Interlocking Apparatus.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Recent Interlocking Apparatus.

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

Figs. 98 and 99 show Mr. Easterbrook's method of effecting this. Each catch rod has a prolongation extending some distance below the floor. On the outer side of this rod are notches $\frac{1}{2}$ inch wide, and 1 inch pitch. Adjacent to these, horizontal bars, also notched, are so placed in guides that the teeth of the bars engage into the teeth of the catch rods to prevent their movement. When the bars are slid along so that a notch comes opposite to a catch rod, then that rod can be moved.

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

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

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

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

a locking bar with notches cut in it, moving in a to-and-fro direction.

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

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

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

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

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

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

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

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

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

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

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

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

In attempting simplification, the Author determined to disregard all previous systems, and to commence, as it were, *de novo*. The subject was successfully reasoned out as follows: As a first

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

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

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

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

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

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

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

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

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

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

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

Switch Locks.

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

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

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

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

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

Fig. 121 shows the position of the locking bolt when the points are locked for the main line; Fig. 123 when locked for branch line; and Fig. 122 when unlocked. The switch *bar* has a T-shaped aperture, Fig. 121. The locking bolt has one end 4½ inches broad on the horizontal line and 1 inch thick, the middle part is 1 inch square, and the other end is 3 inches broad on the vertical line and 1 inch thick. Now in the mid-position of the lever, the lock, Fig. 122, is in mid-position also, and the switches can be moved either way. If the switches be moved in favour of the branch, then the locking lever can only be got home by bringing it down in favour of the branch also, and *vice versâ*, because the horizontal limb would not enter the vertical hole. This plan ascertains whether the switches have moved in the direction intended or not. It covers the contingency of the fracture of the rod which ought to move the switches; for if a signalman found that the lock lever would not come home in favour of the branch, he would be thereby informed that the switches were not home for the branch, and, of course, all the signals would remain locked.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

EXTRACT No. 1.—MAIN LINE.

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

EXTRACT No. 2.—WIDENED LINES.

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

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

MAIN LINE.

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

WIDENED LINES.

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

Total number of trains 768 per day.

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

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

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

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

On the Great Northern, Fig. 143, passing places are provided from Hitchin to Stevenage, 3½ miles, from Hatfield to Potter's Bar, 5 miles, and from Wood Green to Caledonian Junction, 5 miles—all on parts of the line free from tunnels or other expensive works. In the diagram the passing places or slow lines, and also the branch rails, are shown by a full line, and the main rails by dotted lines. When a coal train arrives at one of these passing places, if the main line is clear and no fast train is expected, the coal or goods train is allowed to go by the main line; but if any fast train is expected, the coal train is directed by the signalman through the facing points on to the side line. When the slow train arrives at the south end of any passing place, it is allowed by the signalman to rejoin the main line, under the protection of the block telegraph. At Hitchin and at Hatfield such long passing places are provided only on the up-line, the up-traffic being most in need of them, inasmuch as the coal trains are heavy on the up-journey and empty on the down; and also punctuality is less certain in the arriving than in the departing trains. On the line between Holloway and Finsbury Park, 56 trains per day are passed over the down main line, and 78 trains per day over the down side line—total 134; and 67 trains over the up main, and 74 trains over the up side—total 141; exclusive in both cases of specials and light engines. This shows a moderate number of trains over each line; but the mere numerical reduction of the number of trains does not represent the whole benefit. The greatest advantage is gained by sorting the trains, so that the trains on the same line are more nearly of the same speed, and consequently preserve more nearly their intended intervals of time and space. At Holloway the accommodation is still further increased by the addition of more lines, and thus along 2 miles of the up through line there are only 25 trains per day, chiefly the express trains from York and Manchester. The fast traffic is thus released from obstruction by goods or coal trains: these latter wait in the Holloway sidings, until such time as convenient intervals between passenger trains admit of their being passed through the tunnel to the goods yard. The junctions at Edgware, Highbury, and Enfield are specially worthy of notice, as they are arranged so as to avoid an up branch line crossing a down main, or a down branch crossing an up main line. At Highbury Junction the line to Highbury leaves the up slow line on the level, and the line from Highbury descends, and passes under the main line at Holloway, curves round and joins the down slow line. At Edgware Junction the down branch line strikes off from the down slow line to the left on the level; the up branch line, which must cross the down main line, does not cross it on the level, but is carried up an incline and crosses over the main lines by a bridge, it then descends and sweeps round into the up slow line. At Enfield Junction the up branch line approaches the up slow line on the level, and the down branch leaves the down slow line by a curve, and ascends an incline and crosses the main lines by a bridge. At each of these junctions the level crossing usual at ordinary junctions is avoided, and the effect is to release the 141 up trains and 56 down trains from having to run the gauntlet of about 60 trains of the Highbury and Enfield branches, and to release the 134 down main trains and 25 up main trains from having to be crossed by about 30 up trains from Barnet. Many other junctions on the Great Northern, London and Brighton, and other railways, are arranged on the same plan.

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

are completed as far as the face of Primrose Hill Tunnel. An additional up line is in use from Nuneaton to Rugby, 14 miles. Additional up and down lines are in use from Huyton to Edge Hill, and in course of construction from Stafford to Crewe. In all these cases two lines will be appropriated to fast traffic and two lines to slow traffic. Between Stafford and Crewe the fast lines will be to the east and the slow lines to the west, as the existing goods accommodation is chiefly on the west side.

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

GREAT NORTHERN RAILWAY.

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

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

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