AMERICAN PRACTICE

IN

BLOCK SIGNALING

WITH DESCRIPTIONS AND DRAWINGS OF THE DIFFERENT SYSTEMS IN USE ON RAILROADS IN THE UNITED STATES.

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AMERICAN PRACTICE IN BLOCK SIGNALING.

INTRODUCTION.

The pages which follow are a reprint of articles which appeared in the *Railroad Gazette* in 1890 and previous years. It was the purpose to give in those articles a short description of the methods of block signaling now in use in this country, summarizing the salient features of each system. It was not within the scheme of the articles to exhaustively discuss or describe principles, methods, or appliances, but to give to one comparatively new to the subject a fairly good grasp of it in general and in detail, and to indicate to him the appliances which he might profitably investigate should he wish for fuller or more accurate knowledge. All of the matter up to page 22 is substantially a reprint of articles published in 1890, although a few alterations have been made to bring the information up to date (1891). The descriptions of apparatus in the appendix were published at various times, as indicated by the dates attached to each.

There are practically two systems of block signaling, of which we may call the first the simple block system. Assuming that every railroad is properly supplied with telegraph offices, this may be said to be merely a code of rules by which the attendant at a given station exhibits a signal to hold all trains moving in a certain direction until he receives word by electrical communication that the last preceding train has reached another station and gone out of the section of track intended to be protected. This is an *absolute block* system. When the regulations permit a second train to be sent over the road before the first one has gone out of the block section, but under instructions to run slowly, the term *permissive blocking* is used.

The signals by which trains are admitted to the sections under a block system may be electrically connected with each other and locked by the Sykes system, so that when an operator, after admitting a train to a section, puts his signal to danger, the lever of the signal is automatically locked, so that the signal cannot again be lowered (placed in the safety position) for another train until the train first mentioned has actually reached the next station and operated an electromagnet. When signals are fitted with these locks, permissive blocking is impracticable, unless (1) the operator disconnects the wires by which the Sykes locks control the signal levers, or (2) the signal is left in the danger position and enginemen are instructed by flag, lamp, or hand signal to proceed regardless of the regular signal. In either case the safeguard provided by the locks becomes inoperative, as, when two trains are in a section, the first passing out releases the signal so that a third may be admitted, while the second may be indefinitely detained within the section.

The second system is the automatic. In this no attendant is provided, but each signal stands ordinarily at "all clear" to admit a train to its section. The train on entering sets the signal at danger by the operation of an electric circuit, actuated by the passage of the wheels, and resets the signal at "clear" when it emerges from the section. The first automatic signal system was the original Hall, which was used in Massachusetts and Connecticut about 1871. In this the electric communication from one station to another was by means of a line wire strung upon poles. Some eight or nine years later the track-circuit system was introduced on the Fitchburg road by the Union Signal Company In this the electric circuit is conducted from one end of a block section to the other through the rails of the track ; and the proper working of the system depends upon the integrity of this circuit. The presence in the section of even a single pair of iron wheels connected together by an iron axle allows the passage of the electric current from one rail to the other, and withdraws the force that holds the signal at "clear." If a train breaks apart, the exit of a portion of it from the block section does not clear the signal at the entrance, as is the case with a simple line-wire system.

The most common form of track circuit signal is that in which the signal consists of a disc operated by clockwork, the latter being controlled by the electric current. In the pneumatic track-circuit system the signal consists of a semaphore operated by compressed air, which is controlled by the electric circuit.

THE SIMPLE BLOCK SYSTEM.

The most extensive block system in this country is that of the Pennsylvania Railroad, which is substantially the same as that in use on the great majority of the railroads of Great Britain, though there are numerous differences in the detail of operation. The Pennsylvania uses the simple block system (without Sykes locks). When the system was introduced the number of trains had already grown so large that it became necessary, in order to accommodate them, to establish stations especially for signaling, the regular stations being too far apart. These intermediate stations are generally two-story buildings, and are termed "towers"; and these buildings, being characteristic of the system, have come to be regarded by many people as an essential part of it; but, in point of fact, many of the block-signal operators are located in ordinary station offices. On those sections of the Pennsylvania where trains are most frequent the block sections are from one to two miles long. Near large terminal stations the intervals are in many cases considerably less than a mile. Regular telegraph stations are used wherever possible, but the larger stations have to have two telegraph offices, one for block signaling and one for ordinary business. Special stations are established between the regular stations at such points as will best divide the space and maintain an approximately uniform length of block. On portions of the road where trains are less frequent the sections are made longer, in some cases four or five miles. Each station has a fixed signal. This consists of a semaphore with a single light, which shows red when the arm of the semaphore is at "danger" (horizontal) and white when the arm of the semaphore is dropped, to indicate "all clear." There is a separate semaphore arm for each track, but the eastbound and westbound arms are generally placed on one post, and a single lamp answers for both. The older form of signal was a disc, but these are being gradually displaced by the semaphore, which is now standard. The electrical apparatus consists simply of a Morse telegraph line, with the usual instruments. On the passage of a train the operator places the signal at danger to stop following trains, and reports the time to the station which the train last passed and to that toward which it is proceeding.

Summary of Pennsylvania Rules.—A block section is called a "block." Trains will be governed absolutely by fixed signals, and will not observe the time-space rule. The old form signal has a green disc to indicate caution. With semaphores a position midway between horizontal and the nearly vertical position is employed to indicate caution. These cautionary indications are of course used only in permissive blocking. The signal normally stands at danger. After being changed for a train, it must be returned to danger as soon as the whole of the train has passed the signal. A train must not be backed after stopping at a block station. In case of failure of wires, or the operator for any reason cannot get orders for a train, he must give it written notice of the reason for the proper signal not being displayed. Trains must not be admitted to a block section under the permissive system to follow a passenger train, and a passenger train must not be admitted to follow permissively *any* train until it is first stopped and notified that there is a train ahead. Exceptions are, however, made to the last paragraph. A train intending to use a crossover between the block stations must notify the operator. A train must not be reported as having passed until the rear end has got 300 ft. beyond the signal. Trainmen are not relieved from observing all ordinary rules in regard to the protection of their train.

The customary place for the signal is immediately opposite the telegraph office. Where this is at a passenger station, inconvenience sometimes results from the fact that the train held by the signal is not in a convenient position for discharging and loading passengers. To provide against this the station should be equipped with two signals, a "home" and a "starting," the former to stop trains before they reach the station, and the latter to hold trains which are standing at the station. By this means, if the block section in advance is occupied, a train may be safely admitted to the station while yet it is kept under control, so that it cannot leave without the permission of the operator. If a train is detained at the station, the following train need not be held back at the en-entrance of the next preceding block, one, two, or more miles away, but may be allowed to come up to the home signal, whence it can proceed, without delay, to the platform as soon as the one in advance has made way for it.

A danger in signaling is the possibility of trains entering the main track from a siding or at a crossover track midway of the section without the knowledge of the operater at the entrance to the section. To provide against this, all switches connecting with such sidings or crossovers should be under the control of the operator. This may be effected by an electromagnetic lock, so arranged that it cannot be released except from the operator's office, the latter being connected with the switch by wire; or an ordinary switch may be locked by a special key, which must be obtained from the block-signal operator. Neither of these systems is used to any extent in the United States. The regulations of the Pennsylvania, as noted above, require simply that a conductor intending to turn a switch between two block stations for the purpose of using another main track than that on which he belongs must notify the block operator beforehand, and get his acknowledgment, with authority to so use the track. In view of the difficulty of controlling these outlying switches satisfactorily, an essential point in preparing a road for operation under a block system is the lengthening and alteration of side tracks so that as many as possible of such tracks shall connect with the main track *at a station*—that is, between two signals, a home and a starting signal, which are controlled and handled by the same operator.

A train must of course never pass a block signal until its indication is absolutely known. When there is a fog or a driving snowstorm, or the signal is obscured by steam from a locomotive or any other cause, a fast train approaching a block station must be slackened in order to permit the engineer to make sure of the indication of the signal before it is too late for him to stop. The annoyance from numerous delays to fast trains from this cause has led to the introduction of cautionary signals, erected at a distance from the home signal, and indicating the position of the latter. Home and distant signals generally differ in color, and the end of the distant signal blade is notched. Customarily the positive signal blade is painted red and the cautionary green. The light on the cautionary signal is made to indicate green for caution and white for "all clear." The cautionary signals are erected at from 1,000 to 2,000 feet from the home signal. If an approaching engineman finds one of them in the "all clear" position, he knows that the home signal has been pulled to "all clear," and that he need not expect to be stopped at that signal. This distant (cautionary) signal must of course be interlocked with the home (positive) signal so that it can never by mistake be pulled to safety until the positive signal has actually been so pulled.

Illuminated blades, which are extensively used for switch signals in yards (for movements other than those of fast trains on main tracks), have been used to a limited extent for fast-route signals, and are equally applicable to the block system. The term "illuminated blade" means a blade in connection with which a lamp (hidden from the engineer) is attached to the post is such a position that it throws light directly on the face of the blade. The engineman can thus see its position at night the same as in the daytime, and a signal lamp is unnecessary. Illuminated blades are prescribed for all new work on the Pennsylvania lines west of Pittsburgh, and the standard color of blades there is yellow. By this means the color indication can be entirely discarded.

The painting of arms yellow or some color which has not by common custom received some definite significance is a step in the right direction, as there is an inconsistency in painting the face of a semaphore arm white or red, because it must indicate when horizontal, the opposite of white, and when down the opposite of red. Green being generally used for caution gives a wrong indication when the arm is either up or down.

The chief fault found with illuminated blades is the difficulty of making them visible at the proper distance. To overcome this the Union Switch & Signal Co. has introduced a blade carrying a corrugated reflecting surface of brilliant, non-corrosive metal. Koyl's parabolic semaphore, manufactured by the National Switch & Signal Co., consists of a semaphore arm made on the lines of a section of a parabola, so as to more efficiently reflect the rays of light in parallel lines. Both these signals may or may not be arranged so as to throw a red light upon the blade when it is in the horizontal position, and a white light when it is pulled down. These devices are familiar to those who have followed the progress of the art in the columns of the *Railroad Gazette*, and are described in detail in the appendix.

Cost of Maintenance.—The principal item of cost is of course the wages of operators and inspectors, to which is to be added the maintenance of buildings, with fuel and lights, where a building is erected especially for this service. At stations where operators have no switches to attend to, and no other work of any kind, they work 12 hours each per day, seven days in the week. The pay of these men is from $45 to $55 per month. Where the duties are more complex the pay is higher, and, where a considerable number of interlocking switches is operated, the working time for each man is eight hours daily. The men at these important towers are paid, on the Pennsylvania, from $50 to $70 per month. On the New York, Lake Erie & Western some of the operators, who work 12 hours daily, alternate weekly between day and night work. The duties of the inspectors are light, so far as simple block stations are concerned. Their work is chiefly in connection with interlocking towers, which at all important stations are operated, as intimated above, by the same man who attends to the block signaling, and the time spent inspecting simple block stations is treated as a secondary matter. For more detailed estimates of expense the reader is referred to a subsequent chapter on the Sykes system. As in the system here described the cost of inspection is but a very small fraction of the total expense, and as the latter must depend upon conditions which must be calculated in each case by itself, further consideration of the subject here is unnecessary. A recent estimate on a prominent road showed that 100 miles of its line could be worked under the block system, with block sections four miles long, by the erection of only three towers between regular stations. When it is considered that trains running at 40 miles an hour and on 10-minute intervals are $6\frac{2}{3}$ miles apart, the possibilities of the block system will be readily recognized.

The West Shore, the Chicago, Burlington & Quincy and the New York, Lake Erie & Western are the principal roads, outside those controlled by the Pennsylvania, which use the block system as above described. Others use it on very short sections of road or for only a portion of the trains. It is scarcely necessary to say that this system has given full satisfaction wherever used. No officer on a road using it ever thought of abolishing it or of diminishing its use in any way. Operators have admitted a train to a section when it was not clear, and engineers have disregarded danger signals, causing collisions ; but the excellent record on the Pennsylvania, where the system has been in operation on 500 miles of double track for over ten years, shows that these defects of discipline are not to be regarded as incurable. The first step toward abating them by mechanical means is the adoption of the Sykes system, which we shall next consider.

THE SYKES SYSTEM.*

The most common ıorm of electric locking, as an additional safeguard to be used in connection with the block system is that known as the Sykes system. In fact, this is the only apparatus of the kind yet put in use in this country. It is in use on the New York, New Haven & Hartford, the New York, Lake Erie & Western and the New York Central & Hudson River. The latter company has only about 18 miles of road equipped with this apparatus (all in New York City); but as the system has here been in use longer than on either of the other roads named, and has to meet the most trying conditions, we shall base our description on the information given by officers of this road. The New York Central allows no permissive blocking whatever where the Sykes instruments are in use.

The apparatus consists essentially in a series of electromagnets so connected with the levers by which the operator moves the outdoor signals that the operator at the outgoing end of a block section controls the lever by which the operator at the incoming end admits the trains. Thus after *A* sends a train to *B* and puts his signal at danger, he is unable to again pull the signal to "all clear" until *B* unlocks his (*A*'s) lever, and *B* of course refuses to do this until the train has arrived and passed out of the section. To provide against a possible mistake by *B*, who might prematurely unlock *A*'s lever, there is also an automatic arrangement by which *A*'s lever, after having been put through the motions to admit a train, cannot be unlocked until the train itself actually passes out of the section. This is secured by running an electric circuit, which controls *A*'s lever, through two or three rail lengths of the track at a point just beyond *B*. The circuit goes from the battery to one rail of the insulated section of track, thence by line wire to *A*'s signal, which it holds locked at danger by energizing an electromagnet. On the passage of a pair of wheels over these insulated rails, the circuit is led through the wheels and axles from one rail to the other and thence back to the battery without going to the electromagnet at the distant station, thus demagnetizing that instrument and allowing the signal to be again operated.

It will be seen that where trains are run permissively—that is, where a second train passes *A* before the first one has passed *B*—the automatic feature of this system becomes useless, as the first train will release *A*'s signal while the second train is still in the sec-

* Drawings and detailed description are given on page 22.

tion, and the apparatus will then afford no protection against a careless operator admitting a third train to the section before the second has cleared it.

One section of seven miles of double track, on which there are seven stations, was equipped by the New York Central in 1882. The cost of this, including two interlocking machines for handling three switches and six switches, respectively, was $8,300, of which $2,050 was for the seven cabins and 25 semaphores. The cost of operating these seven stations is, per year:

Salaries of cabin men	$9,480
Salary of electrician	1,000
Four men attending signal lights	1,920
Cost of repairs (estimated)	1,000
	$13,400

This estimate would be too high for a system comprising many stations, as the salary and wages account would be distributed over more stations. On another road the cost of maintaining 24 stations using Sykes locks was estimated at $3,043 per year, divided as follows:

Battery supplies	$ 153
Battery men and inspector of electrical apparatus	1,440
Ordinary inspector (occupied partly with other duties)	300
Miscellaneous repairs, materials, paint, etc	150
Deterioration (estimated)	1,000
	$3,043

This of course does not include the wages of the operators, who in this case have at many of the stations other duties to perform.

If we add the salaries of the operators to this estimate, the average cost per station per year will be, in round numbers:

Two operators (day and night), at $55 each per month	$1,320.00
Battery supplies	6.50
Inspectors	72.50
Miscellaneous repairs	6.50
Deterioration	41.50
	$1,447.00

This takes no account of lamp lighters. Where there are no distant signals the operator can generally light the lamps himself. In both the cases cited there are but few distant signals. Where these are near regular stations the work of attending to the lamps can be economically devolved upon the man who attends to the ordinary switch lamps. The expense chargeable to block signaling for this service is to be added to the total above given ($1,447), while on the other hand this sum can be diminished by an amount equal to such portion of the operators' salaries as can be fairly charged to ordinary station work.

The Sykes instruments, like most other electromagnetic devices, require constant and careful inspection. One inspector has told us that from a careful record he found his instruments to fail once in 20 days. He did not give the number of trains, but, as the causes of the failures were mostly on account of inadequate inspection or too infrequent renewal of battery, he had no doubt that by the increase of his force of inspectors he could reduce these failures to practically nil. On another section, where he was able to provide sufficient men to look more carefully after the apparatus, a number of signals had been worked under a very heavy traffic for more than a year without a single failure.

SINGLE-TRACK BLOCKING.

Within the past seven years a number of railroads have introduced the block system on single-track lines, modifying the regulations somewhat to conform to the different conditions. This system, as used on the Canadian Pacific, was described in the *Railroad Gazette* of Dec 2, 1887. Its operation on a division of the Chicago, Milwaukee & St. Paul was described June 22, 1888, and the same system, with a novel arrangement of telegraph wires and sounders, as used on the Chicago & Council Bluffs division of that road, was described in the issue of Jan. 17, 1890. An account of the system as employed on the Wabash was given Feb. 8, 1889. The salient feature of these applications is the moderate cost, which has been reduced to a minimum. There are several cases in the United States in which the trains both ways on a single-track road aggregate more than the trains one way on most double-tracks; but naturally a single-track road has fewer trains than a double-track line, and in nearly or quite every case the improved system has been put into effect wholly by the employment of regular station operators, no towers being established, and the only important additional expense being the employment of night operators at some stations where otherwise the office would be kept open only during the daytime. There is no practical difficulty in making this system as effective as the regular double-track block, but most or all of the companies using it have put it in as a necessity, and have not felt able to incur the expense of new signals, carefully located for purposes of block signaling, of distant signals and of protection for sidetracks and other facing-point switches between stations. They have treated the block system essentially as an adjunct of the train-dispatching system. While by no means perfect, there can be no question that the system is a valuable safeguard against rear collisions. Assuming that conductors and engineers are properly disciplined so as not to depend upon the system for protection against dangers which it does not pretend to cover, its value as a substitute for the uncertain flagging system, especially in cold and stormy weather, is undoubted.

The rules under which this system is operated vary considerably on the different roads named, as will be seen by reference to the accounts cited above. One of the most valuable rules in connection with this plan of working is that which requires inferior-class trains to time themselves so as to be wholly out of a block section before the time at which a superior-class train is due to enter it. Another is that which provides that when a train is to take a sidetrack at a station the operator must not open the block for another train until this one has completely cleared the main track. All the roads named, we believe, employ the ordinary train-order signal for stopping and starting trains, though the Chicago, Milwaukee & St. Paul has a semaphore for block signaling and one of the old-style disc signals for train orders. The use of two danger signals at the same station would seem to be of questionable expediency, as locomotive runners would probably be as likely to overlook one of the signals as an operator would be to make a mistake in using one signal for two purposes. A number of roads which use the block system on single-track allow train dispatchers discretion in suspending rules during clear weather and on portions of the road free from curves, when traffic can be hastened thereby; and these rules are used temporarily during fog or severe snow storms on a good many miles where the companies have not yet seen their way clear to incur the necessary expense of their constant operation.

On the Canadian division of the Michigan Central passenger trains are kept one or more stations apart by the regular train-order system, the dispatcher giving a special written order to the operator in regular form for each operation; and this system is extended to freight and other trains during fogs and snow storms.

Cost of Operation.—As intimated above, there is generally no special item of expense connected with this system, except the employment of additional operators. The Wabash employed three at $45 each per month on a section of 20 miles. The Chicago, Milwaukee & St. Paul added six on a section of 130 miles. On this 130 miles the cost of new semaphores and a line wire with electromagnets (sounders) of a special form was $30 per office, these averaging four miles apart.

A recent letter from a Wabash officer gives details of operation of the system on a 20-mile section of that road which were not fully explained in the article above referred to. We quote a paragraph:

"When a train passes a station, the operator reports the time, and adds, 'signal out.' This report is watched for by the operator at the station the train previously passed, and he then responds 'signal in,' releasing the block. The dispatchers overhear these reports, and know always that the proper responses are being made, but the operators are so trained that it is not necessary to call them to release the block after the train has passed the next station. There has not been a single occasion when it was found necessary to suspend the operation of this system in order to avoid delays. It is true that some delays to trains occurred by reason of the use of the system, but we have had no accidents, although it is a very busy piece of the road; as high as 60 trains a day being moved over the 20 miles of single track between Decatur and Bement. I know of no instance where an operator has made a mistake, or permitted a train to go into a section when it was dangerous to do so."

This correspondent refers to delays. These cannot be accurately compared, as between a time-interval and a distance-interval system of spacing trains; but, as every one knows, the efficiency of a block system as a means of running trains close together depends wholly upon the length of the block sections. On the Wabash they are about four miles long. With stations half a mile apart, eight times as many trains could be run, and with perfect safety, at any speed, provided a caution signal were erected at a sufficient distance from each block signal to allow a train to be got "under control" before it reached the block signal.

Although the Canadian Pacific was the first road whose single-track block system was brought prominently before the railroad public, the eastern division of the Lake Shore & Michigan Southern seems to have been the pioneer in this respect, and we therefore add here an extract from a letter from one of the officers of that road:

"We have used for the last fifteen years positive block on passenger trains following each other, only allowing one train between the same stations at the same time. We only use positive block on freight trains during foggy and stormy weather. The positive block on passenger trains is solely in the hands of the telegraph operators, but, at the same time, the train dispatchers oversee the work, and see that it is done properly. The positive block on freight trains is in the hands of the train dispatcher, to whom the state of the weather is given every hour, and on whose judgment the necessity for the use of positive block depends. If a fog or snow storm should suddenly come up, the operators immediately notify the train dispatcher, whether it is the regular time to report or not. If the train dispatcher directs the use of positive block for freight trains, then it is wholly in the hands of the telegraph operators, under the same conditions as the passenger trains. The same rules also apply to trains on double track."

AUTOMATIC CLOCKWORK TRACK-CIRCUIT SIGNALS.*

The most common form of automatic block signal in this country is the Union Switch & Signal Company's "Union system." This system is in use on the Boston & Albany, Old Colony, New York, Providence & Boston and a number of other roads. The same apparatus is used on these and many other roads as a station signal; but these applications should not be confounded with the block system, as in nearly every case there is only one signal at a station, and the regulations under which it is used make it a cautionary signal.

The arrangement of the apparatus in this system is, briefly, as follows: The battery is placed underground (or in any position where it is protected from freezing) at the outgoing end of a section, and from this the electric current is conducted, through one of the rails of the track, to the signal at the incoming end of the section; thence, after passing through the signal relay, it returns to the battery through the opposite rail. At switches the current is led through a circuit breaker which is opened whenever a switch rail is moved so as to break the main track. The circuit is also led through the rails of side tracks for a short distance, so that a train entering a side track is protected, the same as when on the main track, until all its cars are fully clear of the main line. The signal itself is a disc fixed to a vertical spindle, with which it is made to turn one-quarter of a revolution every time the circuit is opened or closed. The turning is effected by clockwork, actuated by a weight, which has to be periodically wound up. A lamp fixed to the upper end of the spindle gives the same indications as the disc. The electric current flowing through the rails does not operate the disc directly, but by means of a relay opens and closes a more powerful local circuit which starts the clockwork. The operation of the signal is simple, the presence of a pair of wheels on the track in any portion of the block section serving to devitalize the electromagnet which holds the signal at "all clear." This condition continues as long as the train or any portion of it is in the section.

The signal post is placed about 100 or 150 feet within the block section, so that an engineman on approaching it and finding it "all clear" may see it change to danger (for the protection of his own train). If it fails to move from white to red, he knows that

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* **Drawings and detailed description are given on page 30.**

some part of the apparatus is out of order, and he must then assume that there is danger ahead.

By a proper combination of relays and by the use of a section of line wire (on poles) the signal for each block section may be so arranged that it will not be restored to "all clear" until the train has passed several hundred feet beyond the outgoing end of the section, thus providing, in effect, a distant signal.

The roads using these signals give, in general, very favorable reports of their behavior. Reports made to railroad commissioners and other official bodies have given detailed records of the number of stops occasioned by the signals, subdividing the lists into those caused by a preceding train in the section, switch misplaced, broken rail, failure of battery or instruments, carelessness of custodians or inspectors and other contingencies; but the records available show such widely divergent results that they cannot be regarded as a proper basis upon which to form an opinion. Many of the failures and delays were the direct result of inexperience or lack of proper supervision. The practical question, however, with regard to stops caused by imperfect operation of any automatic signal, is, how numerous and how serious will be the delays to trains? And the remedy for these faults lies in constant and careful inspection and great care in securing the very best material and workmanship. The difficulties in this direction have not been entirely overcome, as is evident from the changes in the methods and means of taking care of signals; but that the results are in general satisfactory is evidenced by the erection of new signals by those roads which have tried them the most carefully. The Boston & Albany is now completing the equipment of a whole division of 54 miles, and other New England roads use them largely and with satisfaction. The Union Switch & Signal Co., however, regards its electro-pneumatic system (with semaphores) as so greatly superior to the clockwork system that it takes no special pains to spread the use of the latter.

The possibility that track circuit signals may indicate safety when danger exists, which is a vital question with all automatic signals, will be discussed hereafter in connection with the pneumatic system.

A point in favor of the clockwork signals, which is regarded as important by some experts, lies in the fact that the day signal is a disc and not a semaphore. All automatic systems must make some provision for releasing a train when the signal, through some accident or mishap, stops it while the track is in fact clear. The common way of doing this is to require trains to come to a full stop, and then, after one, two, three, or any prescribed number of minutes, to proceed under control through the section. To do this the engineer must pass the signal while it stands at danger. If such unnecessary stops occur frequently, engineers, becoming habituated to passing signals standing at danger, will be liable to carelessly pass danger signals in yards and at other points where discipline imperatively requires that a train shall never pass a signal showing danger. But with all such yard signals made in semaphore form, and all automatic block signals made in disc form, it is argued that the engineer need not fall into the careless habit mentioned, because the differing forms will always be a guide to him in deciding their different degrees of importance.

One of the roads using this system has given us the following memoranda concerning cost of erection and maintenance. Sixteen signals, covering 16 blocks in which were 36 switches, cost $8,076.54. This is divided as follows:

16 signals at $300	$4,800.00
36 switch connections at $40	1,440 00
Labor, signals, average $96.78 each	1,548.54
Labor, switches, at $8 each	288.00
	$8,076.54

On one section containing 83 signals, all within a territory 11 miles in length, the expenses for maintenance for one year were $7,062.67. Of this, material and supplies are charged $2,831.85, and labor and superintendence $4,230.82. This makes a total of $85.09 per signal per year. On another section 160 signals cost for one year $86 91 per signal. This last included important renewal work (10 miles of new poles and a large amount of underground wire).

On another road the expense of maintenance was estimated at $90 per signal per year, the employment of the inspectors on other work for a considerable portion of their time making a more accurate estimate impossible.

THE ELECTRO-PNEUMATIC TRACK-CIRCUIT SYSTEM.*

The main difference between the apparatus of these signals and that of the clock-work signals is in the motive power and the form of the signal. In the pneumatic system the signal, which is a semaphore, is cleared by compressed air and goes to danger by gravity. The compressed air is supplied to the various signals by a pipe running alongside the track, a stationary steam engine or other power for compressing air being located at a central point where it can supply a number of signals. Pneumatic signals were used on the West Shore road as early as 1883, but the system there was abandoned principally because the pipes for conveying compressed air, and other details, were not properly maintained. When the time came for renewing the apparatus the prosperity of the railroad company had declined and no action was taken.

The electro-pneumatic semaphore has also been in use on the Fitchburgh road since 1883, and its operation there was described in the *Railroad Gazette* of June 15, 1888.

The latest form of electro-pneumatic signal was described in the *Railroad Gazette* of Dec. 21, 1888, and Aug. 23 and Sept. 6, 1889. These improved signals are in use on the Pennsylvania road east of Pittsburgh, where six miles of four-track line have been operated for about two years, and a portion of it since 1884. The officers of the road say that these signals have given them no trouble whatever. Seven miles of the four-track line of the New York Central & Hudson River, between 138th street and Woodlawn, New York City, are being equipped with this system, and it was put in use last year on seven miles of the Central of New Jersey.

This system, as operated at the places named, embraces important features not yet employed in any other automatic signals, and the plan is in many respects an ideal one. The signal is a semaphore. It is placed exactly at the entrance of a block, and therefore does not turn to danger in the face of the engineer. There is a distant signal for each home signal. Each block section is worked with a single circuit, and the distant signal is controlled by a wire circuit upon poles.

It has been regarded as an important principle in automatic signaling that the locomotive engineer should witness the operation of the signal as he passed it, thus having constant evidence that the signal is in working order. The location of the signal precisely

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* Drawings and detailed description are given on pages 45, 46 and 49.

at the entrance of the section, as is the case with the pneumatic signal on the Pennsylvania, makes this inconvenient, if not impossible, as it is hardly to be regarded as expedient, even if it were practicable, to require an engineer to turn around and look at a signal after he has passed it. By the enforcement of adequate discipline the brakemen of a train could, however, be utilized as monitors for this purpose ; and we understand that something of this kind is done on the Pennsylvania. This is, however, a question of practice. There is no reason why the electro-pneumatic signals or any automatic signals cannot be placed in advance of the entrance to the seection if desired.

The track circuit system is an ideal automatic block signal system. It promises more complete protection than is possible with any other. The electro-pneumatic system as now in operation on the Pennsylvania, New York Central and Central of New Jersey is the highest development yet reached by the track circuit; but any track-circuit system requires not only perfect construction, but the most careful maintenance. Of course the most serious failure of any automatic signal is when it indicates safety when it should show danger. We have heard of a few such failures of the electro-pneumatic signals. We would not say that these false indications have come from unavoidable defects in the system. On the contrary, there are no stronger advocates of the electro-pneumatic system than those who have used it most.

If an automatic signal stands at safety, and fails to change when the train passes it, the engineer must, according to the rules, proceed cautiously; but by this reduction of speed the train loses time and the next following train may soon be too close upon it. If, on the arrival of this second train, the condition of the apparatus has undergone a change, so that the signal changes from safety to danger in the proper manner, the engineer, observing this movement, proceeds at full speed. A train should, therefore, be protected by hand signal whenever it enters a section, unless it is *known* that the signal indicates danger behind it.

The cost of erecting these signals, with the necessary apparatus for compressing and conveying the air, is rather high as compared with other systems, but the use of compressed air in place of manual power for the operation of switches and signals in yards. which is often highly advantageous, affords a means of dividing the expense. The latest statistics we have concerning the cost of maintenance of pneumatic block signals are those reported for the ten miles on the Fitchburg road in the article above referred to. The cost per signal per year there was $133, or approximately 50 per cent. more than that of maintaining clockwork signals.

THE HALL SIGNAL.*

The Hall wire-circuit automatic block signal is the oldest automatic signal used to any extent in this country, and the instruments put up by Mr. Thomas S. Hall on 16 miles of the Eastern Railroad (now the Boston & Maine) in 1871 are still in use; but the company has recently been reorganized, after several years of inactivity, and the signal, as now offered, may be regarded as substantially a new device, the improvements over the old pattern being radical in many respects. The apparatus and some of its applications were described in the *Railroad Gazette*, June 13, September 12 and December 5, 1890. The signals are used extensively on the Hartford Division of the New York, New Haven & Hartford and on the Boston & Worcester Division of the Boston & Albany The latter road in 1890 equipped 33 miles of double track with continuous blocks. The New York Central & Hudson River has recently equipped 8½ miles of double track (described in the *Railroad Gazette*, December 5, 1890) and the Michigan Central has also 15 miles of double track so protected.

The Hall Company makes no use of the track circuit, claiming that the adjustment of battery and of instruments is such a delicate operation that it cannot be made to give satisfactory service. The connection from one signal to another is by line wire upon poles, and passing trains actuate the signals by means of levers placed at right angles to the rails in such a position that the wheels depress one arm, and, by the elevation of the other, open or close an electric circuit. The signal is a disc of very light weight, inclosed within a wooden case in which is a circular opening covered with glass. This disc is attached to the armature of an electromagnet in such a way that when the magnet is energized the disc is held up out of sight, and on the cessation of the current falls by gravity in front of the glass covered opening. It is colored red, and the surrounding surface of the case is black, so that when visible it indicates danger. At night a light is placed back of the opening in the case, and indicates safety or danger according as the disc is held up or is dropped, the disc being of red silk and translucent. The signal magnet in this system is operated directly by the primary circuit, no relay or other device for multiplying power being necessary. The current whose continuity is necessary to maintain the signal at "all clear" is, by the entrance of a train to the section, broken at two places, and one of these contacts is so broken that it cannot be

* Drawings and detailed description are given on pages 53–58.

restored except by the action of the track instrument at the outgoing end of the section.

The merits claimed for the Hall signal over the track-circuit system are:

All operations are by positive making and breaking of metallic connections. "Shunts." by which a small portion of a current still flows through the instrument intended to be devitalized, are not used. With this apparatus the amount of battery power may be variable within wide limits, and extreme delicacy of adjustment of magnet armatures is not important. The number of electromagnets is reduced to a minimum and the labor of care and inspection is correspondingly less. With these advantages, supplemented by good design and workmanship, the number of unnecessary stops is claimed to be largely reduced. In fact, the company shows records of signals which have run a year without causing a single unnecessary stop. It is claimed that such a thing as showing safety while danger exists has never been known, and is, in fact, impossible.

The Hall wire-circuit system does not indicate the presence of a detached car in the block section. The company admits this point, but claims that the superior reliability, with reduced cost of the system, is of enough value to outweigh it, and also that the use of air brakes on freight trains, and the exercise of good discipline otherwise, practically provide for such a contingency. The prices charged are about the same as those asked for the Union clock-work signals. The company also furnishes a combination of track instruments, interlocking instruments and relays by means of which, when two or more trains enter a section of, say, one mile in length, the trains being a half mile apart, each train will, on passing a track instrument 2,000 feet after entering the section, break the circuit controlling the signal in such a way that only the last train can restore it to "all clear"; in other words, a train passing out of a section cannot clear the signal at the entrance of the section if a following train has already got 2,000 feet within it.

The cost of operation of the Hall signals cannot be stated with accuracy, because the form now being used most extensively has not been in operation long enough to afford a good basis for estimating. The maintenance of a number of the signals on the New York, New Haven & Hartford has cost about $65 per year, but the battery power of the later patterns is greatly reduced, and the cost of material and of labor is correspondingly less.

BLACK'S MECHANICAL BLOCK SIGNAL.*

This apparatus is used on the Manhattan Elevated (New York City) and other passenger lines in the vicinity of that city. The Manhattan has a series of 32 continuous block sections in operation. The instrument consists of a small semaphore, the post being cast iron, which is set to danger by a lever actuated by the wheels of a passing train. The same signal is connected by a gas-pipe rod, extending along the road, with another track instrument at the outgoing end of the section, and the train, on striking this, resets the signal at safety. The maximum length of block operated is about 1,700 ft., and at this distance the signals have worked with great success for two or three years. It will be understood that the moderate speed and uniform length of the trains on these city railroads permit the use of a signal whose capabilities for longer blocks or for more varied service are limited.

SUMMARY.

To briefly summarize the salient features of the different systems of block signaling, it may be said that the simplest form, that which we have termed "single-track blocking," and which is used on various Western roads, is cheap, readily adapted to nearly all roads of light traffic and generally to a road of any traffic, and is an absolute necessity to any road which would avoid the well-known difficulties connected with protecting trains from rear collisions by flags, lamps and torpedoes. The drawbacks to the use of this system are the liability of officers and trainmen to expect more of it than it can, in the nature of things, perform. Where there is only one signal at a station, while there may be two or a half dozen switches, and where the distance between stations is so long that trains must sometimes be allowed to follow each other within the same block, the *block system* is not responsible for and cannot be charged with the various dangerous contingencies that may arise. In fact, the system can in such cases be used only a part of the time. The danger is that when or where it is not in use the men are liable to assume, perhaps unconsciously, that it is in use, instead of adopting other precautions such as would be taken had the block system never been heard of.

The block system in use on the Pennsylvania is simply a more careful and systematic application of this same principle. The only reason why scores of roads do not imitate the Pennsylvania seems to be simply a lack of the courage requisite to incur a considerable expenditure for first cost, and a failure to appreciate the fact that short

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* Drawings and detailed description are given on page 62.

sections are not essential to the utility of the system. Officers too readily assume that a large expenditure for operators (to give their exclusive attention to block signaling) is indispensable, whereas the system in many cases could be advantageously adopted without going to that expense.

The Sykes system is admitted by the best judges among those who have used it to be valuable, but its cost both for introduction and maintenance is rather high. Its use is still limited to the busiest lines, even in England. Its value is largely or wholly neutralized if permissive blocking is practiced, and very few roads have progressed to the point where they wholly forbid that practice.

The special merit of automatic signals lies in the possibility of reducing the running expenses 90 per cent., more or less, below the cost of a man-operated system. Assuming that such imperfections as they are now burdened with can be eliminated, and especially that they can be made perfectly self-detecting, the question concerning their general availability is, will the unnecessary stops caused by the failure of apparatus and extraneous accidents delay traffic to such an extent as to compel a resort to the regular block system (with operators at each station)? Some English experts claim that this will be the ultimate outcome. It is to be remembered, however, that they judge largely by experience on the most crowded lines, and that by reason of the low rates of wages in that country the question of operating expense does not assume the importance that attaches to it here. Granting this point, it still remains true that many hundred miles of road in this country now carry a volume of traffic sufficiently large to demand a block system of some sort, while, at the same time, they will not for many years be used by a sufficient number of trains to make five-minute delays intolerable.

It may therefore be said that there are three classes of roads in this country which afford fields for three different kinds of block signaling respectively:

1. Those parts of large roads which lie in the vicinity of the principal cities, where yards are located very close together, and where the traffic is very heavy—these need man-operated signals, with short blocks.

2. Many double-track roads of less importance need the block system, but cannot afford to establish stations as close together as is necessary to run trains at short intervals. This is the field for automatic signals.

3. The roads of thin traffic and with long stretches between stations cannot afford special block operators, and cannot afford even the few hundred dollars per block necessary to establish an automatic system. These should block by means of their regular station operators. This is especially true of roads where, by reason of heavy grades, prevalence of fogs, or other conditions, the speed of trains cannot be maintained at a reasonably uniform rate, and of those located in northern climates where flagging in winter is dangerous both to the men and the trains.

APPENDIX.

THE SYKES BLOCK-SIGNAL APPARATUS.

[*October* 3, 1890.]

What is known as the "Sykes System" is the application to an ordinary manual block system of certain electrical and mechanical devices which insure that the signal governing the entrance to a given block cannot be cleared until the preceding train has passed out of it and the operator at the end of the block has given his consent.

Under the practice of The Union Switch & Signal Co., which has proprietary control of the Sykes system for this country, these results are secured by the use of a Sykes lock instrument, an interlocking relay, and a short insulated section of track, with proper metallic circuits connecting these; also a bell wire or telegraph line for communicating between adjacent block stations.

The Sykes lock instrument is placed in the operator's office immediately over the lever by which he controls his signal. The interlocking relay is located in any convenient place, usually in a closet. The insulated section of track is located at the entrance of the block, and is usually two rails in length (about 60 ft.). The bell-wire push-buttons are placed near the signal lever and the Sykes instrument.

The connection and relative operation of the signal lever and the Sykes lock instrument are illustrated by Figs. 1 and 2, which show two operating levers and two lock instruments, the regular equipment of a block station working blocks in both directions.

The important connections are the lock bolt, the lock bar, the lock rod, and the plunger rod. Normally, the signal lever being home and the signal at danger, the lock bolt is entered in a hole in the lock bar, and both plunger rod and lock rod are in their extreme upward positions, displaying the words "Clear" and "Locked" (Fig. 1), which indicate to the operator that the plunger is free to be worked (and thus unlock a signal lever at an adjacent block station), but that his own signal lever is locked and cannot be moved.

The operation in practice is as follows, everything being normal—levers home, signals at danger, and tracks unoccupied: If the operator desires to allow a train to enter one of

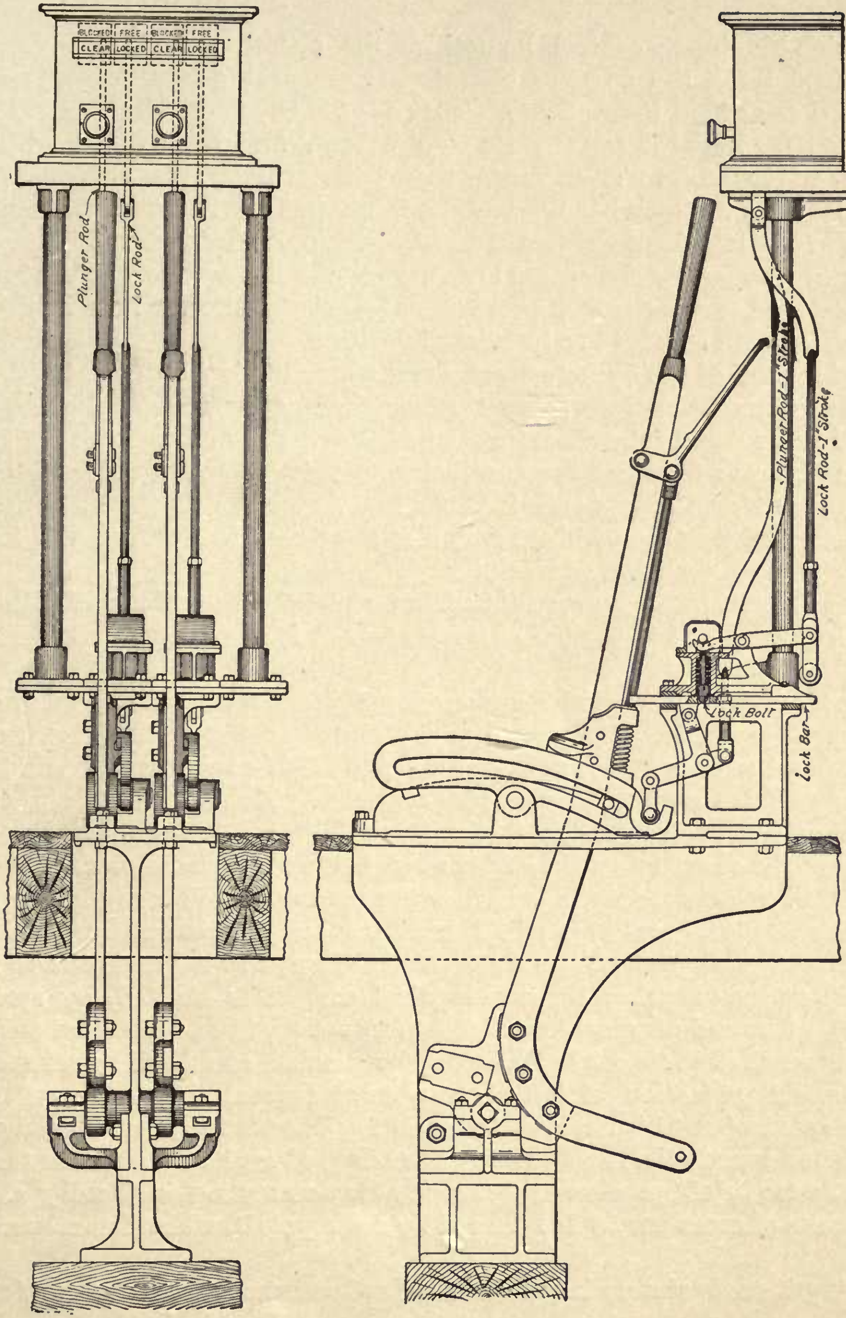


Fig. 1. Levers and Lock. Fg. 2.

the blocks which his signals control, he notifies the operator next in advance (by bell wire or telegraph line); the advance operator, if everything is all right, responds by "plunging" on one of his instruments. That has the effect of releasing the lock rod at the first station; the lock rod falls by its own weight, and in so doing withdraws the lock bolt from the lock bar. The operator then pulls over his lever and clears his signal; this movement forces the lock bar forward, and, through the action of the inclined plane and roller, also forces the lock rod upward to its normal position, where it is automatically held until again released by the operator at the station in advance. This upward movement of the lock rod leaves the lock bolt free to be sprung into the hole in the lock bar, when the lever is again returned to its normal position.

The only function of the Sykes system so far alluded to is that by which the operator, on request of an adjacent operator, may "plunge" and thus release the latter's signal lever. The additional and important function of the combined apparatus is to prevent an operator from plunging a second time until the train for which the preceding operator desired to clear his signal has passed into, through, and out of the block in question. This result is secured by the combined action of the Sykes instrument, the interlocking relay, and the insulated section of track.

The Sykes instrument is shown in position and in connection with the operating signal levers in Figs. 1 and 2, as above referred to. It is shown in detail in Figs. 3, 4, 5, 6 and 7.

Fig. 3 exposes those parts which are employed in unlocking the signal lever. When an adjacent operator plunges he simply passes a current through the electromagnets 21 of his neighbor's instrument, thus attracting and raising armature 22, and imparting a slight rotation to balanced lever 23 about its centre 24. This releases trip 25 (which then is free to rotate about its centre 26) and permits the lock rod 35 to drop by its own weight, and thus unlock the operator's signal lever as explained in connection with fig. 2.

Fig. 5 best illustrates the action and results of plunging. When plunger 27 is pushed in, cross-bar 28 (figs. 5 and 6) is raised, breaking one circuit and completing another by means of springs at 29 (figs. 3 and 6). When plunger 27 is forced out to its original position by the action of spring 30, an electrical contact is effected, by springs, at 31 (figs. 5 and 6). One end of cross-bar 28 is free to rotate, in one direction only, about 90 degrees, but is restored to its original position by a small contained spiral spring ; thus, in fig. 5, the small projection on left of cross-bar 28 causes it to revolve on the upward stroke, and no contact at 31 is effected. But on the downward stroke the same projection presses the flat springs to the left and effects the desired contact. In order that this contact may not be too brief (an electromagnet at adjacent station is thereby charged) the downward stroke of cross-bar 28 is retarded by dash pot 32, which has a small vent hole below.

In plunging there is also an important mechanical interaction between plunger rod 33

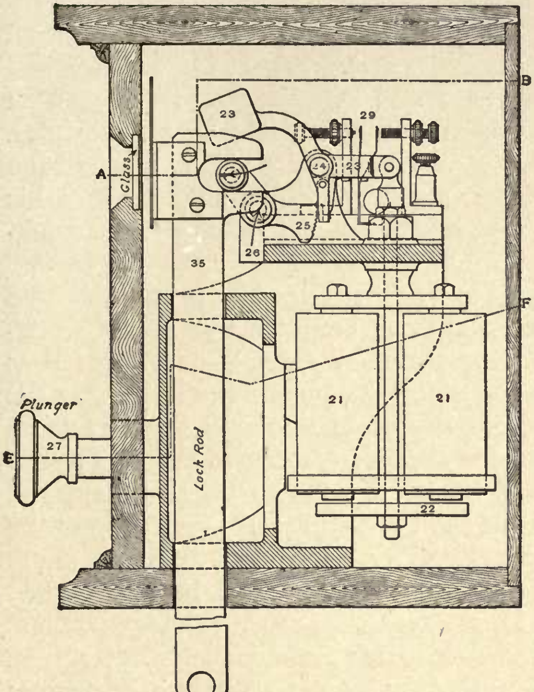


Fig. 3—Section on H K.

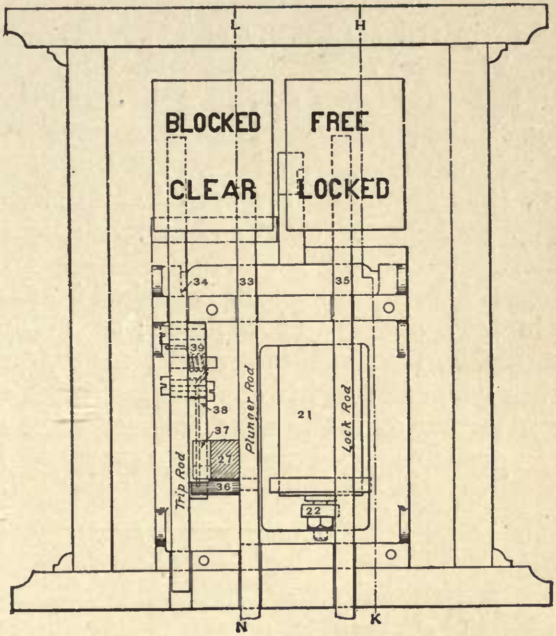


Fig. 4.

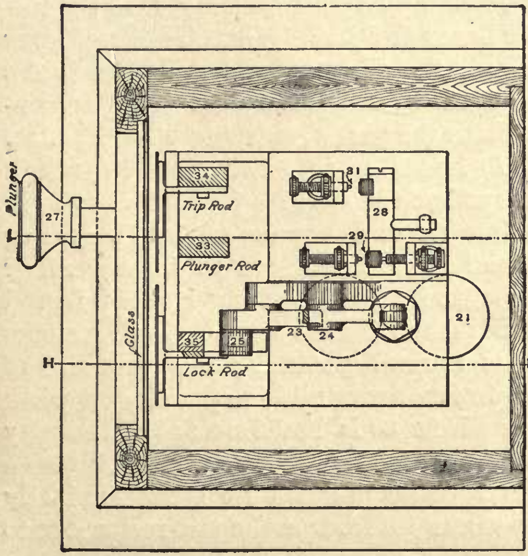


Fig. 6—Section on A B.

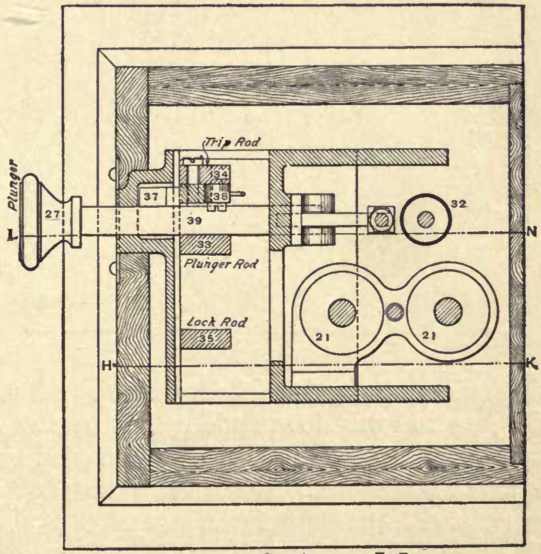


Fig 7—Section on E F.

SYKES SYSTEM—DETAILS.

and trip rod 34 (figs. 4, 5 and 7). Plunger rod 33 has attached to it a pin 36 (figs. 4 and 5. Plunger 27 has attached to it a side piece 37 (figs. 4, 5 and 7). Trip rod 34 has attached to it a pawl piece 38 and a sliding block 39 (figs. 4, 5 and 7). Normally, as shown in fig. 2, the plunger rod is in its extreme upper position. In this position, as shown in fig. 5, the plunger rod 33, by means of pin 36, supports pawl piece 38 and the trip rod 34, thus displaying the word "Clear" (fig. 4) to the operator, which signifies that his plunger is free or clear, and may be operated in response to request from adjacent operator.

When the plunger 27 is pushed in, the side piece 37 forces pawl piece 38 off from pin 36, and trip rod 34 drops; at the same time sliding block 39, previously supported by the pressure of pawl piece 38, drops until it rests on side piece 37, which is then under it. When the plunger comes out, on its return stroke, sliding block 39 falls still farther on to the extension or foot of side piece 37, preventing the plunger 27 from being again forced in. When the trip rod 34 dropped the word "Blocked" was displayed instead of the word "Clear," signifying to the operator that he could not plunge again until certain conditions had been complied with. To release the plunger, the trip rod must be lifted back to its normal position. This can be effected only by reversing the operator's signal lever and again putting it in the forward or home position. When the signal lever is reversed, the plunger rod is drawn to the bottom of its stroke (see fig. 2). In its downward stroke the pin 36 on plunger rod 33 (figs. 4 and 5) forces aside pawl piece 38, which then snaps back in normal position above pin 36, resting on and supported by it. When the signal lever is returned to its normal or home position, and the plunger rod is forced upward, it lifts with it trip rod 34 and restores it to its normal position; the pressure of pawl pieces 38 against sliding block 39 keeps them in the same relative position as when the trip rod was down, and in this way the sliding block 39 is lifted up out of the way and the plunger is ready to be operated again, as is indicated by the word "Clear," which is again displayed. It thus appears that when an operator plunges he is mechanically prevented from plunging a second time until he reverses his lever and again restores it to its normal or home position.

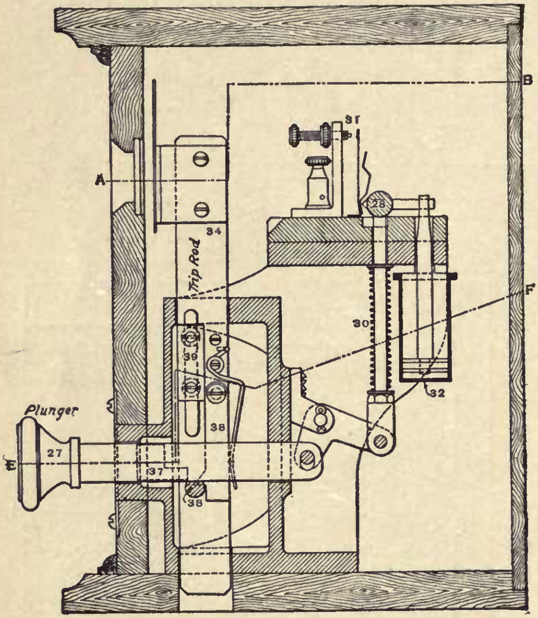


Fig. 5—Section on L N.

It will now be shown that when an operator plunges and releases the lever of the operator next to the rear, the electrical circuit thus utilized is automatically broken, and cannot be made complete again until the train for which the preceding operator desired to give a clear signal has passed over the intervening block. The automatic action

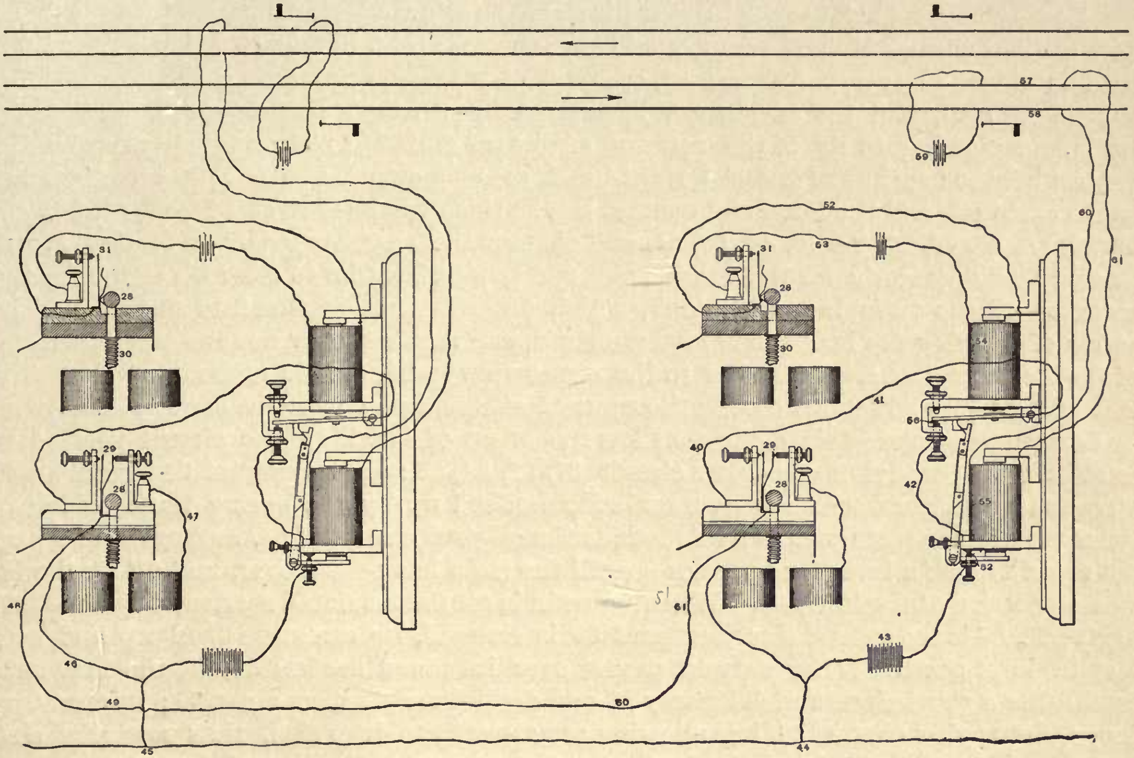


Fig. 8. Fig. 9.

Arrangement of Circuits.

NOTE.—50 *is the lock-wire ; the wire below is the common return for lock and bell circuits.*

THE SYKES SYSTEM.

of breaking and restoring the lock circuit may be understood by reference to figs. 8 and 9, which indicate the relation, connection and mutual interaction of the Sykes instrument, the interlocking relay and the insulated section of track. Two tracks are shown in the plan, but only such instruments and circuits are shown as are necessary for the control of trains in both directions, between two adjacent block stations 8 and 9 For a continuous system two sets of instruments at each station are required. Two different views of the top of the Sykes instrument are given in each, fig. 8 and fig. 9, so as to better display the contacts and circuits which are broken and established by the up stroke and the down stroke of the cross-bar 28 which takes its motion from the plunger 27, as has been previously explained. The interlocking relays are shown in their normal condition, the upper magnets dead (owing to the break in the circuit at 31), and their armatures down; the lower magnets charged from the track battery, and their armatures up.

Suppose operator 8 desires to clear his signal to allow a train to pass 8 towards 9; he uses his bell wire or Morse instrument to request operator 9 to release his lever. If the road is clear and everything normal, operator 9 responds by plunging; this forces cross-bar 28 upward, and the spring 30, restrained by the dash pot, slowly forces it down again. Referring to fig. 9, the upward stroke of cross-bar 28 (lower view) breaks the contact between spring 29 and the right-hand contact screw, and effects a contact between spring 29 and the left-hand contact screw; this completes circuit 29, 40, 41, 56, 42, 62, 43, 44, 45, 46, 47, 29, 48, 49, 50, 51, and charges the electromagnets at station 8, releasing the operator's lever at that point and permitting him to clear his signal for the entrance of the train into the block, which extends from station 8 to station 9. The action of tripping the lock rod is instantaneous, and requires only a momentary charging of the electromagnets. Referring to the upper view in fig. 9, it is understood that that end of cross-bar 28 rotates during the upward stroke, and effects the contact 31 only on its downward stroke; this contact 31 has the effect of breaking the circuit previously established. Contact 31 completes circuit 31, 52, 54, 53; electromagnet 54 thus charged attracts its armature, which is automatically hooked up by the spring hook on leg of armature of electromagnet 55; this breaks the original circuit at 56, and operator 9 cannot again unlock a lever for operator 8 until the train has passed over, and off of, the insulated section of track 57, 58. When no train is on the insulated section, circuit 59, 57, 61, 55, 60, 58 is complete, electromagnet 55 is charged, its armature held up and contact 62 kept good. When a train passes over insulated section 57, 58, the first axle establishes a short circuit with battery 59 and devitalizes electromagnet 55; its armature drops, destroying contact 62, but allowing armature 54 to drop also, thus restoring contact 56, which was previously broken. Contact 62 cannot be restored, however, as long as the short circuit at the insulated section of track exists. Each axle of the train is a possible short-circuit path, so that the entire train must have passed over and off the insulated section before the short-circuiting ceases; then the original circuit 59, 57, 61, 55, 60, 58 is re-established, electromagnet 55 is charged, its armature attracted, and contact 62 restored and maintained; and the original lock circuit by which operator 9 plunged and released a lever in station 8 is again made complete. Operator 9 had to reverse his signal lever in order to admit the train to the insulated section of track, and in putting his lever home or into its normal position he unlocked his own plunger, so he could again plunge for 8. If the train had passed completely over the insulated section of track, the lock circuit would have been restored and his plunging for 8 would be effective, and he would release his lever for another train.

In the case of the first block station in a series it is necessary to introduce some device by which each train entering that block under a clear signal will automatically set that signal to danger again. This is accomplished by the use of what is known as an "electric slot" in the connections between the operator's lever and the signal blade. This electric slot involves an electromagnet normally charged and taking current from a battery through the two rails of an insulated section of track: when the current is passing through the electromagnet the connection between the operating lever and the signal blade is preserved complete, and the operator has full control over his signal. When a train reaches the insulated section of track, however, the first and all other axles establish a short circuit; the electromagnet is thus discharged, the connection broken and the signal set to danger by the action of its counter-weight. The operator cannot again get control of his signal except by putting his signal lever normal; when that has been done and the circuit restored by the complete passage of the train, the connection between lever and signal blade is automatically restored and the operator again has control of his lever, subject, of course, to the action of the operator next in advance, who may plunge and unlock him if all the conditions are favorable.

It has been shown: First, that an operator by plunging may unlock the signal lever of the preceding operator. Second, that in so doing his plunger is automatically locked up, and can be unlocked only by reversing his lever and putting it home again (in other words, giving a clear signal and then the danger signal). Third, that the lock circuit utilized by the inward stroke of the plunger is automatically broken during the outward stroke of the plunger, and can be restored and made complete only by the passage of the train onto, over and off of the insulated section of track.

The resultant effect of the combined apparatus under these several conditions insures that "the signal governing the entrance to a given block cannot be cleared until the last train which received a clear signal to enter that block has passed out of it, and the operator at the end of the block has given his consent."

AUTOMATIC SIGNALS ON THE BOSTON & ALBANY.

[*June* 24, 1887. *Written by G. W. Blodgett.*]

This road has had a larger experience with electric signals than almost any other in the country. A large portion of the road is now equipped with such signals, and additions to the plant are constantly being made. A brief description of the apparatus employed will be followed by some account of its practical working and the results obtained.

The road has double track throughout its whole length, except the first ten miles, where there are four tracks. This short distance and some other detached portions of the road have continuous overlapping blocks. The remaining applications (with a single exception) are "station blocks" so called; that is, there is a signal each side of the station about one-half mile distant, which is connected with every switch in the track to which the signal belongs, and the function of which is to protect a train while standing at a station or switching. As traffic increases, or for other reasons it becomes advisable so to do, these applications can be made parts of a system of continuous blocks with no other change than simply overlapping the sections.

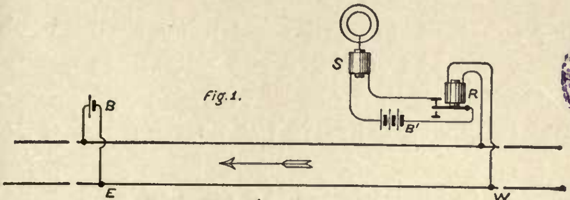
For the first mile from Boston all trains are of the same class and run on the same tracks. After that they diverge, express passenger and freight trains running westward on track No. 1 and eastward on track No. 2, while suburban passenger trains travel westward on track No. 3 and eastward on No. 4 for 10 miles, to the end of the four-track section. A large part of the suburban trains go no farther, and beyond this point all trains again run on two tracks.

In the first mile the signals are about ¼ mile apart, then ½ mile for two miles more (which includes a large yard for outgoing and another for incoming freight trains, besides two important junctions), and then about a mile apart as far as the continuous blocks extend.

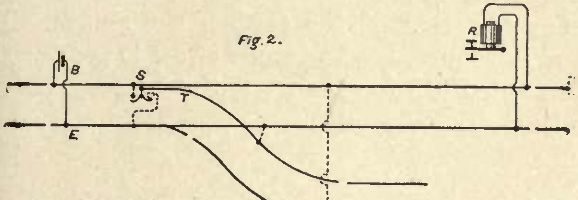
The larger part of the road is equipped with the rail circuit clockwork signals of the Union Switch and Signal Co. The first applications of this signal were made in 1882, when 6 blocks were put up as an experiment.

BLOCK SIGNALS WITH RAIL CIRCUITS.

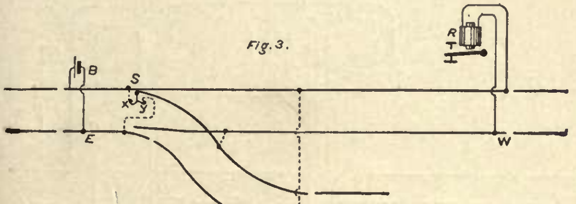
The road is divided into sections of varying lengths according to the amount of traffic or local circumstances, as above mentioned, each of which sections has a signal at the



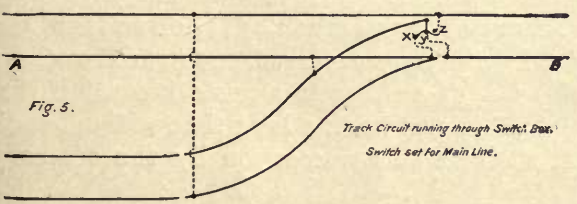
B. Main Battery. B' Local Battery.
R. Relay. S Electro Magnet controlling Signal.



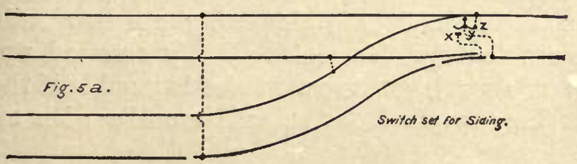
Switch set for Main Line.



Switch set for Siding.



Track Circuit running through Switch Box.
Switch set for Main Line.



Switch set for Siding.

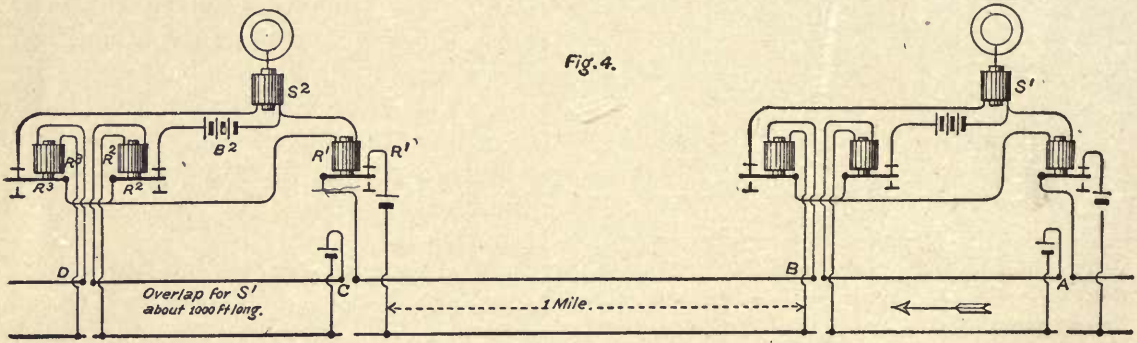
beginning (operated by clockwork and a weight), which is set to the position indicating danger whenever a train enters the section from any point, and restored to that indicating safety when the train leaves the section. Each section is electrically insulated from those before and behind it. At the end farthest from the signal is an electric battery giving a constant current, which is connected to the track, one pole to each rail; at the signal end of the section the coils of a relay are connected to the rails in like manner, so that there is a constant flow of electricity from the battery through one line of rails to the relay, thence through its coils to the other line of rails, thence by these rails back to the battery. This relay controls the local circuit (so called) of another battery connected to an electromagnet in the signal, which governs the motion of the clockwork operating it.

Fig. 1 shows the track clear, relay *R* holding the local circuit through *S* closed.

The successful operation of signals by means of rail circuits requires that the electromotive force (or pressure, as it may be considered) of the battery connected to the rail shall be so small that there will be only slight leakage from the rails even in wet weather. It is found advisable, therefore, to include in the track circuit only the coils of a relay of low resistance, and make this relay open and close the circuit for another battery of any size desired, which shall operate the signal mechanism. There are then two electric circuits for each signal; one through the rails controlling another through the signal. Both circuits are normally closed ; that is, there is a constant flow of electricity through the whole length of each. The clockwork is so constructed that when the current is passing through the magnet the signal is held in the position of "all clear" or "safety." When this is interrupted, the signal makes one-fourth of a revolution to the position indicating "danger" or "stop."

When a train enters the section the current in the rails takes the path of least resistance, through the wheels of the train instead of the relay magnet. The armature of this magnet then falls off and opens the circuit of the battery controlling the signal, and this takes the "danger" position as long as the section is occupied. When the rear of the train passes out of the section the circuits are again closed and the signal shows clear; but if so much as a pair of wheels remains in any portion of the section the signal will continue to show danger until the obstruction is removed. The same effect is produced whenever, for any cause, either circuit is interrupted—if, for instance, the battery fails,

Fig. 4.



Signal S1 goes to "Danger" at A
" " " "All clear" " D

Signal S2 goes to "Danger" at C.
" " " "All clear" " End of next overlap.

or the wires are broken, or the clockwork is run down, the signal shows "danger." If a rail in the track is broken, and the parts separated by so much as $\frac{1}{100}$ of an inch, the signal will be at danger. Many instances of this kind have occurred, and not a few where the indications was most timely. Indeed, the use of automatic signals has often discovered broken rails which might have remained in the track a long time without such displacement of parts as would have rendered them liable to detection by the ordinary methods of inspection.

To make perfect electrical connection between the rails, a wire extends past each joint, the ends of which are connected to the two rails by a tight-fitting pin in a hole drilled in the flange of the rail. While rails are new and fish-plates tightly screwed up, this is not absolutely needed, but as soon as they begin to rust there is trouble if the rails be not connected by the wires. Signals have worked for several months with an unwired track, but ordinarily they will do so only for a few weeks, even if rails and fish-plates be perfectly new.

Figs. 2 and 3 show the circuit breakers connected with each switch, and the wire connections by which the rails of side tracks are included in the track circuit, for the purpose of keeping signals at "danger" until trains entering the side track are fully clear of the main line. In fig. 3 points *X* and *Y* are connected by the curved flat brass which is held against them by a spring, and the two rails are thus electrically connected, the same as when a pair of wheels is upon them. In fig. 2 the switch rail *T* having been withdrawn from the main-track rail, has pushed the brass connections away from *X* and *Y*, breaking the connection between the opposite rails.*

When the block signals are continuous—that is, with no spaces between the sections—the safety of trains following each other at short intervals is very greatly increased by making the sections *overlap* each other. This causes a signal to remain at danger until the train has passed a certain distance (usually about 1,000 ft.) beyond the next signal. While the train is running this short distance there are *two* red signals behind it, one at the beginning of the section where the train is, and the other at the beginning of the preceding section.

The arrangement of circuits which accomplishes this is shown in fig. 4, which assumes the block to be one mile in length. The principal track circuit for the signal S^1 passes through the armature of a relay, R^1; the coils of this relay are in a wire circuit connected with the battery B^2, which is controlled by a relay, R^2, placed at the end of the overlap. The coils of this last relay are connected to the rails of the overlap. It will be seen that a train on any portion of this short section will operate the relay R^2 and consequently R^1, and set both signals. Hence, so long as an engineman does not pass a red signal he can never approach a preceding train nearer than the length of the overlap.†

Signals are placed a short distance (usually about 200 ft.) beyond the beginning of the section, in order that an engineer may see the signal operate for his train. Should it fail to do so, he is to stop, the same as for a danger signal, and proceed only as the way is known to be clear. The engineer of every train stopped by a signal must without delay report the stop and the cause *if known* (on blank cards provided for the purpose) as, for instance, a preceding train in section or an open switch. If the cause be not apparent to the engineer, he simply reports "cause not known," and it is put in the hands of a repairman to investigate. When the latter has ascertained the cause (for instance, a broken rail, failure of battery, derangement of some part of the apparatus or other cause not at first apparent) he returns the card with his explanation indorsed

* In figs. 2 and 3, *B* is the battery at one end of the block section, and *R* the relay controlling the signal at the other end. The switch *S* (or any number of switches) may be at any point between these two.

† When a train is on the section *C D* relay R^2 is demagnetized, thus opening both the circuits through battery B^2; S^2 and S^1 then both show "danger." When a train is in the section beyond *D*, relay R_3 is demagnetized, holding S^2 to "danger." Signal S^2 stands 200 ft. from *C* and 800 ft. from *D*.

thereon. If *he* cannot find out the cause, he returns the card with that statement, and it is usually never ascertained. There is a small fraction of one per cent. of such stops at signals. It is quite certain that some of these are due to previous trains, open switches or other legitimate causes, but in the absence of positive proof they are not so classified. Sometimes employes needlessly cause stops of trains at signals, and to save themselves the consequences carefully conceal the fact, which is not always afterwards discovered, and when this is the case such stops have to be reported "cause unknown." A careful record is kept of all stops and their causes, and every month a debit and credit account is made up of the operation of the signals on each division of the road, which shows at a glance what proportion of stops is due to neglect of employes, defective apparatus, unavoidable causes, etc., as well as all legitimate stops.

The only stops credited to the system are those due to (1) previous trains in section, (2) open switches, (3) broken rails, (4) repairing track, (5) [sometimes] using single track, (6) cars left on turnouts too near the main track. Lost motion in switches, broken track wires, or any other failure of the track circuit is usually charged to the neglect of trackmen; those due to failure of batteries, corrosion of apparatus, and certain other derangements to neglect of signalmen, so that the blame may be placed where it belongs. Employés are held to a strict account for all avoidable stops caused by them, and the ratio has been reduced to one surprisingly small. To the debit side of the account is charged all such stops as are caused by defective construction of any part of the apparatus. The number of these has heretofore been unreasonably large. First-class mechanical construction costs but little, if any, more than such as would not pass inspection in any good machine-shop, and gives immeasurably better satisfaction in service. There remain a certain number of stops due to "unknown" causes, and certain stops due to climatic conditions, unavoidable accidents to the apparatus, derailments, lightning, etc., which are grouped by themselves under the head of "accidental." Longer experience will doubtless suggest ways in which the number of these may be diminished.

The severe tests of actual service under all varieties of climate and temperature show that the perfect railroad signal has not yet been invented. In each system certain deficiencies, or failing cases, must be provided against in order that the signal may work regularly or be used with safety.

The most dangerous error an automatic signal can make is to show clear when a train is in the section. The Union signal is, perhaps, more free than any other from such failures, but they are by no means unknown. The cases which have come under my own observation have been due to (1) a failure of the track circuit relay to drop its armature when the current was shunted out of the magnet; (2) too much battery on the rail circuit; (3) crossed wires between the signal and overlap relay; (4) failure of the signal magnet to release the clockwork when the circuit was opened; or (5) the sticking of some mechanical part of the apparatus which should have moved freely. Of these the first is by far the most common, except in ice and sleet storms; like the fourth, it is usually due to fixed magnetism in the cores or armature of the relay, and could be prevented by the use of better iron in their construction. The second cause is the fault of the signalman, and the third may also be. This last may be remedied by a different arrangement of circuits, which the Boston & Albany will adopt in all new work. The fifth may, or may not, be the signalman's fault. A rainstorm sharply followed by freezing weather wiil stick every signal in an hour in the position it happens to be at the time. A heavy fall of damp snow will sometimes (but rarely) do the same thing.

Another failing case of bad repute is when the signal stands clear with a switch open This usually shows a faulty connection in the switch-box. There is no way (with the arrangement of circuits shown in figs. 2 and 3) to know beforehand whether opening the switch will set the signal. A far safer connection is shown in figs. 5 and 5a, where the current in the rails is made constantly to pass through the switch-box, when the switch is on the main line. The switch-box must be in good order or the current cannot pass. All the switch connections on the Boston & Albany are now being changed to this style.*

A multitude of causes may make a signal stand at "danger" when no train is in the section or switch open. Any derangement of the apparatus (except the special ones enumerated above) or interruption of the rail circuit by displacement of the track or otherwise will do this. Stops thus caused are principally a matter of annoyance and expense. They do not introduce an element of danger, except that, if very frequent, they would tend to make enginemen careless of the indications of the signal when it did warn of existing danger. Though there may be a considerable number of such stops in a month on some divisions of the road, it is found, when account is taken of the number of trains running, that the ratio of failures to number of operations is very small.

The cost of operating each Union signal, including superintendence, was, during the year ending Oct. 1, 1886, about $75.69, or $6.31 per month.

There are roads equipped with Union signals which claim to have fewer unnecessary stops per signal than the Boston & Albany, and to run their signals at less expense, but they have for the most part no overlapping sections (which would very greatly complicate their application); their trains run at longer intervals, and in some cases the account of stops and their causes is not so carefully kept.

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*The current in the rail $A\ B$, when the main track is unbroken, must normally pass through the points $X\ Y$; when the switch is moved, the connection between X and Y is broken and the opposite rails connected (as by a pair of wheels) through Y and Z.

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[*December* 21, 1888.]

Before entering into a description of the operation of this system, it will be necessary to describe the construction and operation of its several parts. There are a steam-generating boiler, an air compressor, and a condensing tank through which the air must pass before entering the main air pipe. This deprives the air of any moisture which it may have had originally, or collected in passing through the heated cylinder of the compressor, and prevents its collecting in the valves or cylinders where it might interfere with their operation.

Each signal blade is connected directly to a pneumatic cylinder, the pressure to which is controlled by a small valve actuated by an electro-magnet, which in turn is controlled by the operator in the cabin. The air supply to each of these cylinders is taken from a cylindrical tank at the bottom of the post, all of which are connected directly to the main air-pipe; consequently, all signals have, at all times, the full pressure of the compressed air, right at their cylinder valves. The control of this pressure by the electric valve and the valves by the operator will be treated later.

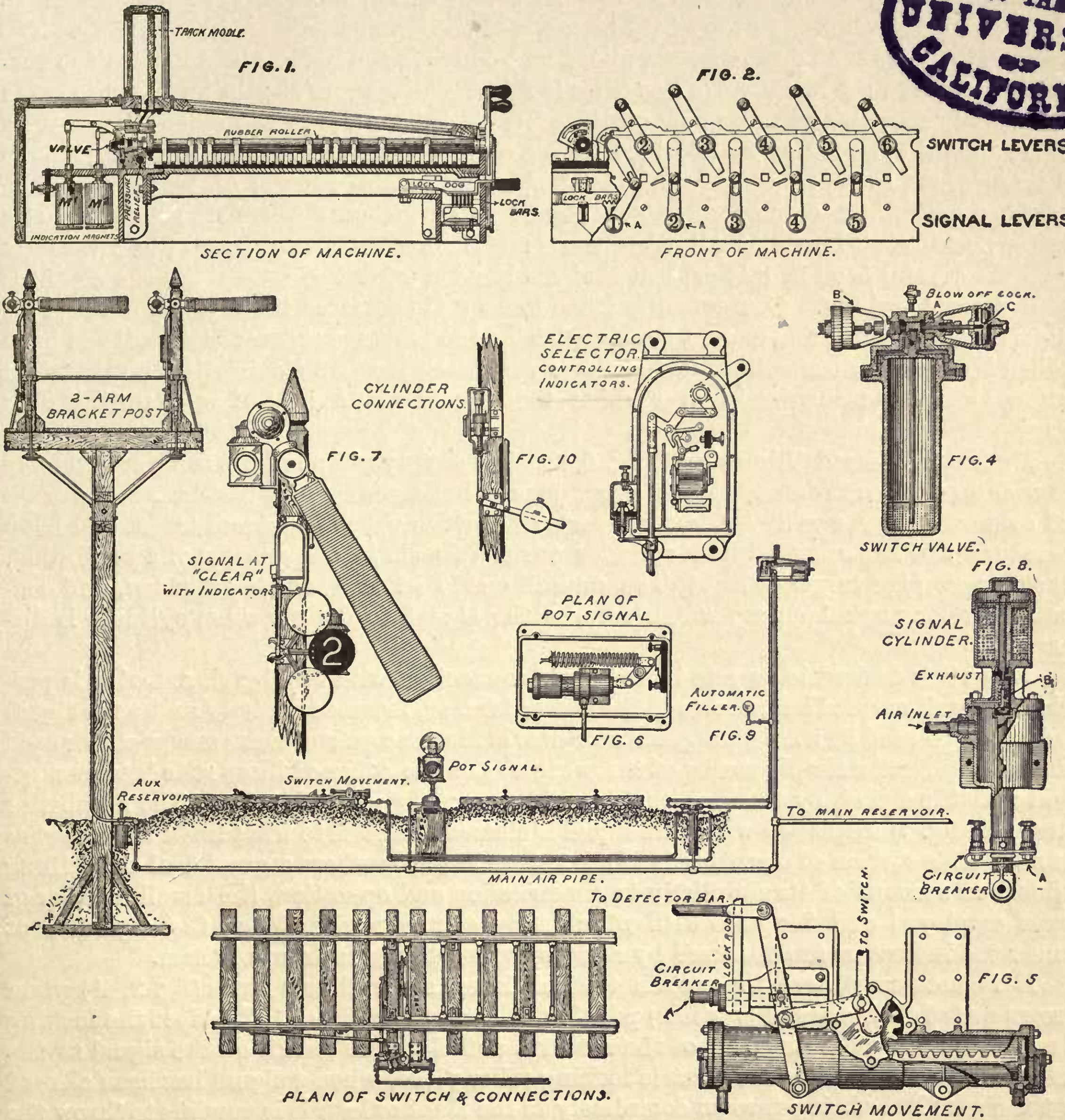
From this same air pipe pressure is conducted to the switch valves, where it is stored in a reservoir, which forms the valve support, and is provided with a cap or plug with three ports formed in it, and a D-valve seated over them, exactly as is done in a steam engine. Encasing this D-valve and its ports (see fig. 4, *A*) is a hollow cap fastened to the reservoir and connected with it so that the full pressure from the reservoir is at all times in it, and consequently on top of the D-valve, holding it seated. One of these ports connects directly to the open air; this is the centre one, while the right and left ones connect each to one end of the cylinder operating the switch. This D-valve is so constructed that it is impossible to admit pressure to one of the ports before having connected the other with the exhaust. It is, therefore, very evident that it is impossible to have pressure on both sides at one time, and also that the full air pressure is always holding the switch in the position last moved to. With this description, it will be clear how the pressure can be changed to one end or the other of the switch cylinder.

The switch movement (fig. 5) consists of a long cylinder, 5½ in. in diameter, provided with two flanges for securing it to the ties, and two studs or trunnions on the opposite side forming pivots for an arm operating the lock and detector bar of the switch, a piston composed of a plunger packed at each end and formed into a rack between, engaging into a pinion which rotates about $\frac{3}{4}$ of a revolution to each movement of the rack piston. This pinion is keyed fast to a shaft on which a crank is formed, and turns with the pinion. To this crank the operating rod of the switch is connected, and also a link joining it to the rod, already mentioned, operating the lock and detector bar. It will be noticed that this crank stands beyond the centre line of its axis continued through the centre of the switch connection, and that it might move a corresponding distance to the right of this centre line before giving any appreciable motion to the switch itself, on account of the small arc thus described. It is the peculiar arrangement of this crank that renders this movement so simple in effecting the motion of the detector bar and the preliminary unlocking of the switch and a final motion of the bar and locking of the switch after it has been moved. By reference to the cut it will be clearly seen that the movement, when normal, holds the switch locked in one of its two positions and the detector bar below rail level. Also that the first motion to take place is the simultaneous raising of the bar and unlocking of the switch. The lock bolt thus operated is of sufficient length to have been fully withdrawn from the hole in the lock rod of the switch before the motion of the crank is imparted to the rod moving the switch. It is also, for the sake of simplicity, allowed to travel still farther from the lock rod during half the motion of the switch, when it again approaches the rod, and by the time it arrives at the bar again the switch must have moved so as to bring the second hole in the lock rod opposite the pin before it will become locked, and indicate it in the cabin in a way to be yet described. On the casting forming a guide for the lock rod, directly in front of the locking pin, is placed a circuit-controlling device (fig. 5, *A*), which, when the lock pin has entered the lock rod of the switch, holds the circuit open, and when the pin is withdrawn permits it to become closed. The function of this device will be described later.

Having described the construction of the switch valve, we will explain the manner of operating it. On each side of the hollow chamber or cap encasing the D-valve, (fig. 4, *B*) are two small cylinders containing pistons, and a stem from each extending through a stuffing-box into this cap or chamber and resting one against each end of the D-valve. Connected to the heads of these two cylinders are two small pipes which run directly into the cabin and to the machine, where they run to the ports of a three-way cock operated by the switch lever (fig. 3, *A*). This cock is identical in operation with the D-valve, in that but one port can have pressure on it at a time, the only difference in its construction being that its seat is cylindrical, or rather, conical, instead of flat on a horizontal plane, as in the D-valve. It is evident that pressure must be on one or the other of these small cylinders, (fig. 4, *B*), at all times. It is also evident that since the D-valve is set between these pistons, any motion of them will be imparted to the valve also, and that the pressure on each piston acts against the other one through the valve, thus making the two pistons and the D-valve act as a solid plunger in a single cylinder. The

D-valve is not in any way connected with the piston stems, but simply guided between them, thus allowing compensation for wear on the seat and under face of valve. It is often desirable to throw two or more switches by the same lever, as is the case with a cross-over or slip switch with movable frogs. In such cases, unless they be too far apart, but one valve is used, and each one of the two or three switch cylinders is connected directly to it in the same manner as is done with a single one. It is perhaps necessary to explain now the necessity of this valve being interposed between the cock at the machine and the switch cylinder, since it will be evident that the operation would be the same if the pipes from the machine went directly to the switch cylinder. While this is the case, still a serious feature in this arrangement prevents its adoption. Owing to the long distance it is oftentimes found convenient to operate switches from the cabin with this system, and the consequent long line of pipe necessary to be filled with air and exhausted at every movement of the switch, it is found not only more economical in saving air, but very much more efficient in operation to place this valve as close to the switch or switches operated as possible, and fill the small pipes leading from the small cylinders of the valve to the machine with water in summer and chloride of calcium, alcohol or some other non-freezing liquid in winter. When this is done and the air from the machine cock is admitted on top of it, it instantly acts against the pistons of the small cylinders of the switch valve, fig. 4, *C*, since the liquid will not compress, but acts as a solid rod. This would not be the case were the air used alone, since it would require some time to compress to the pressure necessary to move the valve, and waste a corresponding amount by connecting the opposite side to the exhaust. In order to compensate for loss of liquid by evaporation or leak, an automatic filler is attached to all hydraulic pipes, fig. 9, which, normally, is opened with all of them not having pressure on them, and automatically closed from them, by means of a check valve, when the pressure is admitted on top of the water in them. This insures a full supply of liquid in these pipes at all times, and consequently a quick action of the switch valve.

The cylinder operating the signal will now be described. As before stated, this cylinder, fig. 8, has the pressure right at the valve controlling its admission to it. This is also controlled by an electromagnet, the circuit of which is controlled by the operator through the machine. The piston of this cylinder is connected with the blade either directly or through a balance lever, fig. 10, and in its normal condition is in the upper end of the cylinder, being held there by the counter-weight blade or balance lever. In this position of the piston the blade is in the horizonital or danger position, and can only be moved from that position by the admission of air on top of the piston, thus depressing it sufficient to give the blade the proper angle (60°) indicating safety or caution, according to the nature of the signal. This is accomplished by a small pin valve, fig. 8, *B*, which normally holds the pressure closed from the cylinder, and the cylinder open to the exhaust. When operated by the electromagnet becoming charged from a current



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sent through it by the operator, the reverse condition takes place; *i. e.*, the pressure is admitted to the cylinder on top of the piston, and the exhaust is closed completely. The pressure thus confined depresses the piston and operates the blade. The instant the current is broken in the magnet the armature is released and the air again unseats the valve closing the exhaust, and again cuts off the pressure, thus allowing the signal to return to danger. This cylinder is also provided with a circuit breaker controlling the current to an electric lock to the lever operating it, fig. 8, *A*. The construction of this lock will be described with the machine, later. This circuit is closed only when the signal is in its danger position, and open at all other times; and since the lock releases the lever only when the current is on it, it is evident that the lever is unlocked only when the signal is in the danger position. Consequently when the signal is cleared the lever operating it is automatically locked; and should the signal fail to go to danger after the circuit has been broken by the lever controlling it, that lever will remain locked electrically, and hold all switches locked mechanically over which that signal gives right of way, until it does return to danger.

The small pot or drilling signal, fig. 6, consists simply of one of the same cylinders as are used to operate the semaphore signals, placed horizontally in a cast-iron box or case and connected to an arm keyed fast to a vertical shaft to which the signal target and lamp are secured. When operated, the cylinder turns this shaft one-quarter of a revolution, thus changing the target or light. The opposite side of this arm is extended, and connected to a long spiral spring, which returns the signal to danger when cylinder is discharged.

When it is desired to operate indicators in connection with the signal, a device is provided in a well-covered box, shown to the right of fig. 10, fastened directly under the signal blade and operated by it. This apparatus is provided with a pair of electromagnets for each indicator rod, and a simple means of throwing one or the other of these rods into engagement with the signal, by them, so that it will be opened rigidly thereby. The number or letter (see fig. 7) displayed when the signal is cleared indicates to what track the switches are set. This system of signaling is of advantage in yards where a great deal of drilling is done, on account of its simplicity in construction and operation, the small number of lamps employed and the ease with which they can be read. When the signal is at danger the indicators are obscured by a screen which hangs in front of them.

It is necessary here to explain that all levers controlling signals (fig. 2, *A*) when thrown out of their normal (vertical) position, *i. e.*, to the right or left, effect the locking of switches during the first part of their stroke, and close the circuit on the signal at the end of the stroke. After the electric locking takes place, when a signal has been cleared by the signal lever being thrown completely to the right or left, it is possible to throw the lever sufficiently far normal again to break the circuit to the signal, but not far enough to release the locking to the switches; in this way the signal must go to danger before the switch levers can be released. The great advantage of this lies in the fact that should a signal stick at safety, it indirectly locks all switches which require shifting in order to set a signal for a route conflicting with it. It is the refore impossible to give two conflicting signals at any time by mistake or improper working of the signals.

The interlocking between levers of the machine is confined to that between switch and signal levers only, and never (unless ordered so) between switch levers themselves. Signal levers are interlocked between each other through the switch levers, as will be described next.

Figs. 1, 2 and 3 will make clear the general construction of the machine, and it is only necessary to explain that the framing is cast iron, the levers, valves, locks, etc., brass, and the top plate of hard rubber, as are the rollers lying horizontally over it. Each switch lever consists of a small brass lever keyed at the centre to a steel shaft which extends through a bearing formed in the front of the machine, a hard rubber roller lying horizontally over the top plate, and terminates in the three-way cock in the rear of the machine, with which it is fastened rigidly. The upper end of this lever is provided with a rubber handle, and the lever end extends down far enough to just clear a dog or latch (fig. 1, *A*) pivoted loosely under the machine, and extending through its front directly under the lever. These latches perform the locking of the switch levers by the signal levers. In the normal condition of all signal levers, all of these latches lie in a notch cut in the locking bars (fig. 2, *B*) in front of the machine, and offer no obstruction to the movement of the switch levers; but the instant a signal lever is moved from its normal position, the latches of all switches affected by it will be raised so as to cause the ends of the switch levers to strike them, and prevent them being moved far enough to open the valves operating the switches.

The rubber rollers referred to as forming part of the switch and signal lever spindles are cast rigidly thereto, and provided with a series of metallic strips or collars (fig. 3, *B*) extending part way round them, their ends terminating each in one of the six slots cut the full length of the roller parallel with its axis. These strips are not all put on in the same relative position with the centre line of the operating lever, but are staggered, so as to either make or break their contact with the upright ends of the strips (fig. 3, *C*) on the rubber plate running parallel with and directly under them, when the roller is rotated by movement of the switch lever. To one end of each of these strips on the rubber plate the controlling wires to the various signals run, and the other ends are joined together and run to one common battery supplying all signals. The other pole of this battery is connected to the main air pipe, which is used as a common return for all circuits. The breaks in each one of these strips are controlled by the levers operating switches over which the signal thus controlled gives right of way, and also by one or more signal levers, as the interlocking may require. It will be very apparent that, before the current to any signal can be established, all breaks in the strip carrying its current must be closed by the bands or collars on the rollers making contact between them. This is done by placing the levers in a position to properly set all switches for that signal. It will be also evident that in, having moved a switch lever to close the strip for one signal, it will at the same time break the circuit at a strip controlling another signal, requiring that switch in its original position. In this way a very simple and effectual interlocking between signals is accomplished.

The strips on the rollers are so arranged that they make contact between the upright strips only when the levers are in their extreme positions, one way or the other. In order to be able to move a switch lever from one side, to the extreme stroke on the other side, and thereby close the circuit for another signal requiring that switch reversed, without any certain knowledge that the switch has moved, a device is attached to the rear end of the roller, which consists of a quadrant (fig. 3, *D*) secured to the roller by a set screw, and having cut through it above the roller a radial slot through which projects horizontally a peculiarly shaped locking lever, provided with a small latch or tongue pivoted near its centre, and capable of a horizontal movement right and left on its pivot, but held in a central position, parallel with the lever on which it is pivoted, by a flat spring on each side. This latch, like the lever, extends through the slot in the quadrant and ends flush with the end of the lever. The lever with the latch thus arranged is pivoted in a suitable bracket fast to the machine, and connected at its far end with the armature of an electro-magnet (fig. 3, *E*), the circuit to which is controlled directly by the lock pin of the switch movement. This circuit is normally open, *i. e.*, when the switch is locked, and closed during its operation. The armature of the magnet, therefore, normally hangs by gravity away from the magnet and keeps the end of the lever, projecting through the quadrant, elevated, so that a small steel pin in the centre of the upper inside slot of this quadrant, when the switch lever is thrown beyond the vertical position, strikes the latch or tongue and carries its free end with it as far as its construction will permit; the lever then will have been moved sufficiently far to have operated the valve, and consequently moved the switch, but not far enough to have made the contact between the strips controlling the signal. Before this is possible the switch must have been unlocked, moved, and then locked in the other position. The unlocking of the switch closes the circuit on the magnet, which becoming charged depresses the end of the lever projecting through the quadrant, into a recessed portion of the radial slot, holding the switch lever still locked thereby. At the same time, the small latch or tongue being thrown below the small pin which had carried it out of its central position, flies back, under the pin, into its central position on the other side of the pin. The latch and lever assume this position as long as the switch remains unlocked, but on being *locked* in the position moved to by the lever being reversed, the circuit is broken on the magnet and the quadrant end of the locking lever is raised from the recess in the quadrant and the lever thus unlocked is free to be moved to the end of its stroke, when the signal circuit becomes closed. Thus the closing of the signal circuit depends directly on, not only the movement of the switch, but the locking of it after it has moved. The electric locking of signal levers is effected by a similar, but simpler device, which consists of an electromagnet whose armature, like that of the indication magnet, is connected to a horizontal lever, fig. 3, *F*, pivoted in its centre, and its far end projecting through a locking quadrant fast to the roller, and engaging in such a manner as to lock it from being moved out of its centre position, if normal, or from being put normal, and thus release the

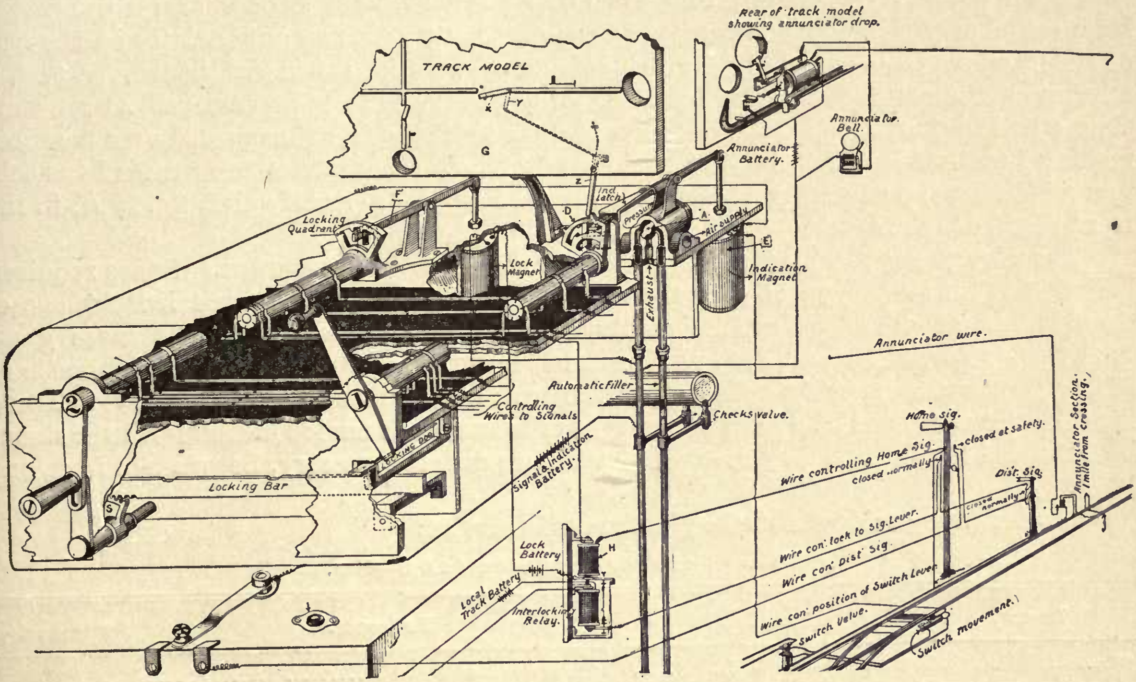

Fig. 3.

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switches locked by it, if out of its centre position, when the current to the magnet is broken through the circuit breaker of the signal controlled by that lever being at safety.

Directly above the machine is placed a miniature model of the tracks operated, fig. 3, *G*, and small movable switches thereon are connected directly to the rubber roller, so that after the indication from the switches is received, and the roller turned as far as possible, these small switches assume the position of the corresponding ones on the ground. In this way the operator can, at a glance, see the condition of his tracks at any time. In order to prevent an operator by mistake throwing his signal back to danger, and then his signal lever normal, and finally a switch, thus released, under or in front of a passing train, an interlocking relay, fig. 3, *H*, is included in the controlling signal and locking circuits, which, after the operator gives the signal, places the lever thus locked out of his control, in so much that while he has the power to throw the signal to danger at any time, it is not in his power to throw it normal and release the switches until the train has passed over the route set for it and cleared the last point of danger.

When within about one mile of the crossing, junction, yard, or of whatever the tracks interlocked consist, an approaching train automatically drops an annunciator on the rear of the track model, so as to display through an opening in the model board, fig. 3, *I*, a number or letter designating the track on which the train is approaching. At the same time, a bell begins to ring, and continues to do so until the train has passed over the short insulated section provided for that purpose, fig. 3, *J*. These drops are restored to their normal (obscure) position by a blast of air controlled by a small valve, fig. 3, *K*, in the front board of the machine, by the operator.

The advantages this system possesses over all others are numerous. Space required is limited, thus reducing size, and therefore cost of towers. The work is light, consequently female operators can be employed, thus reducing expenses. It gives great facilities for special locks. Large yards can be worked from one tower, as distance is of little object, switches half a mile away working as well as those close to the tower. There is no danger of signals being left at safety, as the machine remains locked until the signal has returned to danger. Any number of switches can, if necessary, be worked from one lever.

The following table shows the plants now in service:

Pneumatic Interlocking Systems in Operation.

Levers.	Location.	Railroads.	Put in service.
6	Bound Brook, N. J.	Phil. & Read. and L. V.	1884.
6	Brightwood, Ind.	I. V. and C., C., C. & I.	1884.
12 new style	Wilkinsburg, Pa.	Pennsylvania	1884.
12 " "	East Liberty, Pa.	Pennsylvania	1884.
6 " "	Valparaiso, Ind.	Chic. & Grand Trunk, P., F. W. & C. and N. Y. C. & St. L.	1884.
12 old style	Stock Yards, Chicago	C. B. & Q. and Stock Yard R. R.	1884.
14 " "	Erie, Pa.	L. S. & M. S. and Erie & Pitts.	1884.
24 " "	Oakland, Cal	S. Pac. R. R. Tower No. 1	1885.
10 " "	" "	" " " No. 2	1885.
6 " "	" "	" " " No. 3	1885.
24 new style	" "	" " for " No. 1, shipped Dec. 8	1888.
24 " "	17th st. Pitts. Yd.	Pennsylvania	May 6, 1888.
*24 " "	14th st. "	Pennsylvania	Aug. 19, 1888.

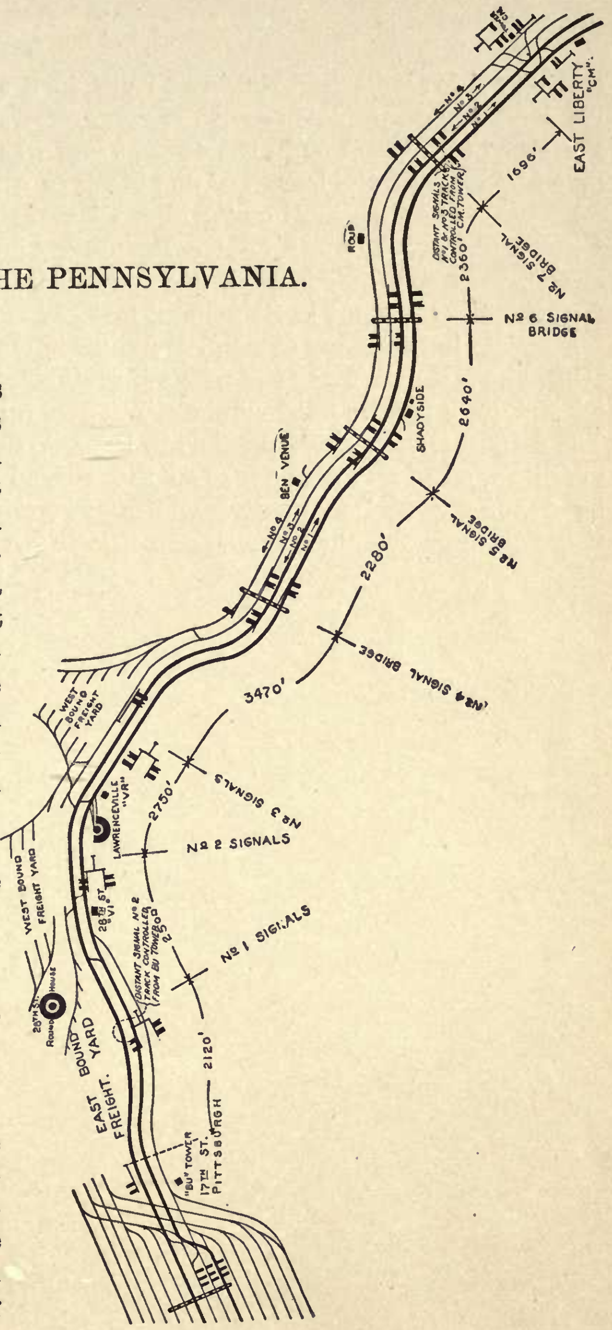
*At the 14th St. Pittsburgh Yard tower, the highest number of movements in 24 hours is 1,500, and the highest number of movements in one hour is 86. The machine is operated by one man.

AUTOMATIC BLOCK SIGNALS ON THE PENNSYLVANIA.

[*August* 23, 1889.]

The Union Switch & Signal Company's rail-circuit system of block signaling is now in use on six miles of the four-track road of the Pennsylvania main line east of Pittsburgh. The system has been in use between Wilkinsburg and East Liberty, about 2½ miles, for 5½ years, with a high degree of success, and it is this that has led the company to equip the additional 3¾ miles. This latter portion of the road, from East Libery westward, is shown in the sketch given herewith, and the signals upon it were put in operation on August 8.

As will be observed from the drawing, the signals are here arranged on the original plan as shown in models exhibited several years ago; that is, the blocks are short, averaging half a mile in length, and each stop or home signal has a distant or caution signal, which caution signal is placed upon the same post with the stop signal of the preceding block section. This simplifies the system for the engineer, reducing the number of localities that he must watch for, and also obviously simplifies the arrangement of the posts and apparatus. The distance between each caution signal and its corresponding



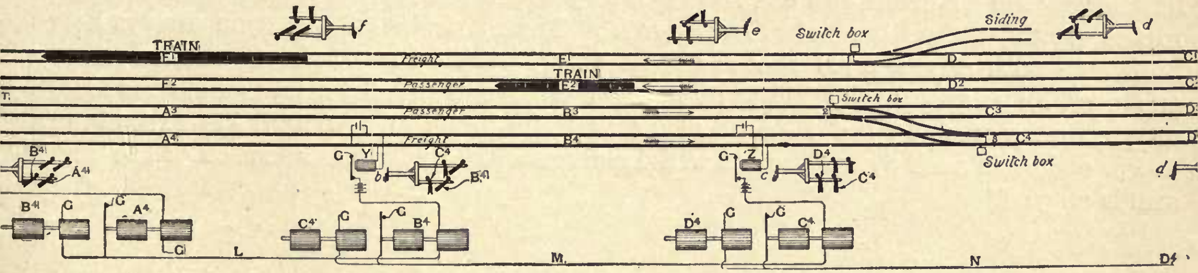
stop signal is ample for bringing a train to a stop, and with caution signals for every block section on the open road the engineman may run at full speed on the most obscure portions of the road or in the densest fog, with the assurance that the signals will always give him at least the length of one block in which to stop, after he has passed the post.

Instead of "banner" or "gridiron" signals operated by clock work (the best known form, and the one in use on the Boston & Albany, Old Colony and other New England roads), the semaphore is used, and the power for moving the arms is compressed air. The apparatus is the same in its general features as that used to operate semaphores in the pneumatic interlocking system, described in a previous chapter (pages 37-44). A pipe extends along the roadway the whole six miles from Pittsburgh to Wilkinsburg, furnishing air not only for the block signals, but also for the interlocking apparatus at four towers. The distant signals are connected to the stop signals by a line wire on poles. The signals are arranged to go to danger *after* the engine of a train passes them. A train stopped by a home signal may, after waiting two minutes, proceed with caution, expecting to find a train on the block aheap or switches not properly set.

ELECTRIC APPARATUS FOR AUTOMATIC BLOCK SIGNALS.

[*September* 6, 1889.]

Following is a plan showing the arrangement of the batteries, electromagnets and wires used in operating the signals described in the preceding chapter. The diagram shows three sections of four-track road, and the signals are arranged in the natural order as related to the tracks. That is, taking post *f* for example, and looking in the direction the train is moving, the two right-hand arms are for track *F* 1, and stand at danger to protect the train on the section. The left-hand arms are for track *F* 2, and show all clear, the section being unoccupied. The normal position of arms is horizontal—danger—as on a failure of battery or other apparatus they automatically assume that position; but their *usual* position is down—safety—as at all times when the track is



ARRANGEMENT OF ELECTRIC CIRCUITS FOR THE UNION SWITCH & SIGNAL COMPANY'S PNEUMATIC AUTOMATIC BLOCK SIGNALS.

clear the power which works the arms is in operation to hold them down. The crossover from track 3 to track 4 in section *C* is shown in position to lead trains from the passenger to the freight track; this, it will be observed, breaks the circuits in both main tracks and throws to danger all the arms on post *c*, as well as the distant signals for the same section, which are on post *b*. The method of connecting the circuit breaker, located in the switchbox, was illustrated in the *Railroad Gazette* of June 24, 1887. (See page 31.)

The arrangement of the electric circuits can best be understood by following out the connections for a single section, say B^4. At the east end of this section is the battery, of which one pole is connected to each rail. The track being unoccupied, the current flows through the rails to relay *Y*, closing it. This closes the circuit through the local battery, and causes the electromagnet in the pneumatic signal cylinder B^4 to actuate the air valve therein and pull down the arm B^4 on post *b*. It will be understood that the cylinders A^4, B^4, C^4, D^4, shown in the engraving on an enlarged scale, are located upon the post with their respective arms.

In the diagram the pneumatic cylinders and the semaphore arms are lettered and numbered to correspond with the track section to which they belong. The circuit through pneumatic cylinder B^4 is carried by a line wire *L* on poles to the distant signal for the same section, located on post *a*, and the current operates to pull down that signal also. All the circuits through the pneumatic cylinders terminate in the ground (*G*). If now, a train enters section A^4 from the west it opens relay *X*, and, through cylinder A^4, throws to danger the home semaphore A^4 on post *a*. Strictly speaking, this need not be allowed to affect arm B^4 on post *a*, as that arm gives an indication for section B^4 and not for section A^4; but to simplify the indications for the engineer and to obviate even an appearance of inconsistency, the opening of the circuit through cylinder A^4 is made to open that through the cylinder shown to the left of it, which actuates distant signal B^4 on post *a* just referred to. This opening is accomplished by a circuit breaker at the left-hand end of cylinder A^4, by which the current from wire *L* is turned to the ground before it reaches cylinder B^4. Thus a train on a section always keeps horizontal both of the arms that are immediately behind it. Of the two arms on any one post, an engineer may find the home arm down and the distant arm up, as is shown on post *e* for track 1; but he will never find the home arm up and the distant arm down, although such a combination will involve no danger if the indication of the home arm is obeyed.

AUTOMATIC SIGNALS ON THE FITCHBURG RAILROAD.

[*June* 15, 1888.]

The Fitchburg was the first to adopt the Union rail-circuit signals for any except experimental purposes. Ten miles of this road were equipped with the old-style instruments of this system about 1879, and gradual extensions have been made since that time. The arrangement of batteries, relays, etc., for these signals is exactly like that described in the article on "Automatic Signals on the Boston & Albany" in the *Railroad Gazette* for June 24, 1887; that is, at the end of the section farthest from the signal is placed a battery having its poles connected, one to each rail, while at the end nearest the signal is a relay with its coils connected in like manner, one pole to each rail. This relay opens and closes the circuit of a local battery, which governs the movements of the signal. The only difference between the two systems is in the form of the signal—which is here a semaphore arm—and the motive power, which is compressed air moving a piston in a closed cylinder. Each signal is placed about 200 feet from the beginning of the section, in order that the engineers may see them operate, and is provided with an overlapping circuit of about 1,000 feet in length, as described for the system referred to.

In 1883 twelve miles of the eastbound track on a 60-foot grade from Ashburnham to Fitchburg were equipped with electro-pneumatic semaphores by the Union Switch & Signal Company. The sections are about a mile in length. The general appearance of the signal is shown by fig. 1. At the top of an iron post about 24 ft. high is placed the semaphore arm, which moves about 60 deg. in a vertical plane in the ordinary manner. The arm itself, however, instead of being connected to a distant lever, is attached to a rod about 3 ft. long which ends in a yoke or stirrup. In the yoke is a box containing an electromagnet and a closed cylinder, fixed to the iron post, within which works a piston actuated by compressed air. The section of this cylinder is shown in fig. 2. The air is supplied through a feedpipe *P*. The valve admitting it to the cylinder is controlled by an electromagnet which is so arranged that when the current circulates in the coils the armature is attracted and the valve is held open, admitting the air to the cylinder. This drives the piston before it to the bottom and brings down the blade. When for any cause the current is interrupted, the valve closes, the exhaust is opened, and the air escapes; a counter-weight brings the signal to danger.

Below and in front of the piston rod is seen an electric circuit-closer attached to a small spindle, independent of the piston rod, but which is operated by the piston itself, when its own movement toward the bottom of the cylinder is nearly completed. This is so adjusted as to keep the auxiliary circuit which it governs closed whenever the signal is "all clear," conveying the indication of this fact to any desired distance; it may also be arranged to ring a bell or give other warning whenever the signal shows danger. The movement of the circuit-closing device is made to depend on that of the piston in such a manner that the completed movement of the piston [and so of the signal] must take place before the auxiliary circuit will be closed (or opened, as the case may be). On the Fitchburg this is made use of only in the case of a few special signals, to ring a bell at certain switches from which the signal cannot be seen or to warn switchmen when a train has entered the section.

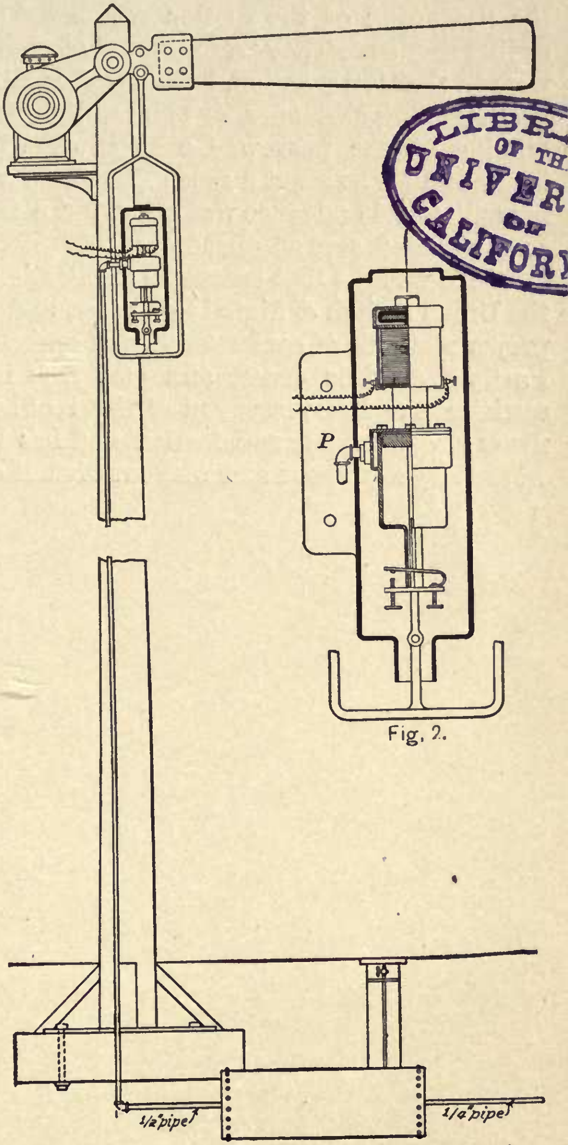
The compressed air at 60 lbs. pressure is supplied by a pump located at Fitchburg. This pump is automatic and similar in principle to that employed for the Westinghouse air brake. The air passes first through a coil of pipe to cool it, thence into a reservoir, with which is connected a blow-off cock to remove the condensed water. The air from this reservoir passes into a 1-in. pipe running between the tracks about 1½ ft. below the surface. At bridges, etc., where it comes to the surface, expansion and contraction are provided for by a long bend or a round turn in the pipe. At each signal a ¼-in. branch is connected with the main pipe. This leads to a reservoir at the bottom of the post, which holds air enough to operate the signal about a dozen times. There is a stop-cock in this branch, which can be closed should occasion require. Stop-cocks are also inserted in the main pipe about every half-mile for the purpose of locating and confining any trouble with the main pipe to a small section, so that only one or at most a few signals need be affected. From the reservoir at the bottom of the post a ¼-in. pipe runs to the air cylinder operating the signal, and when the valve is open the pressure brings the signal clear. The electromagnet is in the circuit of a local battery, which is controlled by a relay, the coils of which are connected to the rails as in the clockwork signals. When a train enters the section this relay opens the local circuit, the armature of the signal magnet falls off and closes the valve leading to the cylinder and opens an exhaust. The air escapes and the signal arm takes a horizontal position until the section is clear. The same thing happens if the batteries fail or a wire or rail breaks. Duplicate pumping apparatus is located at the other end of the grade (Ashburnham), so that in case of accident or repairs to the pump at Fitchburg, or a break in the main pipe, the signals can be worked from the other end as far as the break, for an indefinite time. The air in the auxiliary reservoir at the signal posts is also sufficient for a number of operations.

It is not necessary to run the pump for these signals more than three or four hours per day, and as much during the night. The regular work of the engineer is to run hoisting machinery for a coal dump; in addition to this he runs the pumps for the signals occasionally until the air pressure reaches 60 lbs.; then he stops until it falls to about 40 lbs., when he pumps again.

The number of operations of these signals for two months in 1887 was 48,487, or about 795 per day. The number of failures in the same period was 133, or one failure to 365 operations; 22 disk signals during the same pe·iod made 69,844 operations, and there were 54 failures, or one in 1,293 operations. The cost of 12 electromagnet semaphores with the necessary pumping apparatus, etc., was $11,126, or $927.17 per signal. The cost of 14 disk signals erected in 1887 for another railroad was $6,971, or $497.94 per signal.

The cost of maintenance of the electro-pneumatic signals is about $133.33 per signal per year; that of clockwork disk signals about $75 per year each signal.

The application of these signals in a considerably more complicated form was made on 13 miles of the West Shore road in 1884. The same system was applied to short sections of the Pennsylvania and some other roads about the same time. In this arrangement each block signal was provided with a distant signal at the beginning of the preceding section, so that there were on each post two signals, the upper of which was painted red and referred to the section beginning at the signal, and the lower, which was green and cut with a dovetailed end, belonged to the section second in advance of where the signal stood. Each block signal was connected with its distant signal by a wire circuit, so that the latter reproduced all the movements of the former. Besides this, each red signal when in the danger position was caused to close a shunt circuit around the magnet of the green signal on the same post, so that the latter also stood at danger as long as



Electro-Pneumatic Block Signal, Fitchburg Railroad.

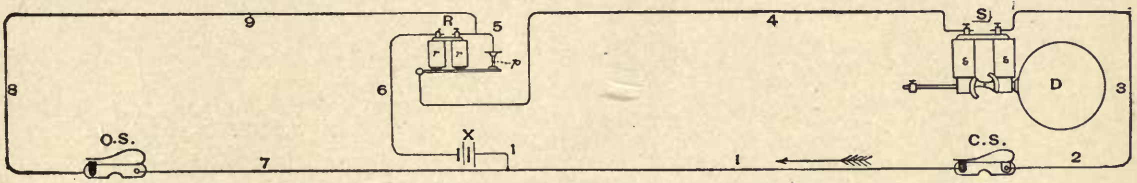
a train was in the section. There were thus three signals at danger behind a train, two at the beginning of the section where the train was, and one at the beginning of the preceding section. They were lighted at night by lamps which showed red when the signals were in the stop position, and green for all clear. If a train found the two arms on any post standing at danger, or two red lights at night, it would indicate that the section beginning at the post was obstructed, while the upper arm inclined and the lower one horizontal (or at night a green light with a red one below it) would mean that the section immediately in advance was clear, but a train or other obstruction must be looked for on the second section ahead.

This was the first extensive application of electro-pneumatic semaphores put up by the Union Switch & Signal Company, and they were then without that knowledge of the proper methods of construction and operation which has been since gained by experience. Partly from this cause, and partly, it is claimed, because the road was new and the settlement and displacement of the roadbed caused many leaks in the pipes, this system never gave complete satisfaction, and has now been discontinued, the semaphores being worked by signalmen and without distant signals.

THE HALL BLOCK SIGNAL.

[*September* 12, 1890.]

The illustrations herewith show the apparatus used in Hall's electric automatic block system. The Hall is a wire circuit system, the circuit being normally closed. The signal is a circular disk of silk stretched upon an aluminum ring and inclosed within a wooden case with a glass-covered opening. The front of this case being painted dark and showing some 10 square feet of surface to an approaching engineman, the signal is a conspicuous object. Fig. 1 shows the arrangement of wires and electromagnets for operating a simple block-signal circuit. At the entrance of the section is located the "block" track instrument, *C S*, the operation of which sets the signal at danger. The similar instrument at the other end, *O S*, is called the "clear" track instrument, its function

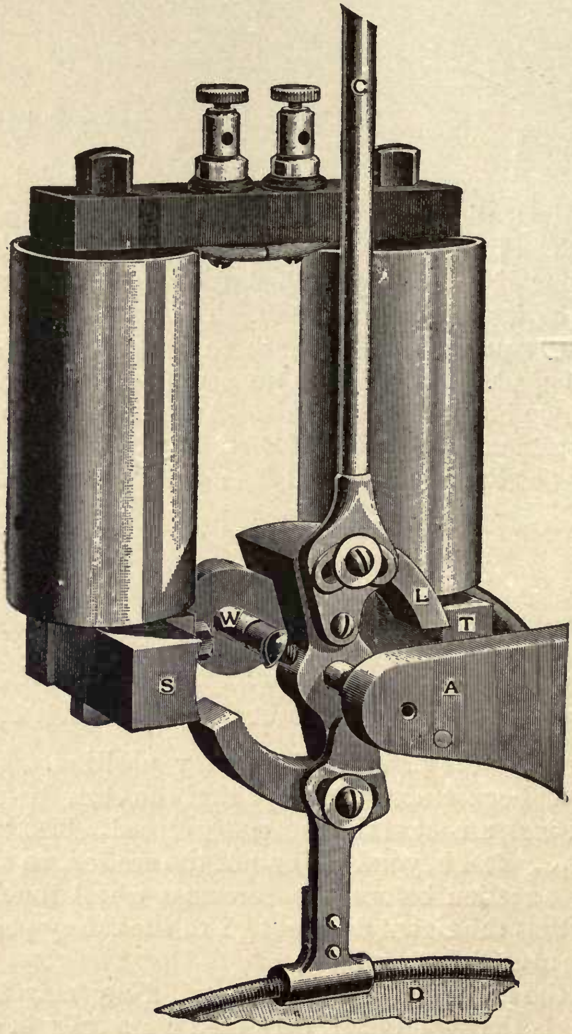


THE HALL AUTOMATIC BLOCK SIGNAL—DIAGRAM OF ELECTRIC CIRCUITS—Fig. 1.

being to restore the signal to the safety position. These two instruments are alike in principle and construction, except that the clear instrument stands normally open, while the block instrument stands normally closed. The "clear" track instrument is located 1,500 or 2,000 feet beyond the end of the section, so that the longest train will be wholly clear of the section before the foremost wheel touches it, though the circuits are so arranged that the signal does not go to the safety position until the whole of a passing train goes over the instrument.

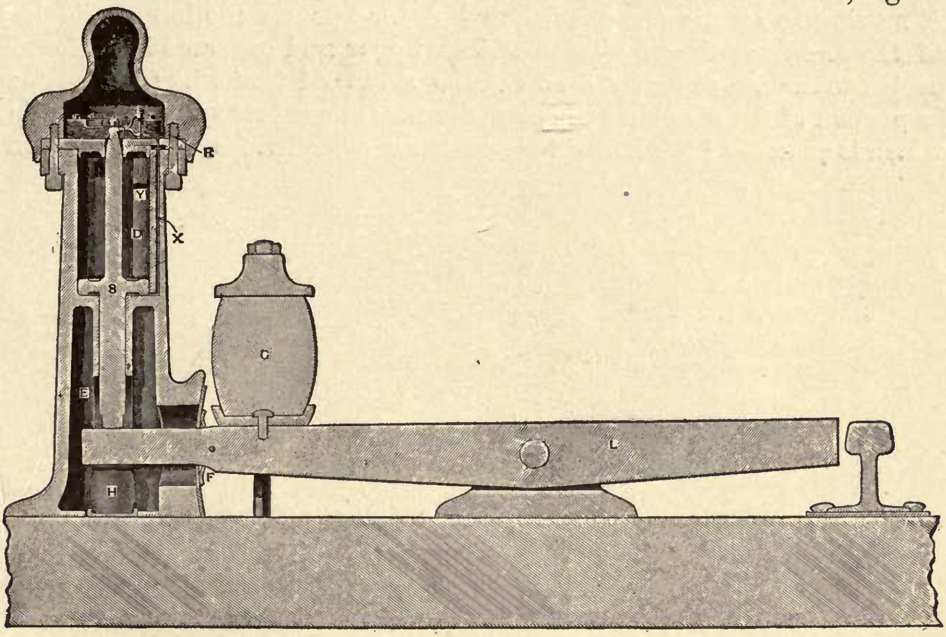
R is the relay and *X* the battery. They may be located at any point within the block. *D* is the signal disk, described more fully in connection with figs. 2 and 3. The circuit is normally closed, and signal *D* is held in the position shown (safety), by the force of the electromagnet, the circuit being completed from the battery *X* through wire 1, track instrument *C S*, wires 2 and 3, electromagnet *S*, wire 4, contact point *p*, wire 5, electromagnet *r*, wire 6, to battery. A train in entering the section opens this circuit, the first wheel of the train breaking the contract between the spring and its anvil $C S$; electromagnets r and s are demagnetized, signal D falls to a position in front of the glass-covered opening (to danger), and the contact at p is broken. After the whole of

Hall Signal—Fig. 2.



Hall Signal Inst·ument—Fig. 3.

the train has passed over the "block" instrument, the contact between the spring and its anvil will be restored; but as the circuit is now broken at p, the signal will remain down (at danger) until the points at p are again brought in contact; that is, until the train, in passing out of the section, completes a circuit that shall energize electromagnet *r*. This is accomplished by the closing of the spring of the "clear" track instrument *O S*, which completes a circuit from battery *X* through wire 7, spring and anvil at *O S*, wire 8, electromagnet *r*, wire 6, to the battery. The contact at *p* is now closed, and the signal circuit is complete, but the signal will remain at danger until the train has entirely cleared the "clear" track instrument, from the fact that as long as the spring at *O S* is in contact with its anvil two circuits are completed, one through the clear-track instrument and the relay magnet and the other through the block track instrument, signal magnet



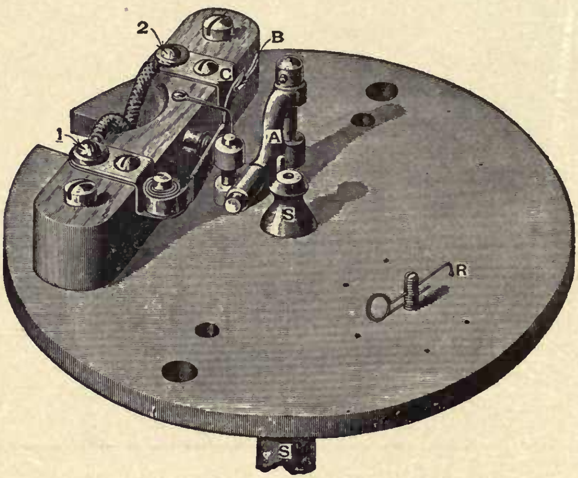
Hall Track Instrument—Fig. 4.

and relay magnet. This divides the battery power and leaves *S* too weak to lift the disk.

Fig. 2 is a view of the case which contains the signal instrument. A white reflector in or behind the case is exposed through the glass-covered aperture as long as the red disk is held out of sight. The front of the case being dark, safety is thus shown by a white disk in the midst of a dark ground. The falling of the red disk before the glass produces the danger signal. At night a lamp is placed between the reflector and the disk, so as to illuminate the latter when it is down and to show clear (white) when the disk is held up. A distant signal is of substantially the same construction, its disk being made of green silk instead of red.

Fig. 3 shows the construction of the signal instrument (*D*, fig. 1); *L* and the corresponding arm below it are the two wings of an armature which revolves on the shaft *W* between the prolonged cores *S* and *T* of the electromagnet, and to which are attached the disk *D* and its counter-weight rod *C*. The disk being heavier than its counter-weight, the signal moves to danger by gravity. When the electromagnet is energized the disk is drawn up out of sight by the rotary movement of the armature.

Figs. 4 and 5 show the track instrument, fig. 5 being an enlarged view of the top plate. The lever *L*, upon being depressed by the wheels of a passing train, forces up the piston *S*, moving in an air chamber *D*, and communicates motion to the key lever *A* (fig. 5) of the circuit-closing apparatus. The upper and lower ends of the air chamber are connected with each other by a port *X*, so arranged that when the piston is forced upward a portion of the air above the piston is forced out through the port *X* and opening *Y*, which is placed a little below the top of the cylinder. When the piston has risen



Top Plate Track Instrument—Fig. 5.

high enough to cover the opening *Y*, the communication with the lower end of the cylinder is cut off and the air remaining in the upper part is confined and constitutes a cushion, preventing the piston rod from being thrown forcibly up against the top cap. The piston rod extends up through the cylinder head, or top plate, as shown in fig. 5. Upon being actuated by the lever *L* its beveled top engages the roller of the swinging arm *A*, which forces the spring *B* to a contact with its anvil *C*, thus completing a circuit between 1 and 2, the wire connections. When the piston has been raised by the action of a passing train, the air forced out by it is driven through the port *X* and enters the air chamber below the piston; so that when it falls back the air so introduced retards it in its fall, thus preventing injurious shocks. *R* is a valve for regulating this air pressure. The lower end of the piston rod moves in a closed chamber *E*, in which the end of the track lever works. This opening is closed by means of movable plates *F*, fixed on the lever and working against the edges of the opening. The lever is confined between two rubber springs *G* and *H*, which are so compressed that any weight less than that imposed by the pressure of an ordinary car wheel fails to operate the piston.

The Hall company provides a modification of this system for permissive blocking whereby a second train entering a section before the first has cleared it cuts out the electric circuit from the signal behind it, so that the signal can be cleared only by the last train of the series. This method is used on the New York Central & Hudson River, and is more fully described on a succeeding page.

The Hall signals have shown some remarkable records. For example, one of the earliest signals (of the latest form), located near Wellesley Hills, Mass., on the Boston & Albany, worked 20 months without a fault. Going into service May 30, 1888, and being used as a positive block signal, it has never got out of order, caused an unnecessary stop, or shown safety when danger existed, thus making a perfect mechanical record. [Jan. 24, 1890.] In consequence of its satisfactory operation, the Boston & Albany equipped the entire line from Riverside to Worcester, 33 miles, double track, with the system, the sections being overlapped.

The New York, New Haven & Hartford uses the system even more extensively than the Boston & Albany, and now employs in regular block service 92 signals, protecting all station yards (also the bridge over the Connecticut River at Windsor Locks, where the two main tracks are intervolved), dangerous points and switches on the main line between New Haven and Springfield, 62 miles. A sample of the records on this road is that given by the supervisor of signals on the Hartford division, to the effect that all the signals in his charge (92) (October, 1890) had worked for 38 days without an unnecessary stop or a complaint of any kind from trainmen.

For single-track working the company provides electric interlocking apparatus, the instruments being made on the principle of those used for the Hall highway-crossing signal. By a simple arrangement a train entering a section sets a signal at danger in the rear, and at the same time the one at the other end of the section is locked in the danger position so as to stop trains from the opposite direction.

HALL BLOCK SIGNALS ON THE NEW YORK CENTRAL.

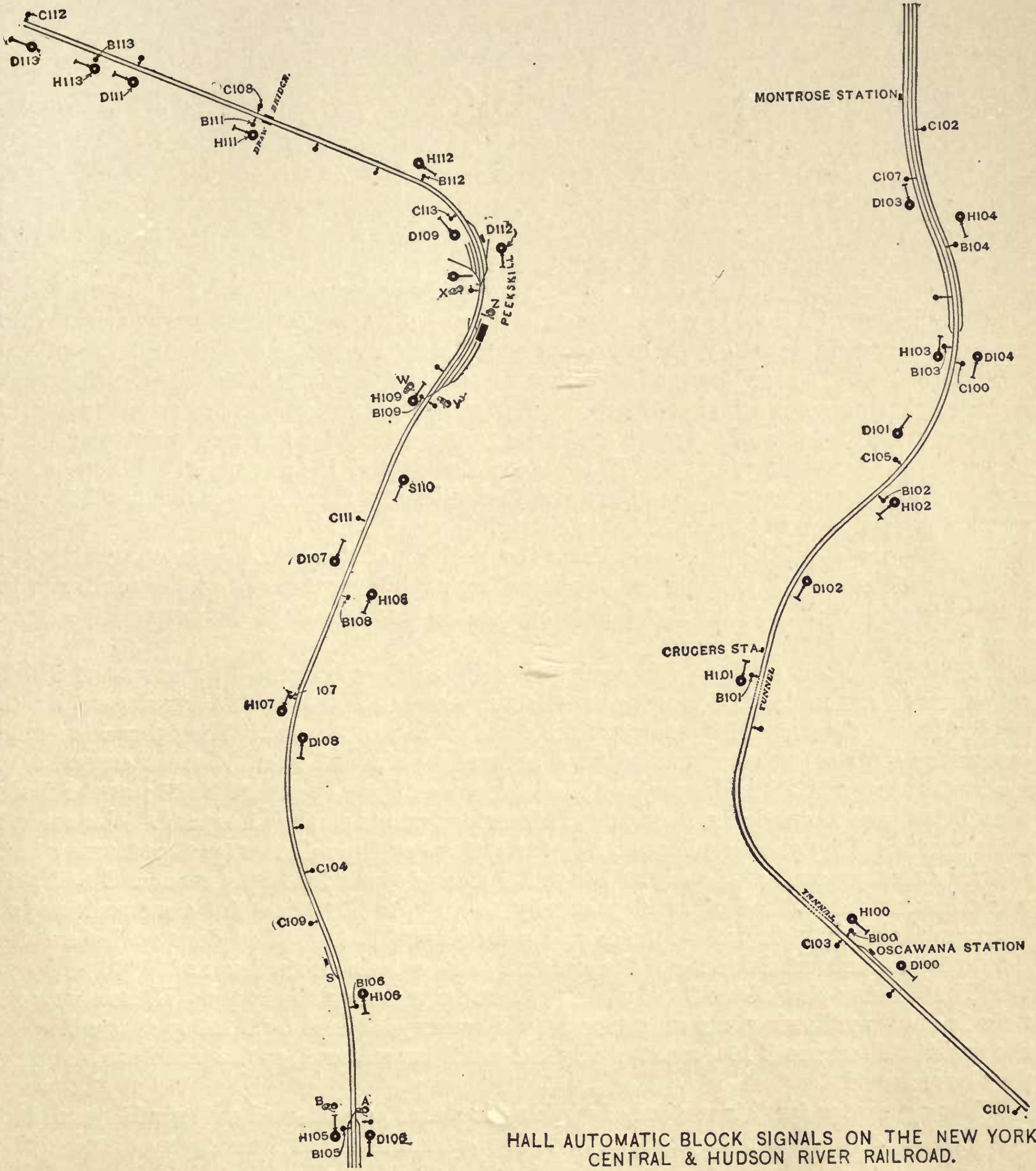
[*December* 5, 1890.]

The automatic electric block system of the Hall Signal Company, which has been in use for two or three years on the Boston & Albany and New York, New Haven & Hartford roads, is now in use on an eight-mile section of the New York Central & Hudson River (double track) near Peekskill, N. Y. This application is in various respects more complete than either of the others mentioned, and we print herewith a diagram showing the arrangement of the signals and giving a general idea of the way in which the road has been equipped. The portion of line blocked extends from Oscawana on the south to near Roa Hook on the north, 8½ miles, and there are six blocks on the northbound track and seven on the southbound. Each block has a home and a distant signal. All switches within the sections are equipped with a circuit-breaker, so that whenever they are moved off the main track they open the circuit and set the signal for that section at "danger." Each distant signal works simultaneously with its home signal.

As will be seen by the diagram, the piece of road blocked is quite crooked, the Peekskill station especially being in an obscure location. There are short tunnels near signals 100 and 101 (Oscawana and Crugers), and there is a drawbridge in sections 111 and 112. There is an ascending grade going south from Peekskill where heavy freight trains are liable to lose time, making block signals specially needful. At Peekskill station there is a grade crossing from which the view is very short, and in connection with the block system the signal company has put in bells, which seasonably warn the gate-tender at this crossing of the approach of trains.

The diagram can be easily read if the meaning of the four principal letters is remembered. These are: H, home signal; D, distant signal; B, "block" track instrument, by which a train sets a signal at danger; C, "clearing" track instrument, by which a train restores a signal to the clear position. Thus for block No. 100, D 100 is the distant and H 100 the home signal; when the engine of a train passes B 100 it sets the signal at danger, and when it passes C 100 the signal is restored.

Track instrument B 111 also sets a-ringing bells *W* and *X*; and B 108 starts bells *Y* and *Z*; these bells are silenced by the passage of trains over the track instruments near them. The track instrument for H 107 starts bell *B*, and B 104 starts bell *A*.



HALL AUTOMATIC BLOCK SIGNALS ON THE NEW YORK CENTRAL & HUDSON RIVER RAILROAD.

These bells are stopped in the same manner as the others. At *S*, south of C 109, is a private siding. The drawbridge is interlocked not only with signals 111, 112, but also with 113.

These bells, as also those in the gate-tender's cabin, are operated on the same principle as that employed in the automatic highway-crossing signal made by this company, which was illustrated in the *Railroad Gazette* of March 28, 1890. Bells *A*, *B*, *W*, *X*, *Y*, *Z*, as will be seen by reference to the diagram, ring continuously from the time a train approaches within a certain distance until it reaches the bell; and this ringing warns the switch-tender not to disturb the main track in the face of the approaching train.

When a train goes into a siding to wait for another train to pass it, the circuit, which would ordinarily be closed by the passage of a train over the clearing track instrument for that section, is closed by the conductor or trainmen by means of a circuit-closer fixed near the switch. The switches of crossover tracks are equipped in the same manner. A southbound conductor arriving at Peekskill, for instance, and wishing to go to the freight sidings on the east side of the main line, goes to the switch for the crossover track, and if he hears no warning from bell *Z*, turns it; this sets H 108 at danger. When he has returned to his own track and set the switch for the main track he uses the hand instrument (circuit-closer) to restore H 108 to safety.

S 110 is a special signal to indicate the position of the switch connecting with the siding north of it. A number of passenger trains whose trips end at Peekskill run in upon this side track, and the signal is introduced so that they need not run slowly all the way from signal 108.

All these block sections are equipped with auxiliary circuits, by means of which trains can be run under the permissive block system, and the track instruments which appear in the diagram without letters are parts of this apparatus. The operation of the permissive circuits can be explained in a general way as follows: A train enters, say, section 104; sets H 104 to danger, as the engine passes it, by operating B 104; at the same time D 104 goes to caution and warns the following train to slacken its speed. This second train, finding H 104 showing danger, stops two, three or five minutes (as the rule may be), and may then proceed cautiously. When the engine of the first train reaches C 102, this track instrument (whose office is primarily to restore H 102 to the clear position) so arranges the circuits that when the second train passes B 104 (if it does so before the first train goes out of the section) the pressure of its wheels on the lever of B 104 will prevent H 104 being cleared by C 104 when the first train passes the latter. If, however, no train is closely following, the arrangement of circuits produced by C 102 is changed when the first train reaches C 104, and the original condition restored, so that absolute blocking may be resumed.

The apparatus for this method of working is not so complicated as it would seem, and it has fulfilled its office perfectly during the two months it has been in use here. The officers of the road say that the whole system has worked very satisfactorily. The only unnecessary stops have been caused by trainmen forgetting to clear signals after entering side tracks, and by improper adjustment of instruments, due to an inexperienced inspector. This last trouble occurred only three times, and these were all during the first week of operation ; since that time the apparatus has worked perfectly. [Dec. 5, 1890.]

BLACK'S AUTOMATIC BLOCK SIGNAL.

[*January* 24, 1890.]

This apparatus, which has beeen in use for two or three years on the elevated roads of New York and elsewhere, is simple and strong in construction and has been found very efficient in operation. The essential parts are shown in the illustrations herewith.

Fig. 1 shows a plan and side elevation of the track instrument. This consists of a

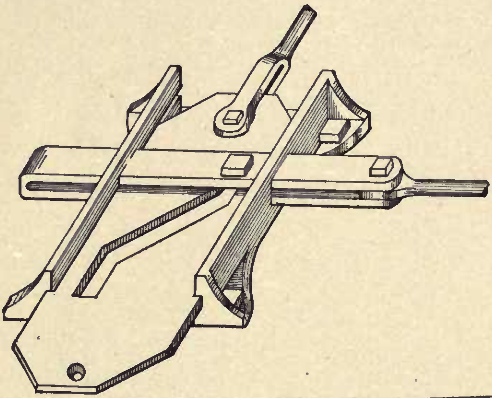


Fig 4.

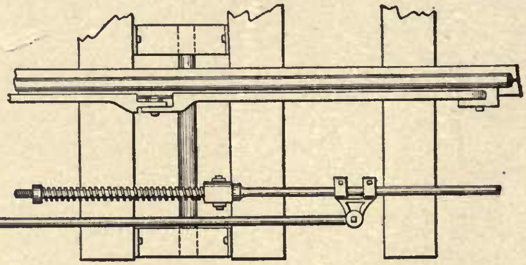
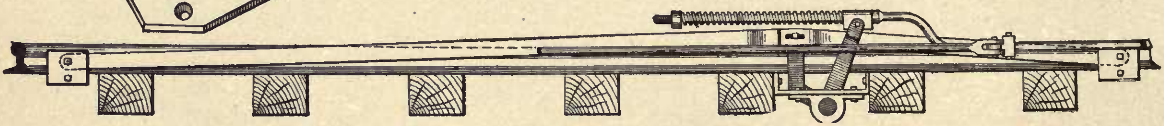



Fig. 1.

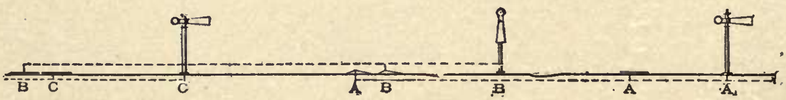


Fig. 3.

BLACK'S AUTOMATIC BLOCK SIGNAL.

lever placed just outside of the rail, which is depressed by the tread of the wheel passing over it. This operates a rocking shaft, which is connected with the ground connection leading to the signal. As will be seen, this connection from the rocking shaft to the ground connection is made by means of a rod having on one end of it a strong spiral spring, the object of which is to prevent severe shocks to the various parts.

Fig. 2 shows the standard form of semaphore signal as used with this system on the Manhattan Elevated. The post, which is of iron, supports a cast-iron shield, behind which the blade is hidden when in the "all clear" position. This shield is painted black, so that safety is indicated by the *absence* of the arm rather than by its perpendicular position. The motion plate, by which motion is transmitted from the line of ground connection to the bell crank at the foot of the signal posts, is shown in fig. 4. It will be seen that this motion plate provides for a certain amount of change in the length of the connecttions from expansion and contraction, or slack. By the use of this device the labor and care necessary to keep the rods adjusted has been reduced to a minimum. On the Manhattan one man attends to the inspection of 54 signals.

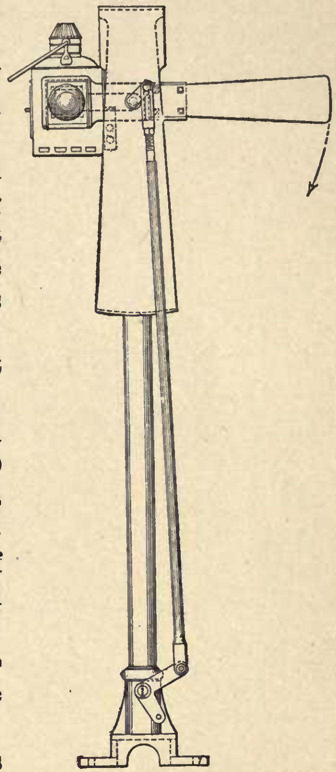


Fig. 2.

Fig. 3 is a diagram, not made to scale, showing in a general way the operation of the apparatus. *A A* are levers operating the connection to signal *A*. A train moving from right to left has passed the signal and has set it to danger by means of the track instrument *A*, near the signal. When the engine arrives at the first lever beyond signal *B* it sets signal *B* to danger, and immediately after, at the lever marked *A*, sets signal *A* at clear. This is repeated throughout the system.

The length of the blocks on the New York Elevated through which this system has been operated is about 1,700 feet. At the regular speed of trains on the Manhattan this distance is traversed in about 47 seconds, which is as close together as trains can be run in ordinary service, this amount of time being generally required at the terminal stations to detach the engine and attach a fresh one at the other end of the train. Discharging the passengers and taking in the new load also requires nearly a minute, although it is often done more quickly than that.

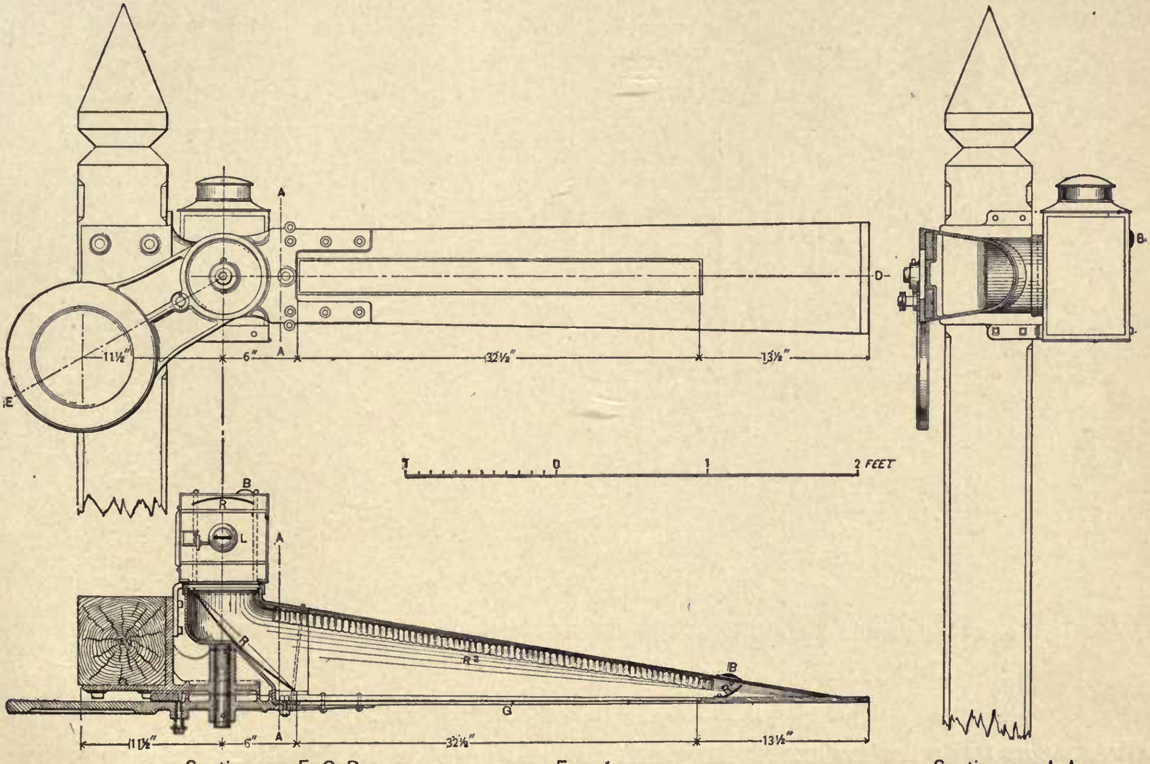
The trains on the Manhattan lines where this signal is used are of nearly uniform length; the invariable maximum is five cars and an engine. Four-car trains are run a good deal, and empty engines make occasional trips, but the variation is immaterial from a signaling standpoint. The signals and track instruments are therefore made to accommodate the five-car trains. The engine sets each signal to danger when the rear car has passed 25 feet beyond the signal, and restores that signal to "all clear" when the rear car has passed the next one; each is therefore a home signal. No permissive blocking is allowed, but every engineman must be prepared to stop *at* the signal.

This apparatus is the invention of Mr. Robert Black, Roadmaster, who has been connected with the roadway department of the New York elevated roads since they were built. The signals are now made by the Black Automatic Railway Block Signal Co., of 192 Broadway, New York City. They are in more or less use on the Staten Island Rapid Transit road, the Kings County Elevated and the Brooklyn Bridge. The Manhattan has a series of 32 continuous block sections in operation on the Sixth avenue line above Fifty-ninth street.

ILLUMINATED SEMAPHORE SIGNALS.

[*March* 30, 1888.]

There are many railroad men and experts in signaling who believe that, all things considered, the indications of fixed signals should be by color rather than position. In



Section on E C D. Fig. 1. Section on A A.

ILLUMINATED SEMAPHORE SIGNAL.

the evolution of signals the semaphore form has gradually come to be considered the best Ordinarily this shows danger or caution by day by color and form as well as by position, but the application of this principle to night signals is more difficult and the use of color alone is still almost universal. Various devices have been employed for illuminating the semaphore blade so as to get a good position signal at night, but they have generally failed from defective illumination. When the lamp is placed in front of the signal it is found that the rays reflected are so diffused that the semaphore is visible at so little

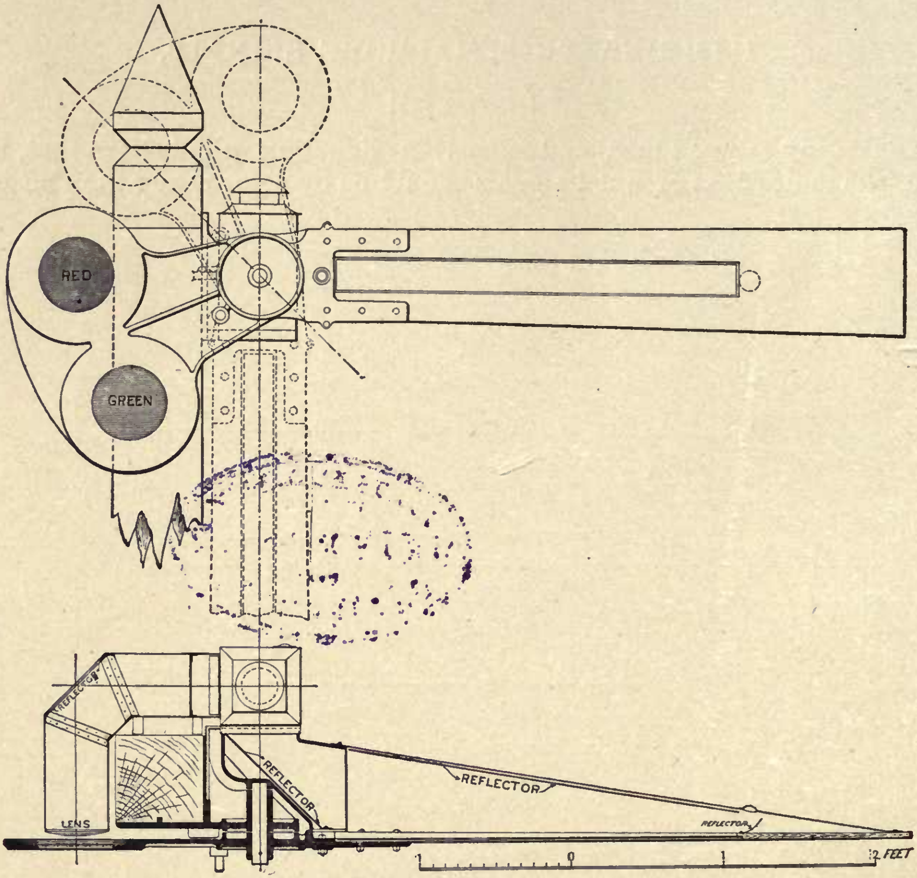


Fig. 2.
ILLUMINATED SEMAPHORE SIGNAL.

distance as to be useless except for yard purposes or other places where trains are moved but slowly. We show two successful semaphores designed to get over these difficulties.

UNION SWITCH & SIGNAL CO.'S ILLUMINATED SEMAPHORE.

This may be used as a purely position signal, or in combination with colored lenses as a combined position and color signal. It is the design of Messrs. Spicer and Schreuder, and has been quite extensively used. In August, 1889, an order was issued on the Pennsylvania lines west of Pittsburgh that illuminated blades should be used for all new work, and this semaphore has been considerably used on those lines.

In fig. 1 the semaphore is shown as designed to dispense with colored disks, and in fig. 2 it is shown with red and green disks for a three-position signal. Another design is also made with only a red disk.

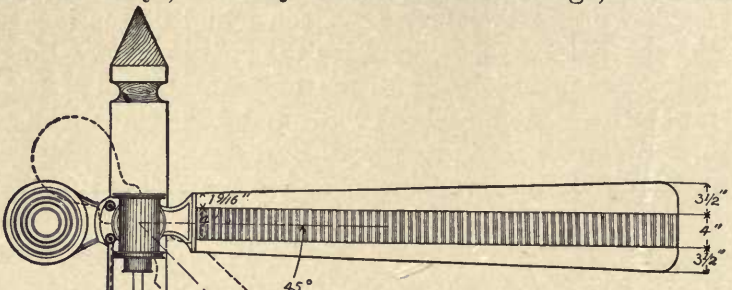
The construction of this illuminated semaphore is very clearly shown in the illustrations. The reflectors are shown at *R R'*, etc. That in the semaphore arm is concave and corrugated, as represented in fig. 1. The reflected light is thrown forward through a plain glass *G*, 32 in. long and 2½ in. wide. The divergence of the rays would naturally make the arm of light so shown appear larger than the actual dimensions of the glass. The glass is put in with rubber packing, to diminish the chance of breaking The lamp *L* is of the same size and power as that used in the ordinary signal of the Union Switch & Signal Co. At *B* is shown a lense for a back light to let the signalman see that the lamp is burning and that the signal goes to its proper position.

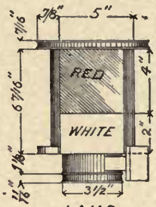
This is a beautifully distinctive signal, and cannot be confounded with any other lights.

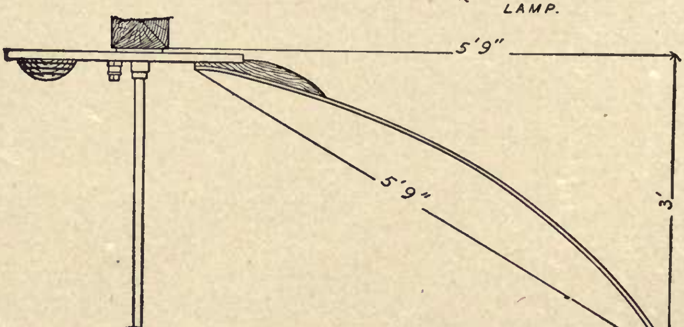
THE KOYL PARABOLIC SEMAPHORE.

[*October* 19, 1888.]

This semaphore is made by the National Switch & Signal Company. It is the invention of Prof. C. Herschel Koyl, formerly of Swarthmore College, now connected with the







Plan.
THE PARABOLIC SEMAPHORE.

National company. This semaphore has been widely tried in the United States and is the standard form used by the makers of it in their signaling work.

The reflecting surface and the frame which incloses it form a longitudinal section of a paraboloid. This is mounted in the ordinary casting which supports the semaphore arm, and rotates about the axis in the post, which is also the axis of the paraboloid, in the focus of which the lamp is placed. To a front view the semaphore presents the dimensions of 5 feet 6 inches in length, from the axis to the end of the blade, and 11 inches in width, and has a reflector 4 inches wide along the centre, from end to end.

A reflecting surface of the form specified has the property of making parallel all rays which fall upon it from the focus, the consequence being that there is sent along the track by this means a continuous band or beam of light of definite dimensions. The specification of the patent also says, "in view of the fact that this band or beam should be of such dimensions that at the conventional distance at which the signal comes under the observation of the engineer it shall be wide enough to extend across the track to which it is appropriated, and deep or broad enough to about cover the observation portion of the cab of the engine, it will be found desirable to slightly modify both the longitudinal and transverse curvature of the paraboloidal section which forms the reflecting surface, so that at such distance there will be sufficient divergence of the rays to produce a beam of the dimensions indicated. To accomplish this result, however, the modification in form of the reflector need be very slight, and it remains to all intents and purposes of the contour of the section of a paraboloid."

The object has been to concentrate upon the track all the light from the arm, and then to diverge it only so much as the necessities of the case may require, the method adopted for diverging it being to slightly corrugate the reflector at right angles to the four directions in which the divergence is required.

The result is a semaphore which presents the same appearance by day and by night, which combines the excellencies of a color signal with those of a position signal. The upper half of the lamp being red or green and the lower part clear, the arm when horizontal appears red or green, and when dropped white.

The reflecting surface is now made of aluminum, which is lighter than glass, tough and does not tarnish.

THE STEWART-HALL TRAIN ORDER SIGNAL.

[*January* 23, 1891.]

The diagram printed herewith shows the arrangement of wires and electromagnets used in a train order signal recently patented by Robert Stewart, Superintendent of Telegraph of the Central of New Jersey, and W. P. Hall, President of the Hall Signal Company. The special features of the signal are, 1, that it works entirely by electricity, so that it can be placed in the most convenient location, and not necessarily in front of the office; and, 2, a provision against letting a train pass while there are orders for it, through the operator's forgetfulness. As is well known, the last mentioned purpose is

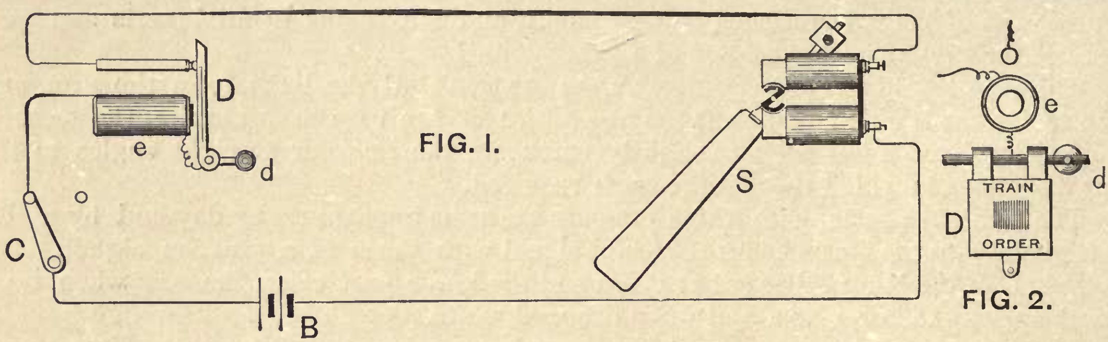


FIG. 2.

THE STEWART-HALL ELECTRIC TRAIN ORDER SIGNAL.
Arrangement of Instruments and Wires.

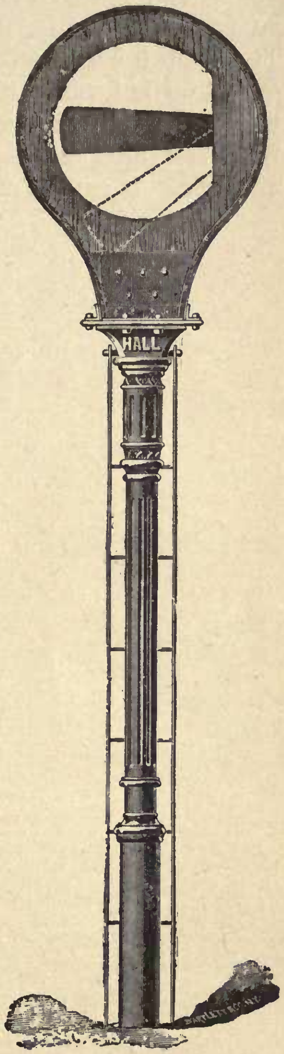
appreciated by practical superintendents and dispatchers, and various devices have been heretofore invented for accomplishing it. The convenience of locating the signal itself some distance beyond the station, so that a train can be held for orders, while at the same time permitting it to stop where passengers or freight can be discharged and the tank filled with water, is obvious. This, of course, requires two signals, one for movements in each direction. The out-door signal may be either the Hall disk signal as used in the block system of this company or the semaphore shown below.

The electromagnet *S*, in fig. 1, represents the signal instrument, the presence of the electric current in the coils holding the signal in the safety position as shown. *D* represents the "drop," which is mounted in a cabinet fixed at some place in the office where the operator must leave his desk in order to reach it. It will be seen that whenever the circuit is opened the armature, in falling away, opens its own circuit in such a way that it can be again closed only by lifting the armature of *D* by hand. As will be seen in fig. 2, this armature carries a tablet lettered so as to warn the operator of the fact that a train order is on hand. The opening of the circuit permits this tablet to fall from its hidden position to a stop which leaves it in front of a glass-covered opening in the case.

On receiving an order for a train the operator sets the signal at danger by opening the switch *C*, which is located on his desk. If now, when the train arrives, he should forget that he is to stop it, and should attempt to clear the signal by closing the key *C*, he would find that the signal remained at danger, and, on going to the cabinet *D*, to close the circuit by lifting the armature, would be reminded by the tablet of the presence of the train order. The lifting of the armature is accomplished by means of a large push button or plunger, and this button can be arranged with a clip to receive a folded order, so that the circuit cannot conveniently be closed without first picking up the order.

Two of these signals have been erected at Somerville, N. J., on the Central of New Jersey, one for westbound and one for eastbound trains, and additional applications are now being made on this and other roads.

THE HALL ILLUMINATED ELECTRIC SEMAPHORE.



The Hall Electric Semaphore.

In connection with the train order signal described above, the Hall company uses the new form of semaphore shown in the accompanying cut. The mechanism for operating this signal is precisely the same as that used in the disk signal. In the disk signal the counterweight is lighter than the signal, but in the semaphore it is made heavier so that the arm shall assume the horizontal position in case of failure of the circuit or operator. The cut shows the signal as actually used at Somerville, the case being a modification of the pattern used for disk signal; but the company is making plans for a case with a glass-covered opening of a different shape. With a rectangular opening of the right proportions the ordinary semaphore can be quite closely imitated, the side of the case answering for the post. The angle shown by the dotted line in the cut does not indicate the limit of the power of the magnet.

The opening in the case, which furnishes a light background for the dark blade, is covered with transparent glass in front, and with ground or painted glass at the back. The lamp for illuminating the signal at night is placed 18 inches or more away from the case, and is fitted with a reflector shaped to diffuse the rays of light equally over the whole surface of the glass. The blade is made of silk or cloth stretched on a hollow wire, the same as the Hall disc, and is therefore sufficiently translucent to show its color at night. It can be made of any desired color that contrasts sufficiently with white.

THE HALL HIGHWAY CROSSING SIGNAL
is described on page 3.

THE HALL ELECTRIC AUTOMATIC BLOCK-SIGNAL SYSTEM.

By the above term is meant the Hall system with a wire upon poles and the Hall disk signal, as shown in the descriptions in this book.* To profitably read those descriptions the reader should first fix in his mind some of the essential conditions of block signaling.

The main features demanded in an automatic block signal are well known. They are: that it shall promptly, on the passage of a train, change from safety to danger, and thus protect the train against a rear collision until it shall have passed beyond another signal further on; that the signal shall instantly go to danger whenever a switch is turned to the side track, and that it shall perform these operations unerringly; that the changing from danger back to safety after the train moves out of the block section shall be done promptly, and that failures to do this, and other failures (which, while not dangerous, cause delays to trains and other annoyances) shall be reduced to a satisfactory minimum. These points are set forth at length in our illustrated catalogue, which is already familiar to most railroad operating officers. *The Hall signal meets all these conditions.* The vital question is, can trains be run close together with safety, regularity and convenience. The first trouble, where trains follow each other closely, is that the detention of one by a signal that fails to operate detains a number of others. This emphasizes the demand for perfect apparatus and constant, intelligent care. The satisfactory way in which the Hall signals meet this test is beyond comparison with the showing made by any other automatic signal. The good records from a few roads, shown in our illustrated catalogue published a year ago, are now repeated on a number of others, and in localities where the service is, if possible, more exacting. These records will be given in detail to railroad officers interested. As most interested readers know, it is next to impossible to maintain good discipline among engineers where they are frequently stopped by signals unnecessarily—that is, where there is some fault in the battery or connections, or something else that has resulted from carelessness; and a signal which thus causes annoyance is, in some respects, as undesirable as one with worse faults. Our records will show that the number of these unnecessary stops can be, and is, kept *very much smaller* with the Hall than with any other automatic signal. There is no mystery about this. The explanation is found in the greater simplicity of the apparatus and the superior mechanical construction of everything connected with the system. Batteries can be kept up by ordinarily intelligent men. The detection of bad connections, wrong adjustments, and other troubles is not such an intricate job as to require an expert with elaborate training. We insist on good men, and require faithful service, but we do not ask impossibilities of them. A chief trouble with track-circuit signals is that the faults of the system, of the apparatus, and of the men, when all combined make up such an aggregate of delays, annoyances and dangers that they are intolerable. The system demands delicate battery power which must be very carefully adjusted; and even then wet weather will often baffle the best attempts at adjustment of the instruments. A vital feature of the system is the shunt, by which the current, when the signal is to be set at danger, is not wholly, but only partially, withdrawn from the signal magnet. This is a feature which probably can never be made to work with the simplicity and certainty of a good wire circuit system in which the circuit is positively and totally *broken* every time a train enters the section. As to construction of apparatus the Hall Signal Company only ask a comparison of their goods with those of any other manufacturer. The opinions of railroad officers who have used our instruments and others side by side will be freely shown. As to negligence of inspectors, the Hall Signal Company expects human fallibility, and, as above intimated, only demands good, intelligent men, managed with reasonable discipline. All we have to say is that such men *have succeeded* in regularly making satisfactory records. The company's standing offer to guarantee the maintenance of signals for *five years* at a fixed low rate per year should be sufficient confirmation of this; but we do not ask roads using our signals to put up with a mere guarantee, for we fully recognize that a money forfeit would be poor compensation for an unsatisfactory signal system; and inspection of signals in satisfactory operation on prominent roads is earnestly invited. We desire railroad officers to convince *themselves* of the merits of our system. The complaint about the deceptions of selling agents shall not be justly applied to the Hall signals.

* We own the best patents on *rail circuit systems* and contract to put in such systems with apparatus possessing all the mechanical perfection which has so long characterized the work of our shops. This is now practicable in consequence of the expiration of patents which formerly kept this company—or rather its predecessor—out of this field. We also make semaphore signals, both inclosed in a case with a glass-covered opening, and uninclosed; but the present chapter is devoted to the Hall system, as it *is now most largely used*.

AUTOMATIC HIGHWAY-CROSSING SIGNALS.

The heavy expense involved in keeping watchmen at road crossings makes a *reliable* automatic apparatus for warning travelers an important desideratum; but most superintendents have had their faith in automatic bells seriously weakened, if not destroyed, by the very poor service given by the devices heretofore made and sold. The Hall bells give perfect satisfaction. This is a sweeping statement, but it is based on the testimony of intelligent and conservative railroad officers. The apparatus is simple and of the best design, and carefully made. The first cost is somewhat higher than that of other makes, but the freedom from annoyances soon overbalances that, while a bell which fails to ring when a train is approaching, and persists in ringing when a train is *not* coming, is dear at any price. The Hall bell is operated by the simple and reliable interlocking magnets used in our single-track block signals (described on a succeeding page), these in turn being actuated by the Hall track instruments. The bell begins to ring when the train passes the track instrument, and continues to ring *until the train reaches the crossing*, whether the intervening time be short or long. By a simple arrangement of interlocking instruments and track instruments, the bell is made to ring by the approach of a train from either direction on a single track, the track instrument which would cause a false signal by being operated by a train moving away from the crossing instead of toward it, being automatically cut out.

AUTOMATIC CROSSING SIGNAL.
The gong is covered by the circular wire screen.

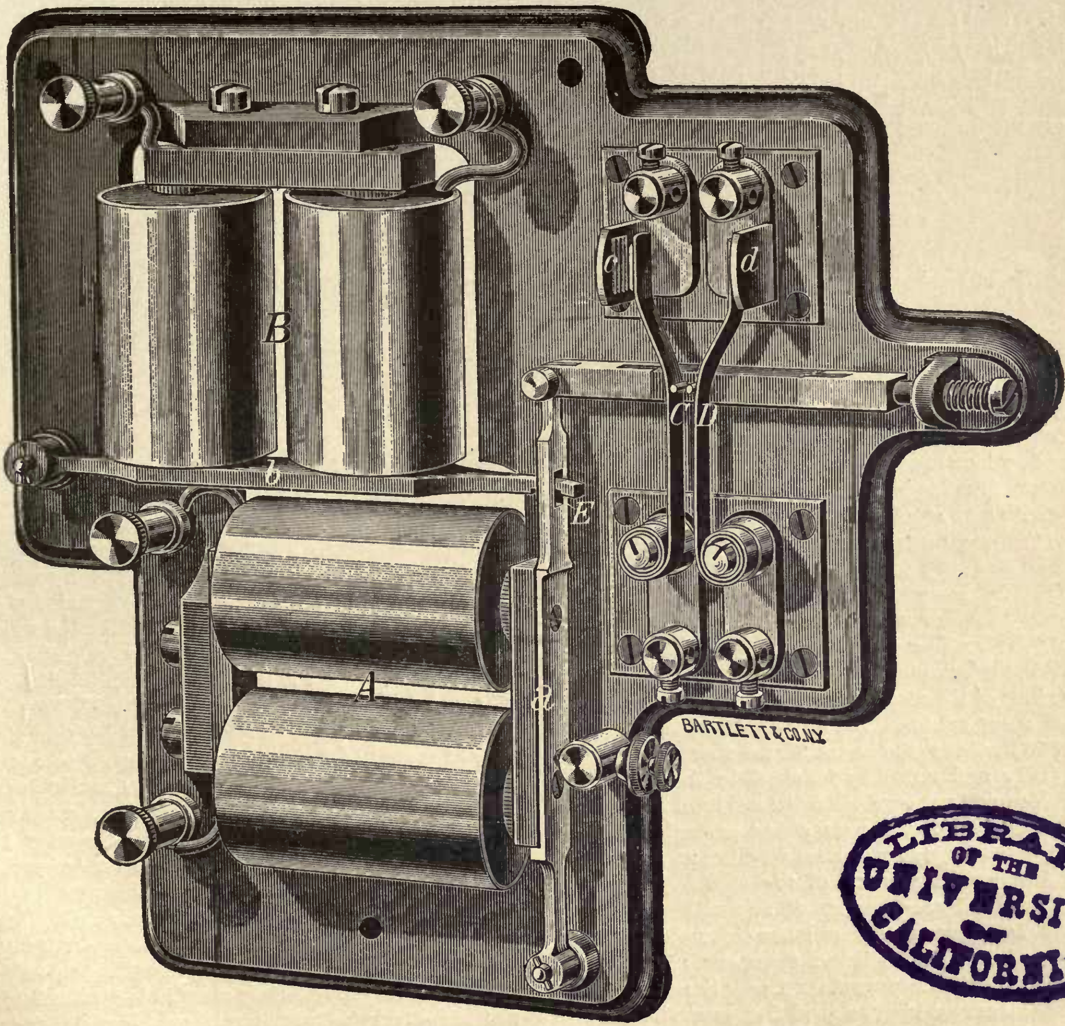
The experience of this company has shown that an open circuit is the most desirable in all respects for the operation of a signal of this kind. The primary reason for using a closed circuit—that the failure of a battery or wire shall automatically reveal itself—is found to be practically valueless in a highway-crossing signal; and, in view of the reduction in first cost of wires, instruments and battery, and of expense for battery material and maintenance, as well as the labor of taking care of the signals, the open-circuit system is far preferable. The records of the operation of these signals on the many railroads using them are such as to substantiate these statements. The bell as used for highway crossing signals is also used with much satisfaction at crossings where gates, with an attendant, are maintained. The certainty of its operations make it a reliable indicator by which the gate-tender may be notified so as to always close the gates in proper season before the arrival of a train; and where travelers on the highway are familiar with the locality the bell will serve as a warning to them at night when the attendant is off duty.

ELECTRIC INTERLOCKING INSTRUMENT.

The highway crossing bell is operated by means of the interlocking instrument shown on the opposite page. When approaching trains strike the first track instrument they lock the advancing and retreating springs in one position, which sets the bell ringing, and when the wheels strike the track instrument at the crossing the springs are instantly thrown to the other position, cutting off the current from the bell.

This instrument consists principally of a main electro-magnet *A* and its armature, and an unlocking electro-magnet *B* and its armature, the latter constituting a locking lever. To the armature of *A* is fastened a horizontal bar which, by means of tappets, actuates the advancing spring *C* and the retreating spring *D*. When the main electro-magnet is momentarily energized and its armature attracted, contact is made between advancing spring *C* and its anvil *c*, while the contact between retreating spring *D* and its anvil *d* is broken. The armature of *B* instantly drops, locking the armature of *A* and retaining the springs in this position. When *B* is momentarily energized and its armature attracted, the armature of *A* is unlocked and contact is made between retreating spring *D* and its anvil *d*, while the contact between advancing spring *C* and its anvil *c* is broken. Thus, when the advancing spring is open the retreating spring must be closed, and when the retreating spring is open the advancing spring must be closed. Upon this principle is based the Hall System of Electric Interlocking.

These instruments are also used in single-track block signaling, in signals for the protection of grade crossings (of one railroad with another), and in signals for the protection of single or double track junctions.



INTERLOCKING INSTRUMENT.

THE HALL TRACK INSTRUMENT.

This instrument, shown in the illustrated description of the Hall block signal, is of such general adaptability that it is used for any and every situation where it is desired to have a train open or close an electric circuit. This is the only device of the kind that has ever given satisfactory service for any length of time. It has been in use for many years (though recently improved) and has withstood the hardest service with exceedingly small expense for care and repairs. The combination of rubber and air cushions for absorbing all shocks gives it great durability and prevents all objectionable noise, a feature that will be appreciated by those familiar with the clanging produced by some kinds of track levers.

DISCS AND INCLOSED SIGNALS.

The Hall disc signal has been objected to in certain quarters because it lacks some of the distinctive features of the ordinary out-door semaphore; but there are advantages in its present form which each year's use makes more apparent. One of the first points mentioned in favor of semaphores is that they can be seen great distances; but this advantage is often neutralized by locating the signal where it has a very poor background, while in other cases the post is made so high (with a view to rendering it visible at a long distance) that engineers, keeping their eyes on the signal, overlook a caboose directly in front of them and run into it. This has occurred repeatedly. The Hall signal case provides a *uniform background* for every signal. This makes even a small disc more effective than a large semaphore, as the background—that is, the outline of the case—attracts the eye as quickly as would a semaphore. The signal is generally only about 12 ft. above the ground, and therefore in the line easily and naturally followed by the engineer's eye. Men will not overlook a red tail light while looking for the signal. The main object in placing signals on tall poles—to give engineers warning at a point a long distance in advance of the stopping place—is better secured by the erection of an auxiliary (distant) signal. In foggy weather, or other obscure conditions, a very tall signal is no better than one of moderate height; while in clear weather there is no necessity for it at all except to get a good background, and that the Hall signal has in any position. As will be seen by the description of the Hall electric semaphore, we combine the advantages of a semaphore with those of an inclosed signal (with a good background) when desired.

It may seem like a commonplace argument to mention here the superior economy found in maintaining and operating inclosed signals, as compared with any automatic signal exposed to wind, snow and rain; but when one takes a broad view of the matter this is really a more important point than it seems, for it reaches into all the future years that the signal may be used. Indeed, the persistent success of our inclosed signals, in spite of the disadvantages (after all, mostly theoretical) they have been believed to labor under, has been largely owing to this favorable feature. If an automatic signal is to work outdoors in spite of the elements, it must have a large reserve power; where a force of 10 lbs. is ordinarily needed, 50 lbs. or 100 lbs. must be provided to allow for variation in weight, wind pressure and other uncertain factors. Now, this necessity for additional power is responsible for most of the inevitable complications and added expense. The task of keeping in order a Hall inclosed signal may be compared to that imposed upon an operator in charge of a simple Morse telegraph instrument, which is almost *nil* as far as *skill* and *time* are concerned; while every outdoor automatic signal thus far tried has been made to give passable service only by being subjected to constant experiments, changes of plan and of apparatus, and other expedients; and after 10 years' trial the prospect of a satisfactory outcome is no better than at the start. In presenting this aspect of the case we may possibly seem to be "retarding the progress of science"; but our labors to provide for railroads (1) just such signal apparatus as the service needs, and (2) such as will do what it seems to do, will attest to all conversant with the facts that we are not unprogressive. It is only by constantly considering *both* of the above factors that any real progress can be attained. 28