant work the hours of signalmen should be varied according to the time of day or night, and according to the severity of the traffic.

The usual wages of signalmen vary from 18*s*. to 28*s*. per week, a rate of pay which cannot be said to be out of proportion to the not very highly skilled class of labour required. Any attempt to give an exceptionally high rate of pay to signalmen would be apt to lead to an artificial class forcing their way into the service to its certain disadvantage.

Many of the railway companies give a gratuity every six months to signalmen who have acquitted themselves without fault. This plan seems a good one, as it effectively passes in review the conduct of all from time to time, and so leads to a painstaking service, quite as much for the sake of the credit attaching to success, as for the sake of the pecuniary reward.

On most lines of railway, a book is kept in each signal box, in which is recorded the actual time of passing of each train, with its number and destination, and any remarks which circumstances may require.

Each signal box ought to be visited by an inspector every day, to see that the men and the machinery are in proper order, and it is a good plan for him to record the time of his visit in the train book.

That all intended movements of bodies in such rapid motion as railway trains should be clearly signalled well in advance is now universally allowed. The means of effecting this signalling are now complete, and the checks against accidental mistakes are such as to reduce the effects of error, whether on the part of the person signalling, or on the part of the person signalled to, to a minimum.

Selection of Signalmen.

All men are not constituted by nature for signalmen; consequently much care is requisite in their selection and training. The Metropolitan railway may be taken as an instance, and perhaps as an example. If an applicant is accepted as a candidate, he has first to undergo a drill of two hours per day for three months. After that he has to go on permanent, but not responsible, duty under supervision until he has performed the duty for fourteen clear days without once requiring the assistance of the responsible signalman. He is then appointed to some intermediate signal box, and his wages are raised from the previous rate of 18*s.* per week as a porter, to 22*s.* as a signalman, with a bonus for good conduct equal to 2*s.* per week more. Every signalman is required to know the working of the signal box on each side of him in addition to his own.

Promotion takes place from intermediate or inferior to more important stations, with a constant advance of pay up to 30*s.* per week. It frequently happens, however, that even very good signalmen decline promotion to the highest places where the traffic is incessant, and requires strong nerves and clear heads.

The bonus is paid quarterly in sums of 25*s.* each, conditionally

…VER AND ABOVE COST OF SIGNALS.

7. Whole Cost of Railway.	8. Percentage Column 6 of Column 7.	Com…
£. 71,604,143	·55	L. N. W…
46,526		*Per M…*
51,339,713		G. W. R…
36,620	·6	*Per M…*
44,875,111	·66	N. E. R…
33,564		*Per M…*
45,791,413	·59	Midland
44,718		*Per M…*
32,495,478	·61	G. E. R…
39,000		*Per M…*
24,164,417	·79	N. B. Ry…
29,080		*Per M…*
23,195,669	·71	Caledoni…
29,090		*Per M…*
21,122,044	·69	G. N. Ry…
36,540		*Per M…*
24,253,849	·76	L. & Y. …
54,380		*Per M…*
20,537,675	·36	L. B. & S…
59,530		*Per Mi…*
18,117,249	·41	M. S. & …
70,200		*Per Mi…*
19,706,107	·43	S. E. Ry.
60,260		*Per Mi…*
3,522,060	·85	Highlan…
10,510		*Per Mi…*
8,359,655	·23	Metropol…
1,114,620		*Per Mi…*
409,084,577	·6	Totals.
40,264	..	*Average… Mile.*

… Board of Trade in 1872-73. All o…

upon no mistake having been made during the quarter. So carefully selected and trained, and so well conducted are the signalmen as a rule, that on the Metropolitan railway, there have not been in ten years more than three instances of failure to obtain the bonus, notwithstanding the strictness of the quarterly investigation.

About one-third of the signalmen on the Metropolitan railway have been sailors. It is found that sailors make excellent signalmen, but soldiers do not.

COST OF THE INTERLOCKING AND BLOCK SYSTEM.

It is almost impossible to ascertain what has been the total cost of the interlocking and block system on any given railway, because the work has been done sometimes on revenue account and sometimes on capital account, and is always more or less mixed up with other work.

A fair estimate, however, may be made as follows:—

COST PER SIGNAL STATION.

15 levers @ £8	£120
15 sets connections @ £7	105
Signal house	60
Block telegraph instruments and wires	60
	15) 345
Per lever	£23

The cost of complete interlocking apparatus, exclusive of the signals themselves, which would be used in any case, but inclusive of the necessary signal house, and of the block telegraph apparatus, does not exceed £20 per lever on an average, and £25 per lever may be taken as an outside estimate.

The number of levers required is approximately as follows:—

For a level crossing, where one railway crosses another, 8 levers.

For an ordinary junction of double lines 10 levers are required.

For a small station, 10 or 12 levers.

For a medium station, two frames, each with 20 levers.

For an important station and junction combined, perhaps three or four frames, of 20 to 70 levers each, averaging perhaps 40 in each frame.

Some idea of the gross cost of interlocking, as compared with the whole cost of a railway, may be derived from table 148.

Fourteen railways, having a gross mileage of 10,160 miles, have, by the Board of Trade returns (for the year 1873), 19,394 points of communication with the metals of the passenger lines, either by level crossing or by switches. Now, allowing 3 signals as an average to every such set of switches, there would be a total of 19,394 switch levers, and 58,182 signal levers, together 77,576 levers; and, allowing also an equal number of switches not communicating directly with the main line, but which would have to be connected to the apparatus, the gross total would be 96,970 levers; and this number, divided by 10,160 miles, gives an average of 9·6, or nearly 10 levers per mile. Now 10 levers multiplied by £25 each gives £250 per mile as the cost of interlocking and block telegraph apparatus, equal to about ½ per cent. on the total cost of the railways.

The cost of signal work is generally very much greater per mile on the railways of higher cost, or of larger traffic, such as the Metropolitan or the Charing Cross; but it is a lower proportion of the whole cost of the railway.

Cost of Maintenance and Attendance.

If the average number of levers in each signal-box be taken as 15, and three men be allowed to each box, including inspectors and extra men, this would make one man to every 5 levers. Now 10 levers are, in the last calculation, the complement of a mile of railway; so two signalmen to every mile of railway would be required.

The number of signal stations and the number of men required by this calculation agree almost exactly with the actual facts, as follows:—

On the Great Northern railway from London to Askern there are 109 block-signal stations in 162 miles; and at the rate of three men per station, this would require three hundred and twenty-seven men for 162 miles = 2 men per mile.

On the London and North-Western railway from London to Stafford, 132 miles, there are 88 block-signal stations; and at the rate of three men per station the total number would be two hundred and sixty-four for 132 miles, or exactly two men per mile.

On the one hand some persons argue that the gathering together of switch and signal levers, enables one signalman on the new system to do the duty of several pointsmen on the old. On the other hand some persons are of opinion that all the signalmen are really additional men. A view somewhere between these two is most probably the correct one The following calculation is based on the supposition that half of the whole number of men required would be additional men; that is to say, one additional man per mile of railway.

CKING AND BLOCK SYSTEM.

1. f Company.	2. Miles of Line.	ta T	13. otal Ordinary Capital.	14. Per Cent. Column 9. of Col. 13.	15. Total Capital.	16. Per Cent. Column 9 of Col. 15.	17. Name of Company.
			£.		£.		
W. Ry. .	1,539	15	36,882,269	·42	71,604,143	·22	L. N. W. Ry.
Mile . .							*Per Mile.*
Ry. . .	1,402	12	13,761,514	·89	51,339,713	·24	G. W. Ry.
Mile . .							*Per Mile.*
Ry. . .	1,337	11	17,229,933	·72	44,875,111	·27	N. E. Ry.
Mile . .							*Per Mile.*
nd Ry. .	1,024	10	17,094,307	·61	45,791,413	·23	Midland Ry.
Mile . .							*Per Mile.*
Ry. . .	833	7	12,428,926	·42	32,495,478	·16	G. E. Ry.
Mile . .							*Per Mile.*
Ry. . .	831	7	5,096,430	1·20	24,164,417	·25	N. B. Ry.
Mile . .							*Per Mile.*
onian Ry.	797	6	7,976,002	·69	23,195,669	·24	Caledonian Ry.
Mile . .							*Per Mile.*
Ry. . .	598	5,	11,864,537	·49	21,122,044	·28	. . Ry.
Mile . .							*Per Mile.*
l Y. Ry. .	446	7,	13,334,594	·55	24,253,849	·30	L. and Y. Ry.
Mile . .							*Per Mile.*
& S. C. Ry.	345	2,	8,191,709	·30	20,537,675	·12	L. B. & S. C. Ry.
Mile . .							*Per Mile.*
& L. Ry. .	258	3,	6,233,573	·60	18,117,249	·21	M. S. & L. Ry.
Mile . .							*Per Mile.*
Ry. . .	377	3,	8,320,095	·40	19,706,101	·17	S. E. Ry.
Mile . .							*Per Mile.*
nd Ry. .	335	1,	1,688,441	·47	3,522,060	·22	Highland Ry.
Mile . .							*Per Mile.*
ol. Ry. .	7½		4,308,370	·21	8,359,655	·11	Metropol. Ry.
Mile . .							*Per Mile.*
Miles of o. . .	10,160	97,	64,419,070	·56	409,084,577	·23	Total Miles of Line.
le . .	..		..	..	..	..	*Per Mile.*
				·20		·08	

to face p. 50.

The annual cost of attendance and maintenance, based on the busiest parts of two of the busiest railways, would then stand as follows:—

	Per Annum. £.	s.	d.
Wages of signalman at 24s. per week	60	0	0
Cost of maintenance of apparatus 10 per cent. on £250	25	0	0
Five per cent. interest on first cost	12	10	0
Total .	£97	10	0 per annum per mile as an average cost.

Table 149 gives the probable maximum number of signalmen per mile, the probable additional number, and the cost of wages and maintenance per mile, compared with the gross traffic receipts.

It is observable that the railway which has nearly twice the average need of protection, viz. the Lancashire and Yorkshire, and which would require nearly twice the average number of men per mile, shows a lower percentage of cost compared with traffic receipts than some of the other lines. This is a satisfactory feature as showing that the more business there is on a line, and the more need it has of safeguards, the better worth while is it to provide them.

The gross traffic returns of the twelve railways in the Table amounted to £41,755,190 last year. This sum, divided by the number of miles, gives an average of £4,110 per mile per annum.

The cost of the block system, being £100 per mile per annum, would thus be 2·2 per cent. of the total receipts.

It is also fair to take into account that more than half the accidents of recent years would probably have been prevented if the block and interlocking system had been universally in use. For some years the fourteen railway companies mentioned in the tables have paid as compensation for injury to passengers and goods the sum of £430,700: to this may be added at least a like sum for destruction of the companies' own property. The accident account would probably then be as follows:—

Annual sum paid as compensation . . .		£430,700
Loss by destruction of companies' property . .		430,700
Loss by delays—50% on the money paid as compensation		215,350
Law expenses, including cost of companies' own board investigations . . .	25% on the money paid as compensation	107,675
		£1,184,425

The Author submits that at any rate half of this sum, viz.,

£592,212, may be set off against the annual cost of the block system, £928,700, and this leaves £336,490 per annum as the net annual cost.

Compared with the gross traffic receipts, this gives the insignificant percentage of ·8 per annum. This may be said to represent the demands of the Government upon the railway companies whenever any compulsory law on the subject of interlocking, &c., may be passed.

It is noteworthy that, whilst such a law is talked of, the Railway Companies are at the same time making a demand on the Government for the repeal of the passenger tax.

The Author would suggest that any compulsory law on the one subject should be accompanied by a just relief on the other. The Companies would thus be enabled to carry out these improvements without loss to themselves, to the great advantage of the travelling public, and with only the slight sacrifice which the public revenue is now so well able to afford.

As another source of ways and means for reimbursement for the cost of the universal adoption of the improvements indicated, there is given in Table 149 a column showing the average annual increase of traffic receipts,—an increase at an *annual* rate of about ten times the net cost of the block system.

The Author has thus endeavoured to fulfil the task of describing the various steps by which the present fabric of railway signalling has been built up; and in travelling over forty years of time, and over ground on which such varied opinions are found, he cannot but feel that the result of his labours must necessarily be far from perfect.

In estimating the cost of accidents he has omitted to speak of the destruction of life and limb which might be mitigated, for the simple reason that he wished to steer clear of what may be called the sentimental part of the subject, and to keep rather to the facts easily ascertainable and to arguments easily demonstrable.

Careful and dispassionate examination will assuredly show, that, on the one hand, much more has already been done by the railway companies than the travelling public have any idea of—as witness the Great Northern, the London and North-Western, the Metropolitan and other leading railways—and, on the other hand, that the most extreme demands of the public will be found after all to be no very serious tax upon the railway property of this country.

The Paper is illustrated by a series of diagrams, from which Plates 27 to 31 have been compiled.

[Mr. Rapier

Mr. Rapier desired to thank numerous friends for the valuable assistance rendered in the compilation of the Paper and the preparation of the drawings. He had only sought to bring forward instances of what had been accomplished, without pretending to make the Paper exhaustive. On many points connected with railway signalling great difference of opinion prevailed, and on none more so than on the subject of permanent audible signals. He had alluded to the probability that if signals were all arranged so as to give the drivers an audible signal in addition to the visible signal, they would entirely rely on the former, and be less careful in looking out for the latter. He had, however, within the last few days had an opportunity of examining on the London and South-Western railway the first *optional* audible signal; this Mr. Burn had erected since the reading of the Paper. The apparatus enabled a signalman to sound the whistle of an approaching engine if the visible signals should be obscured by fog, or if for any other reason the signalman were especially anxious to attract the driver's attention. The signal could of course be arranged either as a negative or a positive one. It might be a rule that no driver should proceed past a signal station in foggy weather without receiving an audible signal. Indeed at present the rule was that if a driver was in doubt as to the signal he was to pull up and ascertain—a rule which it was not always possible to obey.

It had been urged as an objection against interlocking apparatus that a man was apt to get puzzled with having so many levers to attend to. Now the contrary was the fact. A man might be puzzled in having a warm corner to look after, but not by the number of levers. Indeed, the more the better, as, when fully furnished with gear, the man had only one separate thing to do by one separate movement of his own, and had also the protection of the mechanism against mistakes which might involve danger.

The complete equipment of railways with the efficient appliances of the block system had a direct relationship with the dividend-earning power of railways. The question which he was anxious to see thoroughly raised was what was the maximum amount of traffic which could be carried on one pair of metals. If twenty or thirty trains could pass over one pair of metals on the Metropolitan railway in an hour, what were the circumstances limiting the number of trains in the case of other railways? Differences of speed at once intervened, and the question was how to accommodate those differences. The old ten-minutes' interval of the Great Western would obviously be of little service now. But the new fashioned interval of space would do everything, giving as it did the power to pass trains over a given spot within about a minute and a half of each other. The absolute block system, therefore, was that by which a railway could get through the greatest amount of dividend-earning work. He had endeavoured to show in the tables the probable cost of the absolute block system. In the Paper he had taken a low average number of levers in a signal-house (fifteen), which made it appear more costly, because the signal-house and the block telegraph instruments were more costly, in proportion, for a small frame than for a larger one. The amount he had calculated was £25 per lever, which would probably be called in question, by some as being too high, and by others as being too low. The numbers of points given in Table 148 were taken from the Parliamentary Returns of fourteen railway companies. The London and North-Western railway returned 3,132 points of communication on its passenger lines. Taking the high average of three signals for each switch, and allowing for a subordinate switch not actually in the main line, but which would have to be coupled up to the locking frame as well as the parent one, the number of levers would be 15,000, or 10·2 per mile. The Lancashire and Yorkshire railway had 16·55 per mile. The total first cost per mile was shown in Table 148.

Table 149 showed the probable annual cost of maintenance and additional attendance. It gave the number of levers and the probable number of signal stations. The probable correctness of the estimate as to the number of signal stations was curiously confirmed by the London and North-Western railway, London to Stafford, and the Great Northern railway, London to Askern, on both of which portions of railway the numbers very nearly accorded with his own calculation, viz., one signal station to every mile and a half of railway on an average. With regard to the number of men, it was much disputed whether the interlocking and the block system required more men or fewer. On the one hand, it was argued that by doing away with so many ground pointsmen the work could be done with fewer men; on the other hand, it was said that the signalmen were all new men. He had taken a mean between the two, and supposed that half the total men were new men, which he believed to be slightly above the fact. With regard to the wages, interest, and maintenance of gear, he had calculated £100 per man per annum, and he had shown, in Table 149, the probable additional cost per mile per annum, the London and North-Western being £102, and the Lancashire and Yorkshire £166 per mile per annum. When, however, the additional cost was compared with the very high traffic receipts of the Lancashire and Yorkshire railway, the annual cost of the block system per cent. of traffic receipts was less than the percentage on some other railways. He had given a comparison of the block system with the whole traffic, and also the annual increase of the traffic receipts on an average of two years. In the case of the Midland railway it would be seen that there was an increase of £567,000 per annum year after year. If the traffic receipts increased at the rate of 11 or 12 per cent., as in the case of the Midland, or say 8 per cent. all round, it was clear that it would be necessary to face the question how to get the best possible result out of the existing railways.

He had next compared the annual cost with the total ordinary capital, for the shareholder might naturally inquire what the cost of the system would be in the shape of reduced dividend in the first instance. He had next shown the total capital with which it was most fitting to make a comparison. If the original capital were small as compared with the total capital, as in the case of the Great Western (£13,000,000 as compared with £51,000,000), a slight improvement in the profit would affect the ordinary capital, and so would a slight disadvantage in the shape of expense; and if the original shareholders were anxious to gain the one they should be willing to incur the other. The true way was to compare the first cost of the block system with the whole cost of the railway, and the annual maintenance also with the whole capital. The calculations as to the cost of the block system were exclusive of the signals themselves, which would be used in any case, and also exclusive of sidings or additional accommodation, because the cost of additional sidings did not properly belong to the block system. If the system were carried out, it would enable a railway to be worked with less siding room, the same regard being paid in both cases to safe intervals of trains, since it enabled the main line to be more fully and constantly occupied.

After the block system had been carried out, the next thing would be to make additional lines. One way was to make new lines through fresh districts, affording alternative routes, but involving new stations, new staff, and, in fact, a new railway altogether. Such lines might be of two sorts, like that between Lincoln and Honington, forming an important auxiliary for sending the coal traffic, but not shortening the main line; or, like several lines which had been made on the Midland, shortening the main line of railway, as in the case of the line from Chesterfield to Sheffield, and from Trent to Chesterfield, the line from Doncaster to York on the North-Eastern, and the Team Valley line, both the latter affording additional facilities for fast traffic, and going through a new district. Another mode of making additional lines was the system of passing-places, adopted by the Great Northern Company, Fig. 143. By the kindness of Mr. Johnson, chief engineer of that railway, he was enabled to give some information as to the cost of such passing-places. The additional works at Holloway had cost £208,000, but that was not, properly speaking, a passing-place. It might rather be called a terminal accommodation. The lines from Hitchin to Stevenage and from Hatfield to Potter's Bar were, strictly speaking, fast and slow passing-places. The 3½ miles from Hitchin to Stevenage cost £11,000, or £3,200 per mile. The up-line between Hatfield and Potter's Bar cost £20,000 for 5 miles, or £4,000 per mile. The statements as to the cost did not include land in the case of the Great Northern and the London and North-Western Companies. Next came the system of four lines. The cost of converting the passing-places into four lines on the London and North-Western railway would be £980,000. The cost of the previous passing-places, or third line, had been £350,000. The probable cost of completing the four lines on the Great Northern, for the 32 miles from King's Cross to Hitchin, would be about £1,000,000.

There was a great outcry for separate lines for goods and other slow trains, distinct from the fast traffic lines, but it was, for the present, in his opinion, premature. Perhaps in twenty years the London and North-Western might be doubled all the way between London and Liverpool, but now the right method appeared to be to provide additional accommodation where it could be done cheaply. It would not do to lessen the speed. If any one of the three great companies guaranteed to spend two hours longer between London and Edinburgh, it would be about the quickest way of going to ruin that could well be devised. He remembered accompanying two elderly, nervous gentlemen to King's Cross to see them off to Edinburgh. They were full of the glories of the old stage-coach era, and talked much of the dreadful railway accidents as a contrast. He tried to calm their fears and said, "The train you are going by does not travel anything like so quickly as the train before it." On arriving at King's Cross, the Flying Scotchman had not yet departed. One of his friends said, "Do you really mean to say that that train will get to Edinburgh two hours before we do?" "Yes, I do." "Then, George, we will go by it, and we shall be able to get our dinner comfortably at Edinburgh, instead of half choking ourselves at York." Mr. Rapier concluded by saying, that he had endeavoured to place the subject as fully and as clearly as possible before the members, without expressing decided opinions of his own, but rather with the hope of eliciting the views of those who were practically engaged in the working of railways.

Mr. Farmer said he desired to make a few observations with regard to the original invention of the locking apparatus. The Author had apologized for omitting to notice the admirable invention of Mr. Buck; but Mr. Farmer had a list of ninety-two patents for locking apparatus taken out by various individuals from 1856 to the present time, many of which, as well as Mr. Buck's, deserved notice. He wished to allude to the contrivances referred to in the Paper as preceding what might be called the original invention of the locking apparatus. That of Mr. Gregory, said to have been in use at the Bricklayers' Arms Station in 1843, was no doubt a meritorious invention as far as it went; but as there was no mechanical communication between the points and the signals, it did not anticipate the interlocking apparatus. The contrivance in use at East Retford, was one of the hares started by the defence in an action brought by his firm against certain infringers of their patent; but it never got beyond the formality of being included in a long list of legal objections to the pleas in the suit. The contrivance prevented a signal being given for traffic from Gainsborough to Manchester, unless the points stood in that direction; but it did not prevent the signal for the branch being given, although the points stood contrary to the branch; it made no pretence to interlock with any of the other signals or points. Mr. Saxby's interlocking system of 1856, for the first time in the history of railways, provided a mechanical reciprocating communication and action upon all the points and signals of a railway junction, whereby not only those points and signals which were in direct relation with one another were made to work in harmony, but all the other signals of the system were also controlled and locked against improper or dangerous use. The first apparatus, introduced at Bricklayers' Arms, consisted of eight semaphore signals; and there were six pairs of points concentrated within the signal cabin, all so governed and locked that it was impossible to give any signal which was contrary to the position of the points, and it was equally impossible to give any signals which would be in conflict with other signals. He was at a loss to understand how such an invention could have been overlooked, as he ventured to claim for that invention that it was the foundation of the whole existing system. The vital principles of the interlocking apparatus were two:—(1) simultaneity of working and movement; (2) that the movement of the points should in all cases dominate the signals. These principles had been adopted in every locking apparatus since 1856. Whenever a point lever was moved the locking gear with which it was connected was moved simultaneously, so as to lock all those signals which it would then be dangerous to give in the altered position of the points; and all those signals were set at liberty which it would then be safe to give. With regard to what the Author called a *pari passu* movement of points and signals, that was to a certain extent an element in the patent of 1856, but not an essential one; it was only a matter of convenience, and not of safety—a *pari passu* movement of itself, that was to say, without reciprocating influence on other signals, would be absolutely dangerous. He could not understand how, with such a list of inventions (ninety-two in number) so completely covering the field of mechanical contrivance, the Author had contrived to start "*de novo*," and to produce a locking apparatus of which it might be said *ne plus ultra!*

Mr. Imray said the Paper was like the play of Hamlet with the part of the Prince of Denmark omitted. It would be strange to hear a Paper upon the steam engine without any mention of the name of Watt, or one on railways without an allusion to Stephenson. It was generally admitted that the first inventor of the interlocking apparatus was Saxby, in 1856; but nothing was said of that invention. Many patents had since been taken out for various mechanical details; but the fundamental principle of Saxby's apparatus had not been altered. The apparatus at East Retford, referred to as a locking apparatus, was nothing more than a point indicator. Mr. Saxby was the first in 1856 to put into a row together the levers for working the points and the signals. He was the first to apply to those levers the spring catch arrangement. It had been known before, but no one had thought of applying it to that purpose. In 1860, instead of using rocking shafts for communicating the locking movement, Mr. Saxby adopted sliding bars. Since that time various inventions had been made for conveying the movement by sliding bars or by rocking shafts. Mr. Rapier's method of sliding bars was a mere modification of Saxby's apparatus. In 1867 a completely new principle was introduced, also due to Mr. Saxby. In previous methods the locking was effected by the movement of the lever. The lever had to be moved a certain distance before the other levers were locked, and the result was that when the apparatus got slack the signalman might be able to lower the signal when he ought not to lower it. Mr. Saxby's plan was to effect the locking by the movement of the spring catch. Before the lever was moved, the mere intention of moving it effected the locking. This was the most important invention of all, for a wrong signal could not be given either by negligence or by any strain or slackness of the apparatus. Before the lever could be moved the spring catch must be closed, which operation effected the necessary locking. Mr. Rapier had alluded to Saxby and Farmer's invention, but only in terms of faint praise. In other respects he valued the Paper highly.

Mr. D. A. CARR said it had been remarked that the worst policy of a railway company would be to reduce the speed of its trains. Mr. Carr ventured to think that if the 'Flying Scotchman' had gone through a fog on its way to Edinburgh, not only would it have been two hours late, but possibly it would never have arrived there at all. The Author had enlarged on the existing system of interlocking points and signals; but had only made slight mention of any modes of communicating with the engine-driver in foggy or snowy weather. Mr. Carr had, in conjunction with Mr. Crawford Barlow, endeavoured to fill up that gap, and had made a series of experiments with that object. One defect in the present system was the possibility of a malicious signalman pulling off the points, even though he had received the danger-signal. With the view of meeting that difficulty, a system of electrical signals fixed on the weather-board of the engine had been proposed to take the place of the so-called fixed signals. The arrangement for signalling on to the train itself in connection with the present fixed signals was shown in Fig. 1. C was an intermediate block-signal station, with home and distant signals. At the point where the existing distant signal was first seen, the electrical distant-bar was placed, and there was a second bar about 50 yards nearer the box to repeat the signal received on the engine. At the box there was a longer bar or home signal. The three bars were placed in electrical connection with the signal instrument, Fig. 2, which was worked by the levers. The action was as follows:—The signalman had received notice of the approaching train by means of the block instruments. Should the next block length be clear, he proceeded to pull off the home and the distant signals. In doing so he moved the shades in the signal instrument from red to white, thereby changing the distant and the home signal-bars. The approaching train passed over the distant signal-bar at A, received a "clear" signal, which it repeated on passing B, and proceeded to the home signal-bar, where the clear signal was again received and the train proceeded to the next block station. Should, however, the block length ahead not be clear, the

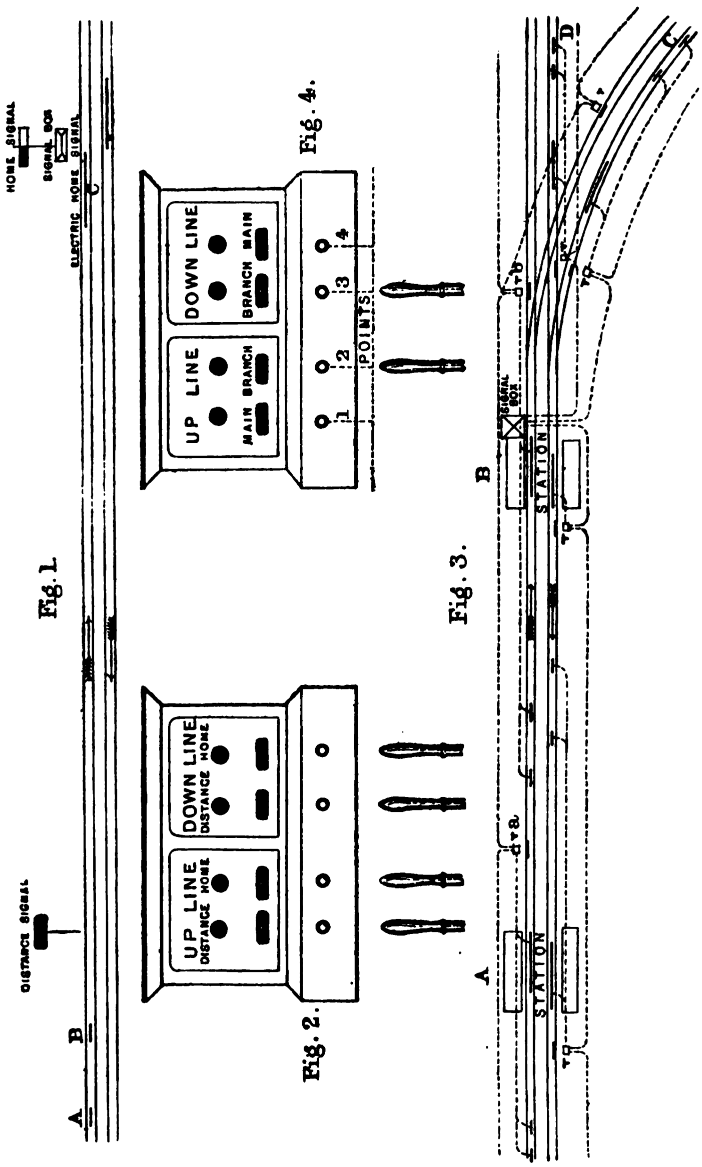


Fig. 1.

Fig. 2.

Fig. 3.

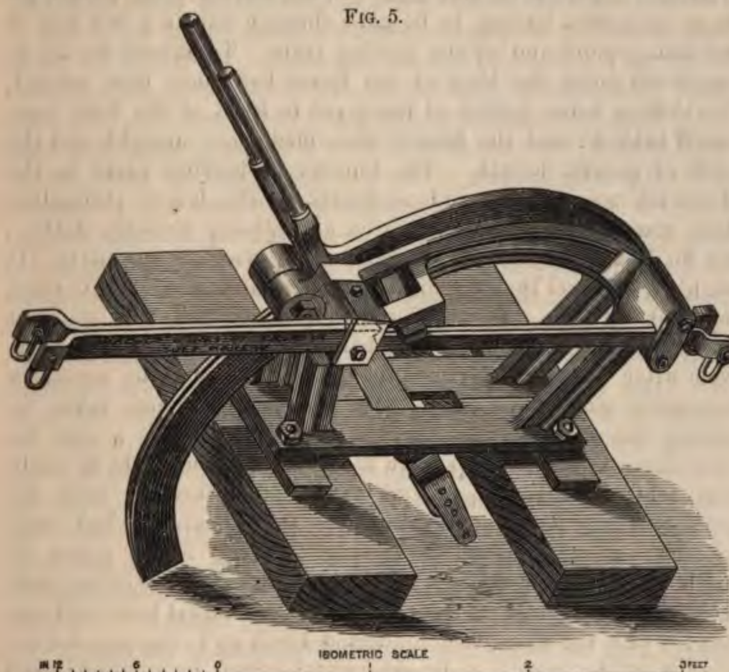
Fig. 4.

signalman left the signals at danger, when the electrical signals also remained at danger. It would be observed that, by means of the repeater, the signalman knew directly the train had come within the distant signal, and could therefore at once cover it. Fig. 3 showed the automatic arrangement for a double junction. A D was a through line with a branch to C. A and B were two stations, fitted with electrical signal-bars, as shown by black lines, and instruments termed transmitters, T. The transmitter was moved by a treadle, depressed by wheels, and a wire passed from transmitter to transmitter, and also to the signal-bars. The action of the train from A to D was as follows:—A train arrived at the distance signal of station A. If the block length was clear between A and B the train received a clear signal, and proceeded past the distance and arrived at the home signal, where it again received a clear signal. It then passed the home signal and arrived at transmitter at *a*, which it depressed in passing, causing bars at A to be set to danger, and at the same time struck an electrical bell in the signal-box at B. What took place in the interior of the signal-box at B, the train being between A and B, was as follows: when the signalman received notice of the approaching train, he depressed the key of the signal instrument marked "Main Line, No. 1," Fig. 4, giving a clear signal to the approaching train; but, as this key was in connection with the wire from the transmitter at *b*, no current was sent into the bars as long as a previous train was travelling between *b* and the block station at D. The instant, however, that the block length between *b* and D was clear, the transmitter at *b* fell, and, the circuit being completed, the bars received the clear signal, which was transmitted on to the approaching train, which then travelled past the distance and home signals as before, and proceeded towards D. If, however, a block had occurred between B and D, the transmitter at *b* had not fallen, and therefore, although the signalman had given "Line Clear," the circuit was not coupled up, and the approaching train received a danger signal at the distant signal, and at once slackened to slow speed, stopping at the home signal at B. For trains travelling in other directions the operation was precisely the same, it being necessary only that if a train was proceeding on to the branch, the switch-handle must first be moved before the signal-key could be depressed. It was to be observed that, as the keys were interlocked, the signalman having depressed the key for the Up Main line, could not depress the keys for the Up Branch No. 2, but could depress either the Down Main Line No. 4 or the Down Branch No. 3, but not both.

Mr. A. R. Poole said, though not a scientific man, he had had in his professional duties something to do with interlocking apparatus, and had himself made some attempts in that direction. It was not always the patentee who was the inventor: the groundwork might have been laid by another. It might be that the invention was taken up and worked by railway companies, though it had never been patented. All that the public, however, could do was to look into the documents in the Patent Office, to see what was really patented, and this was what he had done. The first groundwork that he had found was the patent of Mr. Saxby, in 1856, for working signals and points simultaneously by means of one lever. Then there was Mr. Saxby's patent of 1858, in which, for the first time, a lever was found locking a lever; but he agreed with the Author in thinking that the real groundwork of all the different kinds of interlocking apparatus there exhibited, and at present in use, was the patent of Austin Chambers of 1859 (Fig. 66). By that, for the first time, signal-levers were brought together and connected with point-levers, and for the first time the action of the signal-lever was found locking the point-lever. But the object was not so much to consider how different inventions excelled others, but what were the requirements of the present day. It was for men of science to say what was wanted; and very often an ordinary workman might supply the necessity. Mr. Saxby's patent of 1860 was, no doubt, a great advance upon Chambers' invention. He was informed that there was also an invention, perhaps a patent, by Mr. Stevens of that date, but he had been unable to find it. He had been told, however, that in principle it was much the same as Mr. Saxby's, though perhaps carried out in a different way. At all events, for a number of years those two gentlemen seemed to have gone on upon these inventions. After seven years' working it was found that the locking was apt to wear out, and that if made strong enough it was too heavy. Another defect was that the unlocking could not be performed at the particular moment when it was required. The two requirements evidently were that the lever should not be locked absolutely by the lock, the leverage being too great, and that there should be some movement, independently of the movement of the lever, which should effect the locking prior and subsequently to the stroke of the lever in performing the actuation of the point or signal. No sooner were these requirements ascertained than they were supplied. Two patents were taken out in March 1867, within three days of one another, one by Mr. Saxby, the other by Mr. Easterbrook, both using the catch rod to obviate the first difficulty. The two gentlemen went to law, and Mr. Saxby was worsted. His patent was three days prior to that of Mr. Easterbrook, but Mr. Easterbrook was left in possession of the patent for locking the catch rod. Another step had yet to be taken, namely, to actuate the locking gear by the catch rod, and that was done three months subsequently. Again two patents came out within three days of each other, Mr. Easterbrook being three days later than Mr. Saxby. The same action was taken, and on this occasion Mr. Easterbrook was worsted. The result was most unsatisfactory to the public. No doubt the two patents were really for one invention. When one part was adopted the other was a necessary consequence; but the inference would seem to be that Mr. Easterbrook could lock his catch rods, and Mr. Saxby could actuate his locking gear by catch rods, but that neither of them could do both; and the public could not do both, because these gentlemen would not agree. Since 1867 various methods had been tried to supply those requirements in other ways. There had been several inventions to lock by what had been called prompt locking. This might possibly do before the stroke, when there was a certain slackness, but it would not do at the end of the stroke when everything was tight. Another objection to 'prompt locking' was that, since the locking took place at the same time as the point or signal of the lever was being actuated, the signalman would often uselessly exert his strength, and perhaps strain the lock, before he discovered that the lever was locked. Other inventions had been tried to obviate the other difficulty to which he had referred, but they did not appear to have answered their purpose. Thinking the matter over, and keeping these two difficulties in view, it occurred to him that he could obtain a motion subsequent and prior to the motion of the lever in actuating the point, which would be equivalent to the motion of the catch rod of Mr. Saxby, and the locked catch rod lever of Mr. Easterbrook. He met the latter difficulty by opposing not the lock itself to the lever in its backward and forward movement, but the top plate. He gave the lever a lateral as well as a backward and forward motion. This required a very slight motion at the fulcrum. The lock only prevented the lateral motion. It would be obvious that, as long as the levers (Fig. 104) were in a recess at the end of the aperture of the top plate, they could not move backwards and forwards. They were kept there by a spring which would give if the lever were moved laterally. The signalman could not move the lever backwards and forwards without moving it laterally out of the recess. This movement effected the locking, but it did not move the point. It was like Mr. Saxby's catch rod, actuating everything that ought to be actuated before the point-lever was moved. When it came out of the recess of the aperture it could be moved forwards, and would come opposite the other recess. Then it moved laterally again into that recess, and unlocked everything that ought to be unlocked, but not until the lever had finished its stroke, and had brought the point perfectly home; then it actuated the locking gear. In this way he had endeavoured, as he ventured to think, successfully to supply the two requirements to which he had referred. It had been said that it was advisable to have as few parts as possible. If when several levers should successively depend upon one another they were made to depend upon one only in order to have only one part governing them, that would be a mistake. The parts should not be too many, but it would not do to get rid of anything that was wanted, for the sake of having few parts. It did not much matter if the parts were numerous so long as they were simple and easily worked. Mr. Poole further stated, that in his invention the locking was maintained as follows:—There was a falling bar which came upon a notch on the sliding bar, and there was a pin upon the lever which raised the falling bar as it came between the jaws of the sliding bar. As it left those jaws the pin left the falling bar, which fell into the notch, and held the sliding bar immovable in its place, so that nothing could disturb it until the lever came back, and again had it in control.

Mr. W. L. Owen asked permission to bring before the members a locking apparatus (Fig. 5, p. 65), which he had brought out in 1866, on a system different from any described in the Paper. It fulfilled all the required conditions, inasmuch as it prevented the slightest movement of the signal levers before the switch lever was in the proper position. In designing the apparatus (which was intended to be as economical as possible) the idea of imparting motion to the locking bar by the signal levers or switch levers was thrown aside. Instead of one lever being made to act upon another by moving a lock by means of a more or less complicated mechanical contrivance, the levers in their movement simply rendered it possible or impossible, as the case might require, for the switchman to slide by hand a locking bolt, alternately locking and unlocking the necessary levers. The several levers, which were similar in character to ordinary ground levers, worked side by side in segmental frames of similar ordinary construction, and were provided with segmental tail-pieces (forged solid with the levers) working through slots in the ends of the frames. These tail-pieces were made to the same curvature as the frames. The segmental frames were slotted transversely just in front of the levers, when these were in the backward position, and a sliding bolt worked backwards and forwards through these slots, whereby it was made capable of alternately locking the one lever or set of levers in the one side of the frame when in backward position, while the other levers were free. As soon as the last-named lever or one of the set commenced to move, the segmental tail-piece covered the transverse slot, and prevented the sliding bolt being moved back, and so releasing the first-named lever. The apparatus was designed for small roadside stations. It was applicable to all cases, excepting at the most crowded or complicated junctions, and had been extensively used—at colliery sidings where no box was required; at sidings where no signalmen were kept, the gear being provided with padlock bars and padlocks to prevent interference by unauthorised persons; at facing points on single lines of railway, to

FIG. 5.



lock both the switches and the signals, where they could be readily worked from the same frame—a cheap arrangement, dispensing with long switch rods. Also as a temporary means of locking the signals and switches of cross-over roads, when put in for the purpose of working single line in short lengths during repairs of bridges or other works. At ordinary junctions (where signal-boxes were required), the back locking was easily obtained by a simple arrangement of slots of different patterns cut in the rear end of the segmental tail-piece. This gear had been in operation since 1866, and possessed the following advantages:—It could be constructed and repaired by an ordinary smith, there being no fitter's work about it. It could be fixed in place by a platelayer. The lock was perfect. The levers could not commence to move until all conflicting levers were completely locked. There was great simplicity of construction combined with solidity in the lock. There being no side strain on the lock, the locking was very durable, the repairs being in practice simply "nil." When used as an outlying facing-point lock, no locking bars or detector bolts were required. To move the switches the signal must first be put to danger, the lock be slid over, and the switch lever pulled, all these operations having to be gone through within a few feet of the facing point and of the moving train. To extend its use to longer distances the form of the frame had since been altered. The locking bolts, instead of being put in front of the bars, were placed behind; and the frames were made more upright, and the lever of greater length. The number of moving parts in the apparatus was small. Independently of the levers themselves there was only one moving part for an ordinary roadside station; and for a double junction there were only two moving parts. It might be objected that the operations here described were tedious, and took up time. It was found in practice that this was not so: the signalmen worked the hand-moved locks quite readily, even after being accustomed to those to which the necessary movement was imparted by the levers. The time taken in moving the locks was almost inappreciable; and as a rule the switchmen, knowing what train to expect, had the locks in readiness for the operations about to be gone through with the lever. A further modification of the apparatus had been adopted for the purpose of locking outlying facing points on single lines. A bar was provided in the frame, interlocking with the sliding bolt, and in substitution of the signal lever and segment. This bar was either connected direct on to the signal wire, or worked (by means of double control wires) by an interlocked lever in the main frame at the station. This arrangement was adopted, as it had been found that, in all ordinary wire or bolt locks, owing to the necessary slack in the apparatus, and the play between the end of the locking rod and the sliding bar, the switches could be partially opened while the signal was down;

and the friction of these parts had a tendency to prevent the return of the signal to the danger position, when the signal lever was thrown over for that purpose. These objections did not exist in the form of gear now described: the switch lever could not be moved in the least until the signal was at danger, and whatever strain there might be on the switches, none was transmitted to the locking bar. In this form the gear had been extensively applied to interlock the facing points in connection with such of the signals as controlled trains approaching such points from the facing direction; the cost was but little in excess of ordinary levers in similar situations without the interlocking. When thus used it became simply a cheapened and improved form (in connection with the signals) of switch indicator, giving to an approaching engine-driver ample notice as to the position of the switches, which was not the case with ordinary indicators.

Mr. C. H. Gregory, Past-President, said, without desiring to enter into those questions which it might be thought had already been sufficiently discussed, he wished to suggest one addition to the history given by Mr. Rapier, viz., that the detonating fog signal was first introduced by Mr. E. A. Cowper, M. Inst. C.E., somewhere about 1841 or 1842, and that in a report dated the 14th of April, 1844, General Pasley, the Inspector-General of Railways at the time, recommended it as worthy of general adoption. The Paper under discussion must have cost the Author a large amount of careful research, and it was a valuable addition to the records of the Institution, containing as it did so complete a history of the most important changes in railway signals. Never having patented the application of the semaphore as a railway signal, or derived any benefit from it, he could not but be pleased that in this, the first complete history of signals, the fact should have been recorded that he introduced the semaphore signal, now of almost universal use on railways, and that he had taken what had been described as "an important step" in interlocking signals. From 1840 to 1845 Mr. Gregory was engaged as resident engineer on the Croydon railway, and was actively employed in the mechanical details of railway working. During that time mechanical inventions were introduced by very slow degrees, and while the period of the first introduction of the semaphore was correctly fixed at the end of 1841, or the beginning of 1842, and its use was soon extended from the Croydon railway to the Brighton and the South-Eastern railways, it was some time before it was adopted into general use. The Brighton railway was opened from Croydon to Hayward's Heath in 1841, but it was not till the summer of

1844 that a double semaphore with signal locking apparatus was put up at the Brighton Junction, a few months after the erection of the Bricklayers' Arms Junction signals. The arrangements at the Brighton Junction, as well as at the Greenwich and Croydon Junctions, were at first of the simplest character. A signalman with two flags by day and hand-lamps by night worked the whole of the traffic, which, as far as the Greenwich Junction was concerned, was a very large one. In order to show that such simplicity of working was not only adopted by railway companies but met with the approval of the Government authorities of the day, he quoted a short extract from the Report of Sir Frederick Smith relating to the opening of the Brighton railway, dated July 10, 1841:—"The points of junction with the Croydon and Greenwich lines are also matters of some anxiety; for, unlike the ordinary junction of other railways, these occur where there are no stations, and consequently the safety of the traveller depends mainly on the switchman at each place.

"It is to be borne in mind that, until the new station at London Bridge is formed, and the additional line of rails laid, the engines of the three companies will work on the same rails from the London terminus to the Greenwich Junction. Great vigilance will therefore be required at this junction; and it is desirable to impress upon the directors of the Greenwich Company the paramount necessity of always placing at this important point a policeman of well-established character for strict obedience of orders, steadiness, promptitude, and presence of mind, since at this junction, owing to the frequent passing of the Greenwich trains, and to the circumstance of the Croydon and Brighton trains having to cross both the up and the down lines, it will be chiefly on this servant that the safety of the passengers will depend.

"My present duty, however, is with the Brighton line; and it behoves the managers of this railway to make their engine-drivers and conductors fully sensible of the necessity of the strictest obedience being paid to all signals, and of their approaching the two junctions at such a moderate rate of speed as to admit of their having the trains completely under command."

The selection of good men and good administration were considered the best safeguard rather than the introduction of new mechanical appliances. To show the correctness of Sir Frederick Smith's judgment, it might be stated that for a long period from 150 to 200 trains per day passed the Greenwich Junction without the slightest accident.

As another illustration of the fact that in those days the personal qualifications of the men were looked upon as the best security for safety, he read an extract from General Pasley's Report, dated 14th March, 1843,[1] on the extension of the Eastern Counties railway from Brentwood to Colchester :—" In fact, I have the greatest confidence in the skill and judgment both of Mr. Braithwaite, the engineer-in-chief, and Mr. Hall, the manager, upon whom these details will depend, as I have seen no railway where the arrangements by signals, policemen, &c., for insuring the safety of passengers, are more perfect; and I know, by the declaration both of the directors and officers of the company, as well as from the men themselves, that their enginemen and firemen give perfect satisfaction to their employers, and are contented with the treatment they receive; and on inquiry I found that the number of miles which they drive during the week is very moderate, which is an essential point, not only for the comfort of this important class of men, but for the public safety, which depends upon their not being overworked."

In a Report dated 17th March, 1843,[2] on the projected Peterborough branch of the London and Birmingham railway, in reference to the proposed level crossings on single lines of rails that had been objected to as dangerous to the public safety, the General said :—" In order to judge how far level crossings may be dangerous to the public safety, I have repeatedly passed along the Northern and Eastern railway, from Stratford to Bishop Stortford, which may be considered as a prototype of the Blisworth and Peterborough branch, as it ascends first the valley of the River Lea, then that of the River Stort, in the same manner that the latter will descend the valley of the River Nen; and in consequence of this advantage, the Northern and Eastern railway has been completed with very little labour in earthwork, but it abounds in level crossings, there being no less than 19 or 20 in the space of 28 miles, at all of which, except private or occupation roads, gates have been erected, shutting across the road, and only opened for passengers when required, at which period they are shut across the railway. This is done by a gate-keeper living in a cottage on the spot. The trains of the Northern and Eastern railway never slacken their speed on passing those points, unless the gates should be shut across the railway, which are sufficiently conspicuous by day, and rendered so by a red lamp at night, which is a signal to

[1] "Report of the Officers of the Railway Department for the year 1843." Appendix III. p. 150, folio. London, 1844.
[2] Ibid, p. 154.

stop. This railway has been opened, though not to the whole of its present extent, for about two years and a half, and no accident has ever occurred at any of its numerous level crossings. The example of this line is, therefore, a sufficient proof that level crossings on a railway are perfectly safe, if steady gate-keepers be employed at all those of turnpike, or other public roads; and the management of the Birmingham railway is so very perfect, and all the enginemen, policemen, and others in their employment so competent and correct in the execution of their duty, that I see no danger whatever in allowing them to have as many level crossings as they please in the proposed line between Blisworth and Peterborough, which will not be more numerous in proportion than on the Northern and Eastern railway; for the number will be about 28 in 47 miles, of which the greater part are little frequented, whilst at the crossings of the most important public roads it is proposed to have stations where the trains will stop."

These indications of the spirit of the day, to depend upon men more than upon machinery, were confirmed by a circumstance which occurred shortly after he became resident engineer of the Croydon railway. He then made a tour of most of the railways opened in England, fired with the spirit of mechanical improvement and with the desire to reduce railway rules to a code. The Liverpool and Manchester railway was very well managed, and he asked the manager of that line to let him have a copy of their general rules and regulations. He was informed that they had none, but that they put good men in every place, and took care to keep them up to their duty. As a last illustration, he mentioned that in looking through the Reports of the Board of Trade on railways opened from 1841 to 1845, he found that any reference to signals was quite exceptional.

Admitting that the increase of traffic, and still more the irregularity attendant on its working, had induced the necessity for mechanical appliances, it was to be considered how far those appliances were necessary. There were, no doubt, many railways on which, without a complicated system, the traffic could not be worked at all; but there were some cases in which he could not help thinking that these systems of interlocking switches and signals, and other mechanical appliances might be carried too far, when it was considered what might be the result of the loss of a pin or a bolt, or the slacking of a rod, and the danger of men trusting implicitly to contrivances which were not infallible, and so depending less on their own caution and vigilance. He had investigated the circumstances attending one of the worst railway accidents which had ever occurred in this country, and had come to the conclusion that it was caused by the sudden failure of a special signal which might perhaps have been dispensed with.

Mr. J. Dixon said he was not engaged in the management of railways, nor was he connected with the manufacture of signals; therefore he did not propose to describe the merits of any special patent. The conclusion at which the Author of the Paper seemed to have arrived was, that by a judicious use of the various inventions and arrangements placed within their reach by "signal" engineers, the use by railway engineers of facing points was rendered not only safe but also feasible. It was an axiom, that to run twice over the same ground necessarily involved an increased expenditure of wear and tear. Any one who saw the shunting of a long train must be convinced that the stopping of that heavy mass of material could only be achieved at a great expenditure, which had to be repeated in the back shunt. Between Askern and London many of the slow trains had to be shunted and passed from ten to twenty times by the quicker ones, which must add materially to the average cost and wear and tear on the journey. Again, it was clear that ten minutes' obstruction to a line added a largely-increased amount of risk. If therefore facing points and crossings could be used with impunity, a great advantage in the management and facility for economical working of railways would be gained. On the London and North-Western, at the Watford Tunnel, each train on the same line of rails was practically out of sight before the succeeding train came into view. If that was so, a large amount of rail was practically unused. And why should it be? Why should not the engineers, managers, and manufacturers of this machinery be able to devise such precautions, that each pair of rails might be more thoroughly utilised? That facing points could be used with impunity no one could doubt. No accident had ever occurred with Saxby and Farmer's lock, and that was certainly in favour of what he had adduced. If another illustration were wanted, it might be found in the fact that on the London and North-Western for twenty years the passenger traffic out of Euston was worked by attaching an extra engine. Arrived at the top of the bank, the extra engine slipped her couplings, and rushed forward in advance into a blind siding; the signalman there, trusting alone to his sure eye and steady hand, turned over the points with such success and regularity, that during the whole of the twenty years no accident occurred. It might, however, be satisfactory to know that since the Willesden Junction had been opened all the trains stopped there, and the engine was detached. Captain Tyler was decidedly adverse to facing points, and regarded them probably with some degree of prejudice; but though Captain Tyler's Report for last year showed that a few accidents might have occurred at facing points, there were a large number of cases in which it was probable that accidents might have been avoided if facing points had existed. The complications of the signal and interlocking arrangements were not likely to promote the use of facing points. Moreover he feared that signal manufacturers had an idea that £25 a handle was the price to charge for a locking frame, and for trade purposes increased the numbers. To make one handle do the work of five was a step in the right direction. In illustration of this state of complication, he might mention that an eminent Engineer went, about two months since, to a station not far from London to examine the points and signal apparatus. The superintendent attended and explained the working, and showed how long a time it would occupy for a train to pass through, which, for argument's sake, might be taken to be five minutes. He further explained that on busy days they frequently had ten, fifteen, or even twenty trains in an hour. On its being remarked to him that this would seem to be impracticable, if each train required five minutes to be worked through, the reply was given, "Oh, sir, on them days we pulls out all this gear."

Mr. Robert Burn wished to refer to a point which as yet had not received much attention, namely, fog signalling. He was afraid that mechanics were at a discount, for an explosive signal had been spoken of as the best fog signal. He believed the only mechanical apparatus yet devised was that used on the North London railway, where a lower duplicate arm was fixed to the signal-post so as to come within easy range of the engine-driver's vision, and to enable him in foggy weather to be sure about the signal. This expedient was, however, limited in its application. The Author had spoken of audible signals, and had given a drawing of Mr. Anderson's audible signal on the North British railway. The great fault when an audible signal was fixed to a distance signal was that the gong or the whistle was always sounding. Practical men said this was an objection, because in large stations and complicated junctions the whistles constantly sounding would be a perfect nuisance to every one connected with the railway, especially to the drivers themselves. On one of the large railways running into London there was a standing rule that the drivers were not to whistle even in passing through junctions; if the signals were set for them to go forward they must do so without whistling. To gain experience he had travelled on an engine on a foggy night. The head lights shining upon the fog in front, produced an effect very much like that of running into a white blanket; no object or landmark could be seen. This must tend to bewilder even the most experienced engine-driver, who if he happened to miss the distance signal, might be in a station before he expected it. Cases had occurred where fogs had formed very suddenly, and a train coming up before the fog men were out, serious consequences had resulted from the driver not seeing the signals. If the semaphore signals could not be seen, it naturally followed that some signal should be devised which could be heard; and this was the plan which in an elementary form had been acted upon for the last twenty years—detonating signals had been laid down. He believed that some mechanical contrivance might be introduced to free platelayers from standing out day and night in foggy weather to lay down these detonating signals, as it often proved, at some risk to themselves; and that an audible signal, not always sounding, but which could be made to sound when it was desired, would prove the best substitute. Such an appliance was required to perfect and complete the block system. An experiment which he had been carrying out at Epsom promised to end in this direction. A small gear was erected under the signal-box, by means of which the signal could be worked in fine weather just as at present; there was also a supplementary lever, to pay out a little more wire, and raise a treadle by the side of the line some yards in advance of the distance signal above the level of the rail, to bring it into contact with a trigger on the engine suitably provided and connected with the whistle. In foggy weather, if the signalman wished to give the driver an audible signal, he turned over a small supplementary handle, which at once apprised the driver that the signals were against him. The same results could be obtained by utilising a portion only of the stroke of the ordinary lever for working the signal blade, and the remaining portion for working the treadle. The engine attachment was of the simplest description, merely consisting of a rocking shaft, extending across the engine, suspended by two brackets, with a vibrating trigger on each end, and a small vertical lever keyed on to one end of the same shaft, from which a cord was led through guarded pulleys to the handle of the alarm whistle. The Author said the idea had occurred to him that it might be made an affirmative signal, and it was very clear it might; that when a driver approached a station in a thick fog he was not to go on unless the treadle was raised and the whistle sounded. He hoped that the plan described, or some modification of it, when further inquired into, would commend itself to the members, and that the present cumbrous and somewhat expensive system of fog signalmen might be superseded.

Mr. Richard Johnson said he regretted that mention of the Midland railway was nearly left out of the Paper. Not only had the London and North-Western and the Great Northern, but the Midland Company had, for some years past, paid considerable attention to the important question of providing for the safe working of the increased traffic. For the last thirteen or fourteen years he had been almost every day carefully considering this question of locking apparatus or no locking apparatus. Fifteen or sixteen years since, almost every set of switches in a station was at liberty to be moved by any man who happened to be working in that station either as shunter or porter; and as the traffic day by day increased so did the difficulties in carrying on the increased work. He repeated that for thirteen or fourteen years he had carefully considered this question of working railways, and especially the working of large stations and the safety of junctions through which trains had to pass at high speed; and perhaps no one present had been more afflicted by those gentlemen who schemed these appliances than himself. He had, as far as he could, opposed the introduction of locking apparatus, but it was now only fair to admit, that, in his opinion, every set of switches which communicated in any way with the main line should be under the control of a signalman, and that it should be out of the power of any shunter or porter to alter those switches at will. It therefore came to this, that, more or less, locking apparatus was a necessity. He believed, judiciously applied, locking apparatus saved time, and he was sure it saved men in stations, and so far as he could see, it contributed materially to the safety of the working of the line. Signal engineers erred in this direction, that their machinery was too complicated; if they would turn their attention rather more to simplicity it would be well for them, and it would certainly be well for the Companies. One gentleman spoke strongly in favour of facing points for shunting trains. His experience was the fewer facing points the better. He did not like shunting to any great extent, but it was preferable that a train of thirty or forty wagons should be shunted safely rather than that there should be an excess of facing switches. There were shunting sidings at all large railway stations, and if facing switches were introduced as the means of getting into those sidings, many elements of danger would arise which did not at present exist. He confessed that the number of levers in a box sometimes frightened him. Mr. Rapier had shown a locking frame which he had prepared for the level crossing at Lincoln with eighty-one levers. Mr. Johnson tried very hard to cut it down to sixty, but seeing that this was to govern a level crossing of two railways, many connections on each side of that level crossing, and also the various connections in Lincoln station communicating with the main line, he believed the number had been reduced to a minimum. Then as to the system of block working, he was not sure that the Paper fairly brought that question before the Institution. Most railways were now worked on what was called the absolute or positive block system. There were, no doubt, varieties of opinion as to the manner in which the block absolute was carried out. His opinion was, that it was not quite sufficiently absolute, and that at no distant date, the question should be thoroughly discussed at the Institution. There was so much tendency to crowd on the traffic that he feared railway companies were rapidly approaching a permissive block instead of adhering to an absolute block system. He thought that two trains should not be allowed to be between two block stations. It might be answered that that was the state of things now, but he believed he was correct in saying, that immediately a train had passed—say station B—the practice was to admit a train from A, although the train, which had just passed B might not be moving. He contended that, not only ought that mile and a half, or whatever it might be, to be kept clear, but before the driver started the train from station A he ought to know the state of things at B. If a train was standing there he should approach B with great caution, if not, a collision, some day or other, was inevitable. He thought there was something to be done by way of improvement in that part of railway working at the present day. It was known that third lines were being constructed as rapidly as possible for dealing with the greatly increased traffic on nearly all large railways.

Mr. Spagnoletti remarked that the Paper was an interesting history of the introduction and progress of railway signals. It showed the improvements that had been introduced, advancing from a simple lamp on a post up to a locking apparatus; how signalmen could be educated for their work; and how the large amount of traffic now conveyed on railways was carried by the agency of mechanical appliances. The marvellous increase of railway traffic, and the amount of the earnings of railways for the past ten years, were a proof of how much had been gained by mechanical and electrical assistance in working them; and how the carrying capacity of the lines had been stretched and expanded by appliances of this kind; and, at a comparatively small outlay, with such great results. Had not these appliances been used, the only alternative would have been to have doubled the railways. The expense of this would doubtless have been much more than that of the original construction of the lines, from the advanced prices, which the railways themselves had caused, of land, materials, and labour. This he thought was a strong argument in favour of such appliances, and that, had they not been adopted, the dividends of the companies and the present price of their stock would be considerably less than they were now. Seeing that mechanical appliances had done so much in these respects, he considered that any brought forward possessing desirable improvements deserved a fair trial. Prejudice, generally found to be the want of a better knowledge and comprehension of any object or thing, was an awkward and difficult barrier to get over; but had not experience of past inventions (some of which were now admitted to be quite necessary) shown how long it took to introduce and get existing ones into use? The system of working railways in the present day, from the varied and later developed classes of traffic, was very different from that of the time when the accommodation of the lines was adequate to the demand then made upon them, and he could easily understand how those who had not closely followed step by step the recent improvements should feel doubtful as to their results; but experience should give confidence. Early impressions were always the strongest, and therefore he thought their conclusions were only natural, although perhaps not well founded. Mr. Rapier had pointed out the great advantage arising from sectional lines being laid down parallel with the main line. This would be found advantageous in the working of railways. Trains frequently had to pass each other on the great lines, and fast trains would perhaps overtake several slow trains in the course of their journey. There were many places where perhaps these lines might be constructed on land already held by the company, and the expense would not therefore be so great as if the whole of the land had to be purchased; and by means of the block telegraph these portions of line would simply represent junctions with branch lines. It was true that facing points would in such a system be rather freely introduced; but if these were worked with the locking bar, or the signalmen's cabins were placed so that they could get a good view of them, he did not think much, if any, danger would result from their introduction. If, however, they were considered by any company dangerous, then trailing points could be laid, and the trains could back into these lines. The only delay experienced would be the time of shunting back, and there would be the advantage of being able to proceed as soon as the work at a station had been accomplished, instead of waiting for fast or through trains to pass; which waiting added to the delay and irregularity and to the troubles and dangers of working a railway.

With regard to the block telegraph, expressions had been used to show that, although it was generally employed, it introduced an element of danger; inasmuch as drivers, knowing that they were working under the block system, and getting an all-right signal to start, concluded at once that the line was clear right away to the next station; but without it, as their lives were endangered if anything should happen, they would keep a better look-out. But drivers knew, and no men better, that there were other causes for them to look out ahead than the fact of running into a previous train; because in all cases when trains broke down, it was a rule that the guard went back to stop the train following. The drivers also knew this, and it might be said equally as well to be a system likely to render them more inattentive than they otherwise would be without it. The other causes, such as platelayers being at work with a trolly on the line, or having a metal up, level crossings, cattle or carts passing, or anything having fallen off the previous train, or an accident to a train coming in the opposite direction—all these things were likely to occur, and because his own life was in jeopardy the driver would be careful in all cases to keep a good look-out to see that the line was clear, whether the block telegraph was there or not. With regard to audible signals, he believed they might be used with advantage in the case of a fog, or in a snowstorm, a hailstorm or a heavy downfall of rain, when the men would naturally shelter themselves behind the weather-board. This might be carried out by an electrical arrangement with a bell on the engine, which when set ringing would not stop until the driver stopped it by pressing a knob down; and a spring attached to the engine to rub over a piece of bent iron rail as the train was passing. Placing these pieces of iron rail on a railway 200 or 300 yards from every signal, the attention of the driver would be called to the fact that he was coming to a signal. This would be useful at all times, for even in fine weather he might be engaged in looking at his engine, and perhaps run closer to a signal than he should do, especially down an incline, before he was aware of it. Mr. Spagnoletti then proceeded to describe his fixed signals worked by electricity, they being in size the same as the ordinary semaphore signals now in use on railways, thus getting rid of wires, which had to be strained to work the signals. He also stated he could lock signals and points, and signals and signals together by this electric signal, as was now done, by simply making contacts, and thus remove all the complicated machinery now used, which had been so much complained of. He also showed his arrangement for indicating in a signalman's cabin when the lamp of a distant signal was in or out, when it could not be seen by the signalman working it; and likewise his signal repeater, which showed the signalman the position of the same when the signal was placed out of his sight. With reference to intermediate stations on lines, he said that on the Great Western, the distance between some stations being 5, 6, or 8 miles, it was found necessary to have intermediate boxes; but with the electrical signal, as only instant contact was required to work it, and as it could be worked equally well at any distance, it could be worked automatically by the pressure of the engine on the rail, and thus save the expense of building huts and appointing men simply to act as repeaters of the signals sent to them.

Mr. Rowe, with reference to the locking gear exhibited, said no doubt, with the purse of the London and North-Western, the Midland, the Great Northern, or other large companies, expensive signals were all very well; but he happened to represent two small lines belonging to landowners, where they had not the advantage of such a command of money, and so these elaborate descriptions of locking gear were altogether out of the question. The junction expenses cost £700 for 12 miles of single line. On another little line there were three local stations, and it cost £500 for locking gear before the Board of Trade would allow the line to be opened. He found, what with the friction and the length of the rods, and one thing or another, this locking gear was continually getting out of order, and he was bound to confess, in some cases it was necessary to take out the lock and temporarily work without it. He believed the catch-rod system of Messrs. Saxby and Farmer, Mr. Easterbrook, and others was the right thing, as there was no strain upon the gear. It was all in the man's hand; he had only a certain power in the grip of his fingers, and could not strain the locking gear. No doubt a little more simplicity in the working parts was desirable. With reference to Mr. Spagnoletti's electrical arrangement, he of course could not claim the mercurial lamp as an original invention. Mr. Rowe happened to be connected with it some years ago, in working out the patents of Messrs. Whitaker and Jones, when it was found that the mercury, being so volatile, could not be depended upon.

The vibration of a passing train would sometimes cause it to indicate that the light was out when it was not; it would break contact in fact, and ring the bell. An endeavour had been made to overcome this by using a compound metal bar, which made and broke contact by heat and cold, but the difficulty then was to maintain perfect insulation, as the electricity was continually running to earth; the least speck of dust getting into the connections upset the whole thing. At last he gave up electricity, and succeeded in making the distance lamp relight itself, by applying the unfailing power of the compound bar to actuate a locking rod, which if the lamp ceased to burn or go nearly out, allowed the oil chamber to fly round, and light up another wick by means of ordinary matches. Now matches could be dispensed with, and a lamp could be kept burning any length of time; as the oil chamber in turning round would keep lifting and re-trimming the wick. He was bound to say, from his experience of electricity, that without the aid of a strong staff of electricians, and of gentlemen such as Mr. Spagnoletti to keep them going, he should not like to rely upon it.

Mr. Austin Chambers said the Author of the Paper had given him credit for being the first inventor of locking, but had connected Colonel Yolland's name with it. Now the facts were these: In October 1859, when the Hampstead Junction line was finished, Colonel Yolland told the North London company that he did not consider the Kentish Town station safe without some means of preventing the signalman from making a mistake. Messrs. Stevens and Sons, having the signal work in hand, undertook to so arrange the signals, and the opening of the line was postponed for that purpose. In the following month Colonel Yolland again inspected the junction, when the stirrups that worked the signals had been so arranged that the act of putting down one stirrup disengaged the stirrup that held the other. Colonel Yolland put his foot in the two stirrups at the same time, and thus lowered both the 'Up main' and the 'Up branch' signals, when he refused to pass the line. Being appealed to for information as to how the object could be attained, Colonel Yolland replied, "It is not my province to suggest, but to approve.' Having ascertained what was required, that the facing points must be set for the main line before the 'Up main' line signal could be given, and that the 'Up main' line and the 'Up branch' signal could not be given at the same time, he by the end of December 1859 had fitted up the Kentish Town and Willesden Junction entirely to Colonel Yolland's satisfaction; and he might add that the same locking, which almost amounted to the approved system of the present day, had been working ever since, was now in good working order, and had never been repaired. During the inspection Colonel Yolland made this remark to the Manager, "You see I have not asked for more than could be done, as one of your own staff has provided it; you will some day thank me." The same day he received from the General Manager, in the name of the company, a cheque for £50 to patent the locking arrangement. A few weeks after the patent was offered to Messrs. Stevens and Sons for the sum of £100, but that offer was refused.

The difficulty of keeping locking apparatus in order had been referred to. He had had charge of the signals for the past six months on the Metropolitan railway, where, he believed, the trains were more numerous than anywhere else, and at Moorgate Street Station, with 60 levers in one box, there had never been occasion to repair them in any way. It had been suggested that on busy days the locking was taken out. He could safely say that on a busy day that could not be done, as it would take two or three days to take them out. He therefore thought that more had been made of the difficulty of locking than there was any occasion for. He did, however, find fault with the way in which signal work was generally done. Sufficient care was not given to the quality of the material and the class of workmanship used; and a great deal of the difficulty with the signals was not in the locking, but in the rods themselves. There were two or three causes for this inferior workmanship creeping in. First, from letting the same class of work do for a point rod of 300 or 400 feet long, as for a rod of 3 or 4 feet long; also the rise in the extent of signal work was so sudden that the expense was looked at. Formerly, in the construction of a line, the cost of the signal was almost unnoticeable. About ten years ago the Engineer of the Great Eastern railway told him that if a junction with locking apparatus were to cost £400 or £500 they would be few and far between. This referred to a junction with 10 or 11 signals and 5 or 6 pairs of points. Another cause was the hurried way in which signal work was generally put up. As a rule, it could not be commenced until the other work was finished. It was often done in a great hurry. The Engineer was so anxious to get the line finished, and the signal work complete, that he overlooked quality of work; and the manufacturer and his men would generally condescend to overlook it, from the same cause. It was a common practice, when ordering sleepers and timber for railway work, to specify the quality, and whether creosote was to be employed or not; but it was a very uncommon thing to have the horsings, to which was fastened the crank which held the facing point, creosoted. Again, when iron was ordered for bridge work it was generally specified to bear so many pounds per square inch; but when rods were ordered to work points, it was unusual to specify what they were to be or what they were to bear. Again, when plate or bar iron was ordered, some particular brand was named; but when wire was ordered for signal work this was not always the case. Price generally ruled. The locking was so small an item, and gave so little trouble compared with the outside work, that he should like to see more attention paid to it; and then he was quite certain that, instead of the complication of signals being, as it was called by some, a drawback, they would have great security with very little trouble.

Mr. Allport said the object of the discussion seemed to be to bring before the Institution the various patents for working locking apparatus and signals. Some of the remarks had surprised him, and he feared the tendency of the present day was so to increase the complications of these things, whether by electricity or by sound, that it would be almost impracticable to work railways, unless a stop was put to the introduction of many of these inventions. He understood there were ninety existing patents, and was sorry to hear the number was likely to be still further increased. With regard to the block system, the Midland railway was, if not the first, certainly one of the first to introduce it, nine or ten years since, on their main line. He did not approve of some of the observations as to the system of blocking between stations. In the case suggested, the distance signal at B ought to be a sufficient protection between A and B. He could not sufficiently impress upon those in charge of railways the importance of disciplining the drivers in attending to signals, because he contended that the block system, or any other system, ought not to supersede the necessity of the engine-man attending to the signals. Whether a train was running in foggy or in fine weather, an experienced engine-driver knew pretty well where he was; he knew when he approached a signal, and that a distance signal ought to stop him. There was a general feeling amongst engine-drivers that they need not look out, as other people were taking care of them; and the more this was the case the less care would they take of themselves. He contended that a perfect block system should be maintained, and that when a train had once passed the home signal at B, the signalman should keep his distant signal up until he knew that the train was beyond reach of a second train approaching. That rule should be rigorously observed on all lines, and it ought to be sufficient to secure safety. It had been said that facing points were very desirable, so as to allow a slow train to get out of the way of a fast train, but he would never have a facing point into a siding if it could possibly be avoided. With the block system properly worked there ought to be ample time for any train to shunt from the main line into a siding in the usual way by the back shunt, without the danger of facing points. He objected to the introduction of third lines for short distances, because the additional junctions and facing points must necessarily increase the danger. No doubt the locking apparatus was a great improvement upon the old system; but it was a fallacy to suppose that it would altogether prevent accidents. This was exemplified at Syston Junction, where, for twenty-three years, with the old system, there had never been an accident; but under the new system, introduced at that junction three years ago, one of the most serious accidents took place that had occurred upon the Midland for some considerable time. That accident happened simply because the man was some distance off, and could not see the point under his control. He thought it would be dangerous to depend upon electricity for working the block system at intermediate points, with stations 5 miles apart and a crowded traffic; and that it would be far better to block the whole 5 miles.

Mr. Findlay, manager of the London and North-Western Railway Company, stated that the block system had been adopted on about 800 miles of the 1,630 miles of opened line belonging to that company, and that it was to be extended to the whole of the main line, including also the arrangements for the interlocking of the points and signals in terms of a promise made to the Board of Trade, in common with others of the leading railway companies. Many of the officers of the company held the permissive system, which was first adopted on the London and North-Western railway more than twenty years ago, to be a good one. There were 135 miles now worked according to that system. The company employed 40,000 men, 16,000 of whom were specially engaged in working the traffic. There were 1,600 engine-drivers and 2,000 signalmen; and on their selection and training safety largely depended. The block system on such lines as the London and North-Western meant more sidings, more men, more signals (and he was not prepared to say that an increase in the number of signals was always an addition to safety), and to a great extent a reconstruction of the accommodation works at the principal stations.

Curiously enough, the system had developed a class of accidents not known before. It was impossible to secure perfect safety under any system; probably the block system, which was more expensive and complicated than the one it superseded, interfered too much with the personal responsibility of the drivers and the signalmen. The engine-drivers of the fast and express trains had, in a memorial to the directors, expressed their doubt as to the additional safety of the system. Certainly many modifications and improvements would be required before it attained anything like perfection. The qualifications now required on the part of signalmen were greater than ever; they must know something of mechanics, understand telegraphy, and be able to read and write.[1] In addition to the 2,000 men actually employed, an extra staff of signalmen to the extent of 10 per cent., to fill up vacancies occa-

---

[1] MEMORANDUM AS TO PRACTICE ADOPTED BY THE LONDON AND NORTH-WESTERN RAILWAY WITH REGARD TO THE TRAINING AND RELIEF OF SIGNALMEN:—

(1.) No man is allowed to take up regular duty as a signalman until he has had at least a fortnight's training at the post for which he is intended, his pay during that time being passed as extra.

In cases where men require a longer training owing to the difficult nature of the duties, or from other causes, the fortnight is extended, frequently to as much as six weeks, under the authority of the Chief Traffic Manager.

(2.) At the expiration of the training period, and before the man takes up duty, the Superintendent of the district must forward to the Chief Traffic Manager a form, signed by himself, certifying the man as to—

(1.) A knowledge of telegraphy.
(2.) The working of semaphore and other signals.
(3.) The company's rules.
(4.) Reading and writing.
(5.) Sight and capacity for judging distance.
(6.) Ability of distinguishing colours.

(3.) For the purpose of relieving the men on Sundays and during meal hours, and of providing for cases of sickness, the company employ a staff of about 10 per cent. extra signalmen, who are termed "porter pointsmen," and who when not employed in these duties are utilised on the platforms. Practically, however, it is found that the men are almost entirely occupied in relieving the various signal posts—when so engaged they are allowed the same pay as the men they are relieving, and when sent away from home they are allowed expenses in addition.

(4.) In addition to the appointment of the porter pointsmen, at the smaller stations, one or more of the porters are trained as signalmen—so as to relieve the men at the boxes during meal hours and on Sundays.

(5.) At the most important posts the signalmen are relieved every eight hours, at less important posts, every ten hours; and at stations where the duties are not particularly onerous, every twelve hours.

sioned by sickness and other emergencies, was regularly engaged. No man was allowed to take regular duty as a signalman until he had had at least a fortnight's training at the post for which he was intended, and the time was often extended in special cases to six weeks. A certificate was also required from the superintendent of the district stating that the man had a knowledge of telegraphing, of working semaphore and other signals, of the company's rules, and of reading and writing, the capacity of judging of distances, and the ability to distinguish colours. At the most important posts the signalmen were relieved every eight hours, at less important posts every ten hours, and at stations where the duties were not particularly onerous, every twelve hours. There was an accident and a provident society among the men for relief in case of sickness or death. It was managed by the men themselves, and the company contributed to its funds £3,000 or £4,000 a year. The interest which the men took in their work was remarkable. Not long since a foreman at Bolton had his shoulder dislocated, and was taken home and ordered to be kept quiet. Towards seven o'clock the next evening—he was accustomed to night duty—he said to his wife, "Eh! lass, aw canno' stay here; they canno' get on without me; aw mun go yonder;" and he dressed himself and went to his accustomed post; but had not been there an hour before he was knocked down and lost his leg in the performance of his duty. No soldier in the battle-field showed greater courage or self-sacrifice than some of these men, and he wished to bear the highest testimony to the good conduct and discipline of all the servants acting under him, and to railway servants generally. Signal-boxes of all sizes had been erected. One at Edgehill, near Liverpool, had eighty-four levers. It was desirable to avoid such large constructions whenever it was practicable. That at Edgehill could not be worked without announcing the arrival of the trains by telegraph. In working telegraphic gongs were more to be relied upon than the mechanical gongs first introduced. The mode of working in fogs and snowstorms had received great attention. Fog-signalmen were appointed to repeat the signals, and the company had an arrangement by which the station-masters and traffic inspectors obtained the names and addresses of the platelayers and other persons connected with the line who had posts assigned to them for the performance of that duty. Each man was provided with a great-coat; and if he was on duty more than six hours, he received refreshment. In case of fog or snowstorm the engine-driver had to pull up at the signal, and ascertain personally that the line was clear. The following were extracts from the official circular of instructions to station-masters and others in the case of fogs and snowstorms: —

"Station-masters must arrange with the traffic inspectors to have the names and addresses of the platelayers recorded at their stations, and must come to an understanding with the ganger of the district as to the positions on the line which are to be occupied by the respective platelayers in case of fogs or snowstorms, coming on by day or at night, and also as to their relief at proper intervals should the fog or snowstorm continue.

"If the fogmen are out more than six hours, arrangements must be made for furnishing them with the needful refreshments.

"On a fog or snowstorm coming on suddenly, and the fogmen not having taken up their positions, enginemen are instructed to stop at the main signal cabin and ascertain whether the section in advance is clear.

"*During foggy weather or snowstorms, when a train or engine has stopped at a station, or is shunting into a siding under the protection of the main and distant signal, the signal 'line clear' must not be sent to the block station in the rear until the train or engine has proceeded on its journey, or has shunted into a siding clear of the main line.*

"During frosts or sudden changes of temperature, men in charge of points and signals will be held responsible for having them examined by the platelayers or ganger to see that they work correctly, and that the expansion or contraction of the rods and wires has been properly adjusted by means of the regulator; and in addition to this, it will be the duty of the signalmen, when going off and coming on duty, to ascertain that the points, signal lamps, and arms are working correctly in accordance with the movements of the levers.

"Care must be taken after heavy falls of snow to examine the working of the exposed portions of the apparatus in connection with the signal posts, in order to see that no obstruction has been caused by the accumulation of snow, so as to prevent the proper action of the arms and lamps.

"During snowstorms the platelayer who is employed to repeat the distant signal must look to this; but if no fogman is employed, the ganger on duty must do so while the snow, or its effect, continues."

From the large increase that had taken place in the traffic of the railways generally, it would be impossible now to work the lines on the old time system. He admitted that the block telegraph and the interlocking of points and signals were a necessity under the present conditions of the traffic, but under the pressure that had been brought to bear by public opinion, both had been adopted too hastily, and both were in his opinion capable of improvement and simplification.

Mr. Francis Fox, of the Bristol and Exeter railway, remarked, that although he represented a line of small length and traffic compared with the London and North-Western railway, yet on it ran the fastest trains in England, and probably in the world, and it was worked throughout on the absolute block system. The valuable and admirably illustrated Paper would assist Engineers of railways in the selection of suitable interlocking apparatus, without which the sanction of the Board of Trade could not now be obtained to the opening of a new line, or of a connection with an existing passenger line. Messrs. Saxby and Farmer generally performed their work in a most efficient manner, being well aware of the requirements of the Board of Trade, and understanding the subject of interlocking thoroughly, which had now become quite a science. Mr. Poole's apparatus appeared to be a feasible mode of effecting what was accomplished by the catch-rod system, and it was under trial on the Bristol and Exeter. He was surprised to find railway managers of high position and experience preferring to trust to a man's intelligence rather than to machinery. It was impossible, in his opinion, for intelligence alone to meet the requirements of the present day without the aid of machinery. He advocated the combination of the two, by the adoption of efficient machinery under the control of intelligent signalmen. It would not be possible to work large stations with safety without a concentration and interlocking of signals. The great value of the interlocking system was that it rendered it exceedingly difficult for a man to produce an accident by a temporary loss of self-possession, to which the most intelligent signalmen were liable. Some of the requirements, however, of the Board of Trade he thought carried the system too far, and rendered it very difficult to work the traffic; but the inspectors were generally willing to relax the requirements when shown to be productive of serious inconvenience. The interlocking system had also the merit of economy, it being obviously more economical to employ concentrated effort than effort distributed over a larger area. The old-fashioned disc and cross-bar were still in use on the Bristol and Exeter. They had the advantage of being more readily seen from a distance and of being always positive in their indications, giving no negative signal whatever. The semaphore had certain obvious advantages, such as that of placing signals on the same post for trains in different directions. He did not at all approve of "caution" signals.

They were indefinite and led in practice to various degrees of speed; but there could be no misapprehension of the meaning of "danger" and "all right" signals. He had invented an arrangement by which the disc and cross-bar were pivoted on one bar; and instead of turning round horizontally, they merely turned a quarter of a circle. They were found easier to work at distances of half to three-quarters of a mile. He approved of the regulations which compelled an engine-driver to pull up at the distant signal, and proceed cautiously to the home signal. He agreed in the objection to facing points; they were at best but disagreeable necessities, and should be avoided wherever it was possible. There were several difficulties that had not yet been overcome in the working of facing points by the interlocking apparatus, such as the expansion of the rods, and the necessity for accurate fitting in the bolts of facing-point locks, as the slightest error in fitting might lead to a serious accident. Greater simplicity in the apparatus was still most desirable. The absolute block system was introduced partially on the Bristol and Exeter line in 1861, and entirely throughout the line and branches in 1866 and 1867, no permissive block system being in use. Special regulations were adopted for working single lines. The system was strongly objected to by the then traffic officers of the railway, as being likely to lead to obstruction to the traffic; but it was now approved by all the officials, and was found to facilitate greatly the punctual working of the line. Formerly on that line, and probably on many other lines, a sort of "hit and miss" system was often adopted in the starting of the trains; but now every irregularity was booked. The adoption of the block system had prevented the recurrence of a class of accidents to which they were previously liable, viz., that of collisions between trains following each other on the same line. The signal huts were 2 miles or 2½ miles apart from each other, but in some cases the distances were much shorter. Great care was taken in the selection and training of the men; for the block system, if worked at all, should be worked thoroughly well. The system was also found useful in other ways, such as in enabling the signalman to send forward an intimation of the loss of a tail-lamp to a train and the like. He did not approve of the automatic electric block system, preferring that the control of the signalling apparatus should rest with an intelligent signalman. No shunting was allowed to take place on the Bristol and Exeter line, at stations through which trains passed without stopping, within five minutes of the advertised time of passing. The station-master had to enter the time at which each train ought to pass, and the time at which it actually passed, and had to sign his name as a witness of the fact. Many serious accidents might, in his opinion, be prevented by the general adoption of such a regulation. There were between twenty and thirty trains daily each way on the Bristol and Exeter line; but on portions of the line the trains were more numerous. In certain cases where a siding occurred between two ordinary block stations, rather than run any risk, an additional hut had been erected, and the junction of the siding had been worked as a block station.

Mr. Siemens said it was now generally conceded that the block and interlocking systems were conducive to the safety and development of railway traffic. Nothing could exceed the ingenuity displayed in the contrivances exhibited; but he observed that the electric telegraph was left out of the interlocking arrangements which had been brought forward. It was used only as an auxiliary to signal trains from station to station, but it formed no part of the interlocking system. In Germany and Belgium an interlocking system had been adopted lately with most satisfactory results, in which the three elements of the switch, the optical signal, and the telegraphic signal were combined into an automatic system; so that it was impossible for a train to leave a station, for the optical signal to be raised for its departure, and for the switch to be put right, until the telegraphic signal had arrived from the next station to say that the line was clear. He thought that no interlocking block system could be looked upon as safe and complete unless it combined the three elements alluded to; and he was strongly of opinion that a block system, if adopted at all, should be made absolute and complete, and not permissive as had been advocated in the course of the discussion.

Mr. Fox, through the Secretary, desired to add the following remarks by way of explanation:—He did not wish to be understood as objecting to automatic electric signalling, if used in conjunction with the employment of intelligent signalmen. In illustration of this statement he might mention that he was introducing electric repeaters for distant signals, to show in the signal-hut during foggy weather the actual position of the disc and crossbar signal, whether at "all right," at "danger," or (owing to the expansion or contraction of the signal-wire) in an intermediate position. He was also adopting an electric indicator for the points of self-acting switches situated at the end of loop-lines on single branch lines, too far from the signal-hut to be safely actuated by point connections, and which consequently opened with the passage of the train from the main line to the branch, and closed for the trains from the branch to the main line. If from any cause the switch-point should not fall quite close to the stock rail, electric contact was broken, and a bell was set ringing in the hut, giving notice of the fact to the signalman, who would thereupon put on and keep the up-branch signals at "danger," until the defect had been remedied. Referring to the cases of sidings joining the main line at places situated between ordinary block stations, it appeared to him that as at all important sidings a man was usually stationed, the proper course was to convert the junction of the sidings into a block station and work it as such. On the Bristol and Exeter railway where sidings situated intermediately between block stations joined one line only, the whole section of that line was blocked, until the train doing work at such siding had passed into the succeeding section. In order to insure that two trains should not be in one section at the same time, starting signals worked in connection with the block system were fixed at the forward end of every block station, and the rule was stringently enforced that "line clear" should not be given from box B to box A until the whole of the train had passed beyond the starting signal into the section B to C, or had been shunted into a siding; and a white target at the tail of every train enabled the signalman (as well as the platelayers and others) to see that the entire train had passed. Allusion had been made to the danger of giving "line clear" from B, at a junction with a branch line, to A on the main line and to C on the branch, at the same time, and that under such circumstances the ordinary signals were the only protection against a collision at the junction. This difficulty was met on the Bristol and Exeter railway by a positive rule that all branch trains should stop before entering the main line and before leaving the main line for the branch.

Mr. W. H. Preece said he had been for many years engaged in the application of electricity to the working of traffic upon railways, and could therefore speak from some experience. Twenty-one years ago he was employed by Mr. Edwin Clark in carrying out what was now known as the Permissive System, and eleven years ago he presented to the Institution a Paper[1] which performed to electric signals at that period the same function which Mr. Rapier's Paper had now performed to fixed signals. The working of railway traffic was fast becoming a science, and a science based, as all sciences should be based, on experience and

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxii., pp. 167-192.

observation. It was a pure example of the doctrine of "evolution," and the principle of the "survival of the fittest" was well illustrated in many of the systems illustrated in the diagrams. Each railway company had been working upon its own experience; and now the joint experience of the whole was being welded and moulded into general practice, and the result was shown in improved working. Statistics did not justify the general outcry against railway management. If the deaths that occurred in factories, or in the streets of London, were published by the press with the zeal that railway accidents were now made known, public attention would soon be diverted from its crusade against railway management. Railway managers and officials had acquired by experience a knowledge of the facts upon which the science could be based, but there was no literature of railway working to which others could refer. Data and authentic facts were required for those who were being educated for the future management of railways, and these were to be found not only in such papers as Mr. Rapier's, but in the reports of the inspecting officers of the Board of Trade. The object of the Paper appeared to be to show that the two great requirements in railway working were uniformity and simplicity. Uniformity was not yet obtained, for the same signals were used for different purposes, instead of being employed for the same purpose. Thus the semaphore when used as a home signal meant "stop;" as a distant signal, "Stop, but go on." The disc on one line meant "danger," on another line "safety." It must not be forgotten that simplicity meant comprehension. What was incomprehensible and apparently complicated to one mind might be simplicity itself to another mind. A signalman, confined in a cabin with nothing else to do but to work and watch a lever, must have a very dull comprehension if he did not thoroughly and speedily master what appeared to an occasional visitor the most complicated array of levers and switches. The importance of the introduction of repeaters had scarcely been dwelt upon sufficiently. Formerly the position of distant signals was fixed with the sole object of keeping them within sight of the signalmen; but the introduction of repeating signals had provided the means of fixing them so as to consider alone the attention of the driver. The effect of slack wires and the numerous causes which interfered with the due exhibition of the signal were compensated for, and the greatest confidence was given to the signalman in the working of the signals. The block system, as an abstract principle, simply meant that trains should be kept apart by an interval of space instead of by an interval of time; but there were innumerable methods of carrying that system into practice. The growth of the system had been slow, and, indeed, sudden changes were not desirable. Opportunities had been given to perfect the apparatus employed. But there were causes which interfered with its general introduction. On the South-Eastern line the system had been uninterruptedly in use for eighteen years; on the North-Eastern it was only just being introduced; on the North London it had been regularly worked for seventeen years; on the London and North-Western line it had only been introduced a few years. The slow progress of the system was perhaps, in a measure, due as much to prejudice as to ignorance. In a Committee of the House of Lords, recently appointed to inquire into the subject, a noble lord, the Chairman of a railway company, asked whether it was possible for little boys to play tricks with the block system, while two others endeavoured to show that the system was inapplicable upon a single line worked by a single engine! A railway official had also asserted that in such a case it would be an unmixed evil and a useless expense; and another said, that when the trains were a long way apart and were few in number the system was unnecessary. The fact was that in each of these cases the trains were kept apart by a space which was infinite. It was objected to the block system that it tended to impair the look-out of the driver, but this objection was as mythical as those adduced against the introduction of railways themselves. It was not to be supposed that when a driver received an "all clear" signal he buttoned up his coat, lit his pipe, and desired the stoker to tell him when they came near the next station. Drivers were as careful of their own lives as of those of the passengers under their charge, and there were many causes besides trains in front of them to occupy their careful watch. The historical "coo," broken rails, fallen signal-posts, detached goods, fouled lines, &c., would always remain to require their careful and incessant look-out. Moreover, practice and experience belied this objection. It was also suggested that the system increased the element of human fallibility by adding to the number of signalmen. Statistics had been given to show that the number of signalmen had been largely increased; but it had not been satisfactorily shown whether that increase was due to the introduction of the block system, or to the increase of the traffic. If the system were carried out in its entirety it would really lead to a diminution of the actual number of men employed at a given time, and it would materially lessen the anxiety and responsibility of keeping a look-out on the part of the signalman. Instead of confidence being impaired by mechanical appliances, he thought they tended to inspire confidence. Machinery did not work of itself; it was not automatic; it did not supply a substitute for manual labour. It introduced delay, but it could not favour accident; it reduced the liability to error, and had the advantage of never sleeping or tiring. It was objected that the block system did not afford perfect security; but its advocates had never contended that it did. Like other machinery, it was to some extent dependent upon the skill and attention of those who worked it. Care and attention were more than ever required on the part of those who worked it, but it involved less visual watchfulness. Bells and telegraphs supplied certain information, and freed the signalmen from the uncertain exercise of their eyes. All instruments were, however, dependent on human action, discretion. and judgment; and as long as drivers would run past signals, pointsmen pull over the wrong levers, not all the results of experience, the dictates of reason, the inventions of genius, or the skill of the engineer would prevent accident. The true working of the block system was essentially a question of discipline, and its proper maintenance was the result of supervision. The system had the advantage of affording freedom from anxiety. Some years ago the general manager of a railway company, after a series of accidents, had a bell placed in his house, and gave instructions that it was to be pulled day or night whenever an accident took place. At the same time he introduced the block system upon the line, and from that day to this the bell had never been rung. It avoided confusion of mind. The signalman in his box had nothing to do but to fix his attention upon the apparatus before him, and was in no danger of being distracted. There were, no doubt, some defects in the working of the block system upon various lines; but the system itself ought not to be made the scapegoat for the defects of the agents employed in carrying it out. Thus on some lines the objectionable practice was in use of blocking the line before the train was allowed to start, instead of the more natural method of blocking the line behind the train. The necessary result of this pernicious practice was frequently to secure two trains in one section at one time, and thereby to produce accident; and this must occasionally happen, on the doctrine of probabilities, on those lines which continued that practice. It compelled the true exhibition of signals, and thereby remedied one of the greatest causes of reckless driving. It increased the capacity of lines for the conveyance of traffic, as was indisputably shown in the cases of the North London and the Metropolitan railways, and it unquestionably expedited the conveyance of that traffic. By preparing the way for the passage of trains it stopped the nuisance of continuous and useless whistling. It had been stated that the permissive system was still employed to some extent on the London and North-Western line. That system was not introduced for the sake of safety so much as with a view of increasing the capacity of the line. The block system, to be properly worked, should be worked on the same principle as a distant signal. The speaking telegraph in connection with block signals he regarded as an unmixed evil. Its introduction was based on the assumed fallibility of the electric signals; but electric signals gave the least trouble, and worked the best of all the mechanical appliances on railways. Old modes of telegraphing were now giving way to improved systems, based upon the number of beats upon a bell and upon variations in sound. He thought the bell communication between cabin and cabin answered all the purposes which were supposed to be fulfilled by speaking telegraphs. It had been objected that six beats upon the bell indicated one thing, and three beats repeated twice indicated another, and that errors might arise from this identity in the number of beats. There was, however, as much distinction between the two signals as between the words "president" and "secretary." He could see no reason why the block system should not be made compulsory. Where the traffic was light it could be easily carried out with existing apparatus; and as the traffic increased the company had the means of bearing the additional expense. When the system was once introduced upon the main line, there was no difficulty in establishing it upon the branches; and unless the railway companies voluntarily adopted the system, Parliament, as the exponent of public opinion, would probably force them to do so.

Mr. Johnson explained, by the aid of diagrams, the mode of working the block system on certain lines, and expressed his belief that the method generally adopted was an approximation to the permissive block system. He objected to giving "line clear" at a station until a preceding train had started from the station in advance. He also objected to giving "line clear" at a junction for two trains at the same moment.

Mr. W. H. Barlow said that the faulty details in the carrying out of the block system formed no good ground of objection against the system itself. He believed the system to be a good one; but he did not think that it would remove the inconvenience and danger attending the working of mixed traffic, the only cure for which would be the laying down of separate lines for fast and slow trains, which would give additional safety, and greater capability as to the amount of traffic. The block system could be readily applied to lines like the Metropolitan and others in the south, where the great bulk of the traffic consisted of consecutive trains on the same line, having no departure from the line except at stations; but it was very different in the north, where at almost every mile there was a branch or a siding. One great difficulty was to secure attention in foggy weather. The system at present adopted, of calling in the temporary aid of plate-layers, labourers, and porters to place exploding signals on the rails, was a rough expedient, defective in itself and unworthy of the age. The signal should be given on to the engine itself, and not placed upon the line. When mail-bags could be taken into and be delivered from the Post-office vans while running at high speeds, it was obvious that the simple matter of moving a signal placed on the engine was easy to accomplish; and its effect would be to obviate all those accidents which arose from drivers running past signals without seeing them. A diminution of speed would remove one of the great sources of accidents. When trains ran at thirty miles an hour, drivers were ordered to slacken speed to ten miles an hour in passing junctions and important stations. At this speed a man with a hand-lamp or a flag sufficed for safety. The present speed of forty miles an hour requires trains to be run through junctions and stations at speed. He did not deny the advantages of interlocking; but experience showed that, with all the elaborate contrivances and large expenditure in signal arrangements, the accidents were as numerous. That result he attributed to excessive speed over junctions and through stations, to the mixture of trains running at different speeds on the same lines of rails, and to the present imperfect system of signalling during fogs.

Mr. R. PRICE WILLIAMS said the history of the rise and progress of signalling as given in the Paper was exceedingly interesting, more especially as it showed, in a striking manner, that the improvements were but the natural consequence of the remarkable development of the railway traffic in this country. In the days when trains were few and the speed comparatively slow, the simple expedients alluded to for signalling trains were probably sufficient. When, however, the intervals between trains came to be measured by minutes instead of by hours, then those simple expedients could no longer be relied upon, and so by gradual steps the semaphore signal and the block system were arrived at. He considered that nothing short of a distinct space interval, with the additional provision, alluded to by Mr. Johnson, of a caution signal communicated to the station immediately in the rear of the blocked portion of the line would effectually provide for the safe working of the traffic. In confirmation of these views, he might mention that the jury in the case of the Euxton accident had just recommended that such a caution signal should in future be given.

The advantage resulting from the interlocking of points and signals had been questioned by Mr. Allport. However, as a practical mechanic, familiar with the construction and working of various interlocking systems, Mr. Price Williams considered that, with good workmanship and the use of sound and well-selected materials, which should alone be employed for such critical work, he saw nothing to warrant their not being most implicitly relied upon. In fact, he would as soon distrust the working of the complex machinery of a locomotive as that of the present admirable interlocking apparatus, within at least such reasonable distances as 800 yards. The effect of the alterations of temperature upon the long switch rods, which had been the chief obstacle in the way of their safe use, had now been surmounted by the simple expedient of the compensating bar. The beneficial results which had followed the introduction of the system of interlocking points and signals had been described by Mr. Fox. No greater contrast, perhaps, could be afforded than in the case of a roadside station Mr. Price Williams had recently had occasion to revisit after a long interval. There, instead of the point-lever handles—which he had remembered in former years scattered about the place, a stumbling-block and offence to all who unfortunately came in contact with them, and at the mercy of any one who, impelled either by malice or want of thought, chose to meddle with them—he found the switches all connected up to and worked from a raised signal-hut which commanded a complete view of the station and far beyond. No one, he thought, could fail to recognise in this case—which ten years ago was the ordinary type of a roadside station—the removal of a real source of danger in railway working. The Cannon Street Station signals might be mentioned as another striking instance of the beneficial results arising from the adoption of the interlocking system. Passing in and out of that station, as he had done during the last eight years, on an average twice a day, he could testify to the most perfect working of the system, under circumstances as difficult and complicated as it was possible to conceive; with a double junction at one end of a viaduct, and at the other one of the largest and busiest stations in the kingdom, with its multitudinous arrival and departure platform sidings, cross-over and through roads, &c., all controlled and worked from the signal-hut on the viaduct, and worked with the most perfect ease and safety.

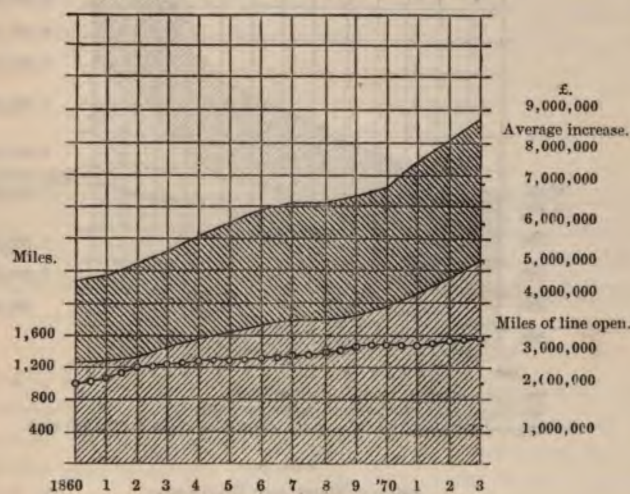
He had frequently had an opportunity of carefully examining the mechanical arrangements of those signals, and could bear testimony to the great simplicity of their working. He had noticed as many as four trains passing at the same time under the Cannon Street signal-box, and some of them traversing right across from the lines at one end of the viaduct to the arrival sidings at the other end of the station, and yet, to his knowledge, not one single accident had occurred there in the period referred to.

The question, however, to which he more particularly wished to draw attention was, how far the block system, with all the concurrent advantages of the interlocking of signals and points, was capable of meeting the future requirements of the constantly increasing traffic on the principal main lines of railway. In order more clearly to explain his views on the subject, he had placed upon the walls, with the permission of Mr. Oakley, a diagram (Plate 32), which was a graphic representation, or chart, of the working time-table of that portion of the Great Northern railway between London and Peterborough. It showed the times of departure from London, and the times of arrival at Peterborough and the intermediate stations during each four and twenty hours. He should explain that the thick black and the thin blue lines represented the coal trains and the slow goods trains respectively, the thick blue lines the fast goods, the light red the ordinary passenger, and the thick red lines the express passenger trains. It would not fail to be observed, that the express passenger trains intersected the slow trains at a number of points between London and Peterborough. Without the agency of the block system, it would be impossible for the necessary shunting of the slow traffic to be carried on with the freedom from risk of accident which characterised the working of the traffic on that line. A glance at the diagram sufficiently showed that already a good account was there given of the time during the four and twenty hours; and it was a question worthy of consideration how far, even with the aid of a really perfect block system, provision could be made for the future development of traffic. His belief was that if the time had not already arrived, it would soon do so, when, having regard to the rapid rate at which railway traffic was increasing, the fast and slow traffic on the principal main lines must of necessity be separated.

In illustration of the rate at which railway traffic was increasing, he might mention that the gross receipts in England and Wales had increased in the ten years, 1861 to 1871, from £24,021,928 to £41,383,065, or rather more than $5\frac{1}{2}$ per cent. per annum, a rate at which the entire traffic would double itself in every thirteen years. Figs. 6, 7, and 8 showed the receipts from passenger and goods traffic on three principal English railways, viz.: the London and North-Western, the Midland, and the Great Northern. The rate of increase of the passenger and goods traffic on the London and North-Western had averaged a little over 5 per cent. per

FIG. 6.

LONDON AND NORTH-WESTERN RAILWAY.

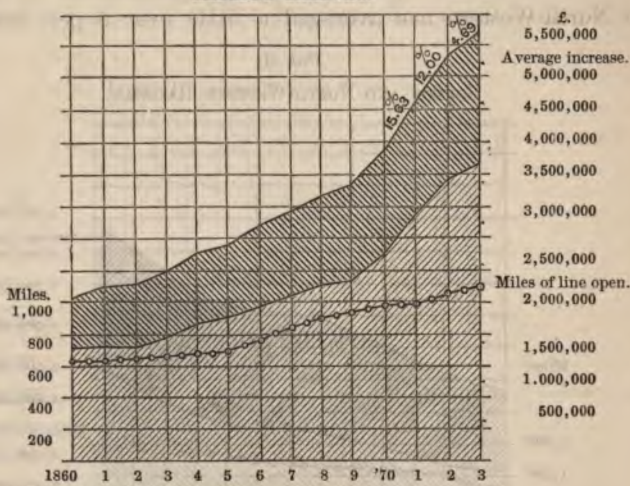


The lighter shading represents Goods traffic.
The darker shading represents Passenger traffic.
The average annual rate of increase of the total traffic is 5 per cent.

annum during the last thirteen years. This, however, scarcely gave a fair idea of the amount of the increase. He might, however, state that in that time the number of passengers had increased from 18,000,000 to 31,000,000, or at an average annual rate of increase of about 8 per cent.; in other words, the passenger traffic was doubling itself in every nine years. On the Midland and the Great Northern railways the increase of the traffic receipts was still more remarkable, averaging, in both cases, fully 7½ per cent. per annum; rates of increase which, if maintained, would double the traffic in ten years, and quadruple it in twenty years. It might be urged that in this increase of traffic no account was taken of the concurrent increase of the mileage of new lines opened during the period in question. That, however, had, he considered, very little bearing upon the question, since those extensions were of the character of small tributaries, which served but to add to the volume of the traffic upon the main lines. Timely provision, therefore, should, he thought, be made for this natural growth of traffic. From what had been said, it appeared that already the

Fig. 7.

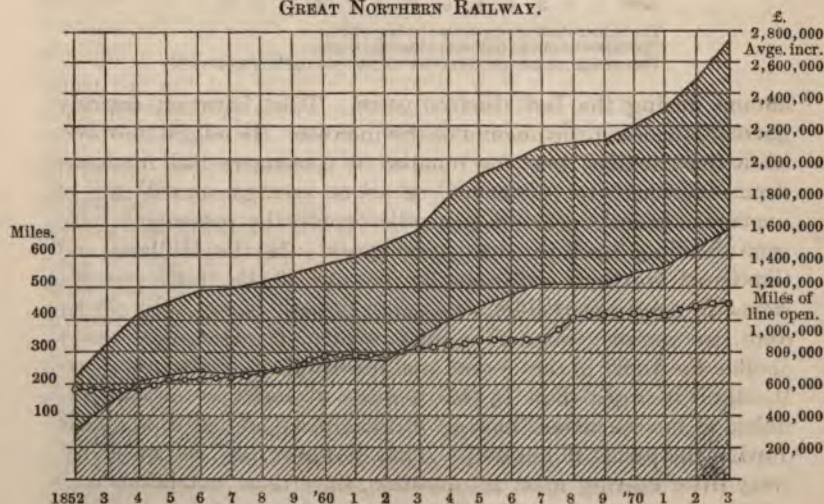
Midland Railway.



The lighter shading represents Goods traffic.
The darker shading represents Passenger traffic.
The average annual rate of increase of the total traffic is 7·74 per cent.

Fig. 8.

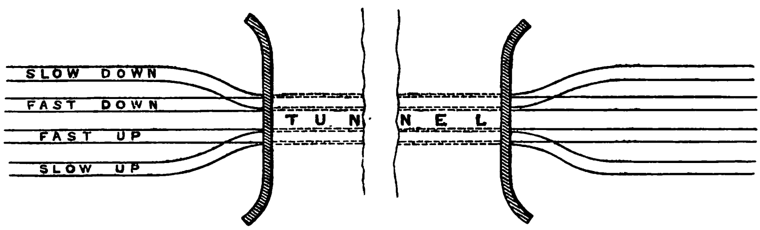
Great Northern Railway.



The lighter shading represents Goods traffic.
The darker shading represents Passenger traffic.
The average annual rate of increase of the total traffic is 7·49 per cent.

Midland Company was taking steps to provide for the increase of traffic by the construction of long sidings; but these sidings involved either the use of facing points, or the alternative of trailing points, through which the trains would have to be shunted, involving much loss of time, to say nothing of the risk. Pending the quadrupling of the main lines to meet the growth of traffic, he thought some such plan as he had indicated in Fig. 9, might be used with advantage, as a means of avoiding the necessity for either facing or trailing points; the long sidings being con-

FIG. 9.



tinued side by side with the main lines through the tunnel. One great advantage would result from quadrupling the lines at the London end of the principal railways, and the consequent separation of the slow from the fast traffic, that would be the simplification of the working of the interlocking gear, and the removal of that tendency to complexity which had been so much objected to in connection with it, as directly the slow and the fast traffic were worked on separate lines each line would have its own separate system of signals and points.

A great deal had been said and written lately with regard to the increase of railway accidents. He thought the rapid increase of the traffic had not been sufficiently taken into account in considering this question, as it followed that, whilst the same or even greater precautions might be taken, the tendency to accident must necessarily increase in a far higher ratio than the direct increase of traffic.

He was glad to be able to confirm the statement of Mr. Chambers as to the share which Colonel Yolland had in the discovery and application of the interlocking principle. He remembered that in 1857, when the Welwyn Junction signals were being put up, Colonel Yolland laid great stress upon the necessity for connecting the signals and the levers; and the repeating signal adopted there was, he believed, Colonel Yolland's own suggestion. It was a matter of regret that the distinguished officers of the Board of Trade, who might have greatly added to the interest of the discussion, were not present to state their views.

Mr. E. A. Cowper said he believed the method suggested by Mr. Price Williams for separating the two lines of rails by a few inches (although the trains ran over the same ground) was an excellent one for avoiding the necessity of facing points, and was adopted with good effect in the tunnels at Primrose Hill and Watford. He agreed that the commencement of interlocking dated from the time when Colonel Yolland and Mr. Gregory expressed their views on the subject, and he thought the complete interlocking system, insuring the safety of the signals and the switch apparatus, was largely due to Messrs. Saxby and Farmer. The apparatus as at present used, could not possibly give conflicting signals. As to facing points, with express trains running through them at forty miles an hour, in his opinion, they should only be used under exceptional circumstances. He thought something further was required in the way of communicating between the man on the road and the man on the engine in foggy weather, in addition to the fog signals which he had had the pleasure of introducing into the railway system. With respect to the calculation as to the cost of accidents, he hoped it would not be understood that the loss of life and misery produced by them were disregarded. He did not think shareholders would hesitate to sanction the small additional outlay of 0·5 per cent. for the sake of securing additional safety. But the best system would provide for the largest amount of traffic, and ought to be adopted, if only as a matter of economy. It was really a question whether there should be an increase in the number of signalmen, or a decrease in the number of the public. He was glad to hear the statement that some signalmen did not work more than ten, or, in some cases, eight, hours a day. He knew of cases in which they worked twelve hours, and when they left work they were often in a state of complete exhaustion. There could not be a better argument in favour of the block system than the diagram of the working time-table of the Great Northern railway between London and Peterborough (Plate 32); it was in fact simply an unanswerable argument for keeping the trains a certain distance apart.

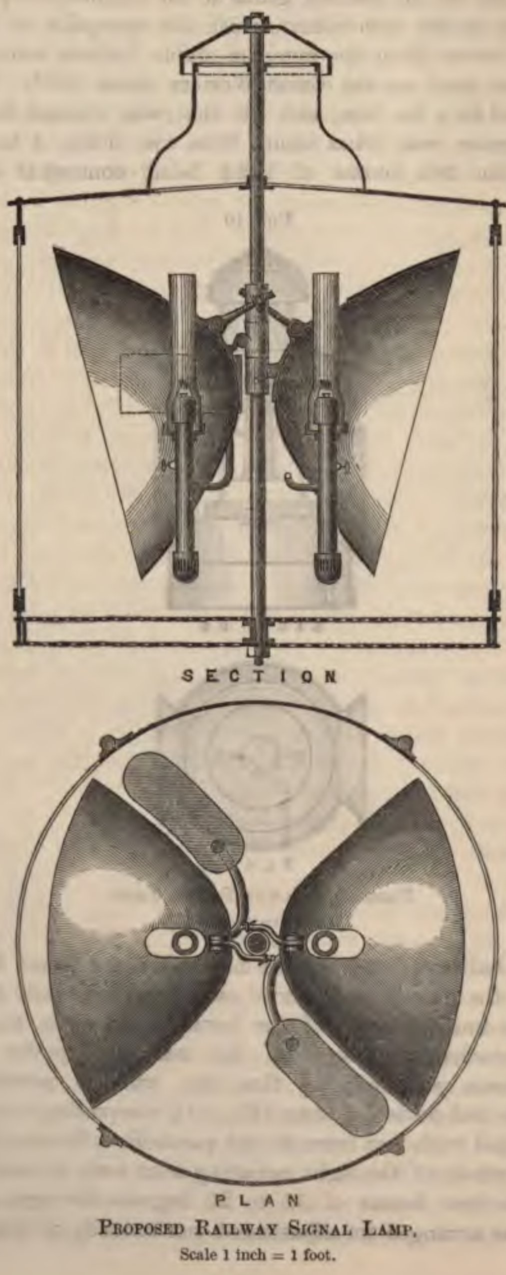
Mr. Jas. N. Douglass said he understood it had been intended to include in the Paper a chapter on the subject of signal-lamps, but that this had been abandoned owing to the length of the communication. He greatly regretted this, as railway signal-lamps were still very inefficient. The present lamp (Fig 10), which should be an efficient guide to the engine-driver by night in all states of the atmosphere, with the exception of thick fog, was little better than the common stable lantern referred to as having been used on the Great Western about 1837. The light was inclosed in a tin box, and all that was utilised for the intended purpose was what issued from two holes, 4 to 5 inches diameter, the two beams of light being somewhat condensed

Fig. 10.

Present Railway Signal Lamp.
Scale 1 inch = 1 foot.

by a glass bullseye fitted in each hole. He had found by experiment, that the maximum power of each beam was only four times that of the unaided power of the burner; and when the red and green spectacles were applied, the maximum power of each coloured beam was only $1\frac{1}{2}$ time the unaided power of the burner. He had devised a lamp (Fig. 11), comprising a cylindrical box, provided with two burners and parabolic reflectors, in which nearly the whole of the light radiating from each burner was condensed into two beams of 18 to 20 degrees divergence. Each reflector was arranged for adjustment horizontally or vertically to

Fig. 11.



Proposed Railway Signal Lamp.

Scale 1 inch = 1 foot.

meet any curvature in the line or elevation of the signal-post. The maximum power of each beam from this lamp would be about 120 times that of the unaided power of each burner. Therefore, assuming that the burners consumed collectively the same quantity of oil as the present lamp, the relative efficiency of the proposed and the present lamps would be as 15 to 1. The cost of such a lamp as he had described would be from £10 to £12. If economy of oil were a matter of primary consideration, he would suggest a plan which had lately been adopted with success at some English lighthouses, that of having two powers for each burner; a single power sufficient for a clear atmosphere, and a double power for thick weather. His remarks as to the insufficiency of signal-lamps would also apply to the roof-lamps of railway carriages: with the present lamps no passenger could read with any degree of comfort, although more than sufficient oil was usually consumed for the purpose.

Mr. Oakley said, referring to the diagram (Plate 32) representing the working of the trains of the Great Northern line between London and Peterborough, that the block system was adopted, together with the "in-and-out" system of telegraphing, by which each station had two advices of the approach of a train before receiving the "be ready" signal of the block system. For instance, in starting a goods train, it would be telegraphed to eight or nine stations forward; and each station, as the train passed, took up the tale, and telegraphed to two or three stations beyond, so that it might be known when the train would arrive, and that the line might be cleared accordingly. When the train was at the last block station the "be ready" signal was given, to which the reply was returned, "come on," or "stop." In order to afford the necessary facilities, there were twenty-two separate shunting sidings on the down line, and about as many on the up line, besides two lengths of a third line 5 miles each. A working time-table was supplied to every station-master, driver, guard, and signalman, containing a list of the sidings, so that it was known where a train could be safely housed in case of accident or delay. The other sections of the line were worked in a similar way. With regard to the observations as to the necessity for additional lines, he could only say that he should be happy to undertake to provide for double the present traffic over the same road without any difficulty. As to facing points, they were like good dinners—the fewer one had of them the better. When the facing point was opened for the main line, and the train had not to impinge on the tongue, no limit was placed to speed; but if the tongue was closed a reduction of speed was insisted on, since the point could not be so safe as the continuous rail, however well it might be locked. The method adopted on the North-Eastern line, at the suggestion of Mr. Harrison, the President, which method pinned the tongue at the extremity, appeared to him to be the nearest approach to safety. The point of the tongue was the weakest part, and it was to that that attention should be directed. With regard to signals at junctions, experience had shown that they ought not to be placed on one post. Each line should have a separate post, and the signal should be from 50 to 70 yards from the fouling point, so as to leave sufficient margin between the train and danger. It would, he thought, be found necessary to extend this practice to stations. These precautions were needed not so much to provide for a crowded state of the line as for an unusual or unexpected occurrence in the ordinary course of working. The training of signalmen was a matter of the greatest importance. They should be men of a peculiar class, who thought practically of nothing but signalling. A genius or an intelligent man might be wandering when he ought to be looking at his signal. With regard to fog signals, the regulations were printed and placed in every block box and at every station. The platelayers, who could not work in foggy weather, were told off to the different boxes when the fog began. It was the duty of the platelayer to go to the signal-post, and if he found the signal at danger to put down a fog signal, removing it only when the signal at the post was at safety. It was suggested that there should be a self-acting signal that could be put down immediately. Managers would be glad to consider any proposal in reference to that subject; but it should be remembered that to put down a fog signal at a signal post was, practically, to lessen the space between the signal and the station where the danger lay; for, ordinarily, a man saw a danger signal 300 or 500 yards before he approached it. That was the point to which attention should be directed—to provide something, say 1,500 yards from the station, which was simple, economical, and that could be depended on when used. It might be, as had been stated, that inventors were sometimes an infliction; but railways could only be successfully managed and developed by the combined efforts of the mechanic and the manager; and railway managers were under too many obligations to the inventive genius of their countrymen not to be grateful for it, and to desire that inventors would go forward in the same direction, in the full belief that they would find in railway managers ready acceptors of their methods.

Mr. J. G. Picking described, by means of a diagram, "Ager and Pickering's Improved means of Signalling on Railways" in foggy weather. To the side frame of an ordinary locomotive engine was attached a wrought-iron plate, extending downwards to within a few inches of the top of the rails, and also a few inches outside the metals. Near the bottom of this plate a small roller was fitted at a right angle, free, of course, to turn on its axis, and also to move vertically; in the latter case pushing up a small rod, which acting by cranks and levers, took direct hold of the spindles of the driver's whistle, and by means of a spring, locked it open, making it absolutely necessary that some act must be done on his part—the mere pressing of a button—to cause the whistle to cease sounding. Now, say 50 yards in advance of the distant signal was fixed either to the sleepers of the permanent way, or in brackets bolted to the rails, and free to turn on its lower and long axis, a steel yielding spring camber connected to the same wire and lever, or it could have a separate arrangement, working from the signal-cabin the ordinary arm or light. This bow, or camber, when vertical, had its crown slightly above the line of the bottom of the roller, fixed as described to the engine; but, as it was yielding, it never received a blow, however fast the train might pass over it, the only effect being to elevate (slightly) the roller, and open the whistle, &c., as described. This only happened when the semaphore, arm, or light was at "danger," and the driver was unable, from obscure or foggy weather, snow-storms, in tunnels, &c., to see a signal against him. Upon the whistle sounding he reversed the engine, applied the brakes; the guard was also aroused, and the impending accident was prevented. In the case of the permanent way being under repair, the superintendent had only to put one of these temporary cambers, say 100 yards on the advance side of the road under repair, and casualties to workmen would be prevented. The question of the cambers standing the speed of a fast train had been proved by the fact that they had been passed over by the engines of the London, Chatham, and Dover Railway, attached to their daily continental tidal trains now for three years, without the slightest appearance of injury.

Mr. Rapier, in reply, said, if any proof were needed that the signalling system was far from perfect, it would be found in the able observations made in the course of the discussion. The diagram (Plate 32) of the working time-table of the Great Northern railway was very valuable; and he might add that, but for the example set by Mr. Price Williams in connection with previous Papers, the present communication might not have been illustrated so extensively as it had been. Mr. Douglass was right in saying that there was great room for improvement in signal lamps. His suggested improvement was not a mere theory, but had been found a practical necessity, notably on the Great Eastern railway, which was specially subject to fogs. Mr. Siemens's proposal had received more attention on the Continent than in England. At present, signalman B informed signalman A that a train had passed or had not passed; but the new idea was that signalman B locked up signalman A, so as to take it out of his power to signal any additional train forward. It had been urged by Mr. Johnson that at a junction the signal "line clear" ought not to be telegraphed back to both lines at the same time; while, on the other hand, Mr. Allport had expressed his preference for the plan which did not give the driver too much information at once, and suggested that permission to leave a block station and approach a junction ought to be taken strictly as permission only as far as the distant signal, and that giving them too much warning was as bad as giving them too little, as that led to "nursing" the drivers. Both these views were the result of long practical experience, and formed one of many illustrations of how carefully all these things were considered by railway authorities, and how difficult it was to arrive at hard and fast lines on many points. With regard to audible signals, again, objection had been taken to "nursing" signalmen and drivers; but a foggy day was an exceptional period, when he thought some additional care ought to be taken. If a driver could not be signalled through the medium of the eye, signals might be used which should appeal to the ear. He thought it would be most objectionable to give an audible signal in all cases, but it was desirable to have the power of doing so in cases of fog. If it was desired sometimes to give an audible signal and sometimes not, a special mechanism must of course be adopted, and then it would be a question whether the advantage gained was sufficient to balance the inconvenience of having appliances whose use was to be only occasional, and which might, therefore, be out of order when their application was required. Mr. Barlow's pertinent question as to the case of a siding between two block stations raised a point that ought to be clearly understood. The block system was often blamed for faults not its own. Expression was frequently given in the newspapers to inconsistencies of this sort, "This accident happened in consequence of the block system; the home signals were at danger, but the distant signals were at safety." Now that was not the block system, and it was absurd to call it so. Similarly, if a siding were interposed between two block stations, and could not be fully controlled by either, that was not the block system. The only safe way in such a case was to constitute the siding itself a block station. To this course it was objected that this would lead to a great multiplication of block stations. To meet this objection he could only urge, that it was now found necessary to guard every point of connection with the main rails, and if it were necessary to have the profit and advantage of more communications with the main rails, the expense of making them reasonably safe ought not to be feared. The danger arising from complication was certainly less with three block stations than with two block stations having a siding situated somewhere between them. It had been said, that on busy days at the times of fairs and races, the locking gear was often taken out and no harm done. But on very busy days, when there was a congestion of traffic, accidents rarely happened, because the trains were generally travelling at a slow speed at all stations or points of junction, and, in fact, were often within sight of one another; every driver knew that he was acting on his own responsibility, and went as far as he could see and no farther. Accidents more frequently happened from exceptional circumstances on ordinary days. To attempt to carry out the block system without the interlocking system was hardly fair to the unfortunate signalman who had to work it. With reference to the machinery adopted for this purpose, he could say that the railway managers had plenty of choice; there being now several very good machines for the purpose; but in almost all of them the inventors appeared to have overlooked the great axiom in mechanics that the great point to be attained in any contrivance was simplicity and fewness of parts. In many of the machines now in use there were from a dozen to fifty pieces of mechanism between the lever which locked and the lever locked by it. It was impossible for two levers to lock each other, and yet have independent motion, without the intervention of some part or parts, but if a lever was made to lock another by the intervention of only one piece between them, then the locking was performed undoubtedly by the least possible number of pieces. Further, if the same additional piece was made to do duty for several levers, such mechanism must as a natural consequence be very simple. It was with this view that he had contrived the locking apparatus which had been described, believing that the machine with the smallest number of parts would be found to be the most practical in use.

With regard to future expectations of traffic, and the probability of the railways being able to cope with it, by means of improved systems of working, some conclusions might be arrived at by taking into consideration the changes that had taken place in the traffic in the streets of London. Fifteen or twenty years ago, when the traffic in the streets of London was far less than it was now, the delays were far greater. Now, at all important points of junction policemen were stationed to control and direct the traffic, and the drivers of all vehicles now understood that the signal of a policeman's uplifted hand was a stop signal which must be obeyed; and the result was that method and system were able to work a greatly increased street traffic, almost entirely free from those vexatious delays which used to take place. By comparison, the traffic of the railways at present with what it would be twenty years hence might be said to be as the traffic in the streets of a market town was to that of London. In his opinion the true solution of the problem would be found to lie in adopting that system of working which should make the railways capable of the greatest amount of dividend-paying work.

With regard to the question of speed, that had long since been settled; and it would be useless to attempt to go back to the old rate of speed. He ventured to say that, with a sufficiently long purse and a fair prospect of dividends, there were many engineers of experience who would not hesitate to make a railway for trains to travel at the rate of 100 miles an hour. There was no physical impossibility in the way; but it was a cardinal axiom of the profession that all outlay should be remunerative. He, therefore, had great hesitation about such proposals as doubling the lines, building additional viaducts, and erecting costly works. He thought that every cheap expedient should be exhausted before any such extravagant luxuries were indulged in. These might be obtained in the course of the next twenty or twenty-five years; but there would be still the necessary crossings for the transference of trains from one line to another, and new trouble would then arise in getting the fast and slow traffic across each other at stations and junctions. There was no panacea, no palladium, no Utopia, and they must, therefore, work, and work, and still work on.

Mr. Harrison, President, said he was sure all would unite in giving their best thanks to the Author for the valuable Paper and Diagrams he had contributed, which would be preserved in the Minutes of Proceedings, and be a valuable record of the rise and progress of railway signalling. With regard to speed, he was not in the slightest degree afraid of it. As a rule, express trains were the most punctual and the most safe. It was not that they ran faster, but that they stopped at fewer stations, and, carrying fewer passengers, they were less liable to detention. With reference to the diagram exhibited by Mr. Price Williams (Plate 32), it was a most complete method of showing the day's work of a railway, and he had himself been accustomed to employ a similar plan for that purpose. When managers objected to the use of such diagrams, he could only conclude that they did not understand them. As to accidents, he believed it would be found that most of them, although perhaps occurring at different places, arose from very similar circumstances. A map, on the principle of a wreck chart, showing the accidents arising from year to year, and their positions, was a most useful help in investigating the causes, and would indicate that most accidents took place at junctions and at stations. Such a map would show the railway companies the special points to which attention should be paid. The question of facing points had been alluded to; and indeed there was nothing more urgently needed than a complete facing point, protected by wedges, or by any other mechanical contrivance which would enable trains to run over it at full speed. He believed the time was not far distant when that would be accomplished. He did not pretend to say what would be the best plan. He had successfully adopted for some years a plan of his own; but he was not prepared to say that it might not be greatly improved upon. He had so great a horror of facing points, knowing the accidents occuring at them, that on the line between York and Berwick, for many years, except at the stations at Darlington and at Newcastle, there were only three facing points in a distance of 160 miles; but the increase of traffic had of late necessitated the introduction of a few more. If a safe facing point were really attained, nothing would more facilitate the passage of a large amount of traffic over the lines. With regard to fog signals, no system he had seen could be said to be perfect; and as many accidents occurred during the foggy season, it was obvious that the question was one of the greatest importance. Not long since, on the Great Northern railway, during a dense fog for twenty-four hours, it was found necessary to stop the goods traffic over a portion of the line. In reference to the block system, he thought it had been lately forced upon the companies rather more rapidly than it was possible to provide efficient means to work it. In former times nearly all the pointsmen and signalmen were taken from the class of plate-layers, or guards, and they had a complete knowledge of the working of railways. But when a company was called upon to provide suddenly 500 or 1,000 men for signalling, it was impossible to find the requisite number of properly qualified men. The situation—being shut up in a box eight hours continuously, and not to speak or be spoken to—was a most unpopular one; plate-layers would not willingly go, and the men engaged, though they might go through a month's training, could not be regarded as at once efficient. He did not say that time would not overcome the difficulty, but a special class of men would have to be trained for the work. Signalmen were liable to fall asleep, and the occurrence was not a rare one. He had known a dozen trains, stopped at different intervals because a signal could not be obtained from the station in advance. A fireman had to be sent on, perhaps a distance of 3 miles, and he found the signalman fast asleep. Again, a signalman, on awaking from his slumbers, might forget what train had passed, and give a wrong signal; and he might admit a train within the block when there was another train on the line. These things actually occurred, but were not necessarily brought before the public; and such errors, resulting from human fallibility, must be expected to give rise to a number of accidents. As to the cost of the block system, he felt sure that if a perfect system were brought before railway directors they would not hesitate to adopt it; but he thought the estimate of the Author fell considerably short of the mark, and that many things that added largely to the cost had not been taken into account. The suggestion of Mr. Douglass, with reference to lamps, was of considerable importance; for, as Engineer to the Trinity House, his attention had been for years devoted to the subject, and he had produced lamps of the greatest possible power. It had occurred to Mr. Harrison at the time that some modification of the Trinity House Lamp of the First Order, exhibited at Mr. Hawksley's Conversazione in 1873, might be adopted for railways, which would add alike to the comfort and the safety of the passengers.

April 14, 21, and 28, and May 5, 1874.

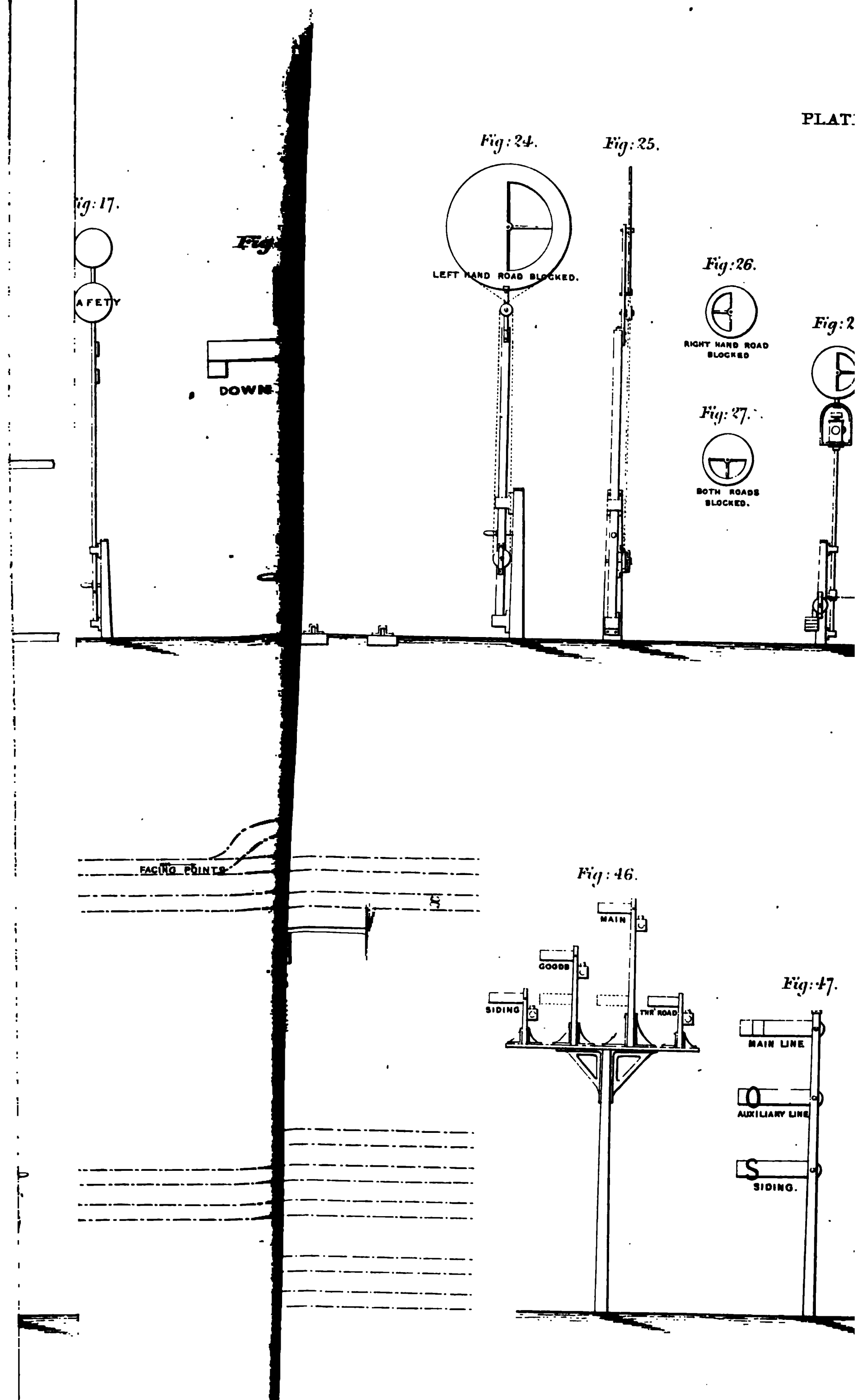
THOMAS E. HARRISON, President,

in the Chair.

The discussion upon the Paper, No. 1,393, on "The Fixed Signals of Railways," by Mr. Richard C. Rapier, occupied the whole of these evenings.

LONDON:
PRINTED BY WILLIAM CLOWES AND SONS,
STAMFORD STREET AND CHARING CROSS.

PLAT



THOS KELL, LITH. 40, KING ST COVENT GAR