JOURNAL

OF THE

Association of Engineering Societies.

BOSTON. CLEVELAND. MINNEAPOLIS. ST. LOUIS.
CHICAGO. KANSAS CITY. MONTANA. ST. PAUL.
DENVER. VIRGINIA. SAN FRANCISCO.

CONTENTS AND INDEX

OF

PAPERS AND PROCEEDINGS.

VOLUME XIV.

January to June, 1895.

PUBLISHED BY

THE BOARD OF MANAGERS OF THE ASSOCIATION
ENGINEERING SOCIETIES.

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RAILROAD SIGNALING.

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[Read January 17, 1894.*]

IN the most primitive method of operating a railroad all trains are scheduled and have stated meeting points. Each meeting point must be made within a given time limit. This plan primarily requires no signals; in other words, the absence of a danger signal means safety. Carrying out this general idea, switch stands are sometimes made with but one target; the edge of that target faces the train when the main line is clear, and the whole target shows at danger when the main track is not clear.

As the business on a road increases, this primitive method requires extension and change. At given points along the road, at distances as nearly uniform as possible, telegraph operators are stationed, who, acting under a dispatcher, give special train orders, using a danger flag or its equivalent when orders are at hand.

In the next advanced step, all train-order stations are equipped with fixed signals, each conveying one of the three ideas—danger, caution and safety—and controlled by the operator under the direction of a train dispatcher. The absence of a signal still means safety, and a fixed time interval is required between all trains. French roads are mostly operated on this plan, and it is said that, notwithstanding its defects, good results are secured, the system being carefully worked out. Many miles of railroad in this country are still operated on this plan.

Under the next more advanced plan the movements of trains are governed by telegraphic orders in addition to time tables. This requires a number of offices along the line of the road, with an operator on duty in each, and a fixed signal under the control of the operator, directed by the train dispatcher. Each signal shall show danger except when changed to safety to allow a train to pass, after getting orders, or after ascertaining that there are no orders. In this system the absence of a signal means danger, and requires a stop, with the protection of the trains under the rules. The time interval is in force, since there are often more than one train between two train-order offices at the same time. Very many miles of road in this country are operated under this system. The distance apart of the train-order offices is determined by the amount of traffic to be handled.

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* Manuscript received March 11, 1895.—*Secretary, Assn. Eng. Socs.*

A still further improvement, both in safety and in rapidity of train movements, is secured by dividing the road into blocks; *i. e.*, approximately regular spaces, and placing at each end of each block an operator controlling the signals under the direction of the train dispatcher. In this case the operator may show three forms of signals: first, a signal signifying safety and giving the information that the track is clear, subject to the regular schedule; second, a cautionary signal, showing that a train has preceded at a given number of minutes constituting the time interval; or, third, a danger signal, showing that the track is occupied or requiring a train to stop for orders. This system, in its most complete form, is known as the "Block System," and, in its most complete manner of operation, is known as the "Absolute Block." The time interval is no longer used, and but one train is allowed in a block at the same time.

In operating the block system, either no signals at all are required, as in the case of the staff system; or, if operated by signals, the road must be very completely equipped with them. In the staff system, the engineer of a train receives at the entrance of a block a staff, which is equivalent to an absolute train order over that block and gives him right of track until he delivers it to the operator at the other end of the block.

In addition to the blocking of the road for the operation of trains, grade crossings, junction points, yards, etc., on a busy road, require their switches to be interlocked for safety and thrown by one operator from a tower. This necessitates a complete system of signals for the government of trains at such points, and, of course, this system must be in harmony with whatever form of signaling is adopted along the main line of the road.

In the following I will attempt to describe some of the systems employed, and the methods of signaling; and first I quote some definitions expressing the views of the American Railway Association on block signals, but make note that items 7 and 8 below are omitted from the definitions last issued.

(1) *Block.*—A length of track of defined limits, the use of which, by trains, is controlled by fixed signals prescribed and established for that purpose.

(2) *Block Signals.*—Fixed signals prescribed and established for the purpose of controlling the use of a block.

(3) *Home Block Signal.*—A fixed signal at the entrance of a block, to control trains on entering and using said blocks.

(4) *Distant Block Signal.*—A fixed signal of distinctive character used in connection with a home block signal to regulate the approach thereto.

(5) *Advance Block Signal.*—An auxiliary fixed signal placed in advance of a home block signal and worked in connection therewith.

(6) *Block Signal System.*—A series of consecutive blocks controlled by block signals.

(7) *The Absolute Operation* of a block signal system permits but one train at a time to occupy the block.

(8) *The Permissive Operation* of a block signal system permits under certain regulations, more than one train at a time to occupy a block.

(9) *A Telegraphic Block Signal system* is one which is operated manually, as directed by telegraph.

(10) *A Controlled Manual Block Signal system* is one which is operated manually, but which, by its construction, prevents the display of a "clear signal" while the block is occupied by a train.

(11) *An Automatic Block Signal system* is one which is self-operative, whether by mechanical, electrical, pneumatic or other device.

A block signal may or may not be of the same form as those used for interlocking or for train orders. The practice of roads in this country and in different countries varies greatly in this respect.

According to the practice in this country, the position of signals is most generally to the right of or directly over the track governed. This practice is not uniformly followed in Europe, however. It is a fundamental law of signaling, that, when out of order, signals shall go to the danger position, whatever that may be; that is, they should go to danger automatically.

The meaning of a signal may be conveyed either by color or by position. In this country the general practice requires that the meaning is to be conveyed by a combination of color and position. The three plainest colors are red, white and green; hence, these colors have been adopted for railroad signaling. In this country white is generally used to signify safety; green is used to signify caution, and is, therefore, used for distant signals, while red is used to signify danger and an order to stop. From the fact that when the glass of a night signal is broken, a white light would appear, it has been thought undesirable to use white to signify safety, and consequently, in England, safety is signified by green, danger by red, and a signal showing white is to be regarded as a danger signal. In England, therefore, there is no distinctive color for a distant signal. Red is used, and the fact that it is a cautionary signal is shown only by its location along the track. In France the same colors are used for signals as in this country.

These colors are generally obtained by lights with white or colored lenses.

Day signals, both in this country and in foreign countries, may be colored disks, the same colors being used as at night. Colored disks are generally used in France. They are used also on a number of roads in this country. However, it is generally conceded that a colored arm, projecting from a post, is a more distinctive signal than a disk, except, perhaps, in tunnels. For this reason the semaphore signal is used very extensively in this country, in England and in Germany.

The most common practice in this country requires that the post be about 20 feet high, painted white, and situated to the right of the track governed by its signals. The semaphore arm projects to the right of the post and is painted red in case it is a block, home or train-order signal; or green if it is a distant signal. In the last case the end of the semaphore is generally notched. However, practice is not uniform, even in this country. In the case of roads with more than two tracks, semaphores are placed on bridges and are then directly over the track governed.

In a horizontal position, a block, home or train-order signal signifies danger, or "stop." Inclined at an angle of 45° or over, it signifies safety, or, in case of a permissive block system, if inclined at an angle of less than 45°, it gives a train permission to go ahead under control. A green semaphore signifies caution when in a horizontal position, and safety when in an inclined position.

More than two semaphores are often arranged on the same post where they govern over two routes. In this case the upper blade generally controls the high-speed route, and the lower ones govern the routes in order from right to left. However, this practice is not entirely uniform, even in this country.

In order to fully protect a junction or a set of switches at a station by an interlocking system with sephamore signals and to secure a prompt and safe movement of traffic, signals have become quite numerous.

To show their variety, the attached statement is appended:

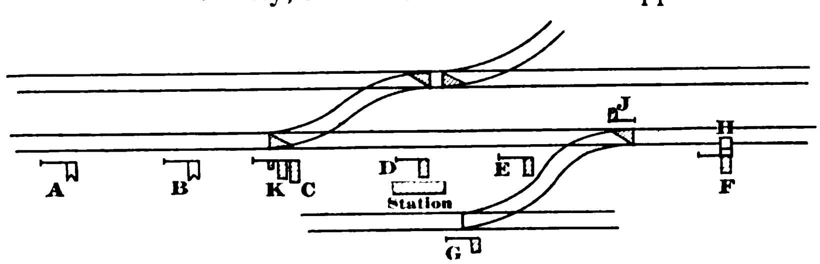

FIG. 1.

A.—First distant.

B.—Second distant, for suburban traffic or for very high-speed roads, say, ninety miles per hour.

C.—Rear home (a route signal).

D.—Home, protecting train standing at station.

E.—Starting, conveying order to start and covering siding switch.

F.—Advance. This is placed a train length in advance of siding switch to cover switching movements.

G.—Siding. This covers departure of trains from siding.

H.—Wrong track, governing west-bound movements on east-bound track.

J.—Shifting.

K.—Calling on signal. This signals trains to advance slowly past the tower for clearing home signal *D.*

The above list is given more especially to show how complicated a system of signals may become. It should be stated that the complication of signals is not looked upon with very much favor.

As intimated above, there is some difference of opinion as to the best form of signals. It is generally conceded that a very strong light, whatever its color, is the best for night. Some, however, wish to adhere to the position plan and go to considerable expense in order to illuminate their semaphores at night, as in the Koyle signal and the Union Switch and Signal Co.'s hollow box blade. There are others who think a disk is suitable for day, and confine themselves to the color method by day, and who are also able to use the same form of disk and the same colors as at night. Some recommend, for block signals, a form of signals different from that used for interlocking. This would allow of the use of a disk signal for blocking and a semaphore for interlocking. The Boston and Albany Railroad uses two white lights placed in horizontal position for danger, and two green lights placed in a vertical position for clear. The Old Colony Railroad has two red lights placed horizontally for danger and two white lights placed vertically for clear. In this way they secure position signals at night, just the same as by day by the use of the semaphore.

Having described the signals, it is necessary to describe their method of operation. In interlocking plants, both the switches and signals are controlled and thrown by an operator in a tower or signal station located generally near the switches. In case a mechanical device is used, a Saxby & Farmer or a Stevens machine is used, either in original form or as modified by recent improvements. These improvements have been very great in the last ten years. A lever is not only provided to throw switches and signals easily, but the switches and signals are all interlocked by a series of locking-dogs or their equivalent, so arranged on the machine that no switch can be thrown without its corresponding signal and that a signal, even for a desired route, cannot be given until all the switches have been safely placed for that movement. By such a machine, switches 1,200 feet distant from a tower in each direction can be thrown by pipes of 1¼ inches diameter, which are used to transmit the motion; and signals distant about 3,000 feet, on each side of the tower, can be operated by the use of double wires. I will not attempt to go into the details of these machines and their connections.

An improvement on this method of throwing switches and signals is obtained through the use of compressed air. In the system known as the Westinghouse electro-pneumatic, controlled by the Union Switch and Signal Co., both switches and signals are thrown by air under a pressure of forty pounds per square inch. The air necessary for this purpose is compressed by pumps located at or near the signal station, and is conveyed in pipes to whatever switch or signal it may be desired to operate. This switch or signal may be several miles distant from the tower. At each switch or signal is a cylinder, with a piston, and air is conveyed to the signal piston through valves, which are operated by electricity. In the case of the switch cylinders, the air acts on oil, which latter conveys the motion directly to the piston, the air valves being opened by electricity. With this system the operator has only to turn a small switch, no larger than an ordinary electric switch, in order to throw any switch or signal connected with the signal plant, covering, as stated above, several miles in extent. This system requires a plant for compressing air, careful laying of pipe lines and the necessary mechanism at the switches and signals to move them. It also requires a telegraph line, so that electricity can be used for opening the valves and for locking them. The switches and signals are interlocked, the same as in the mechanical plants already described, the interlocking device being located in the tower, but occupying a very small space as compared with that required for the mechanical device. In the tower is always placed a tell-tale apparatus, on which is reported every movement taking place in the track; and this movement is not shown on the tell-tale apparatus until it is completed in track. Electric bells and annunciators, for showing the location of trains, complete the system. The Stewart Avenue Plant, Chicago, is the latest one of this system installed. By this plant, 86 signals, 37 single switches, 22 double slip switches and 22 movable frogs are thrown by a machine having only 90 levers and occuying a space of 5 x 24 feet. A mechanical machine, to do this same work, would require 187 levers, and the machine would occupy a space of 14 x 77 feet. All signals are lighted by electricity supplied from the power-house.

A pneumatic system, as described above, is also used for block signaling over long distances. The system is used at many important points on the Pennsylvania Railroad. At Jersey City three trains can pass over the same track out of that station within 1¼ minutes under the operation of this system.

This system is applicable to very large plants. It is too expensive for small interlocking plants, or even for those of ordinary size. It is undoubtedly the most complete system of its kind at present in use anywhere.

In Italy, glycerine has been used to transmit motion for switches and signals, as also an unfreezing mixture of water; but the hydraulic pressure used there is from 50 to 60 atmospheres, and this pressure is too great for very successful use.

At St. Louis bridge a hydraulic pressure system was first used in 1883, controlling tracks along a distance of three miles, and operating switches on twenty-eight miles of sidings. This was not an entire success, however, and air is now used to transmit the motion, but hydraulic pressure is used at the valves. This plant consists of 108 levers, throwing 138 switches and signals, and handling about 131 trains daily.

Another system, striving for the same end as that of the Union Switch and Signal Co., is a new one recently brought out by the Electric and Auto-pneumatic Railway Signal Co., Rochester, N. Y., and now being tried. This is strictly a pneumatic system, but, in this case, not only are the switches and signals moved by compressed air, but the interlocking of the switches and signals is secured through the same means, and the pressure of air necessary for operating the switches and signals is only ten pounds per square inch. A plant of this form has recently been put in use on the Delaware, Lackawanna and Western Railroad at Buffalo, N. Y. The movement of the switches and signals is controlled by a small lever and a seven-way valve. It is through this peculiar valve that the interlocking is secured.

Electricity also has been used in interlocking apparatus; *i. e.*, electricity both for throwing switches and for throwing signals, as well as interlocking them. The Ramsey-Weir interlocking apparatus, which is being tried on the Cincinnati, Hamilton and Dayton Railroad, Cincinnati, is an example. The power is obtained from a gasoline engine operating an Edison dynamo of 125 volts, and a storage battery, which is charged every twenty-four hours by a dynamo working for eight hours. The plant, operated in this manner, consists of ten switches and ten signals. The cost of fuel for the engine is placed at seventy-five cents per day. The apparatus, as a whole, is very complicated and its success has not yet been entirely proved.

The most complete purely electrical system is the Siemens-Halske, of Germany. This system is used for blocking as well as for interlocking. The signals are operated by a Siemens machine producing an alternating current generated by the operator turning a crank. This system has not yet been introduced in this country.

Having described the various signals and their operating plants in interlocking, it is proper to take up the details of

BLOCK SIGNALING.

On very busy main lines the block system is required for perfectly safe operation; but the kind of system to be adopted depends upon the character of the traffic, and considerable study is necessary to determine what is necessary and best in any given case. The systems of operation are the train-staff system, the telegraph block, the controlled manual block and the automatic system.

The electric train-staff system is very much used in England, and is considered the safest for single track. The Webb & Thomson form requires, at every block station, an operator, and a patent staff machine, which is about 5 feet high and is provided with a slot to receive the train staves, which are each about 15 inches long. At the top of the machine are an electrical lock, an annunciator and a key for communicating with adjacent block stations. The construction of the machine is such that only one staff can be taken out of it at a time, and, having been taken out of the machine in the first station, the staff must be deposited in the machine in the second station before a second one can be issued from the first station. Likewise, Station 2 cannot issue a staff for a train bound for Station 1 if Station 1 has already issued one. The staves are readily exchanged between an engineman and a signalman on route. In case of moderate speeds a bag is used, with an apparatus working on the same principal as a mail crane.

Another machine on the same principle, but more compact, is Tyre's Train Tablet Apparatus. The working of the block is exactly the same as that above described, but in this case, instead of using iron staves, small iron tablets are used. An engineman, holding either a train staff or a train tablet, has an absolute right on the section to which it belongs, it being equivalent to an absolute train order; and it is utterly impossible for a train, moving in either the same or an opposite direction, to get upon the same block with another under the block rules.

The operation of this absolute block system requires no block or order signals whatever, but they may be used to give notice of staff.

The telegraphic block system calls for signal stations at the ends of all blocks, and the block signals should be controlled by signalmen only. The normal position of the signal should be at danger, so that they shall require clearing in order to allow a train to pass. Signals should be restored to danger after the rear of a train has cleared the signal station a distance of 100 yards. The operator at that station is then in position to report to the preceding station, or to the dispatcher, that that block is clear. In this system, either the home signal should be placed in advance of switches near the station, or a starting signal should be placed in advance of the home signal and in advance of all switches, this to be interlocked with the block signals and to be used for starting trains. The simple telegraph system secures no check on the operators.

The Mozier system, which is extensively used on the New York, Lake Erie and Western Railroad, is an improvement on the simple telegraph block. The block signals are arranged for three positions. A semaphore in a horizontal position by day, or a red light by night, signifies danger; the semaphore inclined upward by day, or a green light by night, signifies caution; and a semaphore inclined downward at an angle of 45° by day, or a white light by night, signifies safety. As operated on the New York, Lake Erie and Western Railroad, the cautionary signal is not used for passenger trains; in other words, passenger trains are run under an absolute block system, while freight trains are run on the permissive block system, using the cautionary signal. All trains are under the direct control of the dispatcher. The operator's key is locked with the signal, so that it cannot be used unless the signal is at danger. The operator sets his signal under the direction of the dispatcher, who orders red, green or white as desired on the approach of a train reported by the operator. The dispatcher signs his initials, and the operator repeats the order. To adopt this system over the old form of train orders required an increase of 40 per cent. in the number of train orders, but the orders are very short, and it is reported that the system is liked by both the dispatchers and operators, and that an increased amount of traffic is handled. No distant signals at block stations are used, and, therefore, an accident is possible in case of freight trains using the permissive block.

The Controlled Manual Block system requires that the operator shall not be able to give a clear signal for a second train until the advance block has been cleared. It requires, further, that all sidings shall be interlocked at the block stations. It is further recommended that a bell or other audible signal be attached to such switches in a block as may not be interlocked, so that information may be given to the train about to use such main-line switch to leave a siding when the block is clear. The use of the Sykes Block system, with all switches interlocked, covers these requirements. This system is in extensive use on the New York Central and Hudson River Railroad, and on the New York, New Haven and Hartford Railroad, as well as some others.

The Sykes system calls for an electric-locking device, enclosed in a small box, which is placed in the signal station at the end of each block, these instruments being connected together by wire. A miniature semaphore arm over the box shows whether the advance block is clear or not. In addition to this, an annunciator shows whether or not the signal lever is locked.

With three signal stations (*A*, *B* and *C*), *A*, having a train for *B*, signals him accordingly by bell. If *B* is ready to receive the train he presses a plunger in his instrument, which causes the words "Train On" to appear in the opening in his instrument, the word "Locked" to disappear in the opening in *A's* instrument and the word "Free" to take its place. *B's* plunger is locked and remains so until the train has passed his home signal, while simultaneously *A's* starting signal is unlocked. He lowers it and allows the train to go towards *B*. This action, however, brings forward the word "Locked" in *A's* instrument. *A* then raises the starting signal to danger, and it cannot be lowered again without *B's* permission. Before *B* can lower his starting signal, the train must pass an insulated section of track at his station, and he must go through the same action with *C* that *A* has previously gone through with *B*. Further, *B* is obliged to raise the starting signal to danger behind the train he forwards to *C*, before he can permit *A* to send him another train.

It is, therefore, an absolute block in every sense of the word.

In its most complete form, the system calls for home, advance and distant signals at each block, and requires the release of these signals to take place in the order : *home*, *advance* and *distant*. It further requires the electric control of outlying switches. This is accomplished by derails in every siding connecting with siding switch through one lever in a small hut at the switch, and an electrical lock is placed on this lever, which is controlled at the tower at the outgoing end of the block. The tower and hut are connected by a bell code. The detail is in use on both the roads above named.

On the New York Central and Hudson River Railroad, in order to secure the best possible service, a special cable is used for the wires in the system. It is an eight-conductor, aërial cable, suspended 12 feet above the ground on Western Union telegraph poles, with an intermediate pole, the cable being supported by a No. 6 iron wire.

In case of the failure of the electric line under this system, the operator on the New York Central and Hudson River Railroad is not allowed, under any circumstances, to unlock his Sykes instrument. But the operator, knowing that his advance block is in proper condition, allows a train to go forward under a written order, thus temporarily reducing the block from absolute to permissive.

The Sykes' system is used in the Fourth Avenue tunnel, Harlem. The disk signals here used are supplemented by torpedo-exploders and gong-signals. The torpedoes may be placed on the track ahead of a train and the gongs may, if necessary, be sounded by the action of the operator at any time during the passage of a train. Both of these signals are in harmony with the visual signals. Further than this, in the cabin is shown the position of all signals in the tunnel, and the condition of every light is shown by a simple device acting in such a manner that when a light is out the continuous electrical current is broken by the contraction of two zinc strips placed close to the light. In this case, the automatic signals are used in addition to the Sykes system, the automatic blocks being properly overlapped, and all these visual signals go to danger upon the passage of a train, these automatic signals being operated through a track circuit. As a double check on the entire system, all the distant automatic signals are controlled by the wire circuit, and home signals by the track circuit. Under ordinary circumstances, therefore, the automatic system is used in this tunnel, and the Sykes system is put in use whenever, from any reason, the automatic system fails.

Before the New York Central and Hudson River Railroad adopted the Sykes apparatus, it used extensively two forms of automatic signals —the " pneumatic," and the " Hall "—but it was found that these automatic signals could not be worked under absolute rules. Engines had to be allowed to pass the block signal at danger, provided they waited a time interval; and any automatic signal must have such a rule. It was for this reason that the Sykes system was adopted on the New York Central and Hudson River Railroad.

The Siemens-Halske system, already mentioned, is exactly similar to the Sykes in its results. The most important difference between the two is in the use of the electric current generated by the operator, instead of the battery circuit, to which, of course, there is some liability of accident in case of storm. In this system the power necessary to change a block is generated by the operator, who turns a crank at his locking instrument, twenty-one alternating currents being required for this purpose. This block system is not in use in this country at present.

Another form of controlled block system is the " Lattig," advanced by the National Switch and Signal Company, and claimed to be applicable to both single- and double-tracked railroads. By means of the adaptation of the electric slot to the signal, it is automatically set at danger by the passing of a train, and cannot be lowered by the signalman until the train has passed on to the next block. In other words, the signal is automatically set at danger and is so maintained, but is set to safety only by hand. The system may be used either with the wire circuit or with the track circuit. The latter, of course, gives the most complete protection while it is worked properly. In this system the current is always on. This requires considerable expense in maintaining batteries and they are liable to get out of order. Further, the electrical slot arrangement attached to each signal, in order to secure an absolute block, is a somewhat delicate apparatus and liable to get out of order. The system cannot be regarded as proved.

We will now pass to the *Automatic Block system.* To this system belongs the Westinghouse Pneumatic-Automatic, extensively used on the

Pennsylvania Railroad, also used on the Chicago, Burlington and Quincy Railroad; and on the Central Railroad of New Jersey. Fig. 2 shows the arrangement of signals on the Central Railroad of New Jersey.

In brief, the track is arranged with double or overlapping blocks, separate posts being furnished for each track. There are two blades on each post, the upper one red, with red lamp at night, and the lower one green, with a green lamp at night. When either of these blades is lowered to a safety position, a white light is shown at night, and an engineman passing a signal with the red arm lowered to safety and a green arm at danger position, must slack up and be prepared to stop at the next signal. The blocks are short, say, about one mile in length. The lengths of the blocks would naturally vary, with the traffic requirements of the road.

In this device the track circuit is used, consequently a block signal cannot go to safety while a train, or any portion of it, is in the block. This end is secured by the fact that the signals are locked to their danger position by electricity, and are placed in the circuit with the track. The

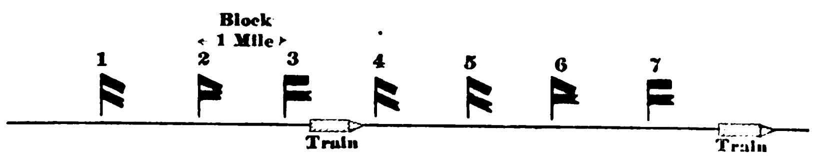

FIG. 2.

power to move the signal arms is derived from compressed air, conveyed in pipes along the track. This compressed air acts upon a piston enclosed in a cylinder placed at each signal, as described in detail under the head of Interlocking. The track circuit is so arranged, in passing through switches, that the circuit is not complete unless closed to the main line. Therefore, the signals cannot go to safety unless all switches are properly set. The system is a very complete one, but is expensive and is generally considered to be out of the reach of a single-track railroad. Of course, it is possible for these automatic signals to fail, from two causes:

(1) From any defect in the pipe line or in the cylinder attachment at the signals.

(2) From any failure in the working of the electric current.

In case of either of these failures, however, the signal goes to danger, in which event the train must proceed under special rules.

The Electric and Auto-Pneumatic Railway Signal Company, of Rochester, N. Y., is attempting to introduce a pneumatic block system carrying out its principle, which is described under the head of Interlocking. This system uses compressed air, both for moving the signals and for locking them; also, for locking switches, and it does not use the electric circuit, and, therefore, does not attempt to protect the track so thoroughly as does the device of the Union Switch and Signal Company, already described.

The Hall Signal Company has a very complete automatic signal system extensively used on the Illinois Central Railroad. It is used also on the New York Central and Hudson River Railroad, New York, New Haven and Hartford Railroad, the Central Railroad of New Jersey, and many others. It is purely an electrical device, electricity being used to throw all signals. The signals are disks in three colors—red for danger, green for caution and white for safety. The night signal shows the same as the day signal. The block signals may be placed at any desired distance apart, and may be overlapped as much as may be thought necessary for safety on any given road. The signal may be operated by a wire circuit, in which case iustruments, operated by the passing of a train to close the electric circuit, are used along the track. These track instruments have been proved to be a very complete and unfailing device.

A train, entering a block, passes a block track instrument which breaks the current, and the signal falls to danger. The same train, passing out of this block, goes over a clear-track instrument, which closes the circuit and raises the first signal to safety. The current is, therefore, closed except when a train is in the block or when a switch is open in the block.

In this scheme, therefore, the normal position of all signals is at safety. A signal will always drop to danger in case a train is in a block, or in case of an open switch or an accident to the apparatus.

The Hall signal may, however, be operated by a track circuit. In this case the rail circuit is made very complete by the detail of the wire fastenings used at the joints, and the rail current is carried through switches by means of a special switch instrument. The track is divided into blocks, the rails of which are insulated from each other. In the normal safety scheme, while there is no electrical contact between the two lines of rail in a block, the block signal is at safety. A train entering this block short-circuits the track battery through the wheels, and the signal falls to danger; or, in case a switch is open in the block, the signal circuit is broken and the signal falls to danger. A train passing out of this block causes the local signal battery to restore the signal to safety.

In the normal danger scheme, signals stand at danger, and are cleared only when an approaching train reaches a given point in advance of the block signal and in sight of the engineer. It is again dropped to danger when the train reaches it, and is locked so that it cannot be cleared by a following train until the first one has passed out of the block and is under the protection of the succeeding signal.

This last scheme is a very complete and effective system of automatic block signaling, and costs but about one-third as much as the pneumatic-automatic system. Applied to a single-tracked railroad, its working is shown as follows (Fig. 3):

Head of train at *A* blocks opposing signal 2.

Head of train at 1 blocks signal 1 and opposing signal 4; opposing signal 2 remains at danger.

Rear of train at 2 clears signal 2; signals 4 and 1 remain at danger.

Head of train at 3 blocks signal 3 and opposing signal 6; signals 1 and 4 remain at danger.

Rear of train at 4 clears signals 1 and 4; 3 and 6 remain at danger.

Head of train at 5 blocks 5 and signals in advance, signals 3 and 6 remaining at danger.

Head of train at 6 clears signal 3; 5 remains at danger, etc., etc.

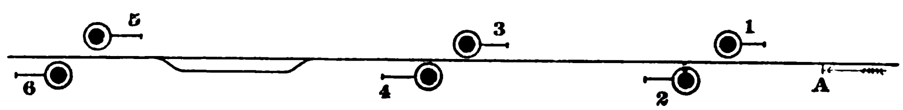

FIG. 3.

Upon a road which, under the controlled manual block system, required operators four miles apart to handle the traffic, the introduction of this system would enable the placing of the operators twelve miles apart, each operator having control of the signals at a passing siding through an interlocking board and tell-tale at his station.

The extension of this system announces trains approaching all block stations, passenger stations, road crossings and switches.

In attempting to make any comparison between the controlled manual system and the automatic system, it is generally considered that the manual signals are more liable to be obeyed by enginemen than the automatic, as disobedience of the former leads to a report from the operator, while no reports are possible in the latter case. In the case of accident to the automatic system, it is inert; while in case of accident to the manual system men are at hand to take action to provide against accident and to straighten out obstructions to traffic. However, the cost of operating the manual system is greater than that of the automatic, in some of its forms (such as the "Hall"); but, further, the automatic is applicable to a more complete protection of the track, road-crossings, etc., than is possible with the manual.

As compared with any telegraph or train-order system, block signaling is generally considered more economical, as it affords a better protection of the track, and avoids danger of small rear collisions, and this to such an extent as to cover the cost of the blocking.

The devices mentioned show methods of protecting track and securing a constant check upon operators. The check upon engineers is not quite so complete, although their obedience to signals is in many cases assured dy derailing switches, and in other cases, as in tunnels, by the use of automatic torpedoes or gongs. Still further advancement is constantly being effected. The Electric and Auto-Pneumatic Railway Signal Co., of Rochester, N. Y., who are introducing a pneumatic block system, already described, have, in connection with their system, a shoe, which is placed between the rails opposite a danger signal, and which projects above the rail whenever the danger signal is not at safety. If, therefore, an engineer passes a danger signal, a projection from the engine, connecting with the air-cock of the air-brake system, strikes the shoe, and this action results in the setting of the brakes. This system is not fully proved.

The Rowell-Potter automatic block signal, which was used on the Intramural Railway, Chicago, uses a track-circuit system of block signals, and has also a bar which projects above the rail whenever the signal is at danger. This comes in contact with a rod extending below the front truck of the engine and provided with rollers on its end. This, striking the raised bar, opens the air valve and applies the brakes.

Of other devices many have been brought forward, but thus far not extensively used. One of these is the Kinsman Block system. It is a purely electrical device, and claims to stop trains without the agency of the engineer in case the block in advance is not clear, or in the event of an open switch or broken rail in the advance block In this system the track is divided into blocks two miles or less in length, and the track-circuit system is used. At the ends of the block is a guard rail, which is electrified in case the block controlled by it is not clear in every respect. An electric signal, displaying a disk, may be used in addition, if desired; but with this block system the visual signals are not regarded as absolutely necessary. Each engine is equipped with an arm, suspended between the wheels and adjusted to press against all guard rails, like the flange of a wheel. This arm is electrically connected with an instrument in the engine cab. The latter is directly attached to the air-brake pipe, and this, in turn, is connected with the cylinder of the throttle rod. In case an engine, so equipped, reaches an obstructed block, the suspended arm of the engine takes a current from the electrified guard rail, and the electrical instrument in the cab first acts independently of the engineer, to shut off the steam, and, by opening the air-valve, puts on all the brakes of the train.

The device in the engine cab is, I think, quite complete. The guard-rail device is not yet proved, and, I think, is inferior to the inducing magnets of the Wiley system. The signal recommended in connection with this system is not very good, but it is claimed that the engine equipment can be used with Hall signals, if desired.

This block system was first introduced in 1891. Experiments are now being made on three miles of the New York, Susquehanna and Western Railroad, and on twelve miles of the Chicago, Milwaukee and St. Paul Railroad. On the latter road it is reported by the railroad people that, on account of the electrified guard rails, the experiments are not yet wholly successful. In cost, this system does not vary much from the "Hall" System.

The Wiley Electric Block Signal system, with which the inventors are experimenting to a small extent on the Norfolk and Western Railroad, divides the road into blocks from one to five miles in length, and the wire-circuit system is used, requiring circuit-breakers in the track at each block. Its operation is similar to that of the Hall system wire-circuit, but it is probably cheaper in maintenance as well as in first cost. The signal, in its first form, is inferior, but the makers claim to have improvements under way.

This system may include an alarm signal bell in the cab of all engines, the bell being so arranged as to be sounded in case a danger signal is passed. Inducing magnets, located in the center of track at each signal, are energized whenever the signal is at danger, and similar magnets placed on the engine and suspended four inches over the rail, receive the current, which is conducted to the cab, where it serves to ring an alarm bell. This method of transmitting electricity from the track to the cab of an engine, seems to me to be the most complete I have yet seen, and superior to the Kinsman plan.

The devices last named require special equipment of every engine on the road; and so far they have not met with any very great favor among railroad men, it being feared that engineers would depend wholly on such signals as would be received in the engine cab, instead of being guided by track signals.

In conclusion, I have only to say that new devices and improvements in signaling are constantly being introduced; that many of these have merit, and that haste in adopting any given device is never expedient.

DISCUSSION.

MR. G. R. HENDERSON.—I would like to ask a question regarding the old staff system, of which Mr. Churchill spoke. On a road, locked electrically or otherwise, how are the staves to be carried from one end of the section back to the other, and arranged so that other sections can take them up? Also, was there not some system used before the application of electricity?

MR. C. S. CHURCHILL.—The staves work exactly the same as an electrically-locked staff, except that there is no check or lock on the operator issuing. There is more than one staff—probably some number of staves. The trains running in the opposite direction bring them back.

MR. M. E. YEATMAN.—I think I can explain the system which Mr. Henderson has in mind. By the original staff system it would be impossible to work unless trains were running alternately in different directions, one train taking the staff and the other train bringing it back; but, of course, this rule is absolutely impracticable for general use, and it was very soon superseded by the staff and ticket system. Only one staff is used, but at each end a certain number of tickets or train-order forms are kept in a box, the key of which is attached to the staff, and it is therefore impossible for an operator to issue a ticket clearing a train over a section unless he has the staff. If he knows that two trains are passing, running in the same direction, he gives a ticket to the first and the staff to the second. After these two he could not send any more until the operator had sent the staff back over the section. The operator at the other end might have three trains. This, of course, would necessitate his giving a ticket to the first, a ticket to the second, and the staff to the third. This system would require electrical communication so that it might always be known what was coming. It requires something corresponding to our central dispatcher system, and it was in general use for single track roads when I was familiar with English train service.

THE CHAIRMAN.—Mr. Churchill, I notice that you express no preference. You, no doubt, having gone through a study of all, have arrived at some conclusion as to which is best.

MR. CHURCHILL.—I stated that each of these systems is applicable to different conditions of a railroad. For instance, it is an open question between the Sykes system and the Westinghouse Pneumatic system on the New York Central Railroad and the Pennsylvania Railroad. There are two opinions. The New York Central uses the Sykes, and the Pennsylvania Railroad the Pneumatic. Each, as a matter of policy, would certainly back its own system, and I think the results are probably about equal in both cases. The Sykes is rather the cheaper of the two.

THE CHAIRMAN.—The Pneumatic, I believe, is the oldest system of automatic electrical signaling.

MR. CHURCHILL.—It preceded the Hall, although the Hall was the first electrical device. They have kept right alongside. I went over two sections of the New Jersey Central within the last six months. One of these is equipped with the Pneumatic and one with the Hall, consequently, I had a good chance to compare the two, and there is this to be said about them: With the Pneumatic, there is an air line to maintain. You are obliged to have a system of pipes to conduct the air for operating these signals, and an electrical system maintained to lock and unlock them, the track circuit being used on this road. When you come to the Hall, you have the track circuit and electricity operating the signals, but the motive power is electricity; so that, while in the Pneumatic we have to maintain not only the electricity but the air, in the Hall we have to maintain the electricity alone.

THE CHAIRMAN.—Where the track is the instrument for carrying the circuit, what is the effect of a broken rail?

MR. C. S. CHURCHILL.—The signals would come to danger.

THE CHAIRMAN.—And remain at danger?

MR. C. S. CHURCHILL.—Yes; for the protection of the train.

MR. W. W. COE.—That would hardly be considered objectionable when a broken rail is there.

THE CHAIRMAN.—You have, no doubt, gone over a broken rail many a time.

MR. C. S. CHURCHILL.—Where the rails are not badly broken, and where the ends remain together, it would not affect the circuit; that is, provided you have a generally good track.

THE CHAIRMAN.—You think the principal difference between the wo systems is in the cost of maintenance?

MR. C. S. CHURCHILL.—Between the two systems the first cost is the principal difference. The Pneumatic system is all right on a two- or four-track railroad, but would ruin a single-track railroad.

MR. W. W. COE.—Suppose the single-track road was going to grow—was in a progressive form?

MR. C. S. CHURCHILL.—It would cost something to locate it—something like $1,200 per mile for the Hall, as against $4,000 per mile for the Pneumatic.

MR. W. W. COE.—Two systems, one on single track and another on double track, would not do?

MR. C. S. CHURCHILL.—Not perfectly; still, they are so used, as in the case of the Hall and the Pneumatic on the New Jersey Central. I interviewed an operator there, and he expressed the opinion that there were fewer failures with the Hall than with the other. Understand, by failure I mean only the signal going to danger, owing to some defect in the signal plant. The blocking of the traffic amounted to but very little with either system.

MR. W. W. COE.—As I understand it, an engineer can accept a signal after it has been placed, and it is not required that he see it as it is being turned?

MR. C. S. CHURCHILL.—Well, he does see it in its normal condition. He accepts the signal as given, because, in case of trouble, it comes to danger automatically. I think the railroad people can see that the two systems are very nearly equal in their results. I mean as regards their automatic operation.

MR. SOULE.—I think there is one advantage that ought to be credited to the Westinghouse Pneumatic system, and which Mr. Churchill has not mentioned, and that is this: A great many signal engineers and practical railroad men have come to the conclusion that the semaphore signal is the only decent and acceptable form of signal for a railroad. Now, I do not think that any full-sized semaphore signal, such as is represented there, has ever been successfully operated by electricity, unless enclosed in a glass case and made on a reduced scale, and, in order to reduce its weight and inertia so that it can be operated by electricity and still have the semaphore of good size, it is necessary that the weight be reduced by having aluminum wire frames, with flannels or cloth stretched over them, and the whole enclosed in a glass case, and even then the glass case is likely to be obscured by rain, snow and ice, and the chances that the engineer will get a correct interpretation of this signal are correspondingly reduced. This must be considered in comparing the Pneumatic and electrical systems. The possibility of having a semaphore signal of any desired size, with a fixed and positive action, is an immense advantage in favor of the Pneumatic. It is getting to be not so much a change in color, as a change in position, which shall determine the meaning of the signals. I was quite familiar with railroad signaling up to three years ago. But Mr. Churchill's paper has made me realize that this is a progressive art—that it is going forward. I used to keep up with all of these devices, as mentioned in the mechanical papers, until the past three years, when I have not had the time for so doing. On the Pennsylvania Railroad I was identified with railroad signaling when it first began to be a serious question. The first effort they made to introduce an interlocking apparatus was when they sent to England, in 1874, and contracted for a track-signaling apparatus for the tracks at a junctional point, a simple double-track junction and cross-over. The apparatus was made in London, shipped over here and set up and put in operation by English mechanics. This gave an impetus to American inventors, and Towsey & Buchanan came to the front with their device. By 1876 the New York Central had constructed and put in operation four of these devices. When the Pennsylvania Railroad was getting ready for the Centennial, it was constructing tracks and bridges, but neglected signaling until the last moment, when I was detailed, on the 4th of March, to take up that problem, and was sent to Philadelphia in a hurry. The next day I was told that they wanted seven of these interlocking apparatuses, and that they were to be put in operation by the 7th of May. The General Manager, Chief Engineer and myself went over to New York, and the New York Central officials took us about and showed us all the interlocking apparatuses, and I was left there to study the subject. It was agreed that there was no time to order any apparatus from England, no time to undertake anything novel, and so we decided to avail ourselves of this system, and the New York Central people very kindly consented to lend us all the patterns. After taking a few castings for their own use, the entire outfit was shipped to Altoona, and got there by the 10th of March, and within these two months, before the 7th of May, all of the seven interlocking apparatuses had to be mapped out, made and got in running order. That apparatus was deficient in one essential principle. It did not include the feature of preliminary locking. That is, the modern apparatus is so made that as soon as the operator grasps the handle and closes his hand, so as to draw in the latch of the handle, the locking is accomplished preliminary to moving the lever. This simple grasping of the handle accomplishes the locking. Whereas, with this old style, the locking was not done until the end of the stroke. If certain others are to be unlocked, this is not done by the preliminary movement of the latch handle, but that unlocking is done when the latch snaps into the notch at the end of the stroke. Now this apparatus was deficient in that respect, and did not catch the principle of preliminary locking and the moving of the unlocking mechanism. When you were moving the lever, which was so arranged that you were moving that portion of the apparatus upon which it acted, you had no proof that it was unlocking until the stroke was completed, instead of at the outset. Consequently, every one of them put on the Pennsylvania Railroad in 1876, and some of them put on in two or three subsequent years, have been taken out and replaced by modern interlocking plants, where the principle of preliminary locking is carried out.

THE CHAIRMAN.—We are obliged to Mr. Soule for his interesting history of railroad signaling on the Pennsylvania Railroad. It may be that Mr. Coe could add to it.

MR. COE.—It was very certain in keeping trains apart, but sometimes delayed the movement of the freight.

MR. R. H. SOULE.—I stated that there were seven interlockind plants of this pattern. This was originally intended, but a party nameg Burr, from New York, a lawyer, patentee, and a very clever fellow, inventor, and so on, cropped up, with a proposed system of interlocking and secured consent to put in a plant at one of the double-track junctions. It was very crude, but in all essential features was pneumatic—with a reservoir for the storage of air, and a system of piping running to all the switches and signals. There were no electrical features anywhere. There was a double line of pipes, a supply and return pipe, to and from each switch and signal, and the thing was operated quite successfully. Two or three disasters occurred, nothing serious, however. This was the first attempt at the pneumatic operation of signals and switches, and he got some pioneer patents, which resulted in litigation with the Union Switch and Signal Company, in which he was victorious, so that they had to make a settlement with him and bought in the patents, some of which are engrafted in their plant of to-day.

THE CHAIRMAN.—Mr. Churchill, I would like to ask whether the tendency is not to disregard colors for signals, and if the position, rather than the color, is not relied on?

MR. C. S. CHURCHILL.—Well, that is a mooted question. I think that nearly every railroad will agree to go by the position of the signal during the day, and by the color at night. About a month ago I answered a lot of questions propounded by the Railroad Association of America, and about two days ago received advice of the replies. Replies from thirty-two of the roads were received, and, if I remember aright, twenty-eight were in favor of the semaphore signals by day and of color by night.

THE CHAIRMAN.—Was it not then suggested that if the use of color by night were adopted, red would appear white to a certain extent, when snow was on the glass?

MR. C. S. CHURCHILL.—I think this point is strained. A good red light would show red, even if the snow was on it. Four of the roads wanted a green light for safety, as in the English system, the argument being that if a red light were to break a white light would appear. I do not think that the best glass is liable to break, and, even if it were to break, it would not be liable to break so badly in one night that some of the red pieces would not be left there to show a red signal.

Another argument is, that in approaching a town, an engineer might mix up the town lights with the signal lights and possibly take a town light for a safety signal.

I think that if the make of lens is considered, and if you have a good, strong lens (I think the N. and W. R. R. switch lens in the Westlake lamp is an excellent one), there is no danger of mistaking it for a town light, no matter of what kind, and any good strong lens, carefully put in, produces the same effect. But it is a mooted question, railroad men are still discussing it, and I do not know how it will be decided. You see what it has led to in England; two colors for three signals. I think it is a great mistake to compel an engineer to remember two signals, both showing a red light, which is a danger signal in one case and a distant signal in the other. He may turn to fix his engine just as he is approaching a distant signal, and, by the time he looks up, he may have passed it, and he does not know whether it meant safety or not. Then when he comes to the danger signal, he cannot tell, unless he knows all about the country, whether it means danger or caution, and he is simply obliged to hold his train. If there is to be any change at all, we should still have three lights for the three signals, danger, distant or caution, and safety. In your first question, you asked about the comparative merits of the systems. It might be well to state here that the Pneumatic is better than the Hall in that it enables the operator to throw any switch in a block. This is a great advantage. Mr. Soule's point about these signals has, of course, considerable merit, and yet you will find, as I brought out, that in the tunnels in New York they use disks in preference, and the New York Central people write me that they will stick to the Hall, that, after using it, they find it answers their purpose better than any other automatic signal. Again, take a road like ours (the Norfolk and Western Railroad) a single-track road, with double-track work going on. It is not necessary to equip the whole line with a device like the Hall; or with a Pneumatic, at a great expense. To secure greater safety on a road with a telegraph block, like ours, you can make your block more rigid than at present; make it an absolute block, and then check your operators by using the Sykes system. The Johnson people are very enthusiastic in the praise of their system (the staff), but they admit that theirs is only for a single-track railroad, and we are double-tracking, so that the most progressive plan may be to put in the Sykes. When you desire to add automatic signals, you can do so, and still not throw away any of the plant then in use.