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“The Signalling of the London and North-Western Railway.”

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RAILWAY signalling has become so important a branch of engineering, that the time will shortly arrive when the services of engineers, specially trained in this branch of the profession, will be required to carry it on.

That the work has not hitherto attracted the attention it deserves, is perhaps in a large measure due to the fact, that nearly all railway companies have placed it in the hands of contractors, and consequently, many who would have trained themselves for the work have been deterred by the absence of a demand for their services.

The system is not one calculated to effect that uniform arrangement which is so desirable; for although contractors have, as a rule, carried out their work satisfactorily, they have never had the advantage, which the Signal Engineer possesses, in the almost daily reports he receives of slight failures and other occurrences, which teach him where a faulty construction exists, or where an improvement in the arrangement of signals can be made. It may not, therefore, be unreasonable to predict that the more important railway companies will, ere long, manufacture their own signal-apparatus, and appoint engineers to superintend it; and the study of the subject will not be time ill-spent.

A brief history of signalling on railways will be found in Mr. R. C. Rapier's Paper, “The Fixed Signals of Railways,” read before the Institution in 1874.¹ That Paper describes the successive steps by which signalling had arrived, from its first introduction, to its then comparative perfection. The object of the present Paper is to continue the history, by a brief description of the Signalling of the London and North-Western Railway, which the Author thinks may be taken as representing a good example of modern practice.

In 1873 the Directors of the London and North-Western Railway Company, in view of the large outlay which would be necessary in connection with the signalling and interlocking of extensive widening and other works then in course of construction, and also

¹ Minutes of Proceedings Inst. C.E., vol. xxxviii., p. 142.

for the completion of the interlocking of the line with as little delay as possible, determined to place the work in the hands of an engineer who could devote the whole of his attention to the subject. They had for some time foreseen that the rapidly-growing importance of the work, which had already cost more than £1,000,000, would compel them, sooner or later, to relieve their District Engineers of the duty; and the work which was done by contract had led to the introduction of several types of locking-apparatus and signal-fittings, which necessarily caused delay and extra expense in carrying out alterations, or in effecting repairs.

Acting on the advice of their Chief Mechanical Engineer, Mr. F. W. Webb, M. Inst. C.E., the Directors instructed him to prepare shops and machinery at their works at Crewe for the manufacture of every appliance necessary to carry on the signalling of the line, and they instituted a Signal Department and appointed an engineer to superintend the work, and assist Mr. Webb.

In accordance with these instructions, Mr. Webb provided large fitting- and erecting-shops, carpenters' shops, and saw-mills, supplied with special machinery; and arrangements were made at the Company's steel works for rolling the Bessemer steel-point rod, locking bar, and other iron, and the stamping of the corrugated steel signal arms; while provision was made in the foundries and smithies for the large amount of cast- and wrought-iron required. Simultaneously with the fitting up of the shops, plans were prepared of the locking-apparatus, and other appliances requisite for the signalling of the line.

Locking-Apparatus.—It may be of some interest, before describing Mr. Webb's apparatus, briefly to trace the growth of the locking-apparatus.

The first arrangement for locking a point with a signal is that of Mr. Atkinson, which was provided at East Retford in 1852 to lock a signal with a pair of switches. In the following year Mr. Whitworth proposed a notched bar, in connection with the signal-wire, and crossing at right angles another notched bar working in connection with the points. It may seem a simple matter to group a number of these bars together, with the point- and signal-levers in a frame, and so produce a complete locking-apparatus, but fourteen years elapsed before the combination was proposed by Mr. Cariss in 1867.

The credit of having produced the first complete locking-apparatus is now generally given to Mr. Austin Chambers, who, in the latter part of 1859, provided frames at Kentish Town and Willesden

Junction. Shortly afterwards, Messrs. Stevens and Sons and Messrs. Saxby introduced improved apparatus. Between the years 1864 and 1866, schemes were proposed by Messrs. Anderson, Jeffreys, Bell, Skinner, Lea, Livesey and Edwards, and Owen, possessing, however, no features of great value. In 1866 Messrs. McKenzie, Clunes, and Holland produced the apparatus which, in an improved form, they are now manufacturing; the locking is of a strong but somewhat heavy type, and the parts numerous, but it is a good machine. An apparatus somewhat similar in principle is that of Mr. Brady, largely used by the South-Eastern Railway Company.

In 1867 Messrs. Saxby and Farmer introduced a spindle locking-apparatus, which was extensively used on the London and North-Western Railway; and many of them are still working well. In the same year Messrs. Easterbrook and Saxby brought out their catch-rod locking-apparatus, and between this date and the year 1870 schemes were proposed by Messrs. F'Anson, Kitchen, Easterbrook, Saxby, Buck, Baines, Baker, Rapier, Hannaford and Cochrane.

In 1870 Messrs. Stevens and Sons brought forward an improved form of apparatus, in which the locking is prompt and secure, and it is in every respect trustworthy. In the same year Mr. Smith introduced a pedal actuation apparatus, a well-designed and simple frame, which has done its work well.

In 1871 Mr. Saxby introduced a rocker catch-rod apparatus, which his firm manufactured for some years; and in 1872 Mr. Imray designed a catch-rod apparatus of an improved form, the best catch-rod frame at that time, which has been modified and adopted by the Midland Railway Company.

In 1873 Mr. Poole invented an apparatus, the locking being actuated by a side movement of the lever; and in the following year Mr. Saxby brought into use the improved form of rocker catch-rod apparatus; the locking is a modification of Messrs. Smith and Imray's, and it is in all respects a machine to be relied upon.

In the same year Mr. Webb introduced a catch-rod locking-apparatus, embodying several details of value, together with a simple form for outlying sidings, which is largely used by the London and North-Western Railway Company (Plate 2, Fig. 1); and in the following year he improved the apparatus, the motion of the catch-rod being communicated to the locking-bar through a cam-slot formed in the head of the vertical locking-bar (Fig. 2).

In 1876 Mr. Webb proposed a locking-frame, the locking being actuated by the lifting of the lever, the catch-rod acting as a fulcrum; and in the same year he introduced the apparatus now in general use on the London and North-Western Railway, which

the Author considers, both as regards design and workmanship, to be unrivalled (Fig. 3). The amount of wear and tear in a frame working a busy junction is so great, that, if badly constructed, it is sure to be frequently out of order, and at a time when perhaps it is almost impossible, on account of the traffic, to effect the necessary repairs. Mr. Webb, therefore, kept prominently in view the advantage of having a strong machine, of the simplest possible construction, few parts and these interchangeable, large wearing surfaces, and the whole easily accessible for cleaning and repairs; and he decided that it would be more economical in the end to fit it up with as much care as is bestowed on a locomotive engine, relying on special machinery to cheapen production, rather than, as it were, to throw rough castings together without fitting, as had been too frequently the case. Somewhat hampered at the start by the claims of inventors, an apparatus was produced which embodied all the characteristics constituting a good machine.

Instead of casting the quadrant-plate in one piece, to contain from ten to fifteen levers, as is the usual practice, each lever is centered on a casting (A, Fig. 3), which forms its own quadrant; and these levers and quadrants are, so to speak, threaded together to form an apparatus of any desired size.

A special rose-cutting machine is employed in facing the quadrants, and the facings C, D, E, F, G, H, I, are cut at one operation, which ensures all quadrants being exactly alike, and thus a lever can be renewed, or an additional lever added to a frame, without any fitting being necessary on the spot.

The locking-frame is of the horizontal and vertical bar type, but much more carefully constructed than usual. The horizontal bars (J, Fig. 3) are of Bessemer steel, rolled to a shallow channel section (Fig. 4); the locking-studs are squared to fit the channel, and are then secured by riveting. The vertical notched bars (K, Fig. 3) are also of steel, the notches being punched out cold. Each vertical bar is guided by a channel the length of itself, and one wall of this channel is made deeper than the other, and notches are cast in it to act as guides for the horizontal bars, the notches being faced by a special drifting-machine at the rate of thirty-five notches per hour.

The locking is known as "lever-locking," to distinguish it from "catch-rod-locking," and the motion of the lever is communicated to the vertical notched bars by a double hook-shaped lever (L, Fig. 3), centered on the lever, which hooks over a projection (M, Fig. 3), cast on the lever-quadrant casting. Upon the lever being moved about $\frac{1}{32}$ inch, the hook-lever is tilted

up, communicating sufficient motion to the locking-bars to effect all necessary locking; and it is further tilted when the lever is within $\frac{1}{32}$ inch of its pulled-over position, communicating additional motion to the locking-bar to effect the necessary unlocking.

Owing to the position of the centre upon which the hook-lever turns, any strain put on a locked lever is taken principally by the main framing, and the locking, which is of a light design, is thus saved from undue strain. If the apparatus be large, and the locking-bars numerous, the vertical notched bars are divided in the middle by a short compensating lever, and being thus counter-weighted, any length of bar may be used; a frame in course of construction for Rugby has bars 18 feet deep. A detail, highly appreciated by the signalmen working these frames, is the loop handle (N, Fig. 3) which Mr. Webb has substituted for the spring catch-handle usually provided.

Of the twenty-six thousand five hundred levers on the London and North-Western Railway, about one-half are of Mr. Webb's pattern. Their working has been everything that can be desired; and although many of the frames are at very busy junctions, notably Crewe, with one hundred and forty-four levers, and Springs Branch, with eighty levers—in which latter cabin nine thousand nine hundred and sixty-five levers are pulled over and put back in twenty-four hours—the cost of maintenance has been trifling.

The largest frame of Mr. Webb's pattern is that provided at Crewe, where six lines of railway meet at a common junction north of the platforms. Previous to the erection of this frame the junction was controlled from two signal cabins, and some doubt was raised as to the wisdom of concentrating so much work in one cabin. A single cabin containing one hundred and forty-four levers was, however, provided, with the result that the junction has been worked more economically and with increased safety, misunderstandings likely to arise out of a joint control being avoided.

An apparatus in course of construction for working the south junction at Rugby will contain one hundred and eighty levers, eighty-four horizontal locking-bars each 83 feet long, and one hundred and eighty vertical bars each 18 feet deep. The cabin will be 96 feet 6 inches long by 12 feet wide, and 23 feet high.

Signal Cabins.—These do not need special notice. The upper portion is, as usual, constructed of wood, and the lower portion, as a rule, of brick. All the timber-work is cut to template,

and the length of the cabin is determined by the number of sashes, which are of a standard size.

The following list gives the sizes of the cabins, and the number of levers they are constructed to contain :—

	Feet.	Ins.	Feet.		Lever.		Feet.	Ins.	Feet.		Lever.
A . .	6	0	by 6	to hold	5	K . .	32	3½	by 12	to hold	50
B . .	9	0	„ 9	„	10	L . .	35	0	„ 12	„	55
C . .	13	5½	„ 12	„	15	M . .	38	7½	„ 12	„	60
D . .	16	2½	„ 12	„	20	N . .	44	0	„ 12	„	70
E . .	18	9	„ 12	„	25	O . .	48	9	„ 12	„	80
F . .	21	6	„ 12	„	30	P . .	54	1½	„ 12	„	90
G . .	24	1½	„ 12	„	35	R . .	65	6	„ 12	„	112
H . .	26	6	„ 12	„	40	S . .	80	4½	„ 12	„	144
J . .	29	8	„ 12	„	45	T . .	96	6	„ 12	„	180

All cabins holding more than fifty levers are warmed with hot water, and this is found to greatly improve the working of the long locking-bars, the uniform temperature counteracting the expansion and contraction which takes place in a large cabin heated by an ordinary firegrate or stove. When hot-water heating is adopted, gas-stoves are, in addition, supplied for the signalmen to warm their food. The number of signal cabins is one thousand three hundred and forty-four.

Signals.—The semaphore type of signal, introduced on the Croydon Railway in the early part of the year 1842, by Mr., now Sir, Charles Hutton Gregory, K.C.M.G., Past-President Inst. C.E., has since been adopted on all British railways. It is rather singular that this simple form of signal, which was in use for signalling purposes as far back as the seventeenth century, should only have been generally adopted after almost every other conceivable form had been introduced. Revolving disk-signals of various forms were the most common, and there are many still in existence, a large number of the distant signals on the Midland Railway still being of the disk form, but semaphores are being rapidly substituted to comply with the regulations of the Railway Clearing House.

That signals on all railways should be uniform in type is most desirable, and it is to be hoped that the time may come when railway companies will not only adopt a uniform type, but will pay greater attention to the grouping and general arrangement. On an ordinary double line of railway there is little difficulty in arranging signals so as to be easily read by the dullest driver; but now that four lines of railway are becoming common, and large stations are erected with four or more separate, and perhaps parallel, lines, meeting at a complicated junction, the

ingenuity of the Signal Engineer is exercised to the utmost, to present to the view of drivers an arrangement of signals which cannot easily be misread. The too common system of grouping a large number of signal-arms on one pole applying to several approaching roads, or providing prominent signals for subordinate lines or shunting operations, dotted up and down an important junction, regardless of the appearance they present to drivers, should not be tolerated.

No doubt a great deal of this bad signalling is due to the fact that the plan of the permanent-way is agreed to, and the roads perhaps laid down, before the Signal Engineer has been consulted; and consequently he has to content himself with such sites, in many cases quite unsuitable, as are available for signals. To avoid this, the plan of the permanent-way and the plan of the signals should invariably be schemed together, so that not only may suitable sites be left for the signals, but an opportunity afforded the Signal Engineer to suggest such alterations in the roads as may be found necessary to secure a satisfactory arrangement.

The signal adopted by Mr. Webb (Fig. 5) is of the ordinary semaphore type, the poles being of pitch-pine timber, varying in size from 9 inches by 9 inches to 15 inches by 15 inches at the bottom, according to the height of the post, to 6 inches by 6 inches at the top, upon which is placed a galvanized iron cap. The bottom part of the post, for about 7 feet, is left the full size of the timber from which it is cut, and thus, at the "wind and water," or ground level, where the process of decay is most rapid, 18 inches or more timber is left, which, after being charred, is well coated with gas-tar. The signal-arm is formed of a thin steel plate, stiffened by two corrugations running lengthways of the arm; this is riveted to a galvanized cast-iron centre, upon which is fixed an adjustable frame for the spectacle-glasses, made sufficiently heavy to counterbalance any accumulation of snow on the arm, and to keep it in its danger position should any of the fittings fail. The arm works on a spindle squared to receive it at one end, and the back-light lever at the other, and the spindle turns in a casting fastened to the post by four $\frac{5}{8}$ -inch bolts, which also serve to secure the lamp-bracket placed at the back of the arm; this is of sufficient width to form a stop for the arm when in its danger position.

Bracket signals are fitted in the same way as single posts, and the only detail that need be mentioned is the light wrought-iron bracket (O, Fig. 5), which has been substituted for the heavy cast-

iron bracket usually employed, as the latter adds an unnecessary weight to the post, holds more wind, and is more troublesome to erect.

For siding signals, a simple form of ground disk-signal is employed (Fig. 6).

The London and North-Western, and most other railway companies, still retain the white light as an all-right signal for intermediate block cabins and unimportant stations, and the green light as a caution signal for junctions and important stations.

The Great Northern Railway Company has, however, abandoned this practice; they treat the white light as a danger signal, as well as the red light, and employ a light-green light as the all-right signal. A little more than one-half the signals on the London and North-Western Railway exhibit red and white lights, and the rest red and green.

The Great Northern Company has also adopted a signal-arm centered midway in its length, as shown by Fig. 7, so that any accumulation of snow on one end is counterbalanced by the accumulation on the other end—a somewhat unnecessary refinement, however, the object being equally well attained by a counterweight, without departing from the form of semaphore generally adopted.

The number of signals now in use on the London and North-Western Railway is as follows:—7,785 semaphore posts, with 11,542 arms; 1,985 siding ground disk-signals; 21 point-indicators.

To ensure a uniform arrangement of signals, instructions have been issued to the men as given in Appendix I.

Signal Slot.—This is an apparatus invented in 1862 by Mr. Gill, an assistant engineer of the London and North-Western Railway Company, who fixed the first one made to a signal at Shap, near Carlisle. The apparatus is employed when it is necessary for a signal to be jointly controlled by two or more signalmen. At one time it was used for controlling junction-, home-, and starting-signals to act as distant-signals for a cabin in advance; but this practice has been abandoned, as it led to drivers being called past such signals when at danger, to perform shunting operations, &c.; and not only were drivers thus educated to pass signals at danger, but mishaps were continually resulting from hand signals being misread, or the road not correctly made, due to the fixed signal, which alone controls the locking, not being used. Lower distant arms have been substituted, and a large expenditure has been involved by the change. These distant arms are fixed 7 feet below the home arm, and slotted with the top arm, so that the

distant arm cannot be off when the home arm is at danger—an obvious and very necessary precaution.

When, however, signal cabins are so close together that the distant-, home-, and starting-signals are common to both, there is no objection to the control by a slot, and this arrangement is adopted when necessary, although some companies have abandoned it. The form of slot adopted by the London and North-Western Railway Company is shown by Fig. 8. In 1880 the Author introduced a wheel-slot (Fig. 9), an apparatus which enables any number of cabins to control a signal by a single wire, which has effected a saving of some thousands of pounds in first cost.

Adjusting Apparatus.—Difficulty has always been experienced in counteracting the expansion and contraction of long lengths of wire used for the working of distant signals. Many schemes have been proposed, but they all have proved complicated and unsatisfactory. The best position for a compensator is at the signal-post, but a satisfactory arrangement in this position has not yet been found, and there are difficulties connected with it which are practically insurmountable.

Apparatus fixed midway between the signal and the lever works fairly well, but, with one exception, all kinds have the grave fault, that should the wire between the apparatus and the lever become slack, either by the wire breaking or a joint drawing, there is danger of the signal being pulled off. The only scheme which gets over this difficulty is the recent one of Mr. Johnson, who employs glycerine in tubes. Grip apparatus, fixed on the lever in the cabin, is the least complicated, and most trustworthy. When self-adjusting apparatus is not provided chains should be fixed as near the cabin as possible, or means afforded by which the signalman can adjust the wires without leaving the cabin.

Point-Rods.—The most common form of rod for working points is ordinary 1-inch gas-piping, the joint at first being formed by the usual screw-ferule. The screw-threads of the ferule, however, corroded and stripped; and the joint was consequently superseded by one through which a spigot was inserted, and secured by two riveted pins, in addition to the ferule. This joint was in use for a considerable time, but many failures having occurred, cotters were finally substituted in lieu of the pins; and in this form it has been adopted by all the principal railway companies who employ gas-piping, with the exception of the North-Eastern Railway. This company still uses a ferule only, the ends of the piping, however, being made solid, and the ferule somewhat

longer. For some years the Midland Railway Company used solid round rod-connections, laid down in long lengths, and joined by means of a wrought-iron hexagon adjusting screw, but steel piping has lately been substituted.

In view of the large number of facing-points, in many cases worked at a distance of 150 yards from the signal cabin, and over which trains travel with undiminished speed, a strong and thoroughly trustworthy connection is of the utmost importance. Mr. Webb decided to adopt a steel rod of a channel section (Fig. 10), which is not only stronger than gas-piping, but rods of this form weakened by corrosion are readily detected and removed. The use of gas-piping was abandoned, as it is frequently manufactured of poor iron, and corrosion goes on rapidly in the interior of the pipe, so that it is almost impossible to detect when a rod has become insecure. The steel channel rod is rolled at the Company's works at Crewe, and it is sawn off in lengths of 18 feet. Before leaving the works it is heated and dipped in oil, and when laid down permanently it is coated with red lead. The joint is formed by a fish-plate of a section to fit into the channel, and secured by six $\frac{1}{2}$ -inch bolts. The fish-plates are rolled and sawn off to the exact length, and the six holes are then drilled at one operation by a special machine, the corresponding holes in the rod being also punched at one operation. The rod runs on small rollers, cast to fit the channel, and these rollers are carried by cast-iron frames. The rod has been in use on the London and North-Western Railway for nearly ten years, during which time there has not been a single failure. It is now being adopted by the Lancashire and Yorkshire Railway Company.

Point-rod Compensators.—Of the various compensators, the London and North-Western Railway Company retains the old form of lever fixed vertically, as being simple and thoroughly efficient.

Point-rod Adjusting-nuts.—Slight mishaps having occurred, due to the breakage of the cast-iron adjusting-nut, Mr. Webb adopted a steel nut of hexagonal form (Fig. 11). The nuts are rolled at Crewe, and sawn off to the right length, and then drilled and tapped. At a distance of $1\frac{1}{2}$ inch from each end a detector hole is provided, so that the signal chargeman in going his rounds may ascertain if the screw has been driven too far by the platelayers in adjusting the points. This is a very necessary precaution.

Goose Necks.—Several patterns of this so-called fastening between the point-rod and the switch-tongue are in use, and the London and North-Western Railway Company has adopted the joint (Fig. 12), it having proved thoroughly trustworthy.

Facing-Point Locks.—After some serious accidents had occurred at facing-points, due to the points not closing properly, or the signalman moving the lever when a train was travelling over the points, the necessity for additional security became manifest, and the simple and now universally adopted locking-bar introduced by Messrs. Livesey, Edwards and Jeffreys, in the year 1867, and which was afterwards improved by the addition of a bolt, &c., by Mr. Saxby, supplied the want.

The apparatus (Fig. 13) consists of a piece of T- or angle-iron, somewhat longer than the widest wheel-base of the carriages running on the railway, fixed on the inside or the outside of the rail, in advance of the facing-points, and carried by short levers. The bar in its normal position lies just below the flange of the wheel, and, when in movement, rises to the level of the rail, and again drops to a position below the wheel flange. In connection with the bar is a plunger, which enters a hole in the point stretcher-rod, and thus the points are firmly secured in position. The apparatus is worked as follows :—When the signalman has moved the points to the road on which a train is to travel, he pulls over the lever which actuates the bar—thus securing the points and releasing the signal. The signal-lever is then pulled over, and the facing-point and locking-bar levers become locked. But should the signalman put the signal back when the train has passed it, and attempt to move the locking-bar lever when the train is running over the points, it is locked by the flange of the wheels, and thus the train secures the locking whilst passing over the points, and the danger of a train running over facing-points at a high speed is, by this invention, reduced to a minimum. Shortly after the introduction of this apparatus a slight defect was made apparent by several accidents, due to the breakage of the rod working the points. This enabled a signalman to lock the points and lower the signal for the main line, when the points were unmoved and standing open, say, for a loop- or bay-line. To obviate this, Mr. Rapier proposed a bolt of two different sections, one section locking only for the loop-line, the other for the main line. This was followed by a scheme by Mr. Saxby for an improved method of working the bolt, which was again succeeded by a duplex bolt proposed by Mr. Webb. All these schemes, however, added complication; they have not been adopted, and attention has been confined to improving the connections. As an additional precaution, however, it is desirable, at important facing-points, to provide a detector-lock, in connection with the main line signals. The lock adopted for this purpose by the London and North-Western

Railway Company is one designed by the Author (Fig. 13a). The chief novelty is the provision of a separate rod for each switch-tongue, thus ensuring that should either tongue be out of position the fault is at once detected, which would not be the case if one rod only were provided.

To save the additional lever required in connection with the locking-bar and bolt, several schemes have been proposed, and on some railways largely adopted, for working both the points and locking-bar and bolt by one lever. But the arrangement is one which should not be recommended, as the stroke of the lever—short enough in the ordinary apparatus—is reduced by two-thirds; one-third being required to withdraw the bolt, one-third to work the points, and one-third to bolt the points again; consequently, if the movement of the point is obstructed by a stone, and the connection not very strong, there is a chance that the signalman may pull the lever over by buckling the rod, as he does not feel the obstruction until the lever has made nearly two-thirds of its stroke.

Several forms of locking-bar apparatus have been introduced by Messrs. Bell, Brady, Buck, Edwards, Harrison, Luke, Stevens, Webb, and the Midland Railway Company; but the London and North-Western has adopted the Livesey bar as improved by Mr. Saxby.

At all facing-points, a strong gauge-tie is provided, and to this the plunger-casting is bolted. The apparatus in the 4-feet way should be carefully boxed in, and the lids which open to enable the cranks, &c., to be oiled and cleaned, should be hinged, so as to prevent a chargeman leaving the lid on the rail.

There are 1,629 facing-points on the London and North-Western Railway; all, with the exception of a few on unimportant branch lines which are padlocked, are either fitted with locks and bars, or secured by a train-staff lock.

Locking-Bars.—Frequent mishaps result during shunting operations, from the signalman moving the points before the train is clear of the line. It is a good plan to provide points, which are a long distance from the signal cabin, with a locking-bar to work in connection with them, and a considerable number of the points on the London and North-Western Railway are so fitted; but in busy station-yards, where there is a great deal of shunting, bars are not to be recommended, as they are often broken down by vehicles striking their end whilst being pulled over.

Detector-Bars.—It frequently happens that a signal cabin is so placed, that the signalman cannot clearly see whether vehicles

standing, say, in a bay-line, are clear of a platform-line from which he wishes to signal a train, or whether a bay-line is clear, into which a train is about to be signalled. To meet the difficulty Messrs. Park and Pryce introduced their "train protection bar" (Plate 2, Fig. 14, and Plate 3). This is a light locking-bar actuated by the same wire that works the signal, and so arranged that, as the signal-lever is pulled over, the bar is lifted to the level of the rail, or nearly so, and thus the signalman is prevented from pulling off a signal should a vehicle stand on the bar.

To prevent the bar being left at the level of the rail whilst the signal remains off, the lever actuating the bar is provided with a pawl, which engages with a quadrant-piece attached to the shaft working the bar; as the signal is pulled off, the pawl carries the quadrant-piece round with it, until the bar is nearly at the level of the rail, when an incline on the bracket raises the pawl and allows the bar to drop again to its normal position; the signal being put to danger again, the pawl re-engages with the quadrant-piece, and the bar is again in a position to be raised and act with the signal.

The bar is useful at stations where it is necessary to have an advanced starting-signal in a tunnel; four or five bars may be laid down between the tunnel mouth and the starting signal; but in this case it is better to work the bars by a separate lever and a rod connection—the lever being so interlocked that it must precede all levers adjusting signals for trains to enter the tunnel. Bars are being provided for this purpose at New Street, Birmingham, and other places.

These bars are also suitable as "duplicate bars" when provided in lieu of repeater signals at junctions where the outlying signals are more than 200 yards from some of the facing-points. The Author has arranged the bars for this purpose with as many pawls as there are facing-point locks in advance, and worked in connection so that the locks cannot be withdrawn so long as a train is travelling over the detector-bar; thus the objectionable practice of placing repeater signals in the middle of a large junction can in most cases be avoided.

Train-Staff Locks.—For locking the points on single lines, a cheap and simple plan is to provide a lock at the points, and secure the key to the train staff. Any lock of a strong pattern will do, but it must be impossible, when the key is inserted, and the points unlocked and moved, to withdraw the key until the points are put back and locked again. This arrangement dispenses with all signals, and it has been adopted to a large extent on the

London and North-Western Railway, the lock employed being shown by Fig. 15.

The train-staff system of working single lines of railway will ere long, no doubt, be superseded by the more convenient system, recently introduced, of "electro tablets," when some arrangement will have to be schemed to take the place of the staff-key.

Locks for Outlying Sidings.—A simple and inexpensive arrangement for locking a siding, too far removed from the signal-cabin to be secured by bolt-lock, was introduced by Mr. Annett in 1875 (Fig. 16). A strong lock, of any ordinary pattern, is fitted to the siding points, and a similar lock to the locking apparatus in the signal-cabin, one key common to the two locks being provided. The lock in the signal-cabin is so arranged that the key cannot be withdrawn until a bolt is shot, which locks all points and signals for the road with which the siding connects; the key can then be carried to the siding, and the points unlocked. The points being pulled over, the key becomes locked, and cannot be withdrawn again until the points are put back, when the key can be turned to lock the points and withdrawn.

At the suggestion of the Author, this simple arrangement has been employed on the London and North-Western Railway for cheaply interlocking unimportant roadside stations, and it has proved to be very safe and satisfactory. Take, for example, a roadside station with a level crossing, a cross-over road and sidings connecting with the up and down lines, the staff consisting of the station-master only, who has to attend to everything, including the block instruments. Interlocked in the usual way, a signal-cabin and locking-apparatus would be provided, and costly connections laid down to work the siding-points, which are perhaps only used once or twice during the day, at a cost of £300 or £400; and, in addition, a signalman is necessary, at a further cost of £60 per annum. In carrying out the interlocking of such a station by means of keys, a small ground frame would be provided, either in the booking-office, where the block instruments are placed, or on the platform close to the door of the booking-office, and it would contain levers for working the signals only. Three locks, with keys, would be attached to this frame, and in connection with the locks three bars would be provided, the movement of which, by the withdrawal of a key, would effect the necessary locking. The action is as follows (Fig. 17):—Say a train arrives on the up road, and has a wagon to pick up from the up siding. The station-master places the up signals at danger, and withdraws the key of the up siding, which may be called Key A; the withdrawal of the

key locks the up signals, and, if necessary, the cross-over road and level-crossing gates. Or, should the down siding have to be used, Key B would be taken, locking all down signals. If the level-crossing or cross-over road is to be used, Key C is withdrawn, locking both up and down signals. Thus a small road-side station may be securely interlocked, and the appointment of additional staff avoided, at a trifling expenditure, and the arrangement would undoubtedly have been welcomed by companies who can ill afford the serious cost involved by the ordinary mode of interlocking. But the Board of Trade, whilst acknowledging the complete efficiency of the arrangement, raise an objection on the plea that it does not accord with the regulation—made, by the way, when interlocking was in its infancy—that the levers working points shall be grouped with the levers working signals on a raised platform, a plea which, it is to be hoped, will be withdrawn after further consideration.

Electric Locks.—For an outlying siding too far removed from the cabin to be bolt-locked, and when too much time would be occupied in carrying an Annett's key between the cabin and the siding, several arrangements of electric locking have been devised, the London and North-Western employing one designed by its telegraph engineer, Mr. Fletcher, which satisfactorily meets the requirement.

Gate Locks.—When level-crossing gates are worked from a signal-cabin, the gearing in the signal-cabin is usually locked, but there are many gates which are locked only, and the most common system is to provide a plunger-bolt at the head of the gate, and a feeler bolt and quadrant at the heel.

A neater arrangement was introduced by Mr. Black in 1877 (Fig. 18); he fixes a special form of lock on the gate-post, controlled by a rod from the signal-cabin, a bolt in the form of a key being attached to the gate. To open the gate it is necessary, first of all, to withdraw the rod worked from the cabin, and so lock all necessary signals; the key-bolt attached to the gate can then be turned and withdrawn, and the gate opened. The withdrawal of the key back-locks the rod from the cabin, and thus the signals are kept locked at danger until the gate is closed, and the key-bolt inserted and turned again.

A simple arrangement is shown by Fig. 19. In this case a strong lock, with a long bolt, is attached to the gate, and a similar lock attached to the locking-frame in the signal-cabin, one key common to both being provided. To unlock the gate, the key is withdrawn from the lock in the signal-cabin, its withdrawal

locking the necessary signals. The key is then carried to the gate, and the long bolt unlocked, raised, and the gate opened; the raising of the bolt locks the key, which cannot be withdrawn again to unlock the signal until the gate is closed and the long bolt replaced.

Level-Crossing Gates.—The wear and tear of the apparatus working a busy crossing, and the strain on the connections, are so great, especially when the gates are large, that it is very important to adopt connections and gearing of a strong and substantial design, as otherwise the gates will be continually out of order, the repairs perhaps involving the pavement of a busy roadway being taken up. The pattern adopted by the London and North-Western Railway (Fig. 20) is of a very substantial design. Steel rods of a channel section are used for the connections, and the gates are worked by heavy sectors rack-gearred with the rods. Many gates have been put up, and their working is everything that can be desired, the cost of maintenance being trifling compared with gates worked by chain gearing.

Interlocking of Block Instruments.—To prevent a signalman from signalling a train into a forward section unannounced, or before "line clear" for a preceding train has been received, or giving "line clear" for the section in the rear before a train previously accepted has arrived, apparatus has been proposed by Messrs. Preece, Sykes, Hodgson, Siemens, Tyer, Langdon and others, for electrically controlling the starting signal for a cabin in the rear, and mechanically or electrically locking the block instruments with the out-door signals and points; the proposal undoubtedly adds complication, but it has been adopted with advantage on some busy Metropolitan lines. On trunk lines, where the block stations are far apart, and the trains are run at greater intervals of time, the necessity for such apparatus is hardly felt; but as traffic increases, and block stations become more numerous, it will no doubt in certain cases be advisable to adopt some such additional means of security.

A description has now been briefly given of the principal apparatus employed by Mr. Webb in the Signalling of the London and North-Western Railway. Details of minor importance have been omitted, a description of which would have been of interest had space permitted.

The number of indoor men employed at Crewe in the manufacture of signalwork is two hundred and thirty-two.

New works are carried out by an out-door gang, consisting of three inspectors, ten foremen, and from ninety to one hundred

and fifty men, the number varying with the amount of work in hand.

For the maintenance of the signalwork of the line (1,783 $\frac{3}{4}$ miles) district store-sheds are provided at Watford, Rugby, Stafford, Crewe, Abergavenny, Craven Arms, Warrington, Tyldesley, Heaton Norris, Lancaster, and Llandudno Junction, the maintenance staff consisting of eleven district inspectors, eighteen sub-inspectors and foremen, sixty-three chargemen, and four hundred and twenty men. The cost of maintenance per annum is £38,500, giving an average cost of £1 9s. per lever.

In addition to the company's book of rules, each man employed on the out-door work of the department is supplied with a book containing the instructions, given in Appendix II., which are strictly enforced to ensure the safe conduct of the work.

The Paper is accompanied by numerous illustrations, from which Plate 2 and the figure in the text have been engraved.

APPENDIX I.

LONDON AND NORTH-WESTERN RAILWAY.

(Circular No. 1706.)

SIGHTING SIGNALS.

Instructions to Inspectors.

To secure uniformity in the arrangement of signals the following rules must, as far as possible, be observed.

The arrangement of the signals shown on the plan prepared by the Signal Superintendent should be adhered to, and sighted for as nearly as possible as shown on the plan—any modified arrangement suggested by the Inspectors on the ground being sighted for and added to the plan as a rider.

Distant Signals.—These signals should be fixed at an uniform distance of 1,000 yards from the home signal, unless the gradient is a rising one, in which case a distance of 800 yards will be sufficient. In special cases a distant signal may be fixed at a distance of 1,200 yards from the home signal, provided the Signal Inspector agrees that he can obtain a sufficiently direct route for the wire connections to ensure the signal working freely. On no account must a signal be fixed at a greater distance than 1200 yards from the cabin.

Home Signals.—These signals should be seen by a driver from the distant signal, and must be fixed as close to the cabin as possible, so that a driver whose engine is standing at the signal may be verbally communicated with by the signalman.

Junction Signals.—The same rule applies to the sighting of these signals as for home signals. They must be fixed near the facing points to which they apply, and in no case must they be at a greater distance than 200 yards from the facing points, unless repeater signals or duplicate locking bars are provided.

Junction signals for protecting a junction in the trailing direction should be fixed so far from the fouling point as to afford a margin for a driver should he accidentally draw past the signal.

Junction signals must not in any case be placed on the same post one above the other, but a separate post must be provided for each signal.

This rule need not apply to bay starting or other subordinate signals; in these cases the signals may be placed on a single post, one signal above the other. The top signal must then apply to the road leading off to the left-hand, the second signal to the next left-hand road, and so on.

Platform Starting-Signals.—These must be sighted at a height of about 15 feet above rail level, and it will be sufficient if they be seen by a driver the length of the platform.

This rule will not apply if the starting signal post carries the distant signal of a cabin in advance, or if the starting signal acts as a home signal for a cabin in advance; in these cases the signals must be sighted as distant and home signals respectively.

Advanced Starting-Signals.—These signals may be sighted of an uniform height with platform starting-signals, of 15 feet above the rail level; they should be seen by a driver from the platform starting-signal, and must not be at a greater distance from the cabin than 350 yards. If an engine or other obstruction standing at the advanced starting-signal cannot be clearly seen by the signalman, the signal must not be provided, and it will then be necessary for the sidings in advance of the platform starting signal to be worked in the block.

Bay starting and other subordinate signals should be of an uniform height of 15 feet above rail level, have short arms, and *be provided with purple lights.*

A distant signal for a cabin in advance must never overlap a home or starting signal for a cabin in the rear, but must be fixed on the same post 7 feet below the home or starting signal, and be controlled by the home or starting signal, to prevent the distant arm being off when the home or starting arm is at danger. When a distant signal is placed below a home or starting signal, no other signal must be placed on the same post, excepting “fog” or “calling-on” arms.

When the distant signals for a junction have to be combined with the home or starting signals for a cabin in the rear, then the starting signal post must be nearest the line with the distant arm for the right-hand junction placed under it, and the distant signal for the left-hand junction must be carried by a separate post to the left of the home or starting post. Both distant arms must be controlled by the home or starting signal. This rule will not apply if the junction to the right is a goods loop or other subordinate line; in this case, the distant signal must be carried on a separate post to the right of the home or starting post.

Lamps must never be placed nearer together than 7 feet, with the exception of bay starting or other subordinate signals, for which the lamps may be fixed closer together.

Back Lights, which cannot be seen by the signalman working the signals, must be dispensed with unless they can be seen from a station platform; in this case they may be retained if it is considered desirable.

Signals elevated more than 45 feet above rail level must have a lower or fog arm, worked in connection with the top arm at an elevation of 15 feet above rail level, but a single lamp only is necessary, to be opposite the bottom arm when practicable.

Signal Cabins should be so placed that the signalman can see all points and signals from the levers working them, especially facing points, which must be in all cases clearly seen.

Electric Repeaters must be avoided, as far as possible, even at the expense of higher signals. If a repeater cannot be avoided, then the signals should be only sighted at such an elevation as to give a driver a good sight.

All Signals should be fixed on the left-hand side of, and as near as possible to, the road to which they apply.

A signal cabin or signal placed on a passenger platform must not be at a less distance than 6 feet from the nosing of the platform, and a cabin or signal must not be erected at a less distance than 4 feet 6 inches from a passenger line.

The Inspectors must each consider the general arrangement of the signalling. It will be the special duty of the *Traffic Inspector* to see that the signal cabin is suitably placed, and that the signals are seen by the Signalman. It will be the special duty of the *Locomotive Inspector* to see that the drivers' sight of signals is good, and that the signals are fixed at a suitable distance from the fouling points. It will be the duty of the *Signal Inspector* to see that the points and signals are placed in such a position as to be satisfactorily worked, are suitably arranged, and in accordance with the plan.

APPENDIX II.

LONDON AND NORTH-WESTERN RAILWAY.

SIGNAL-DEPARTMENT REGULATIONS.

All employes of the Signal Department must make themselves thoroughly conversant with the following Regulations, which must be strictly observed, to ensure the safe conduct of the work of the department :—

REGULATION I.

Cleaning and Repairing Locking Apparatus, Facing-Points, Locks, &c.

When cleaning or repairing a locking apparatus, or the signals and points connected with it, necessitating their disarrangement, the following regulation must be carried out by the signal-fitter or other man sent to do the work.

Before interfering with the locking apparatus, all distant signals must either be disconnected or the levers in the cabin working them fastened in their danger position ; and, before interfering with points, signals, and their connections, the distant signals for the roads affected must be fastened in their danger position. When it is necessary to disarrange the locking apparatus at a junction or station where there are facing points, the home or junction signals, as well as the distant signals, must be fastened to danger. When a facing-point or bridge bolt has to be disconnected from the cabin, the home or junction signals for the roads affected must also be fastened to danger, as well as the distant signals. At large junctions, however, where there are a number of facing-points, and only one has to be disconnected, the distant signals must be fastened at danger ; but special instructions will in each case be issued by the Inspector as regards the fastening of the home signals to danger. When this has been done, the signal fitter or other man must inform the signalman that he is ready to commence the work, when the signalman will, on seeing that the flagmen are properly placed and instructed, enter in the Train Register Book the words "Locking disarranged," with his signature, the fitter adding his signature also.

After this entry has been made the signalman will be responsible for working the frame as if the whole of the locking was absent, and he will do so until the fitter has informed him that the work is completed, when he will enter in the Train Register Book the words "Locking restored," the book again being signed by the signalman and the signal fitter.

When working at a signal box controlling facing-points, the signal fitter must report to his Inspector every case where Rule 149 is not strictly adhered to.

The Signal Inspector will, previous to the work being done, instruct the fitter

as to whether any of the facing-points or trap-points may be spiked over during the progress of the work, in which case the fitter must see that the flagman or other man appointed has properly secured the points before he commences his work.

REGULATION II.

Locking not to be interfered with except on Sundays.

No locking-frame at a place where there are facing-points, no facing-point, facing-point lock, locking-bar, or bridge bolt, is to be disarranged for the purpose of cleaning, oiling, or ordinary repairs, on a week-day, under any circumstances whatever. Such work must invariably be carried out on a Sunday, and Regulation I. strictly adhered to. This Regulation will also apply to places where the traffic is heavy, although there may be no facing-points.

REGULATION III.

A list of junctions and stations will be exhibited in each stores-shed, showing where cleaning, oiling, and ordinary repairs, necessitating the disarrangement of locking, &c., may be carried out on week-days. The district Signal Inspector will appoint a day for the work, give the usual slackening notice, and arrange for flagmen; the work may then be carried out, Regulation I. being strictly adhered to.

REGULATION IV.

When it is absolutely necessary on a week-day to interfere with locking or connections, as mentioned in Regulation II., on account of breakage or failure likely to endanger the safety of the line, the necessary repairs must be carried out without delay. The fitter or chargeman, before commencing work, must apply to the station-master for a flagman, or, if at an intermediate box, application must be made to the signalman on duty, and should a flagman (platelayer) not be at hand, the fitter or chargeman must send his assistant for a platelayer, who will receive his instructions from the signalman. The flagman having received his instructions, the work may be commenced, Regulation I. being strictly adhered to.

REGULATION V.

Under no circumstances must a lever in a signal cabin be moved by Signal Department men, even with the sanction of the signalman on duty. Should a fitter require a lever moved, he must request the signalman to do it; and under no circumstances whatever must a fitter or other person belonging to the Signal Department instruct a flagman.

REGULATION VI.

No locking frames, or point or signal connections are to be disarranged for the purpose of cleaning, oiling, or ordinary repairs, without the permission of the district Signal Inspector, who will appoint a day, and make arrangements through the Signal Superintendent for the necessary flagmen, in accordance with Rule 149A, and for the issue of a notice to engine drivers and others.

REGULATION VII.

Signal fitters, chargemen, and others, must make themselves specially acquainted with Rules 144, 145, 146, 147, and 149A in the Company's Book of Rules, and see that the instructions contained therein are strictly carried out.

REGULATION VIII.

All men belonging to the Signal Department must, before starting work at a signal cabin, enter the time in the Train Register Book and sign their name, and they must again enter the time and sign their name when their work is completed for the day; they must then fill up their time-sheets, entering the date, their name and grade, the description of the work, and the time as given in the Train Register Book, and present it to the signalman on duty for signature, who will sign it after satisfying himself that the entries are correct.

REGULATION IX.

Chargemen and their assistants must give special attention to the connections working facing-points, and facing-point locks, which should be carefully examined every time a place is visited, and any weakness or fault at once dealt with.

REGULATION X.

Chargemen and their assistants must frequently examine point-rod adjusting screws. Detector-holes are provided in the barrel of each adjusting screw, and the rods are centre-punched, and should the screw be found adjusted beyond the detector-hole, arrangements must be at once made for the rod to be lengthened. The screws for facing-points and facing-point locks must receive special attention.

REGULATION XI.

When painting signal arms, painters must be very careful that they do not pull the signal-arm down, as such a practice is liable to lead to serious consequences.

REGULATION XII.

Chargemen and their assistants, when cleaning cranks, wheels, &c., are cautioned against leaving the box-lids too close to the line, several mishaps having occurred due to a neglect of the precaution.

REGULATION XIII.

All Signal Department men are cautioned against leaving tools or other materials on station platforms, several accidents to passengers, and claims against the Company, resulting from a neglect of the precaution.

REGULATION XIV.

In carrying out signal alterations, great care must be taken that the old signals are kept in their danger position until the new signals are brought into use.

REGULATION XV.

When it is necessary in hoisting signals or carrying out other work of the department to have guy-ropes across the line, under no circumstances must a train be allowed to pass unless it has previously been brought to a stand; and to avoid delay to passenger trains, such ropes, when practicable, should be cleared away at least ten minutes before the time the train is due.

REGULATION XVI.

A diagram is given below, which shows the clearance space required for a passenger line, or goods line, and Inspectors must see that no signal-cabin, signal-post, balance-weight, or other obstruction comes within the space dimensioned, and chargemen and others must report to their Inspectors any case where the necessary clearance has not been allowed.

REGULATION XVII.

Wooden covers or boxing over facing-point locks, or other apparatus, in the 4-feet, must not stand higher than 1 inch above rail level; and if the covers are hinged, they must not stand more than 3 inches above rail level when thrown back. Chargemen must report any case where this regulation has not been adhered to.

[DISCUSSION.