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 $3\frac{1}{2}$ 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

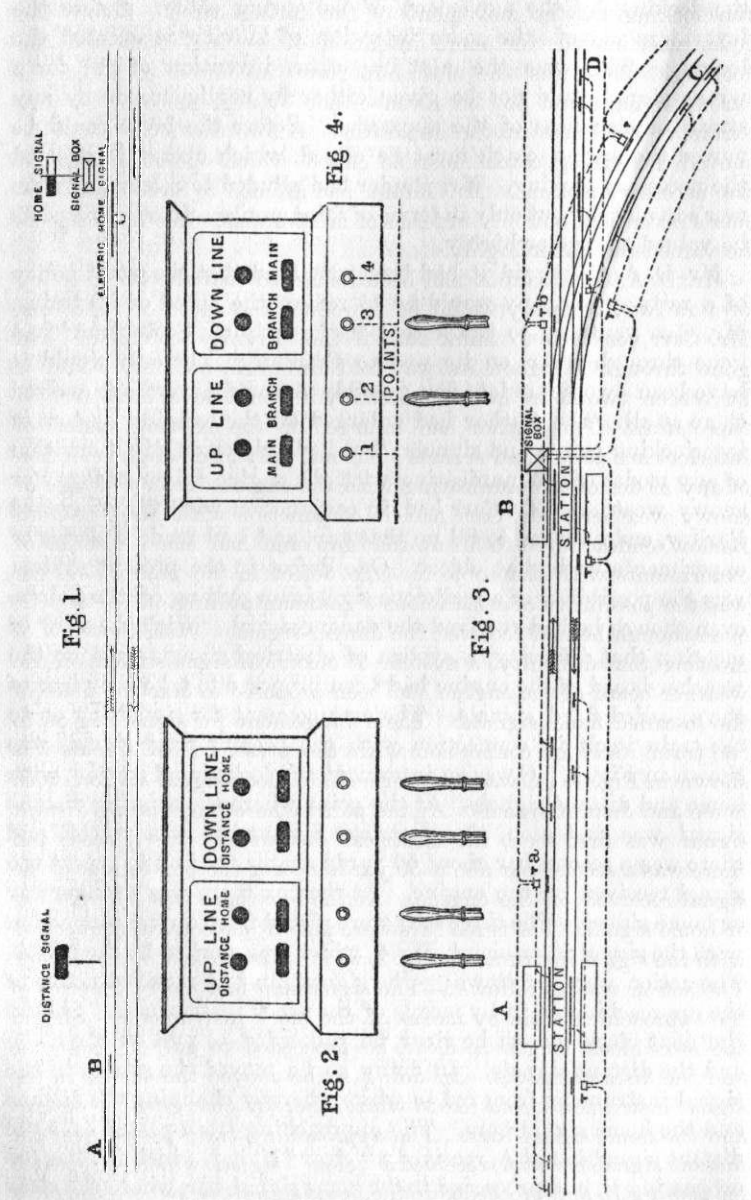


Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

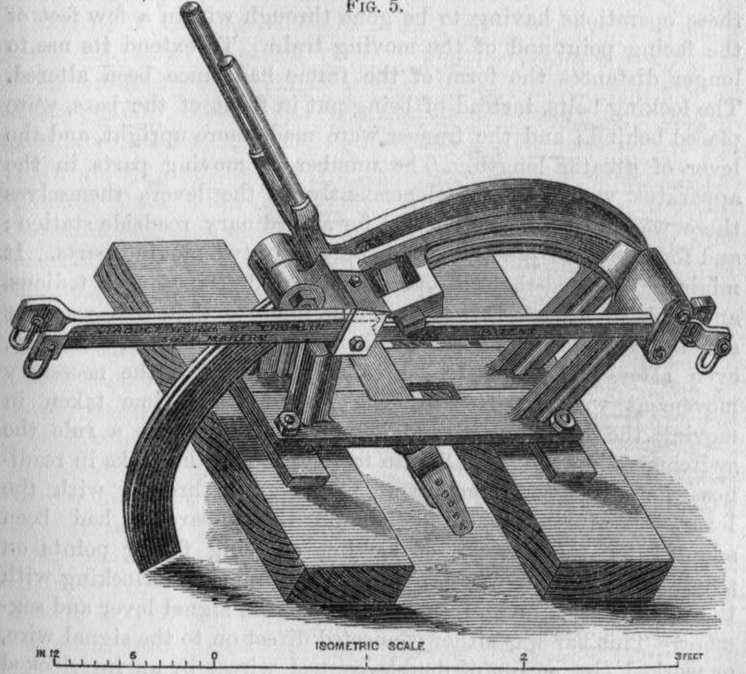
signalman left the signals at danger, when the electrical signals also remained at danger. It would be observed that, by means of the repeater, the signalman knew directly the train had come within the distant signal, and could therefore at once cover it. Fig. 3 showed the automatic arrangement for a 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 $2\frac{1}{2}$ 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.

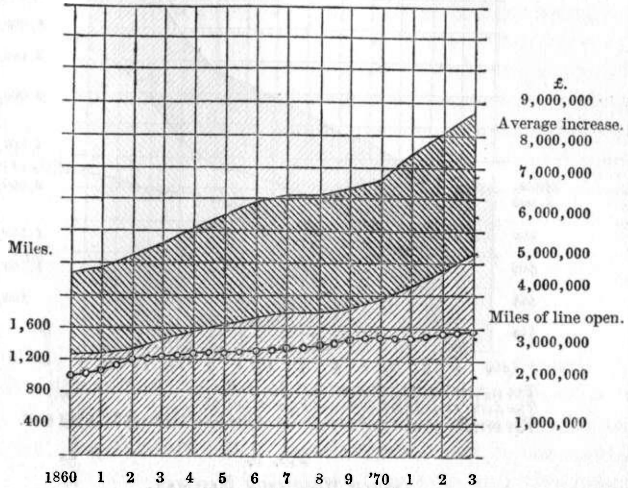
The question, however, to which he more particularly wished to draw attention was, how far the block system, with all the concurrent advantages of the interlocking of signals and points, was capable of meeting the future requirements of the constantly increasing traffic on the principal main lines of 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.

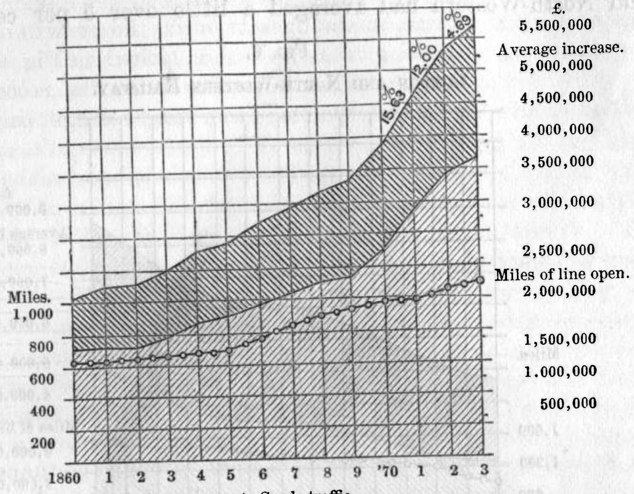


The lighter shading represents Goods traffic.
The darker shading represents Passenger traffic.
The average annual rate of increase of the total traffic is 5 per cent.

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 $7\frac{1}{2}$ 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.

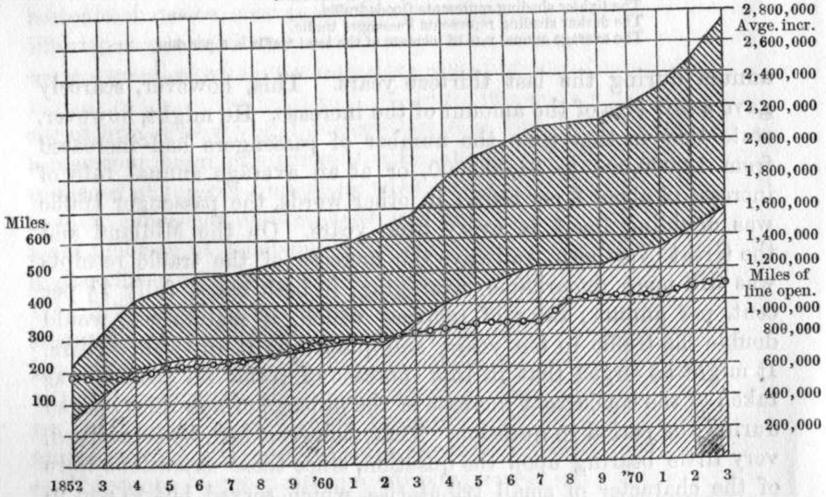
Midland Railway.



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.

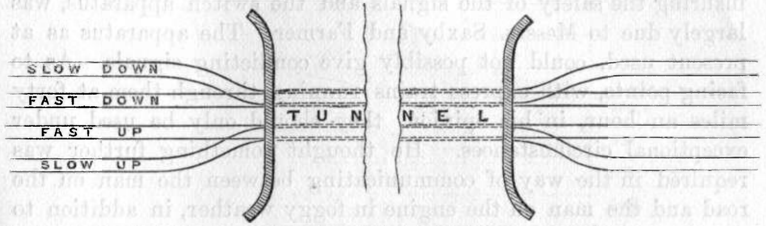
Great Northern Railway.



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.

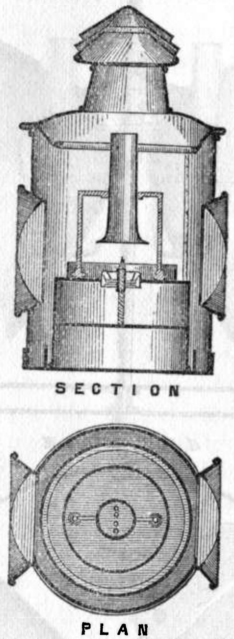
He was glad to be able to confirm the statement of Mr. Chambers as to the share which Colonel Yolland had in the discovery and application of the interlocking principle. He remembered that in 1857, when the Welwyn Junction signals were being put up, Colonel Yolland laid great stress upon the necessity 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

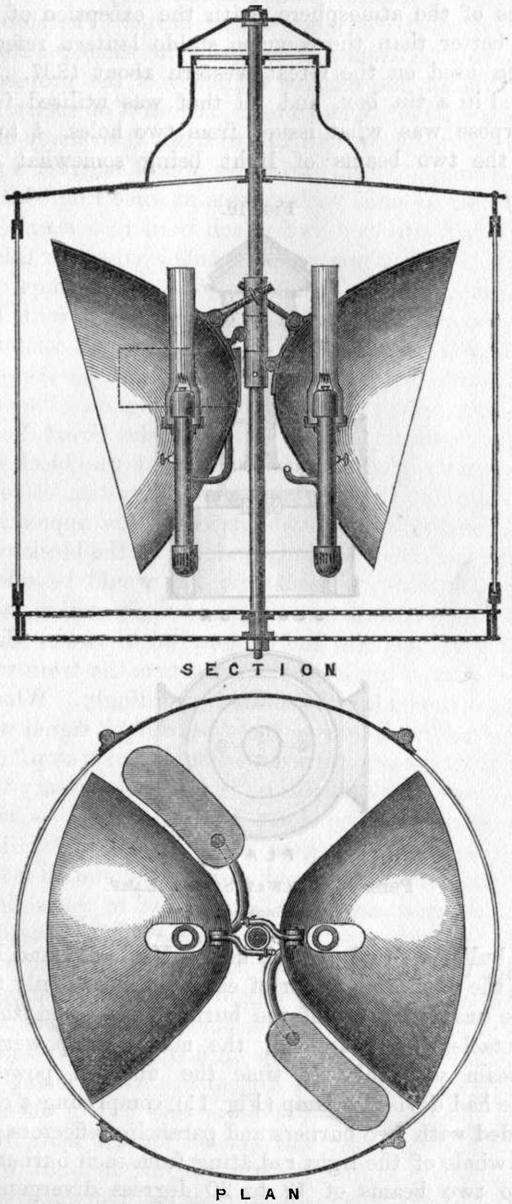
Fig. 10.



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 plate-layers, who could not work in foggy weather, were told off to the different boxes when the fog began. It was the duty of the plate-layer 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.

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