

The Author. a feature of lock and block nowadays, so much complication ensued from so many points occurring at which the line could be fouled or cleared. Moreover, a feature of the lock and block, as at present applied, was that a releasing-key was required to provide against failures, and instances had occurred in which these keys had been improperly used, in some cases resulting in accident, the Author believed. It was very gratifying to find from Colonel Yorke's remarks that the Great Western Railway was in such good repute in regard to its signals so long ago as 1841. The Author found himself entirely in agreement with Colonel Yorke, as well as with Mr. Byles and Mr. Johnson, in regard to its being somewhat premature to spend money upon complicated devices until the best value had been obtained from the manual block, with possibly additions of track-circuit control, where such could be made an additional protection. The interlinking of the distant signal with the block telegraph device could be applied to the home signal as well as to the distant. Dealing with Colonel Yorke's question as to its being possible or otherwise to devise a reliable and practical signal disengager or replacer, the obtaining of a thoroughly reliable device of the kind was one which the Author had very much in view for the company he served. With regard to Colonel Yorke's question as to the distance of the outer home signal from the inner home signal being always $\frac{1}{4}$ mile, the Author saw no reason why this distance should not be varied to suit circumstances. The Great Western Company had already experimented with an automatic train-signal recorder of the kind suggested by Colonel Yorke.

Correspondence.

Mr. Bell. Mr. W. H. BELL remarked that the question of picking up current for signalling purposes was a point upon which further information would be acceptable. It had often been stated by railway-engineers that anything in the nature of a blow between the engine-contact and a ramp, especially at high speeds, would very soon cause the apparatus to fail. Had the Author experienced any difficulties from such a cause? It had always appeared to Mr. Bell that this was the most important link in the chain of any audible system of signalling which aspired to supersede the present visual system.

Mr. H. S. BALLIET, of the Grand Central terminus, New York City, Mr. Balliet. noticed that the practice described in the Paper differed considerably from that in America; in England signal-bridges were apparently unknown, though he did not quite grasp the reason. The question of distant signals for junction-points was of importance, and he believed that the American practice of using a signal working in three positions was a good one; the intermediate or 45° position being the cautionary or "proceed" position to the next signal, and the vertical or horizontal position being equivalent to a distant indication of the signal ahead. Junction-points where diverging routes of equal or nearly equal value occurred could be readily guarded by the use of two arms on the signal approaching the interlocking, thus giving the driver sufficient information as to the conditions ahead. In his experience the use of distant signals fixed permanently at "caution" caused the men in time to ignore their use. It had, he believed, a bad effect on the engine-driver when he compared this fixed-arm indication with the movable one used at other points; and the practice of placing a suitable sign or marker, illuminated or outlined, as the case might be, was by far preferable. This was particularly applicable to the case mentioned where distant signals were set permanently at caution when speed was required to be reduced to 15 miles per hour or less. In connection with the use of electric repeaters for distant signals, the question arose whether or not provision was made for the use of these circuits in addition to repeating the position of the arms, also to control the improper operation of the home-signal lever should the distant arm remain falsely at "proceed." This was a practice in vogue in America. He was very much impressed with the method of interlinking the distant signal with the block-telegraph system so as to guarantee that the signalman would not give "line clear" to the station in the rear when the distant signal was falsely at "proceed"; it certainly was an excellent arrangement. On p. 157 the statement was made that this arrangement ensured that the distant signal had gone properly back to danger; he interpreted this as meaning that it would return to the stop position and remain there. The method of indicating tracks by signals, and arranging them in the manner indicated, so that the driver could readily pick them up, was very good. He noticed that the practice was to use separate arms for all fast-running lines, and only to use route-indicating signals at slow points of detouring or internal stations. With reference to the goods-loop train-indicator used for the purpose of warning a driver

Mr. Balliet. of the condition of a refuge-loop, he was not clear how the man who drove a train on to this loop would know the total length of the trains already occupying it. If two trains were on the loop, and they were so long as to be equivalent to three average trains, the indicator would show two trains on the loop, and how could the driver regulate his speed to approach the rear end of train No. 2 safely? Or was it possible, if the two trains were equivalent to almost three, for the signalman to pull off indicator No. 4? Without some knowledge of this kind, the use of such an indicator would seem unnecessary; the American practice of giving a low-speed arm which meant "proceed, prepared to stop within your vision," would serve the purpose equally well. Again, if train No. 1 went to the extreme end or the outgoing end of the loop, and train No. 2 was merely drawn out of sight of the signalman, but not behind train No. 1, the information would be somewhat misleading to the third driver. The practice of doing away with red lights in subsidiary signals was sound, but Mr. Balliet was curious to know what had been substituted for these red lights. Were they burning continuously, being covered or obscured until required for use, or was, for instance, blue substituted, as was quite a common practice in America? The so-called "long-burner" lamp was used very extensively out there, and the practice of filling the lamps but once a week and trimming them twice a week was also similar. A great many lights were blown out, and they also grew dim, and the question of substituting electric light arose. In the vicinity of the Grand Central Terminal, and on the division adjoining, several hundred electric lights were used in signals. They were arranged on a porcelain block, two lights being placed in multiple and burning continuously. A few had switch arrangements for cutting them out when desired. One of these lamps, which, generally speaking, were of 3 candle-power and for 55 volts, cost for maintenance and current 1 cent per day, and during 4 years only twelve lights had been extinguished. The use of electric lights made it possible to obtain a better focus on the lens, and consequently a far superior light to that obtained by using oil. The use of 50-foot instead of 16-foot detector-bars appeared to him to be a good illustration of the development of modern rolling stock and signalling, and he was very much interested in the assisting-springs placed in rods working facing-point bars. It certainly was an excellent arrangement to reduce the load on the lever and consequently the manual labour required. He gathered from pp. 162 and 163 that power-working of signals really related to what was commonly known as an electric interlocking installation.

The Author stated that in his experience the maintenance-cost was excessive, but Mr. Balliet found the cost of maintenance to be not so high as that of a mechanical interlocking plant, lever for lever. They had a large number of plants operated in this manner, and also of electro-pneumatic, mechanical, and similar plants. It might be of interest to mention that they were now building-on a semi-completed terminal at 42nd Street and Park Avenue, in New York City, and were placing on two separate floors of the same building the equivalent to a 760-lever interlocking machine of the electric type. It was arranged on two floors in order that the operating forces might more readily be separated, a considerable amount of confusion in directing the operation of the levers being thus saved. He stated this as an indication of the work that was going on, as compared with the fine work which the Author had outlined as having been accomplished on the Great Western Railway. Electric machines of 50 to 150 levers were the rule rather than the exception with them. This was due to the fact that they consolidated as many points and junctions as possible in one building, and it was a common practice to cover from one interlocking cabin a stretch of 3,000 to 3,500 feet on each side of the building.

Mr. W. H. CANNON felt indebted to the Author for a very interesting description of modern signalling practice, as carried out not only by the Great Western, but also by most of the other principal railway-companies in England. He thought it would be seen from the Paper that the great care exercised by those responsible for the signalling arrangements contributed in no small measure to the reputation for safe working which these railways so happily enjoyed : further, it would be recognized that signalling formed an important branch of engineering. There were minor points of difference from the practice described, but they were unimportant, and he proposed to call attention to a few matters only. The arrangement of signals described was similar to that usually followed on other lines, and it was a good one ; but with regard to what were known as " separate " distant, he doubted the wisdom of dispensing with them for passenger-lines. It was usually the practice of the railways, and a requirement of the Board of Trade, that on passenger-lines a separate distant signal should be provided in connection with each home signal at all important running-junctions. If only one distant were provided at a junction, and it was pulled off only for the straight road, being always kept at danger for the diverging route, engine-men would not know in times of fog whether it was at danger because the home signals were also at danger, or whether it was at danger because the home signal for the diverging route was off. Engine-

Mr. Cannon. men therefore had to be prepared to bring their train to a stop at the home signals, and delay was then caused unnecessarily in many instances. It was no doubt advisable to repeat electrically all distant signals, especially as it was now the practice to place them farther from the signal-box, and the condition of the atmosphere frequently interfered with the signalmen's view of them. The Board of Trade requirement was, "If from any unavoidable cause the arm and light of any signal cannot be seen by the signalman, they must, as a rule, be repeated in the box." Perhaps the Author would kindly state whether the light was indicated, as well as the arm electrically repeated. The Author's opinion as to route-indicating signals being probably only useful at terminal stations was, he thought, correct, because engine-men could not see the numbers clearly at a sufficient distance when running fast. With regard to track-circuits, the Great Northern Railway, which Mr. Cannon had had the honour to serve for 40 years, could probably claim to be the first railway making successful use of it to any considerable extent. Some of the lines at King's Cross station had been track-circuited for many years, with the addition of electric fouling-bars to meet the case of Mansell wheels. Leeds Central station, where all the lines were signalled for both arrival and departure of trains, was similarly track-circuited, and many other parts of the railway were also so fitted, with excellent results. As opportunity offered, the Mansell wheels of Great Northern stock were being bonded, with a view to reduce in course of time the number of electric fouling-bars. It was a question whether the goods-loop train-indicator described always showed the correct number of trains in the loop, as the first train might have departed when the fifth was signalled. Further, trains were not always of the same length—for instance, an engine and a brake-van formed a train—and it might be that the practice of cautioning engine-men from the signal-box when a loop was occupied met the requirements of the case better. A form of signal-wire joint was described in the Paper, but Mr. Cannon had found that joints made with thimbles caused the wire to spin when the signal was worked, and it was then liable to become wrapped round an adjoining wire. Perhaps the Author would say whether he had experienced this. Electrical detectors were used more or less on most English railways, but probably by far the larger number were mechanical, and it might be well to point out that the former had not some of the advantages possessed by the latter, because mechanical detectors locked the detector-rods and thus prevented the points from being moved. He did not wish to decry the audible cab-signal described, which was probably the best of

its kind, but the difficulty was to make one apparatus in the cab of an engine reproduce accurately the various sets of signals as they were approached; and one was inclined to ask whether this formed a reason for dispensing with separate distant signals. An efficient cab-signal would, he thought, be useful in railway work, especially in times of fog and during snowstorms, but it should probably be looked upon only as an adjunct to the ordinary semaphore signals.

Col. H. BONHAM CARTER was interested to see that on the Great Western Railway they had adopted, as a means of getting over the difficulty of "section clear, but station blocked," the system of an outer-home signal, which as explained in the Paper¹ by the late Mr. Hodson was the basis of the modern system of signalling that had been adopted on all the railways in India, where, with block sections often 10 miles long, some such arrangement became particularly necessary. White posts were introduced on some Indian railways more than 30 years ago to indicate to the driver, on the comparatively rare occurrence of a fog or dust-storm, the position of the distant signal. On the State Railways of India, owing to the fact that the maintenance of all wires was in the hands of the Government telegraph-department, and the railways did not employ their own telegraph-engineers, the use of electric repeating devices was less general than elsewhere. On the companies' lines, where, speaking generally, they had found it desirable to retain their own telegraph-department, even though they had been obliged by Government to entrust the maintenance of their wires to the same expensive agency, there was greater development in this direction; and on the Madras and Southern Mahratta Railway in Southern India, where to a large extent they were allowed to maintain their own wires, and where they manufactured their own small electrical appliances, he believed that there was, or would be shortly, no outer-home signal invisible from the station which was not electrically repeated. When safeguards were multiplied, railway administrations had to consider whether the additional safety gained was commensurate with the considerable additional expense incurred, as occurred at times in India on a poor line with a large number of stations. Indian engineers laboured under a great disability in that they had no means of exchanging ideas such as The Institution of Civil Engineers afforded to engineers in England. There was a traffic-conference at which the general managers and traffic-officers met annually and could exchange ideas; and they attempted to do something by offering prizes for

Col. Bonham
Carter.

¹ Minutes of Proceedings Inst. C.E., vol. clxxx, p. 1.

Col. Bonham Carter. essays on various subjects, to disseminate experience. Locomotive-superintendents, again, had their Conference; but civil and electrical engineers in India had to look to The Institution and to the various technical Papers for information regarding engineering progress in India as well as in other parts of the world; and he would be glad to see an engineering conference started, to afford a means of enabling them to learn something of one another's methods.

Mr. Coath. Mr. D. D. COATH pointed out that serious railway-accidents in England in recent years might be divided into two classes—one due to signalmen's mistakes and the other to drivers' mistakes. When it was considered how much depended on the human element, and how easy it was for even the most experienced and apparently trustworthy men to make mistakes, the marvel was not that accidents happened occasionally, but that they were not much more frequent. Clearly the human element was the weak link in the chain, towards the strengthening of which the Author's cab-signalling was undoubtedly a great step: a driver might fail from half-a-dozen causes to see his signals or might mistake them, but it was difficult to conceive how he could fail to hear his cab-signal whistle, which continued until he actually stopped it. From a mechanical point of view the system in use on the Great Western Railway was sound and practical; there was nothing in the nature of a violent blow at high speeds, which was the rock whereon so many previous schemes had been wrecked. This apparatus, however, dealt entirely with the distant signal, and although it eliminated the major risk of the driver missing or mistaking his signals, it left untouched the remaining risk of his failure to act on them, even when he had received them. Drivers had been known to die at their posts or in some unexplained way temporarily to lose their faculties, or to be disabled as in a case at Montreal 2 years ago, when, by the failure of a wash-out plug, both driver and fireman were blown clean off the engine just as the train was approaching the terminal station. The accidents at Slough, Salisbury, Shrewsbury and Grantham might be repeated at any time as long as this risk remained. Such risk could easily be eliminated by applying a modification of the system to the home signal; a short movable ramp projecting, say, a couple of inches higher than that used for the distant signal, could be connected so as to rise and fall with the home signal-arm, and be so arranged that any attempt to pass this ramp when in the raised or danger position would raise the plunger of the cab-signalling apparatus high enough to fracture a diaphragm and so open fully the brake-pipe. As drivers were not supposed to run past a home

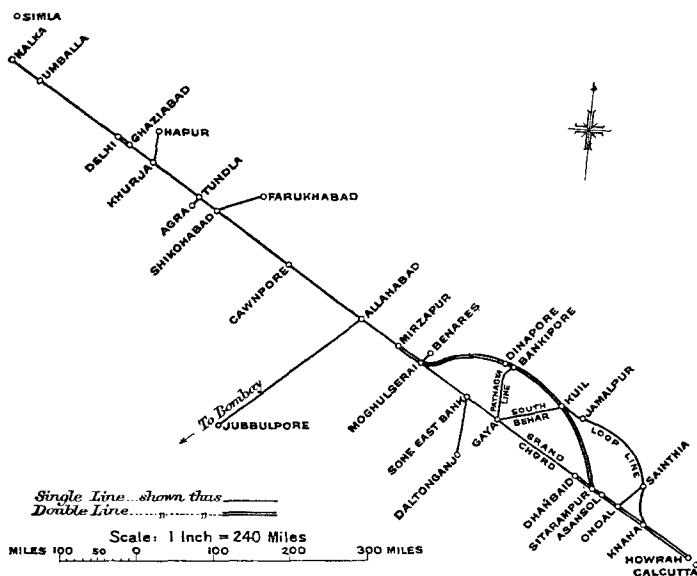
signal at danger under any circumstances, this would come into Mr. Coath. operation only as an emergency stop, and while not in any way interfering with regular working, would render it impossible for a train to run unchecked past a home signal at danger. Of course, it might be desirable to set the home signal a little farther back to allow more space for pulling up a runaway; but even without this a large amount of additional safety could be attained at a trifling cost. Faulty adjustment of long distant-signal wires had contributed its share of accidents; this ever-present source of danger and all the troublesome adjustments, together with the necessary apparatus, could be got rid of entirely by adopting the plan followed on some foreign railways, namely, instead of having the arm horizontal for danger, let it point up at an angle of 45° above the horizontal, and 45° down for clear as at present. By this plan, instead of only one-eighth, one-fourth of the circle would be made use of, and considerable variation in the wire would have no ill effect, any position above the horizontal indicating danger; the arm could then, without causing risk of mistakes, vary by as much as its present whole travel from danger to clear—a very different state of affairs from the present system, where any drooping of the arm could easily lead to disastrous mistakes. The same system might be used for the much-desired method of distinguishing home from distant signals; for instance, the home signals, on account of the shortness of the wires rendering adjustment unnecessary, might be kept horizontal for danger as at present, while the distant arm would be made to point upwards as described. In the daytime the two could thus be distinguished with the greatest ease, even under the most unfavourable conditions.

Mr. CHARLES A. DUNHAM, of St. Paul, U.S.A., gathered from the Mr. Dunham. Paper that the development of the art of signalling on the Great Western Railway was typical of the conditions on other railways in the British Isles, and the experiences of the railway-signal officers there seemed to be similar in many respects to their experiences in America. It was apparent that the English railways were working towards a uniform system of signalling, and it also appeared that simplicity as well as uniformity was sought. He was convinced that these two were the prime considerations, and that lack of uniformity and simplicity in American block-signalling and interlocking installations of former years was the principal criticism which could justly be made by the traveller who had investigated existing conditions and practice the world over. When they had arrived at uniformity and simplicity in accepted signalling practice, the question of

Mr. Dunham. standardization of parts and materials should not be a difficult matter. The need of continued careful active work on the part of the signalling-officers was not questioned, and he, for one, would look for good results as an outcome of the consideration of the present Paper.

Mr. Dutton. Mr. S. T. DUTTON thought that a few remarks concerning the progress made on the East Indian Railway during the last few years might be of interest, as that line had done more than any other in India in the way of signalling and block working. It was the first railway to appoint a signal-engineer, and he had had

Fig. 21.



the honour of holding that post since it was established in 1898. As in the case of the Great Western and many other railways the signal-engineer was in charge of all telephones, telegraph and block instruments, and all mechanical and electrical appliances used in connection with signalling. In 1898 there were only seven stations or junctions with signals and points interlocked; the stations on the Howrah-Asansol section (*Fig. 21*), consisting of 132 miles of double line, were provided with distant, home, and starting signals, but no attempt had been made to interlock them with the points,

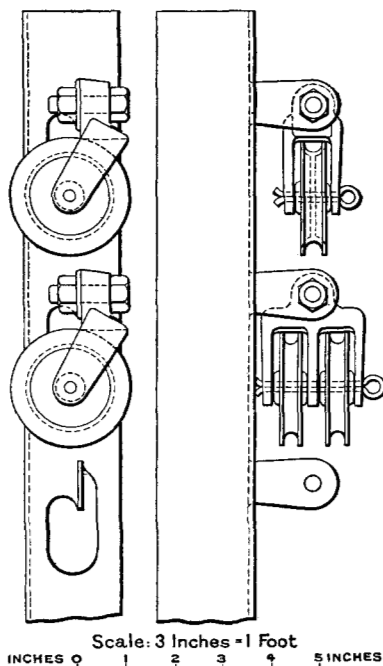
the latter being worked by ground-levers and secured by means of Mr. Dutton. a bolt through the switch and stock-rail, the bolt being cottered and padlocked. Throughout the rest of the line the equipment at each station consisted of a two-armed main signal on the platform, and a stop-signal for each direction fixed about 2,500 feet from the centre of the station. At the present time, with the exception of about twelve large yards which required to be remodelled before they could be interlocked, all stations between Howrah and Kalka, between Allahabad and Jubbulpore, and from Sitarampur to Moghulserai via the Grand Chord, had a complete equipment of signals, which were interlocked with the points. As regarded the more important branch lines, the work of interlocking all stations on the loop through Sainthia had been practically completed, and the stations on the South Behar branch were interlocked when that line was constructed. With regard to block signalling, in 1898 both on the double and single lines "line clears" and "arrival reports" were transmitted by telegraph, and in the case of single-line working the driver was given a form, filled in and signed by the station-master, to act as the "line clear" or "authority to proceed." On certain sections of the single line the "train following system" had been permitted, by which two trains running in the same direction were allowed to be in a block section at the same time, being separated by a time-interval which occasionally was not sufficient to prevent an accident. At the present time the whole of the main line and all branches were worked on the absolute-block system, under which a train might not leave a station unless the block section was clear. The Government-of-India rules also provided that every train should be protected by at least two stop signals or by one stop signal plus an adequate distance of, generally speaking, $\frac{1}{4}$ mile. The section between Howrah and Sitarampur (138 miles) was worked on the "lock-and-block" system, in which the starting-signal was locked at danger until "line clear" had been received, and when a train had started, the block instruments remained locked until the train passed over an electric treadle at the station ahead. If a train was shunted, the instruments could be freed by the co-operation of the station-master and the signalman. The remaining sections of double line were worked by ordinary three-position block-instruments for which three line-wires were required. On the single line, tablet instruments (or their equivalent) were in use throughout, except on the least important branches. Where block or tablet instruments had been provided, the stations were placed in telephonic communication with one another. In 1898 the Morse telegraph-instruments and the few telephones then in use were the property of,

Mr. Dutton. and maintained by, the telegraph-department of the Government of India, the railway paying a fixed monthly charge for each instrument. The introduction of block and tablet instruments necessitated the employment of men specially trained in that class of work, and it was soon recognized that with very little additional expense the block-signalling staff could look after the Morse instruments and telephones. Accordingly the telegraph-department of the Government of India were requested to remove their instruments, and the railway proceeded to fix and maintain its own. It might be of interest to note how the use of telephones had been extended, for whereas in 1898 less than 100 instruments were in use, at the end of 1910 there were more than 1,300. Under the agreement between the Government of India and the railway, the telegraph-line wires were provided and maintained by the telegraph-department of the Government of India, although it would undoubtedly suit many railways to do the work themselves. An all-round rate of about Rs.24 (£1 12s.) per annum was charged for each mile of wire. At seventeen important centres the railway had installed telephone-exchanges with local and through connections. The telegraph-circuit between Howrah and Allahabad (564 miles) was worked duplex.

The conclusion of the Paper led to the hope that its discussion would bring to light further new and interesting details of railway-signalling appliances and their connections. When so much depended upon the certainty of movement of points and signals, it was necessary to keep in view the desirability of working up to a high standard of mechanical efficiency. This could be reached only by taking advantage of the experience gained in everyday working to design gear which was at once mechanically sound, free from complications, capable of being fixed easily and with little chance of error, and, finally, capable of being cleaned and maintained with as little effort as possible. If these points were given due consideration, and if care were taken to fix the gear in a workmanlike way, when an installation was brought into use there would be few mechanical failures, the cost of maintenance would be kept as low as possible, the gear would have a long life, and the signals and points would work without undue exertion on the part of the signalman. It was clear that a railway which had introduced interlocking during the last few years was placed in a very favourable position regarding its choice of patterns, as it would not be obliged to use fittings which were somewhat behind the times, merely for the sake of uniformity and standardization. With the permission of Mr. R. S. Highet, M. Inst. C.E., the Chief Engineer of the East Indian Railway, Mr. Dutton ventured to give a few

details of some of his designs, together with some notes regarding Mr. Dutton. the standard practice on that line. For several years the East Indian Railway had used solid signal-wire of high-tensile steel, No. 10 S.W.G. galvanized, and several other railways had followed suit. In India this class of wire was found more satisfactory than the stranded wire usually adopted. Signal-inspectors brought out from English railways, and accustomed to the use of stranded wire, preferred the solid wire. Most railways found it necessary to keep

in stock two types of wire-pulleys, namely, side and angle; the former being used for wires running in a straight line, the latter when wires were taken round a curve. Provided an angle-pulley hung vertically, it might be used as a side pulley, the only objection being that it was much more expensive, as it required a bracket and two bolts. The stake illustrated in *Figs. 22* had been introduced to enable one type of pulley to be used either as a side or angle pulley, without costing any more than the average price of the two when used in ordinary proportions. It would be seen that the lug or bracket was formed by pressing out a portion of the metal of the stake. As a rule, four lugs were pressed out of each stake, but if it became necessary to add another pulley, the latter was suspended from a lug-bolt as shown. The pulley could be secured permanently at any angle, so that when a wire was taken round a curve there was no loss of stroke and the weight of the pulleys had not to be lifted. A pulley which was capable of being used either for straight runs or round curves appealed strongly to Colonial and Indian railways. An English railway using two types of pulley, could easily replenish its stock of either; but a Colonial or Indian railway would be placed in an awkward position by failure of the stock of either pulley, and could

Figs. 22.

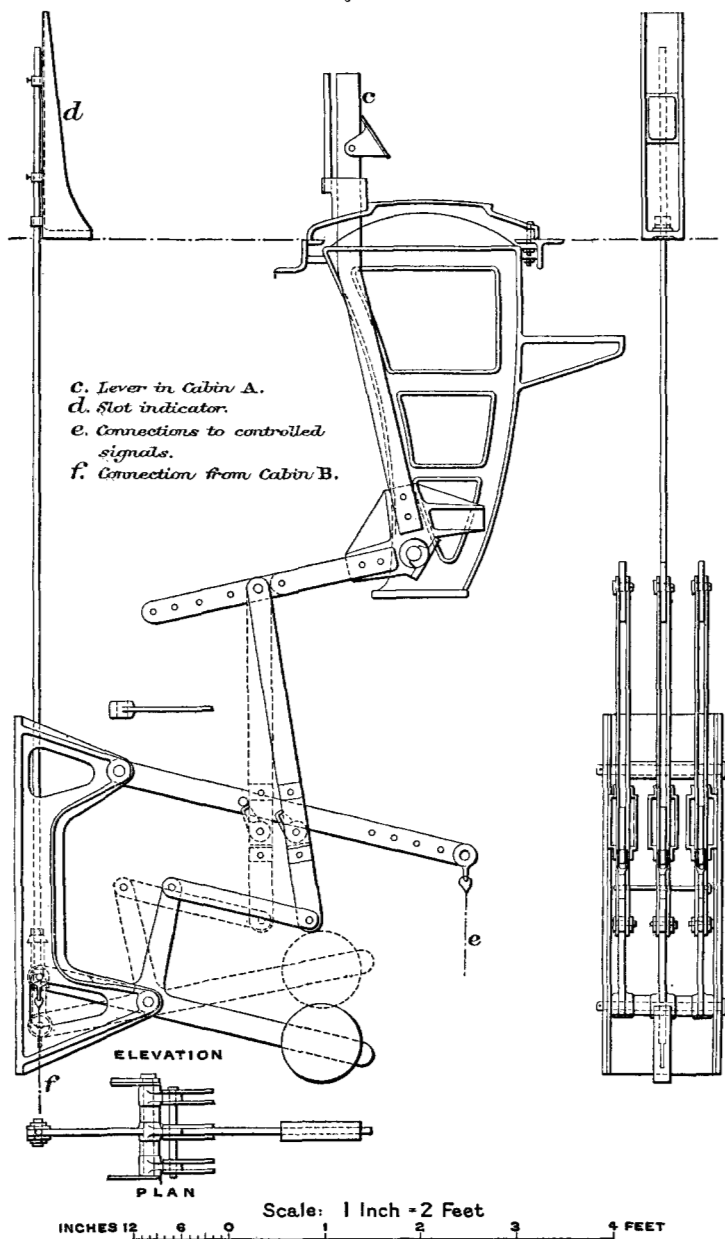
Mr. Dutton. guard against this risk only by holding large stocks. In India it was a decided advantage to use galvanized metal stakes for carrying signal-pulleys, and for many years the standard stake had consisted of a channel-bar about 4 feet long; but the section usually supplied was very poor and had little hold in the ground. A light angle-bar, $1\frac{3}{4}$ inch by $1\frac{3}{4}$ inch by $\frac{1}{8}$ inch, similar to that illustrated in *Figs. 22*, but without the lugs, had been used with much success; it was much stiffer and weighed no more than the channel-bar. The ends of such stakes should be left square, as, if pointed, the stake tended to curve when being driven. In the standard signal-arm and fittings there was no spindle, the arm working on a stud riveted on a cast-iron plate which was bolted to the face of the post. The stud-plate had a projection cast on it to form an emergency stop, which prevented the arm from rising more than 5° above the horizontal. The stud-plate was also provided with slotted bolt-holes to enable it to be moved across the post as might be required, to bring the down-rod in a straight and vertical line with its connection on the balance-lever. The angle of travel of the arm was 60° , but a full green light was exhibited at 45° . The arm was so balanced that during its travel the upward thrust on the down-rod was constant, which appeared to give better results than when, as was usually the case, the thrust varied from about 5 lbs. with the arm horizontal, to about 50 lbs. with the arm fully lowered. The arm itself was made of steel, No. 16 S.W.G. 10 inches wide, with two corrugations. The back spectacle was attached to the front spectacle, and was capable of horizontal adjustment. The back spectacle had a hole through which the backlight of the lamp showed. The size of the hole was such that when fixed concentrically with the lens-frame of the back light, the latter was obscured before any green light became visible through the front spectacle. This hole served as a very useful guide to a signal-fitter in keeping the back spectacle properly adjusted. The lamp-bracket was capable of horizontal adjustment. Until about 3 years ago castor-oil had been used for all signal-lamps. Many types of petroleum-lamps had been tried, several of which had been in use on English railways for many years with satisfactory results, but, owing perhaps to the methods employed by the native lampman, or to the fact that the staff generally resented the abandonment of a valued and much-used commodity, the trials were not successful. Experimental lamps had even been made locally; one type—of which 300 were made—was fairly satisfactory and would probably have been adopted, but at this point several new and improved petroleum-lamps were put on the market, primarily for use with

automatic signals, and after a short but satisfactory trial one was selected, and the whole line was equipped, no less than 7,000 being required. The lamps, however, soon paid for themselves, as the difference in the prices of the oils resulted in a monthly saving of about Rs. 14,000, or more than £900. What, no doubt, had contributed to the ultimate success of petroleum-lamps was the fact of the staff realizing that the railway was determined to use the cheaper oil: also the latter was becoming better known and the proper treatment of such lamps was more clearly understood. In the standard horizontal chain-wheel, the chain-guard was designed so that the wheels might be fixed in close line. The wheel was easily removed if the stud required cleaning. Wheels were sometimes of such a design that either the frame of one wheel interfered with the chain of an adjacent wheel, or else, in order to remove a wheel, it became necessary to open a split pin underneath the frame; and in one design the pin was inserted from the underside of the frame, which meant that the latter had to be taken up in order to remove the wheel. In any case, it might be taken for granted that a split pin out of sight was liable to be left unopened, or, if it had fallen out, the fact might escape notice.

With regard to slotting-apparatus, when a signal worked by cabin A was controlled or slotted by cabin B, it was usual to provide an indicator in cabin A to show whether the slot was "on" or "off." When the indicator was operated mechanically, the gear in cabin A consisted of a vertical wheel and a balance-lever connected by rod with the indicator, which was fixed on the cabin-floor. The balance-lever was usually fixed against the front wall underneath the cabin, and when two or more adjacent levers were connected with slotted signals there was very little space available for fixing the balance-levers in a workmanlike way, and the rod-connections to the indicators had to be cranked or set to get them in. It would be seen, therefore, that when cabin B pulled over the slotting-lever two counterweights had to be lifted, one underneath cabin A, and the other on the controlled signal. It frequently happened that one lever was used to control more than one signal, in which case each additional signal to be controlled meant one extra counterweight to be lifted. In *Figs. 23* was shown a combined indicating and controlling apparatus designed to improve the conditions under which controlled signals usually had to work. It would be seen that the balance-lever was fixed at right angles to the usual position, thus enabling the gear to be fitted to adjacent levers, with all connections straight and in line. The drawing showed the arrangement adopted when it was necessary to control three signals

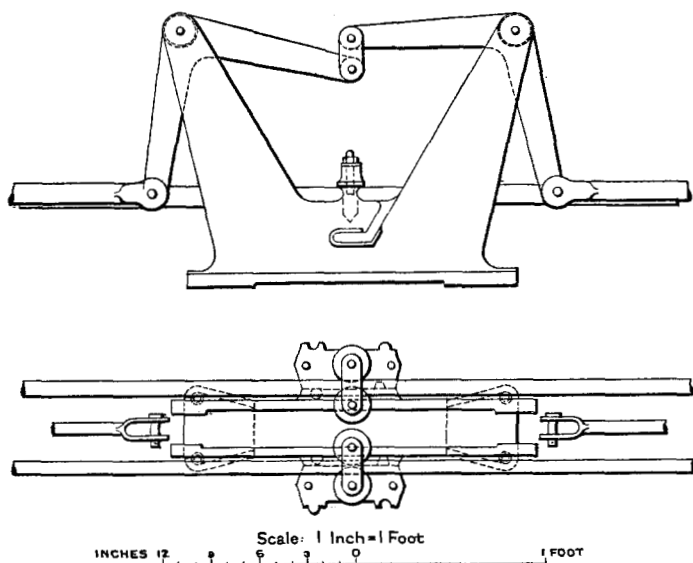
Mr. Dutton.

Figs. 23.



by one lever. The gear for each signal-lever was identical, except Mr. Dutton. that the centre set was provided with two arms, one of which was attached to the controlling connection and to the indicator on the cabin-floor, the other carrying a balance-weight. This form of slotting-gear was particularly suited to a station worked by two cabins, where it was desirable to provide one distant signal for each direction, which when lowered indicated that all the signals in advance were "off." The advantages of the gear were that the length of a controlling connection was considerably reduced, in some cases by one-half ; in operating the slot and the indicator

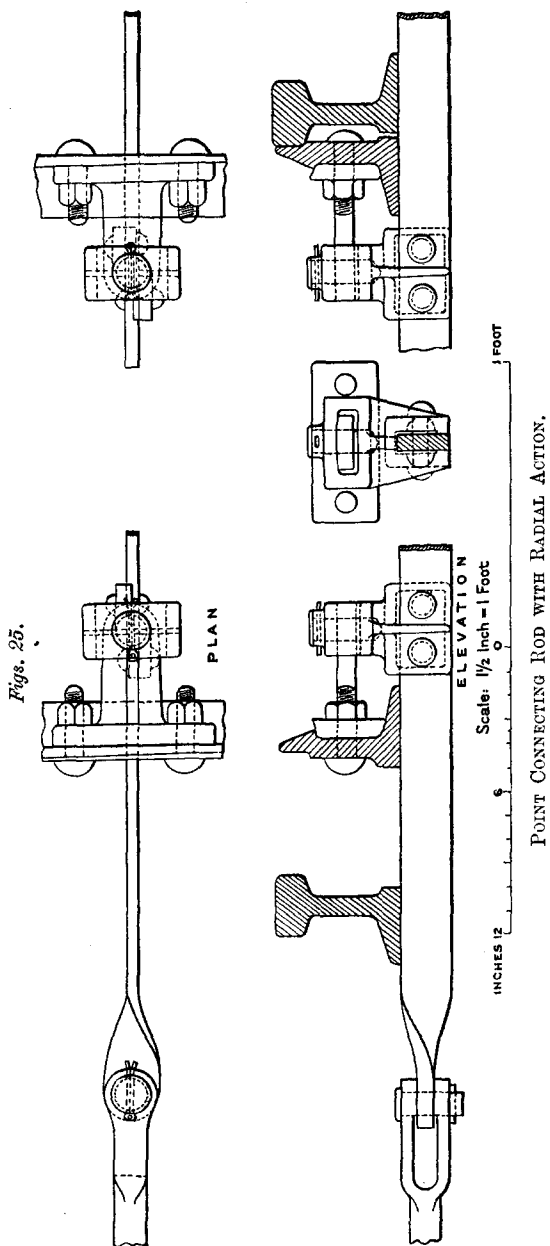
Figs. 24.



only one counterweight had to be raised, regardless of the number of signals to be controlled. A vertical compensator designed to be fixed between roller-guides of adjacent rods, in order to give as great a distance as possible (about 6 feet) between the arms of the compensator and the nearest roller-guides, was shown in *Figs. 24*. As ordinarily fixed, the nearest roller-guides were about 2 feet 6 inches from the arms of a compensator, and during the travel of the latter the rods tended to bind on the roller-guides. In order still further to reduce the binding action of the rod due to the radial movement of the arms of the compensator, the height of the

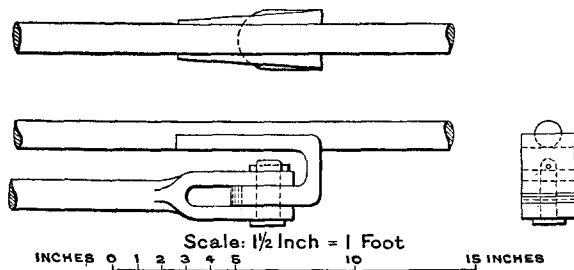
Mr. Dutton. latter was so fixed that when the connection was normal the centre of the joint-pin was about $\frac{1}{4}$ inch above the horizontal centre-line of the rodding; then, with the connection at mid-stroke, the centre of the joint-pin was about $\frac{1}{4}$ inch below that line. This practice should be followed in the fixing of all cranks. A form of cast-iron pedestal for a vertical crank was in use, which had four holes drilled to take the spindle of the crank. The latter could thus be fixed at varying heights, so that the rod from the crank to a low, medium, or high-stud accommodating-crank outside the cabin, might be straight; the fourth and lowest hole was intended to take a crank the connection of which passed underneath the rail. A pressed-steel locking-bar clip, which could be fixed without drilling the rail, had been designed, being fastened on by means of hook-bolts. The design, fixing, and maintenance of locking-bars deserved special attention. A stock-rail should be designed to bring its joint between the first and second, or third and fourth, sleepers in front of the switch. This enabled the first clip to be fixed as near as possible to the nose of the switch. A point which had received little or no attention was that the total length of a locking-bar should suit standard sleeper-spacing and rail-length. Usually bars were made in even dimensions—36 feet, 40 feet, 48 feet, and so on. It was obvious that this might lead to difficulties in erection if the end of a bar came just beyond a sleeper and yet did not give sufficient room for a clip to be fixed: it might then be impossible, owing to the presence of a rail-joint, to respace the sleepers, which meant that a considerable portion of the end of the bar was unsupported. He therefore recommended that, having ascertained the necessary minimum length of bar required, additional length should be provided to make the spacing of the clips as uniform as possible, and to give the same amount of overhang beyond the first and last clips. As a rule it would be found convenient and satisfactory to fix the clips between every alternate sleeper, which meant that there should always be an even number of sleepers between any two consecutive joints of a rail carrying a locking-bar. In one particular type of facing-point lock for slip-switches the gauge tie-plate was carried right through to take all four rails, and took the place of the front slide-chairs. The point-lock was bolted to the tie-plate, but the portion through which the split blades connecting the points passed overhung to get a straight connection from the switch. A connecting-rod had been designed to provide for the slight radial movement of the switch, and the considerable radial movement of the crank by which the switch was operated. This was accomplished by means of the vertical pin-joints shown in *Figs. 25*. As a rule the

Mr. Dutton.



Mr. Dutton. lug of a connecting-rod was vertical, which threw a great deal of work on its pin, unless the crank working the switch was at a considerable distance from the lug. It would also be seen that the connecting-rod was close against the underside of the stock-rail, in order to prevent the nose of the switch from lifting. It was a

Figs. 26.

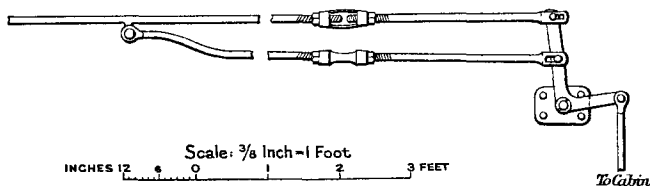


great advantage for the back connecting-rod of a switch to be fitted with an adjusting joint. Where a crank was connected with a lug and joint by means of a short rod, the effect of a radial movement of the crank could be eliminated by using a stamped lug, as shown in *Figs. 26*.

Mr. Fleet. Mr. E. F. FLEET remarked that the Paper, in common with previous Papers illustrating systems of signalling as applied on particular railways, was of undoubted value; it also emphasized the fact that there was great diversity in details, although the object was the same on all railways. The distinction by bracketing between the main- and branch-line signals, as shown in Figs. 1 and 2, Plate 5, was of doubtful value, he thought, because this same form of bracket might be necessary to assist the driver's sight, and also when the signals applied to adjacent lines used in the same direction. With regard to the varying heights of the signal-arms shown in Fig. 7a, Plate 5, some engineers considered that the right-hand signal from the platform-line should be the higher one, as applying from the slow to the fast line, but the practice illustrated was, he thought, the correct one, as speed would be restricted when running through the crossover. Referring to Figs. 6 and 8, Plate 5, the Author might say what appliance was used in these cases to maintain the locking on the points in advance of the junction-signals, when the signal had been restored behind a train, the train not having passed over all the points. The value of the indicator-signal in Fig. 10, Plate 5, depended upon the driver reading accurately the number exhibited,

and was not, he thought, so clear a warning as a lower "calling-on" Mr. Fleet. or "draw-ahead" signal. The signalman, knowing what space there was available, would check the speed of the trains in accordance therewith, by refraining from lowering the signal until the train had come to a stand, or nearly so, as required. Mr. Fleet agreed with the use of white or purple lights for ground-signals, but when those signals were elevated, and, as frequently occurred, were on the same gantry as running-signals, they might be objectionable, he thought, as conflicting with "backlights" and lights other than signal-lights. He had used the double-spring balancer, but thought it was only necessary in cases of special difficulty, and if not carefully adjusted, it tended to raise the bar up to the flange of the wheels and cause greater wear and tear in that way. For several years the North Eastern Railway had had a single spring fixed in or near the down-rod in the signal-box for the same purpose; and it avoided this objection. Another alternative which had proved satisfactory was shown in *Fig. 27*. Like

Fig. 27.



the springs on fouling-bars, these were used only in special cases, for instance, on curves: some engines caused a binding of the rockers, and this called for assistance to the ordinary balance to restore the bar. If the Author had had experience of track-circuits on electrified lines, it would be interesting to hear how he avoided stray or return currents from operating the relays. Mr. Fleet was providing alternating-current relays. With regard to automatic signalling, the $10\frac{1}{2}$ miles of "normal danger" system on the North Eastern Railway between Alne and Thirsk had, from an operative point of view, proved to work satisfactorily. The running-signals were automatic, but where provided for at junctions they were controlled from the signal-box, and the points were worked in the ordinary mechanical way. Should a running train be in occupation of the line within two sections of such points, the levers were kept locked thereby. On the North Eastern Railway the system of audible cab-signalling invented by Mr. Vincent Raven had been under test for some years for a

Mr. Fleet. distance of 14 miles, between Bensham and Durham, the driver receiving a warning (danger) signal 200 yards before reaching the distant signal, which was cancelled on reaching that signal should it be in the "all-right" position. More than twenty engines were fitted with contact-gear for this. Fogmen were displaced by the provision of a mechanical contact-arm (also the invention of Mr. Raven) which was fixed in the 4-foot way, and engaged a swinging pendulum on the engine, thus opening the whistle-valve; the arm on the ground worked in unison with the distant signal. This was in use over the larger portion of the main line. The many devices now introduced to assist signalmen, such as illuminated diagrams which reproduced in the signal-box the movements of the traffic, fouling-point locking, etc., demanded special instructions to signalmen, so that they might be treated only as reminders and safeguards: they were not intended to relieve the signalmen of the duty of keeping a good watch as to the conditions of the line and the movements of the traffic. The Author's experience would have been greatly valued in regard to the present-day use of calling-on arms, shunting-signals in the advance section, the method of dealing with "K" crossings, heel-less switches, and the tendency to increase the throw of switches. It would be interesting to know what amount was spent annually in England for the provision and maintenance of railway-signalling. The amount would prove so great that, he thought, it would justify The Institution, as the premier one in engineering matters, in obtaining a record of the varying practices on the different railways, with the reasons for their adoption, giving full consideration to the varying conditions of traffic. On that information a scheme could be built which would possess the advantage of uniformity, while not preventing the adoption of progressive ideas.

Mr. Moncrieff. Mr. J. C. B. MONCRIEFF found the Paper both interesting and instructive, and although the Author did not profess to state anything new, he evidently spoke from the fulness of intimate knowledge of his subject. There was one important respect in which the practice described differed from that which obtained on the South Australian railways, namely, that on the Great Western Railway engines were allowed to pass distant signals while at danger without stopping. On the South Australian lines every engine must stop if its signal were against it, and the officers in charge considered this to be one of the reasons why the railways in that State had been so free from accidents. He noticed, however, with pleasure, the fact that a single distant signal was commonly arranged to control a number of home signals. The route-indicating signal described

was simple, and having been found effective on the Great Western Mr. Moncrieff. lines would undoubtedly be adopted in Australia when the need arose. Long-burning kerosene lamps for signals were now being largely introduced in South Australia, and were proving serviceable and economical. Track-circuiting had been largely used there for gong-ringing at road-crossings where the traffic did not demand the maintenance of watchmen, and had proved effective. It was also being used to actuate electrically an indicator on a long platform, to inform the driver when the tail of his train had been pulled clear of the fouling point; and it was found to be satisfactory and reliable, the climate being generally so dry that the passage of even a platelayer's trolley would actuate the relays. The "occupation" instruments described formed a particularly interesting feature in the working, and the extension of the system to the control of outlying sidings would be watched carefully as having possibly considerable future influence in allowing sidings of this kind to be constructed at places where the traffic would not otherwise warrant them, owing to the cost of signalling and interlocking them fully.

Mr. WILLIAM PAGAN had read with considerable pleasure this Mr. Pagan. very interesting Paper, and it appeared to him that in Queensland they were not so far behind in the general matter of signalling, although the local conditions tended to modify the requirements which were found absolutely necessary in such a densely populated country as Great Britain. There were several points on which their practice differed from that described, and in order that the local conditions might be fairly understood, it should be mentioned that Queensland had an area of 670,500 square miles, and a population of only about 600,000. The total mileage of open line was 4,000 miles, of 3-foot 6-inch gauge, the longest stretch being from Cunnamulla in the south-west of the State, via Brisbane and Rockhampton on the coast, to Longreach in the central west, a distance of 1,429 miles. The total train-mileage for 1910 was 8,157,427 miles, and from this it would be seen that in a country so sparsely populated there were long stretches of single line with comparatively few stopping-places. The general practice followed at the less important stations was to provide up and down home signals placed on the right of the line, these applying to the main line only. At larger stations up and down distant as well as home signals were provided, the home signal being placed a minimum distance of 3 chains outside points, to protect shunting-operations, while the distant signal was placed about 400 yards outside the home signal, and was repeated if not clearly in view from the station. Crossing loops were provided at suitable distances, the

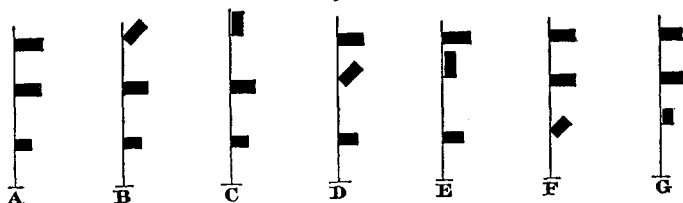
Mr. Pagan. points in all cases lying clear for the main line, alongside which the platforms were built. The loop points were held in position for the passing train, which was signalled into the loop by hand-signals. With the exception of suburban double lines where the manual block was installed, and branch lines near the larger towns, as well as the busiest parts of the main line, where the Webb-Thompson electric staff or the Tyler No. 2 tablet instrument was installed, the trains were run on a staff-and-ticket system. At junctions and principal passing-loops, as well as on double lines, the points were interlocked with the signals. The general type of apparatus used was the McKenzie-Holland tee-bar locking. At the principal station in the State, Brisbane Central, the electro-pneumatic system had been installed. One cabin with twenty-three levers had displaced two cabins with a total of sixty-two levers on the manual system. This was the first power-plant for signalling purposes installed in Australasia, and it had given satisfaction during the 7 years it had been in use, although some difficulty was experienced at first owing to the leakage of air, due to the motors being in the open, and therefore exposed to the large change in temperature between early morning and mid-day. This station was approached on one side through a tunnel $\frac{1}{2}$ mile in length, the rails through which had been track-circuited. On the block system Tyler instruments were used, and the traffic was worked under the general rules applying to block working, with one exception, namely, the "section clear, but station or junction blocked" signal had been omitted, and the outer home signal was substituted. Only one distant signal was used, regardless of the number of branching tracks, and as there was very little difference in speed between the various classes of trains, it was pulled off on the arrival of each train. This signal, although fishtailed by the rules, was practically a stop signal, and if the driver found it at danger, he was compelled to bring his train to a stand before proceeding to draw cautiously forward. This prevented any overrunning of the home signal. At interlocked stations the home signals were of either the semaphore or bracket type, and, as previously stated, they were placed a minimum distance of 3 chains outside the points they protected. Facing-point locking-bars were 32 feet in length, and facing points working with point-detectors were successfully worked up to 300 yards, trailing points being worked up to 350 yards. Anti-friction rollers $4\frac{1}{2}$ inches in diameter, and $1\frac{1}{4}$ -inch black iron pipe with solid, welded, and screwed ends, were used for point-rodding. On single lines ground-indicators were used, working in conjunction with the loop-points, and Mr. Pagan's experience had

been that a number of derailments occurred at these points owing Mr. Pagan. to the fact that drivers neglected to observe the position of the points as shown by the indicator. Trials had been made with long-burning signal-lamps, with a $\frac{3}{16}$ -inch round wick, but they had failed to demonstrate superiority over the flat-wick Barton burner, as even with a reflector they did not give the same volume of light. No special lighting-staff was kept, and the lamps had to be trimmed daily, which ensured their receiving proper attention, although, perhaps, the Barton burner consumed slightly more oil. Trials had also been made of methods of distinguishing the distant signal at night by different coloured lights, etc., the most promising of these being a lamp which showed red and green side by side when the signal was at "danger," with green only when the signal was at "clear," thus adhering to the use of red and green lights only. There was only one burner, and the red glass received the light direct, while the green glass received light from a reflector situated at the back of the lamp in such a manner that the green rays were parallel to the red. If the light failed, no signal was given, which constituted the danger position. Telegraph- and telephone-instruments were used throughout the lines, and the latter were being extended largely on the busy portions.

Mr. F. P. PATENALL offered the following comparative observa- Mr. Patenall. tions on the signalling practice of some English railways and that of the Baltimore and Ohio Railroad, of which he was signal-engineer ; not in the spirit of criticism, but rather to evoke discussion as to methods. In mechanical lay-outs the two types of interlocking frame generally used in the United States were the improved Saxby-Farmer, with tongue-locking arranged horizontally, and the Standard A tappet-locking arranged vertically, both types being of the preliminary latch-locking type, from which excellent service had been obtained. Tappet-locking direct connected to the lever was used frequently, however, in small ground machines, as well as being in connection with the General Railway-Signal Company's all-electric interlocking machine, the all-electric machine locking of the Federal Signal Company and of the Union Switch and Signal Company being preliminary latch-locking. They favoured latch-locking because it was a movement before any motion of the lever, and of course in the result it prevented conflicting latches of levers from being moved: this the direct-connected tappet-locking would not prevent, and generally he thought latch-locking was better. In order to define clearly the position taken on the Baltimore and Ohio Railroad in assigning signals for particular functions, it might be interesting to state that the ultimate idea was not to refer

Mr. Patenall. specifically to routes, but rather to routes, speeds, and conditions combined, it being believed such methods would result in the transmission of the desired information more intelligently and

Fig. 28.



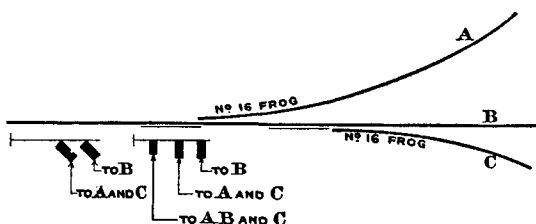
with fewer signals. On this basis all the home interlocking masts in future were to be equipped with three signals as shown in *Fig. 28*, the instructions given by means of these signals being the following :—

	Manual-Block Territory.	Automatic-Block Territory.
A Stop until authorized to proceed.		
B Proceed, maximum-speed route	With caution . .	{ Prepare to stop at next signal.
C " " "	Block is clear . .	{ Block is clear, next signal at proceed.
D " medium-speed route .	With caution . .	{ Prepare to stop at next signal.
E " " "	Block is clear . .	{ Block is clear, next signal at proceed.
F " low-speed route . .	{ At low speed with caution	{ At low speed with caution.
G " " "	{ At low speed, block is clear	{ At low speed, next signal at proceed.

At the same time they were endeavouring to reduce the number of combinations to the minimum, realizing the necessity of arranging signals with the greatest simplicity possible in obtaining the requisite indications. In all the new work upper-quadrant signals were installed, and all the signalling was of three-position type. The running being always on the right-hand road, signal-masts were placed next to the right-hand side of the track governed, wherever possible. If at an interlocking plant there was no high-speed route, the upper signal was fixed, and if no medium-speed route, the second signal was fixed; thus preserving at all times the identity of the home interlocking signal, no matter what other

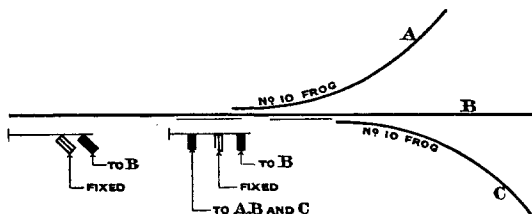
function it might be required to fulfil, such as in manual or Mr. Patenall, automatic blocking. The distant signal carried two arms except in block working, where single-arm distant signals were used; but these had a fixed second arm and lights on the home post, thus distinguishing between interlocking and block home and distant signals; the fixed arm and light when the home signal indicated "Stop" produced the restriction, "Stop, until authorized to

Fig. 29.



proceed," since an automatic signal had but one arm and one light, indicating when in the stop position "Stop, then proceed with caution." For example, in *Figs. 29 and 30* were shown two lay-outs which would appear on the surface to be rather difficult to signal intelligently, without the use of three signals, one assigned to each direction. The arrangement of tracks was the same in these two cases, only the frogs being different. *Fig. 29* had one high-speed route and

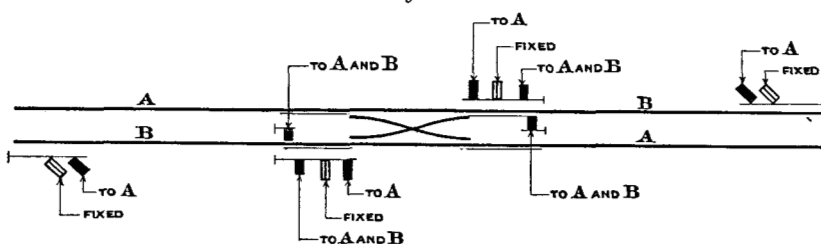
Fig. 30.



two medium-speed routes, therefore it appeared perfectly safe to use the medium-speed signal for either of the medium-speed routes, reliance being placed on the proper selecting of either of these two routes by the signalman as might be desired. Experience had shown that the attempt to provide a separate signal for each route to be governed resulted unfavourably, inasmuch as improper setting by the signalman had not in numerous instances been detected by

Mr. Patenall. the engine-men in time to stop the train before passing on to the route over which it was not desired to proceed. Hence, whilst apparently too much was taken for granted, it was found that very satisfactory operation had been the actual result of such practice in signalling as was shown in this Figure. The arrangement shown in *Fig. 30* was for one high-speed, one medium-speed, and one low-speed route, which appeared to be easily signalled. In *Fig. 31* was shown a scissors cross-over with short leads, signalled for high speeds in the running direction only, the same principles being followed in the signalling as previously set forth. It would be noticed that the practice of repeating the home signals of a junction at the distant signal had been adopted, although this practice was really in the transition stage. Seeing that track layouts were arranged so that a speed of 40 miles per hour over long cross-overs or turn-outs was permissible and safe, there appeared to

Fig. 31.



be every reason why they should be intelligently signalled. If the turn-outs and cross-overs were all short, there was no need of carrying the indications farther than the home signal. At many points, however, with No. 16 and No. 20 frogs smooth and safe riding was obtained at such a speed, and unless sufficient information was given by signal indication, under such conditions it would seem a waste of money to so arrange the track lay-out; further, there was a saving in time in approaching and passing through such points. For the necessary identification of distant signals, where no divergence or junction was covered, the single-armed signal was used, this signal serving as an approach indication to the home block-signal. In the case of a junction-point the situation was entirely different, and, as previously explained, since medium speed with tracks so arranged was allowable and safe, the two-armed signal was used to identify the approach to the home signal of the interlocking protecting such junction, the distant lights being arranged diagonally, in automatic territory.

The distant signals on this line, where operated mechanically, Mr. Patenall were usually placed 1,500 to 1,800 feet from the home signals, as at such a distance the working was more reliable; for that reason the practice of applying repeaters to such signals was exceptional. Signals were operated with back and front wires, which ensured a more concise response of the signal to the movement of the lever. At present, however, they were installing very few mechanically-operated distant signals in connection with the interlockings, as the power-operated distant signal could be better placed, first, at the minimum braking distance to provide information, and secondly, at such a distance from the home signal that in future extensions of automatic signalling this signal could be utilized as an automatic block signal, thus enabling it to perform a dual function. In such instances, as well as using visual repeaters, possibly a little better protection was obtained in the shape of a physical preventive against the hurried changing of a route; at the same time the action of the distant signal was checked, hence the distant signal must have assumed the cautionary 45° position before a change could be made in the route, inasmuch as by this electric check-lock on the home-signal lever the latch was locked in case the distant signal had not assumed a safe position corresponding with its control. Whilst in the past they had had occasion to use, in connection with a home signal, a series of numbers or indicators operating in conjunction with such signals, where the number of routes would make it impracticable to apply a corresponding number of signals to a mast, the practice had been discontinued because they felt that the third or low-speed signal satisfactorily fulfilled this requirement. As previously explained, it was found that the selecting of routes indicated in conjunction with a home signal had not been productive of any greater safety in operation. In reference to the indication in the signal-cabin of certain occupied track sections, in large terminals this was effected by means of lights at the levers involved, and also by the use of illuminated diagrams, both of which had given satisfactory service; but on the line where in manual-block territory power-operated home and distant signals were installed it was the practice to indicate visually the occupancy of the track-sections. Taking the case of the standard lay-out for the protection of a double-track passing-siding, the arrangement of signals was on precisely the same basis as previously described, although in this case the high-speed upper signals, distant, home, and advance, were all three-position, power-operated, and semi-automatic. The second signals, governing the passing-sidings, as well as the low-speed and

Mr. Patenall. dwarf signals, were mechanically connected, because automatic or electric operation of such units had not developed its necessity, such movement being made either at limited or low speed. In this arrangement track sections were used, first, to announce automatically the approach of a train by bell in the signal-box, and secondly, to act as a preliminary control for the distant signal. The distant, home, and advance signals were spaced usually between 4,000 and 5,000 feet apart: this formed a convenient spacing when converting to automatic block working, and it also provided convenient and safe operation in manual-block territory. Dwarf signals controlled by independent levers were used to govern back-up movements. Upper signals all having three positions, in manual-block territory the movement from the horizontal to the 45° position was through the medium of a circuit-controller on the lever, the movement from the 45° to the vertical or clear position being by means of a push-button; so that when such territory was later on automatically blocked, no expensive change in control became necessary, the latter movement then being transposed so as to follow the horizontal to the 45° movement of the signal in advance, thus discontinuing the use of the push-button.

These passing-sidings, or relief-tracks, were usually about 8,000 feet long, and the outgoing switch was manipulated by the train-crew, permission to use it being first obtained by telephone from the box; when it was proper for the train to proceed from the siding, the switch was unlocked from the box, and authority to proceed was also given visually by the clearing of an indicator. This switch was electrically locked, and required, in order to unlock it, both the reversing of the control-lever in the signal-box and the advance signal to be in the stop position. Track sections as shown were all indicated in the signal-cabin by means of semaphore indications displaying the "stop" position when sections were occupied. The indicator shown in Fig. 10, Plate 5, appealed to him as being an exceedingly useful device for transmitting information to engine-men as to the number of trains ahead in a loop—on the assumption, of course, that all trains pulled in so as to occupy the available room commencing at the far end. Should a train enter the loop and break down at a point which, in a regular movement, would be occupied by, say, the third train using the loop, he assumed the following train would nevertheless receive indication No. 1. He presumed, however, that this was a low-speed indicator under all conditions, and, in authorizing trains to proceed, was arranged on the basis that engine-men would run prepared to stop within the limit of vision: such

instructions were issued in connection with the Baltimore and Mr. Patenall. Ohio low-speed signal.

In 1894 Mr. Patenall made a report on the question of using green light for "clear"; at that time the Baltimore and Ohio South Western Railroad Company, then a separate organization, adopted green for "clear," and yellow for "caution," retaining red for "stop." There was a very strong tendency on the part of numerous lines now to adopt these three indications, and many had done so with marked success. As to the oil used for illuminating purposes, the standard, called "carbon" oil, was really what was known locally as "kerosene"; this was purchased under specification, and satisfactorily fulfilled the requirements, both in 12-hour and in long-burning founts. In automatic-signal territory the signals were lit electrically, and from the same battery as was installed to operate the motor mechanism. The lamps were lighted automatically on the approach of trains in the second section in the rear, with very economical results, as when no trains were run no lights were necessary. In territory where long-burning founts were used exclusively, lamp-men were assigned certain districts of sufficient length, or on which there was sufficient work, to enable them to cover the district each third day, although in tests lights had burned for 11 days continuously without attention. They had had experience with many types of wire-compensators, but very few were now in use: first, because the wire-connected signals were not at such long distances from the point of operation; secondly because, at the distance at which the signals were operated, variations in connections could be fairly well taken care of with a reasonable amount of overthrow; and, thirdly, even with the use of compensators adjustment was found to be frequently necessary. All home and dwarf signals were now pipe-connected, thus providing a much more substantial operating condition, and one which absolutely eliminated troubles arising from variations in temperature. The method of making joints shown in *Fig. 19* appeared to be excellent, and it would seem practically impossible to pull out such a joint. On the Baltimore line stranded wire was not used, a No. 9 S.W.G. steel single-strand wire, galvanized, being used instead. The length of detector-bar protection for each switch had been, within the last 6 months, increased to 55 feet, on account of the long wheel-base in the latest rolling stock. It had been the practice for some years to insert compression-springs in detector-bar operating-connections, but only where more than 55 feet of bar was coupled to one lever. In many cases, however, even with 110 feet of bar on one lever they had been found unnecessary.

Mr. Patenall. The form of point-rod joint shown in Fig. 13, Plate 5, was, he believed, worthy of the fullest consideration, especially as similar joints previously applied had failed. In connecting points they used sockets pivoted to the switch-rod and secured to it by means of bolts, thus providing the necessary strength and at the same time admitting of flexibility. For pipe-connections the standard was 1-inch iron or steel pipe, galvanized inside and out, double-riveted at plugs, and with extra heavy couplings; such pipe weighed 1.67 lb. per lineal foot. The Author was quite correct as to the cost of installing and maintaining power-operated units. Twenty years ago the first all-electric interlocking machine was installed on the Baltimore and Ohio Railroad at a point in the State of Ohio, and later on this was replaced by one of more modern pattern. For large terminals or for the handling of sorting-yards there was no question as to the saving in working-costs with power-apparatus; further, a greater scope of territory was possible, such installation requiring the minimum room for lever-space and controlling connections: the cost of maintenance, however, was considerably higher. At the time of writing there were in operation on that line forty-seven power plants, twelve of which were electro-pneumatic, the other thirty-five being all-electric. In many cases the storage-battery for the working of the units was also used for lighting, although that practice had been demonstrated to be somewhat more costly than the use of long-burning founts. With regard to automatic electrical indications, at the present time they had under construction seven machines, each containing forty levers, these being what were known as electro-mechanical machines, specially designed for them. In these machines there were twenty levers for switches, locks, and low-speed signals, operated mechanically, and twenty levers for power-operated signals, lock-and-block and detector circuits, these latter superseding the detector-bar. None of the plants was yet completed. Machines so arranged took up but one-half the room and provided all the required protection possible, which could not be said of an all-mechanical machine; it was believed, therefore, that for lay-outs of considerable size, say, up to sixty-four levers, they could be very safely and economically operated and maintained. By such an application the track-circuits took the place of detector-bars, and the maximum protection against fouling was obtained at cross-overs; siding-switches would be entirely impracticable if the same attempt were made to provide this protection by means of mechanical detector-bars. Track-circuits were liable to fail, but so were men and detector-bars; and it was believed that the track-circuit provided a better and safer means of

checking conflicting operation where detector-bars could not be relied upon to perform that particular function. It was interesting to note the application of audible cab-signals on the Great Western Railway, but he took it that this device was used as an adjunct to outside signalling. The Baltimore and Ohio Railroad had made quite a number of tests of various devices claimed to be proof against all the shortcomings of a signal system and the human factor, and also to give all the required features of safety in the control of a train; but in their experience nothing had yet been brought out which eliminated the necessity of also being governed by outside signals. He believed such a device would come, but in the present state of the art it seemed that cab-signals must be treated more as auxiliary apparatus. At the same time, additional appliances necessarily meant more failures, as well as additional competent men to maintain the apparatus. The explanation given by the Author of the device in operation, however, led Mr. Patenall to believe that its maintenance was not a source of great difficulty, and he looked for further reports as to the performance of this apparatus with much interest. On single lines the traffic of the Baltimore and Ohio Railroad was handled by train-order and under the manual-block system. On some divisions the issue of orders was by telephone, on others by telegraph. No staff system was employed. At points where long single-line tunnels intervened on double lines, track-circuiting and electrically slotted signals were employed, which practically resolved itself into manual-controlled lock-and-block. Gangs carrying out repairs to track did so under the protection of flagmen specially assigned for that purpose. Both telephone and telegraph systems were in use for the handling of traffic; as adjuncts, however, telephones had in many instances been installed at passing-sidings, so that at any time train-crews were able to get in touch with the nearest station, whence instructions were obtained for further movement. Signal-wires on telegraph-poles were in all cases No. 10 B. & S. gauge hard-drawn copper wire weather-proof double-braided, with the intention of obviating trouble from crosses. The position of signal-wires in the telegraph-line was always on the bottom arm.

Mr. G. KENYON ROGERS stated that the system of having distant signals provided only for the straight or "through" roads was being largely adopted in India, on grounds not only of principle but also of economy. The provision of a distant signal-arm to be fixed permanently at danger was not altogether satisfactory. There was a danger of its being disregarded eventually, as it must in time cease to have the same value as a signal known to be in

Mr. Rogers. use. Evidence of this might be found in the history of railway accidents, e.g., Shrewsbury and Aylesbury. Given every distant signal repeated in the cabin, the interlinking of the distant with the block instrument was, from the point of view of the extra safety thereby gained, well worth the small expense such an addition entailed. It was doubtful, however, whether the additional safety would be worth the cost of installation and maintenance of such an arrangement put in purely for this purpose. Such an appliance had lately been introduced for use in India with the Tyler tablet instrument. There the outer home signal was in universal use, and for several reasons its working was often not reliable. In order to make it imperative that this outer signal should be at danger when a train was accepted, the connections were such that it was impossible for A to give B permission to withdraw a tablet unless A's outer home was at danger. Mr. Rogers had introduced somewhat similar applications in India, both on the starting-signal and on the home signal. On every railway, at some time or other, two trains had been allowed into the section on the same "line clear." Among the causes of this was the neglect to restore the starting-signal to danger. In order to make this compulsory the arrangement adopted was such that B gave "line clear" to A (in the rear) only through his (B's) "starting-signal normal," that was, B could not give "line clear" to A unless his (B's) starter was normal. It was thus impossible for B to overlook the position of his starter. As regarded the home signal, when sections were short and cabins lay close together, it was usual to make it imperative for B to obtain "line clear" from C ahead before he could give "line clear" to A in the rear. In order to make this imperative, C was given a control on B's home, and B could only give "line clear" to A when this home was lowered. In the case of the starter the connections for the control could be made either on the lever or on the arm of the starting-signal; the latter, of course, being the safer though more expensive method. In the case of the home, as the signal on which the safeguard depended was worked by one cabin and controlled from another, the connections must be taken out to the arm itself.

It would be interesting to know whether the goods-loop train-indicator was worked by wire or rodding; in either case the question of adjustment must present some difficulty. While no doubt gas was not as good a medium as oil for lighting signal-lamps, the Author said nothing about electric lighting. At large terminal and other stations situated in towns the atmosphere often became temporarily darkened and there were usually a large

number of signals, many often situated near the entrance to a Mr. Rogers. tunnel. In such cases it often became advisable to light up some or all of the signals in certain parts of the yard. If these were grouped together, they could be readily switched on and off from the signal-cabin as desired. It was at large stations and terminals of this kind that electricity would be available, and where, as the Author stated, power installations would more frequently be found. The increasing use of the long-burning lamp, however, would run electric lighting very close, if not put it out of the question altogether. Any signal-engineer who had had to look after the working of signals, the wires of which had been religiously threaded through the facing points of a complicated lay-out, would know how difficult was the question of adjustment. In India electric detection was coming forward, as the larger yards were being remodelled and brought up to date. It was a practice, however, that had not yet reached its final stage, and there were several practical difficulties yet to be solved. A certain allowance for expansion and contraction was always made in the old wire detector. How much might be allowed in the electric detector, and how such a margin was to be provided for, was not known. If the connections were complicated, the total slack in the pins might be sufficient to throw a too neat contact out of use. Taper pins, kept down by strong springs, were useful for overcoming the effects of this wear and tear. But the difficulty of overcoming the effects of contraction and expansion of the various parts was not so easily solved. The arrangement of the circuits lent itself to an interesting study. The usual method was to provide a separate circuit throughout for each signal. This might mean, say, seven contacts at a given pair of points—three in the over position, and four in the normal position—which involved a complicated and expensive equipment. There were only two positions to a pair of points, and only these two positions really required detecting. By the use of economical slides one double detector of the hatchet type might be made to take any reasonable number of wires where mechanical detection of the old type was employed. The use of a box with one pair of “over” and a pair of “normal” contacts connected to a relay, opening and closing all the necessary signal-circuits, appeared to be the latest practice, thus making it possible to use one double detector or contact box only at each pair of points, no matter how many signals had to be detected. A diagram of a simple set of connections would be an interesting addition to the Paper. Given a three-wire block instrument on double-line working, it was a

Mr. Rogers. simple matter to have a telephone connected up cabin to cabin on the bell-wire. This could also be conveniently done on most of the single-line token instruments, and both had been adopted as standard procedure in India. With a single-wire instrument for double-line working the matter was not so simple. In India the telephone had been introduced from motives of economy as much as for convenience. Formerly, when the Morse sounder was the only means of communication, other than a block instrument giving the usual three indications only, it was necessary to employ highly-paid signallers. The introduction of telephones had permitted the authorities to dispense with such men and employ those who owing to lack of knowledge of the Morse instrument had hitherto been debarred, thus widening the field from which recruits could be drawn and at the same time effecting a considerable saving in the wages bill.

Mr. Sayers. Mr. JOSIAH SAYERS remarked that the long-burning lamps used in signals generally burned with a smaller flame than the ordinary kind, and he would like to know whether the Author had had any difficulty in repeating these lights electrically, owing to the lack of sufficient heat to operate the expansion-bar. With reference to track-circuits, the Midland Railway Company adopted for their relays a standard voltage of 0·36 volt for the pick-up and 0·22 for the dropping pressure, and it would be interesting to know whether the Great Western had adopted this or any similar standard. The former company used accumulators for the track-battery in nearly all cases, primarily because the pressure of the cell remained constant practically during the whole of the discharge—a most important feature—and, secondly, because a pressure of 2 volts allowed $1\frac{1}{2}$ volt to be dissipated in the battery-resistances, which was a very desirable feature from the point of view of sensitiveness. The only primary battery they had found at all up to the standard of an accumulator as regarded constancy of pressure was the Gordon cell, and this was used very extensively in connection with track-circuits and signal-batteries for automatic signalling work. The Author gave no particulars of the energy required for operating the automatic signals, nor of the holding-off current. The latter, in practice, consumed the major part of the energy of the cells, and it was very desirable that any automatic signals should be designed so as to take the minimum amount of energy to hold them off. As one who, with Mr. Acfield, had laid down and tried a section of line on the Great Western system of audible cab-signalling, he would like to pay a tribute to the simplicity of the apparatus and the skill shown in devising it. To his mind it

held the field alone at present, and he thought it should be further developed. One point touched on very briefly was the provision of superimposed telephones. The Midland Railway Company had enormously extended their system of superimposed telephones, so as practically to link up entirely the control of traffic-working, and it was not too much to say that that had made it possible, with a very small expenditure of money, to effect a large part of the economies in traffic-working which had been visible in the last few years. As to the correct resistance of telegraph-instruments, it was possible that the usual standard coils were too high for the most economical working and for the lowest pressure on the line, but standardization as much as possible in such matters was necessary, and personally he did not think it practicable to have two or three coils of resistance to suit different circuits. As a matter of fact, the dislocation of a telegraph-circuit by leakage was of such rare occurrence that he hardly considered anything to be worth disturbing on this account.

Mr. E. SIEGLER, of Paris, noticed that on p. 157 signal-wires "sometimes considerably over 1,000 yards" in length were referred to, and he would be interested to know the greatest length of wire that was usual—whether there were many wires of 2,800 or 3,000 yards from lever to signal. On the lines of the Eastern Railway of France they were using the Robert system of signal-wire compensation, which had given satisfaction. A system of audible cab-signals was being tried, wherein the electric current passed from a metallic contact fixed between the rails to a metallic brush on the engine. When the contact was coated with rime, or in frosty weather succeeding rain, current would sometimes not pass, and he would like to hear how the Great Western Railway avoided this difficulty. They considered it desirable to register on the engine the fact of a signal at danger being passed. In the Flaman system employed, the current made a mark on the paper strip of the speedometer, and the device was found to work very well.

Mr. A. STEVEN remarked that many years ago the Caledonian Railway, on which he was employed, was in a very similar position, with regard to signalling and interlocking, to that described by the Author. A number of places required attention, and they were being undertaken as speedily as possible, but keeping traffic-working in view, work of this description could not be undertaken hurriedly. He quite agreed that signalling in all its branches should come under the one head of the signalling-department, and should not be, as at present on some lines, under two or three departments. He had had the opportunity of seeing the stud interlocking referred to. A few years ago when repairing an

Mr. Steven. interlocking frame on the Caledonian Railway, a piece of interlocking of the stud type was found in the frame. This frame was supplied by Messrs. Stevens and Sons, of London and Glasgow, and fixed probably about 1870. The Author had given a well laid-out scheme for the placing of signals for the guidance of engine-drivers; but in planning lines of railway, engineers did not always give the subject of positions for signals and point-rods the necessary consideration. In Figs. 1 and 2, Plate 5, no distant signals were shown for the branch line, and the lines were marked main and branch. The lines were not marked in Figs. 3, and could be taken as two main or two branch lines, distant signals being provided for each. This was not quite in keeping with Figs. 1 and 2 where a distant signal was provided for one of the lines only. He did not agree with the Author's remark that one distant signal should be provided at junctions. There should be a distant signal for each line if both lines were through lines and were used for passenger-traffic. The additional distant signal, when lowered, would indicate to the engine-driver in what direction the junction was set. Engine-drivers should be well aware where they had to reduce speed. He considered that a signal-gantry was a very good arrangement where space was not provided for the erection of signal-posts, and it was more convenient to erect signal-gantries across the rails near large towns, where ground was expensive, than it was to provide space for signal-posts. He agreed that all distant signals (and all stop signals not in view of the signalmen) should be repeated electrically in the signal-boxes, for the same reasons as were explained in the Paper. The special signal shown in Fig. 9, Plate 5, was a very good arrangement. Mr. Steven was more in favour of having the numbers cut out of sheet steel and mounted on light wire-netting, fixed to a movable frame, but also employing the illuminated opal screens described. The numbers were much plainer to see than when cut as a stencil. Could the Author explain how the goods-loop train-indicator shown in Fig. 10, Plate 5, warned engine-drivers of the condition of the loop and the number of trains in the loop? If a train composed of an engine, twenty wagons, and a brake-van, and another composed of an engine, two wagons and a brake-van were standing in the loop, these would be signalled as two trains, but there might be a single train composed of an engine, fifty wagons and a brake-van, and it did not seem easy for the engine-driver to determine then the condition of the loop. On some railways electric light was in use for the lighting of signals, and proved very successful and cheap.

He must admit, however, that it was not as cheap as oil-lighting. Mr. Steven. If gas could be purchased at, say, 1s. 9d. per 1,000 cubic feet, and electric current at, say, 1½d. per unit, it would not make very expensive lighting. Many others who had experimented with automatic signal-wire compensators were like the Author in finding them very unsatisfactory. Mr. Steven had had the arrangement of springs on signal-wires under test on a few signals, and the springs had proved very satisfactory. Facing-point locking-bars were a serious consideration now, owing to the long wheel-base of modern rolling stock, and the working of these locking-bars from the signal-box made heavy work for the signalmen. The springs shown in Fig. 14, Plate 5, were of great assistance in the working of the bars. He would ask, however, whether there was not a liability of these springs getting solid during snow and frost, or the arrangement for holding them in proper compression being altered by unauthorized persons, thus preventing the free working of the locking-bar. Many people had tried to find a satisfactory solution of the audible cab-signalling problem. The arrangement in use on the Great Western Railway was the best he had seen placed on the market; and in case of failure, the danger indication was given to the engine-driver, thus corresponding with the outdoor signals.

Messrs. D. A. and C. A. STEVENSON could not agree with the Author when he referred to the introduction of the system of audible signals in use on the Great Western Railway as being perhaps the most noteworthy development of railway-signalling in recent years. The system necessitated an electrical connection between engine-driver and signalman, which obviously was a somewhat difficult one to ensure. It introduced electrical mechanism on the engine, that was, on the moving body; also a mechanical device attached below the engine, consisting of a movable shoe and plunger; and it further required a 40-foot length of ramp between the rails as an electric conductor. Neither was electrical apparatus in the form of electromagnets a good engineering feature in the contrivance; and the multiplication of such arrangements over large railway systems would produce a multiplication of difficulties of maintenance. The more simple or commonplace a signal system was, the better, provided it were workable, and the acetylene fog-gun fired by electric spark, which had recently been introduced, more especially for marine-signal purposes, would seem to meet the case. In this system the engine might be employed to depress the ordinary bar, thus making contact and firing the fog-gun, or the signalman might have the power of switching on the firing action in time of fog, so as to fire continuously if required. This signal could also be

Messrs.
Stevenson.

Messrs.
Stevenson.

arranged so that the signalman was able to hear the gun sound and assure himself that it was working properly, although placed a long distance away. They had had a gun of this type working for weeks, day and night, without intermission and without any attention. The advantage of the gun to suit particular cases was obvious, as, for instance, when men were repairing a line or on distant signals. The gun had been erected by Messrs. Moyes and Son, of Glasgow, and was at present under trial: it was found to answer all railway requirements. The Author touched but lightly on the subject of signal-lights and their maintenance, but much consideration should be given to these matters as safety depended on them to such a large extent. There could be no doubt that the distinction between a flashing light—giving, say, a flash every second—and a fixed light would be more easily marked than any distinction due to difference in colour or otherwise; and if this were realized and adopted on railways it would result in greater safety to the public and simpler and more evident signals for the employees. Probably the flashing lights should be kept for main lines, showing a flashing light for safety and a fixed light for danger. In connection with lighthouse work, flashing acetylene lights had now been used in Scotland for several years, most of them using the Pintsch flasher. By the adoption of acetylene a light of great intrinsic brightness was obtained, which would be important for railways, and also very little cleaning was required. A group flash could be given if required for further distinctions, besides, of course, colour distinction if desired. There were some railway lines in the country on which the signal-lights should be improved, and by adopting acetylene the improvement of the light was simple; further, if acetylene were used, the addition of the fog-gun almost followed, as the same apparatus which gave the flash could fire the gun. Some years ago a form of light was suggested which could be made visible at a long distance, but only came into view at a certain shorter distance. The application of the arrangement was not difficult, and it would keep out of the eye of the engine-driver many a light which it was not wished he should see and which only tended to confuse him. Messrs. Stevenson's experience showed that, as a rule, lenses should not be employed at all in signal-lamps unless special circumstances necessitated their use, and in some cases they had found so-called lenses used for railway-lamps absolutely obstructing the light in place of reinforcing it. If lenses were to be used at all for railway purposes, the proper form would be azimuthal condensing lenses, in place of the bull's eye in ordinary use.

Mr. I. W. STOKES mentioned that signalling and interlocking on the Great Indian Peninsula Railway had many features in common with the practice on the Great Western Railway, which he considered as occupying a leading position in the railway world with regard to signalling matters. On the former line they used bracket signals, and arranged the arms in the same way as shown in Figs. 1-6, Plate 5. The route-indicating signal described, so far as Mr. Stokes knew, had not made its appearance in India, but as he considered it to be an extremely useful appliance under certain conditions—at terminal stations, for instance—it was probable that it would be given a trial on the Great Indian Peninsula Railway. He would not advocate its use except for places where the speed of trains would be relatively low. He was in accord with the Author as to the advisability of providing distant (warner) arms at junctions for the fast-running lines only, and so assisting to check the speed of a train over a turn-out. The goods-loop train-indicator was a useful innovation, and should materially assist in working long refuge-loops with a minimum of delay. Regarding signal-lamps, experiments had been made on the Great Indian Peninsula Railway for some time, and had proved the desirability of installing a new type of lamp, on much the same lines as that now in use on the Great Western Railway, which was now being done. Long-burning lamps were, in his opinion, hardly suitable for Indian conditions, the usual native not being particularly good or careful in trimming lamps. He had for some time past carried out experiments with springs in signal-wire connections, very much as described in the Paper, and they had been found to give considerable relief, especially on long wires; compensator troubles were also very much diminished. The wire-joint illustrated was ingenious and seemed quite worth adoption. The wire was presumably of mild steel, galvanized. Mr. Stokes, however, had found little difficulty with the ordinary wire-joint, a class of work that the native workman seemed to manage quite well. No power system of interlocking had yet been installed on the Great Indian Peninsula Railway, and he was loath to offer any decided opinion as to its future in India. The saving in cabin-staff was not so large a factor there as on British railways, and the necessity of a highly-trained staff for maintenance purposes, as compared with the requirements of a manual system, was against its adoption in India. The introduction of audible cab-signals to such a large extent on the Great Western marked an important stage in the history of railway-signalling; in Mr. Stokes's opinion this system of indicating distant (warner) signals to a driver was one of great value and had a large future. He had seen it in actual

Mr. Stokes.

Mr. Stokes, working on the railway, and although in the west of India there was little trouble from fogs, its adoption would effectually get over the difficulties of warner signals being out of adjustment and warner lights being extinguished ; it would, moreover, ensure an absolutely correct indication being given to the driver.

The Author. The AUTHOR, in reply, stated that the contact-shoe was so designed that the blow usually found between engine-contact and ramp was minimized, and there was really no difficulty from this cause in the Great Western audible signalling arrangement. The three-position distant signal referred to by Mr. Balliet would hardly seem to be adapted to the English mode of working. The goods-loop indicator would provide for as many trains of standard length as the loop would hold, and drivers would know pretty well where these would end. White lights took the place of red in subsidiary signals. No trouble had been found with the wire-joint described in the Paper from the cause mentioned by Mr. Cannon. Mr. Coath's approval of the cab signalling-device was the more acceptable as Mr. Coath was the inventor of a very ingenious audible signalling apparatus. The Author's objection to solid signal-wire as used by Mr. Dutton was that it gave no notice of impending breakage, while a stranded wire did as a rule, one or two strands giving way generally before the actual failure of the wire occurred. With regard to Mr. Fleet's remarks, where it was desired to retain the locking-on points after the signal behind them had been restored to the normal position, a bar similar to a facing-point lock-bar could be provided for the purpose, ahead of the points. Mr. Fleet's practice with regard to providing alternating-current relays for track-circuits on electrified lines was one which the Author had also employed. In answer to Mr. Rogers's question as to the goods-loop indicator, it was worked by wire and no difficulty had been experienced. Two standard voltages were adopted for track relays on the Great Western Railway. For relays of $4\frac{1}{2}$ ohms resistance the standard values were the same as those quoted by Mr. Sayers, while the values required for the higher standard of 9 ohms were proportionately higher, namely, pick-up voltage 0.50, and drop-off voltage 0.30. The higher resistance relay was generally adopted for working short tracks, say up to $\frac{1}{4}$ mile, and the lower standard was used on circuits exceeding this length. Both accumulators and Daniell gravity cells were used. The accumulator gave very satisfactory results electrically, and was more convenient for maintenance, assuming that power plant for periodical re-charging was reasonably accessible. The automatic battery motor-signals employed on the Great Western Railway were lowered in about 8 seconds, and during

this period required 3 amperes at 10 volts. The power required to maintain them in the "off" position after lowering by the motor was 0·07 watt. In reply to Mr. Siegler, the Author was of opinion that such lengths of signal-wire as 2,800 or 3,000 yards should not be employed, but that signals at such a distance should be worked electrically. As to rime forming on the contact-shoe of the audible signalling apparatus, the shoe was steam-heated, which prevented this. The Author had found no difficulty in regard to the working of assisting-springs from the cause mentioned by Mr. Steven.

7 March, 1911.

ALEXANDER SIEMENS, President,
in the Chair.

The Council reported that they had recently transferred to the class of

Members.

FREDERIC WINFRIED LA TROBE-BATE-
MAN.
WILLIAM FAIRLEY.

MICHAEL BIRT FIELD.
ALBERT EDWIN GRIFFIN.
JAMES MACKENZIE.

And had admitted as

Students.

JAMES HAROLD BRUNSKILL, B.Sc.
(Durham).
REGINALD ERNEST DICKINSON, B.Sc.
(Engineering) (Lond.)
EDMUND CASPALL GREEN.
JOHN SEYMOUR HIDE.
JAMES MOWAT KNIGHT.
ROYSTON ENGLEHEART KNIGHT.
JOHN YOUNGER MACKINNON.

HUGH JOHN MACNAMARA.
HERBERT MEDCALF, B.A. (Cantab.)
FRIEDRICH WILHELM MEYER.
BERNARD RICHARD PETERS.
WILLIAM EDWARD PIKE.
ANDREW ROBSON.
FRANCIS VAUGHAN SIMPKINSON, B.A.
(Cantab.)
MOHAMMED WAHEY.

The Scrutineers reported that the following Candidates had been duly elected as

Members.

HUBERT FRANCIS DAUBENY BURKE.
PHILIP CHARLES HOLMES HUNT.

PHILIP BENJAMIN OSBORN.

Associate Members.

HARRY LATOUR BAZALGETTE, Stud.
Inst. C.E.
HARRIS BOOTH, B.A. (Cantab.)

FRANK WILLIAM COCKSHOT, M.A.
(Cantab.)
ALICK DARBY DRAPER.