A REPORT OF THE DEVELOPMENT OF
RAILWAY SIGNAL SYSTEMS

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

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IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

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In the operation of railroads the protection of its passengers and rolling stock is undoubtedly of great importance. Railroad signals provide a means for such protection, and more attention is being paid to it as the time advances. It is a subject of great breadth and it is practically impossible to deal here, with more than the fundamental principles. Almost from the first inception of a railroad, the necessity of protecting trains was made evident, and the present methods now employed are developments of the first rudimentary principles used.

Signaling may be said to be divided into two main headings, interlocking signals used at junctions, grade crossings, or sidings, and block signals, used for the spacing of trains for the prevention of rear and head end collisions.

It was found that some means of protecting a railroad was necessary, this can be more readily understood when it is remembered that the electric telegraph, was not used until 1840 in connection with railroad operation. Up to that time trains were operated and meeting points were made by the time card. Under this mode of operation it is not hard to see the possibility of collisions, and to overcome this difficulty, semaphore signals were installed certain distances apart, a man being stationed at each signal.

The semaphore signal prior to its application to railroad operation had been used as far back as 1767 for the transmission of messages at considerable distances.
This early form of semaphore signal, has undergone several changes and modifications. At present it consists of a blade or blades, pivoted on a mast and fitted with colored glasses, so that its indications may be read by night as well as by day. These indications are given by a horizontal position of the blade for a "stop" signal, and an inclined position of the blade for a "clear" or "proceed" signal. This same information is given at night, by the display of colored lights, red indicating "stop" and green or white "proceed". When green is used as a "clear" night signal, yellow is very frequently used as the "caution" signal.

As the time of the men engaged in operating was not fully occupied, it became the practice to connect switches in the vicinity of the semaphore by means of mechanical lines of connection, and these switches were operated from a central point, usually a signal tower. This very crude method of signaling led to mistakes, and very often to accidents, as trains were at times turned on to the wrong tracks, due to the oversight and carelessness of the signal men.

In 1856 a simple lock between the levers was introduced by Saxby. It was not until 1859 however, that Saxby and Farmer, and Stevens and sons took out patents; the former for spindle locking and the latter for the tappet locking. As applied originally, this locking was attached directly to the lever; but, on account of the severe strain that could be put upon the lever, this was found to be unsatisfactory, and toward the end of the year patents were taken out, in which the locking was applied to the latch of
of the lever, which is the method now in use.

An interlocking plant consists of a number of switches, derails and signals connected with levers located in a tower house at some central point. These levers are so interlocked that it is impossible for the tower men to set clear signals for the passage of trains on conflicting routes. The combination arranged in the interlockings is such that the switches and locking devices must all be properly set before the signals can be cleared, and when the signals are cleared, the locking precludes the changing of the switches or derails until the signals have been restored to their normal position, which is the "stop", "proceed" or "caution" position as the case may be.

One of the first interlocking plants used in this country was installed at Spuyten Duyvil Junction in New York City in 1874. The interlocking machine used here, was very similar to the devices now in use. From the small beginning made at Spuyten, signaling has grown steadily and developed very rapidly. The demand for signal devices today is such, that, large signal manufacturing establishments are in operation capable of turning out hundreds of levers per day, which includes all the equipment that goes with them.

All of the earlier plants were of the mechanically operated type. During the last ten or fifteen years it has been found desirable to use power in operating large signal plants.

The power systems of interlocking are three in number, the "low pressure pneumatic", the "electro-pneumatic" and the "all electric". In the "low pressure pneumatic" the plant is wholly
mechanical and switch and signal operations are accomplished by compressed air, at a pressure of about two atmospheres. The "electro-pneumatic" system is used quite extensively. It varies from the "low pressure pneumatic" system, in that the control of the air valves in the operating mechanism, as also the return indications are electrical. It is very necessary that the lever man, knows that the switch or signal has followed the lever movement; and to accomplish this, the interlocking machine is so controlled that the locking is not released until the switch or signal movement has been completed. The release of the locking is accomplished before clearing the signal. This system can be frequently used to an advantage. This is especially true where air pressure is available near railroad shops, or power houses. When it is necessary to install a plant for the purpose of compressing air for an interlocking plant it becomes very expensive and the cost of power is high.

The third power system is the "all electric". Under the "all electric" system, each switch, derail, and signal is equipped with a motor, and these motors are controlled through an interlocking machine. The electric power is usually obtained from storage batteries. One of these storage batteries, of 150 ampere hours capacity, will when fully charged provide power for the operation of a large and busy interlocking plant for a period of seven or eight days. Considering the fact that a storage battery can be charged in a very few hours at a small cost, the advantage of the "all electric" system is apparent. The chief advantage of the power system of interlocking over the mechanical system is
that the switches and signals can be operated at much greater distances, while the cost of maintenance and operation is greatly reduced if the plant is a large one.

The block systems of signaling of which there are four will be considered next. Before going into the subject it might be well to understand what a "block" is. A block is a section of track governed by a home signal. The main object in dividing the line into sections is to prevent two trains from occupying the same section of track at the same time. These blocks may be of any desired length, consistent with the economic operation of trains. Let us first consider the telegraph block system.

Under this system, the signals are located some distance apart usually two or three miles, and men are provided at each block cabin to operate the signals. Means of communication are provided by telegraph or telephone, and may be accompanied by a system of bells by which the block operators may communicate with each other. This is a very simple method of signaling but has been found to be quite effective.

The controlled manual block is an improvement over the telegraph block. In this system a block operator cannot clear the signal at his own station without the cooperation of the operator in advance of the proposed train movement. The advantages of this feature are very apparent, and they are made possible by applying electric locks to each signal. Let us suppose we have three block stations "A", "B", and "C". The block operator at "A" has a train ready to proceed towards "B", the operator at "A" must communicate with the operator at "B",
and if the block is clear between "A" and "B", the operator at "B" will unlock the electric lock on the signal at "A", and the operator at "A" will clear his signal and permit the train to proceed towards "B". The block operator at "B", has knowledge of the approach of the train, and he in turn will make arrangements with the operator at "C" for unlocking the signal at "B", this method is continued throughout the system. By this arrangement the operators are continually checking each other, and they have complete knowledge of the train movements in the blocks on either side of his own station. This system originated in England. The only additional expense over the telegraph block system is the electric locking devices. The controlled manual block is especially adapted to single track. By this method the time may come when trains may be operated without the giving of train orders to crews, but merely give them to the block operators.

The staff system is an English invention and is used extensively in Great Britain. It consists of a staff instrument, placed at the beginning and end of each block, the instruments containing staffs of metal which are held in a receiver. The staff instruments at the end of each block are electrically interlocked, so that if the staff is taken out of one of them, both instruments are locked until the staff is returned to one or the other of them, when another staff may be taken out. In operation the engine man obtains a staff at one instrument, which gives him the right of way to the next staff instrument, where he deposits the staff belonging to the block which he has just
cleared. Here he secures another staff for the next block ahead, and in this way makes sure that he has a clear block ahead, as he is in possession of the staff controlling that block. From the above description it might seem that a considerable amount of time is lost, through trains stopping to deposit and receive staffs. In actual operation trains are not ordinarily required to stop. The engine man throws the staff he has obtained covering the block which he is leaving, and in turn receives a staff, controlling the block he is about to enter. When trains are operated above thirty miles an hour, catching devices are arranged on the locomotive. They may be picked up with trains going at a rate of sixty miles an hour, but it is not probable that staff systems will be employed where trains are operated at such high speeds.

In this system the ordinary train order system is abandoned and all train movements are controlled by means of the staff system. The staff system is susceptible of many variations. For instance, it might be desirable to hold two men responsible for train movements, this may be true in a tunnel where a pusher engine is used. In this case a divided staff is employed, half to the engine man on the engine, and the other half to the engine man on the pusher. The block is therefore held until the two staffs are joined together and placed in the staff instrument. A great advantage in a staff system is that the possession of a staff gives the train the full right to use the block in either direction. Staff instruments are often used in the case of emergency. All that is needed is a pair of staff instruments, telegraph wires
between junction points and a few cells of dry batteries. This is done at times when it is desired to throw double track traffic on to single track temporarily. The expense of installing a telegraph block system is nominal. A well regulated controlled manual block system may be installed at a cost of about $200 per mile of railroad. Where cabins are installed add $200 as a cost per cabin. The cost of installation of a staff system is about the same as that of the manual block system.

The automatic block system is installed in two forms, the semaphore and the enclosed disc. Some railroads continue to use the disc signal, because they believe it to be more economical, more efficient and quite as safe as the semaphore signal. The semaphore type is more generally recognized, as mast installations are of that type today. Automatic signals are usually erected to suit the peculiar conditions of the road signaled. In the best practice the blocks are not made extremely long, two miles or under is usually good practice. In this system the rails in the tracks are bonded and cut into track sections by means of insulating the rails from each other at intervals. Each track section is provided with a battery, usually of the gravity type, and a relay. The relay, while a section of track is not occupied by a train, is closed, and is opened by a train entering the block. The signals in turn are governed by means of contacts made by the track relays. The proper car and maintenance of track sections is one of the
important features which must receive very careful attention in this system. Neglect will not however, bring about dangerous conditions, since if any part of the apparatus fails, the signal will always give the danger indication.

Ordinarily the automatic block signals are operated by compressed air or electricity. A very considerable number of signals are being installed which are operated by carbonic-acid gas, and an average of two hundred signal operations can be attained from each pound of gas. Each signal is supplied with duplicate flasks containing about fifty pounds of gas, which will furnish power enough to operate a signal for six months or more. When electricity is used, each signal is provided with a motor, and the current is frequently taken from primary batteries. These batteries have been brought to a very high standard. It may be stated that one set of cells with practically no attention or renewals, will frequently operate a signal on an average of thirty times a day for a period of from fifteen to eighteen months. It would not be advisable to install the compressed air system on double track. It is used on four tracks or more, as the expense of compressing the air and piping along the railroad is very large.

The automatic block signal is very reliable, and railroads will bear out this statement. Quite recently Mr. Platt, a reporter for the International Railway Congress, gathered exhaustive data, the result of which shows that almost perfect service is attained; actual figures showing, one signal failure
in twenty-two thousand signal operations, which is indeed a very small percentage.

A railroad may be protected by automatic block signals at a cost of approximately eight hundred dollars per mile of track. Making an allowance for depreciation and interest on the investment, the operation and maintenance of the system will cost slightly less than twenty per cent per annum on the original investment.

The developments of railroad signaling are at present resolved into practically four standard forms of signaling. They are as follows: Manually operated Interlocking Signal, Automatic Block, Controlled Manual Block and Train Staff. The systems mentioned above are at present in operation on the Great Northern Railway and are results of the developments of various systems. The following discussion will relate to the systems mentioned above as operated on the Great Northern Railway.
MECHANICAL INTERLOCKING PLANTS

The first installation of the mechanical interlocking plant in this country was on a short line between Philadelphia and Jersey City, a road leased and operated by the Pennsylvania railroad. The plant was located at East Newark, New Jersey. The East Newark machine was number 2164 of Saxby and Farmer, London, England. The Saxby and Farmer type of machine is a considerable improvement over previous machines, and has come into almost universal use. The type of machine is used exclusively by the Great Northern Railway and will be described, as to construction, operation, etc.

When an interlocking plant is to be installed, the first thing is to have a plan of the tracks, which is then signaled up, that is, the switches, derails and signals to be operated are noted; the run of connections located; the number of levers, the functions of each, and a diagram of the lead out, is made from the tower. From the signal plan, a locking sheet is then made, that is, the proper interlocking to be used between the levers is determined. From the locking sheet a dog sheet is made, this being a diagram which shows the arrangement of the interlocking parts as they are to be placed in the machine. At each switch or derail, a signal is located to govern traffic over the point where the tracks intersect. The numbers shown at each switch, derail or signal, is controlled by a lever in the machine having the same number; that is lever number one will operate signal number one, lever number two will operate derail number two, etc. Machines are always built up in sec-
Saxby and Farmer Improved Type of Machine.
tions, five levers per section. For instance, an eighteen lever plant will be composed of eighteen working levers and two spare levers; this is done in case an addition to the plant is to be made at some future time. When no movements are being made over a crossing all derails are open, and the signals are set at the horizontal or danger position. When in such a position they are said to be normal, the levers in the tower also being normal, or in the forward position. When a movement is desired over a section of track, it becomes necessary to set all signals, switches and derails in their proper position, for such a movement. The switches and derails are then locked, after which the signal governing a movement over that particular section may be cleared. A manipulation chart is supplied to each tower, which indicates what particular levers are reversed to allow for movements over the various routes. The closing of a derail over a section, will lock all derails on conflicting, routes, and will also keep the signals normal or in the "stop" position. It is therefore easily seen that only one of the conflicting routes can be cleared.

A switch is used for deflecting traffic from one track to the other. A derail may be called a switch, but as the name implies it is for the purpose of derailing a train if the engine-men tend to disregard signals. The derails are located at a distance of about three hundred feet from the crossing, and in this way the section of track which is cleared is protected from any collision, by a train attempting to cross by way of the conflicting route.
Mechanical Interlocking Plant in Operation.
At each switch there is a detector bar which lies against the outside of the rail. When lowered the bar stands one fourth of an inch below the top of the rail. The bar works in conjunction with the lock on the switch, so when a movement is being made over a switch, the wheels will prevent the bar from being raised, thus preventing the towerman from unlocking the switch when a train is passing over it. The detector bar used in fifty feet in length, and is provided for all movable point frogs and derails. They may be operated with either facing point lock or switch and lock levers. On curves the detector bar is placed on the outside rail. The bar is generally made of wrought iron or soft steel, seven sixteenths of an inch thick, and two and one fourth inches in width, the outside upper edge being beveled. In the central position the bar stands not less than seven eights of an inch above the top of the rail. It consists of three sections of equal length and joined together with lap splices.

A switch may be moved and also locked by a single lever. When this is done a switch and lock movement is used being located opposite the switch, the mid-stroke throws it and the last part of the stroke locks it. A switch is locked either normal or reversed depending on the position of the lever. Switch and lock movements are used for all derails. When a derail is connected on a lever used to operate a switch, a facing point lock is provided. A lever is provided for each switch and lock movement.
The signal blade governing a movement on the main tracks are high, and for a diverging movement a lower blade is used. For a movement against the current of traffic a dwarf signal is used. The "home" signal is a high signal with a square end blade. The length of the blades, both "distant" and "home" are fifty four inches. The front of the home signal is painted red, fourteen inches from the extreme end is a strip of white six inches in width. The back is painted as the front, but with white paint instead of red and a black strip. The "distant" signal is forked at the end and painted yellow, with a black strip, and the back is painted white with a black strip. The dwarf signal is eight and three fourths inches in length with a square end. Two and three eighths inches from the extreme end a strip of white one and one fourth inches wide is painted. The back is the same with the substitution of white paint for the red and black for the white strip. When the distant signal is in an inclined position, the indication is "clear" and also indicates that the home signal is "clear". The levers are interlocked in such a way that the home signal cannot indicate "clear" until the distant signal indicates "clear". The dwarf signal in a horizontal position indicates "stop", with the blade inclined, indicates "clear", "proceed" slowly as the movements on or out of a siding or against the current of traffic, should be made slowly and cautiously.

DETAILS OF CONSTRUCTION

Tower and Lead-out

The foundations used for the tower and lead-out are of
concrete. The concrete is placed at such a depth, which insures against settlement and heaving by frost. The tops of the foundations for the tower and lead-out are not more than seven and one half inches below the base of the rail of the main track. The lead-out is supported by six inch "I" beams the spacing being about three feet four inches from center to center. The lead-out apparatus is bolted to four by twelve inches oak planks running the entire length of the building.

Interlocking Machine

The machine used is of the Saxby and Farmer improved type. The machine is supported on a wood or steel frame extending the entire length of the building. When a wood frame is used an intermediate support under each leg is provided. All levers in the tower have the same uniform throw in the quadrant, and when necessary to reduce the throw of the levers, it is made at the end of the line of construction. All interlocking devices are provided with either electric locking or time locking devices as specified. When electric locking is used, a screw hand release requiring not less than one minute for its operation is provided, and so interconnected with the locking that it must be used for each route electrically locked. When a time lock is used a lever is provided for its operation, and this lever locks the derail levers in the route affected, both normal and reversed. When a time lock can be accomplished without the use of a lever, the lever is not provided.

Operating Connections

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All switches, movable point frogs, detector bars, detector rails, locks and home signals are connected with wrought iron plugged pipe, with an inside diameter of one inch weighing not less than one and one half pounds per foot. The pipe couplings are two and one fourth inches in length, and the pipe plugs are provided with one fourth inch rivets, spaced four inches between centers. All distant and dwarf signals are connected with two lines of No. 9 E.B.B. galvanized steel wire. The pipe carrier foundations are of concrete, the top being two inches below the base of the rail in the main tracks. A clearance of five feet is allowed between track pipe lines and wire lines. The pipe lines are laid two and three fourths inches between centers and are supported at intervals of two feet. When fitting pipes an allowance is made due to expansion and contraction due to changes in temperature. Eight hundredths of an inch is taken as the coefficient of expansion for an increase of ten degrees Fahrenheit for each hundred feet of line. A compensator is allowed for each line of pipe over fifty feet in length.

All foundations are of concrete;

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<tr>
<th></th>
<th>Width</th>
<th>Length</th>
<th>Depth</th>
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<tbody>
<tr>
<td>Pipe carrier foundations.</td>
<td>8&quot;</td>
<td>12&quot;</td>
<td>24&quot;</td>
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<tr>
<td>Crank</td>
<td>28&quot;</td>
<td>32&quot;</td>
<td>36&quot;</td>
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<tr>
<td>Compensator</td>
<td>28&quot;</td>
<td>36&quot;</td>
<td>36&quot;</td>
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<tr>
<td>Wheel</td>
<td>18&quot;</td>
<td>18&quot;</td>
<td>36&quot;</td>
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<tr>
<td>Dwarf signal</td>
<td>18&quot;</td>
<td>18&quot;</td>
<td>36&quot;</td>
</tr>
<tr>
<td>Semaphore</td>
<td>28&quot;</td>
<td>28&quot;</td>
<td>72&quot;</td>
</tr>
<tr>
<td>Bracket semaphore</td>
<td>26&quot;</td>
<td>36&quot;</td>
<td>72&quot;</td>
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</table>

The jaws used for connecting are solid wrought iron,
Standard Semaphore with Two Blades

Lower Blade for a Diverging Route.

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the roundell is broken and the spectacle shows a white light, this is regarded as a "stop" signal.

**Dwarf Signals**

The dwarf signals unless otherwise specified display the same signal indications as the semaphore. They are made of wrought or cast iron, and are not more than three feet in height, and are constructed in such a way that the signal will return to a horizontal position in case of breakage in connections. Spectacle castings are provided with roundells three and one half inches in diameter.

**Painting**

The interlocking machine is generally painted with one priming coat and finished with a coat of black. The levers are painted as follows:

- Home and dwarf signal levers ....... red.
- Distant ......................... yellow.
- Switch ......................... black.
- Lock ............................ blue.
- Movable point frog ............... green.
- Switch and lock ................. black and blue.
Standard Bracket Semaphore.
NOTE

5 line prints must be colored in accordance with Original Tracing before leaving office.

WHITE STANDS

Entire white stand except Target to be painted black.

SEMAPHORES

Semaphore Masts to a point 8' above the top of rail to be painted black; balance of mast to be painted while all other parts except Semaphore boards to be painted black.
CONTROLLED MANUAL BLOCK

The Great Northern Railroad Company has installed on certain single-track-lines carrying a very heavy traffic a manually controlled block signal system which is a step beyond the ordinary telegraph block, the lock and block idea being accomplished through a block instrument of a new design.

The apparatus as used is applicable to double track, but the Great Northern has adapted automatic block signals which has been previously described. The machines are constructed by the General Railway Signal Company, and the installation was made by them.

The object of the machine described compels the cooperation of the signalmen at each end of the block before a proceed signal can be displayed in either direction. The system may be operated as a positive block, but on this system it is used permissively. No other train is allowed to occupy a block already occupied by a passenger train, but the rules of the company permit the train dispatcher to authorize permissive movements for freight trains following freight trains. This permissive move is made only under the authority of a numbered caution card which must be authorized by the train dispatcher. In this the train dispatcher uses his own judgment, as to the permissive move, considering train, track and all weather conditions. The use of this system does not increase the operator's duty, while it does provide a good check and a strong factor of safety.
GENERAL INSTRUCTIONS FOR OPERATING CONTROLLED MANUAL BLOCK INSTRUMENT.

- BELL CODE -

1. Long Stroke. To attract attention.
3. Unlock my lever. Ans by unlocking or scan 1.
4. Train has entered block.
5. Block is not clear.
6. Has train entered this block? Ans by scan 2.
7. Clear. Train has cleared block.
8. No.

NOTE:

2. C & P. Indicators.
3. E & F. Plungers.
7. Be sure cranks A & B are always in positions shown, except during use.
8. Always use side of machine farthest away from station from which unlock is asked.
9. Always use bell key "H or G" and telephone on side towards station communicated with.
10. Latches M & N should be pressed in only long enough to release crank "H or L".

- TO OBTAIN UNLOCK FOR CLEARING BLOCK SIGNAL -

- Instructions to Operator: Receiving Unlock -

1st Upon receipt of one ring, acknowledge same by two pushes on bell key.
2nd Upon receipt of three @ rings, move small releasing crank upward as far as it will go and hold in so until receipt of two @ rings, then release crank as operation is complete.

- TO RETURN BLOCK SIGNAL TO STOP POSITION -

Press latch key in and move operating crank forward to normal position.

END BLOCK OFFICE.

END BLOCK OFFICE.
The train order semaphore signals are used at the stations, and exclusive signal stations have been provided at intermediate passing sidings. Each signal is operated by a crank machine of special design, pipe connected to the signal. The normal position of the signal is at danger, and the operating machine is electrically locked in its normal position.

A battery of from ten to twenty volts is required at each station, one battery operating the block in both directions. An open circuit is used. The battery is used from one to two sections during each operation, and one tenth of an ampere is required to do the work. Chloride Accumulators and Westinghouse types of storage batteries are used and it is figured that this battery will provide power for one year, before battery renewals will be necessary. One inspector looks after the batteries as well as checking up in general the work of the block men. The following bell signals are used by means of which operators may communicate. Each block office is also equipped with a telephonr by means of which the operators may communicate with the operator on either side of them independently.

The prescribed Bell signals are as follows:

1 (Long stroke) Answer telephone.
2 All right. Yes.
3 Unlock my lever. Answer by unlocking lever, or 5, or 3-1.
4 Train has entered block.
Block is not clear.

Has train entered block?

Answer by 2, or 2-1.

1-2 Clear, Train has cleared block.

2-1 No.

2-2-2 Previous signal given in error.

Answer by 2.

Has train cleared block?

Answer by 1-2 or 5.

2-4-2 Repeat previous signal.

Have unlocked.

If the signal bell circuit or telephone should fail, the train wire will be used for block information.

In order to display a "proceed" signal for a movement from, say "A" to "B" on the diagram, it is first necessary for the operator at "A" to ask "B" to release his machine, which he does by means of a call bell provided for that purpose. There being no train in the block and the opposing signal at "B" being at "stop", the operator at "B" so manipulates his unlocking key as to close an electric current from a battery at "B" through the interlocking key, held in its proper position, and the coils of an electromagnet at "A". This action releases a hand lock, which is moved to unlock the signal crank, allowing the operator at "A" to clear his signal. After the train has entered the block and has been so reported, the signalman at "A" must return his signal to the "danger" position. In so doing the lock on the operating crank is forced home, thereby compelling the
operator to obtain another release in order to clear the signal again.

No semi-automatic features are employed in the system as installed on the Great Northern Railway, for the return of the signal to "danger" after the train has passed it, by means of gravity, or some device for restoring it to "danger". In order to obviate the danger arising from the neglect of the signal man to restore his signal to the normal position there has been embodied in the rules, that when enginemen do not see a signal change from "stop" to "proceed", such signal must be regarded as an imperfectly displayed signal and regarded as such. The enginemen or trainmen must see the signal change from "stop" to "proceed", otherwise must not pass it irrespective of the position of the signal.

This device as installed does not afford absolute protection in the movement of trains, but holds two signalmen responsible for the proper display of signals, at each end of the block, and furthermore compels the signalmen to keep their presence of mind.

Referring to the diagram a description of the circuits and operation is as follows:

The operator at "A" wishes to clear a signal for a train from "A" to "B". "A" asks "B" to unlock "A's" machine; the conditions being right, "B" closes circuit controller 12. The opposing signal at "B" being in the "danger" position and operating lever 26 locked, circuit breakers 2 on signal arm and 25 an electric lock are closed. The operator at "A" now
closes contact 10 by moving lever 13. Current then flows from battery 28 at "B" over wire 1, contacts 2-25 wire 27, contact 12, wire 5-6-7, through magnet coils in indicator 29 at "B", and magnetic coils on indicator 30, contact 1, wire 9, coils of unlocking magnet 14 to ground A., the interlocking magnet is now energized to release the lever of hand lock 6. Lever 6 being moved in turn releases the lock 17 on signal crank 16. The operator at "A" may now move crank 16 one half revolution to clear the signal. After the train has passed, the signal is restored to the "stop" position by the operator, for, as before mentioned no semi-automatic devices are employed to accomplish this. To restore the signal to the "stop" position, the crank 16 is moved in the same direction to clear the signal, the revolution being completed.

To prevent the crank from being turned around except in the proper direction a ratchet wheel 18 is mounted on the crank shaft. On this ratchet wheel a stud 22 is fixed which, when the signal crank 11 is almost restored to its normal position, so engages with lever arm 23 as to force the lock 17 home, thereby preventing the signal from being cleared, until it has been unlocked again. This machine could be made to operate semi-automatically in restoring signal to "stop" by introducing a slot on the signal and a short section of track circuit. One wire is used for the manipulation of the machine, and is a triple braid weatherproof insulated copper wire, carried on the telegraph poles.
AUTOMATIC BLOCK SIGNALING

Installation

At a cost of approximately one hundred thousand dollars, the Great Northern Railway recently equipped its line between St. Paul and Minneapolis with a modern Automatic Block Signal System, together with "all" Electric interlocking plants at Seventh, Westminster, Mississippi streets and Como avenue. Two mechanical interlocking plants at St. Anthony Park and Fifteenth avenue have been in operation for some time. All signals and switches between the two cities are now operated from the towers.

Construction and Operation of Signals

The signals used are of the three position upper quadrant type. The signals on the passenger tracks are semi-automatic through the several interlocking plants, thus insuring unbroken continuity of signal indications. In this installation the desirability of using the three position signal is brought out strongly in a number of ways. At several points the "home" signal of one interlocking plant serves as the approach or "distant" signal to the next interlocking plant. At these points the distance between interlocking plants is short, and would not admit of locating the "distant" signals on separate masts. Under the old method of signaling, this situation would have resulted in placing the approach signal arms on the "home" signal masts of the next interlocking plant back, which arrangement would mean four or five arms on a mast. With so many lights on
a signal most enginemen are very often confused and are unable to determine quickly the true significance of the signals. Under the newly installed system, the automatic block signals, including those used as approach signals at interlocking plants, carry signal arms and lights, while the "home" signals at interlocking plants carry two arms and two lights. In all cases the second arm or light governs a diverging movement with the current of traffic. The dwarf signal governs a movement against the current of traffic and in the same way the lower arm denotes a diverging movement against the current of traffic. In some cases there is no diverging route, at such points the lower arm is non-working, and serves only as a "mark" of distinction as between signals which are permissive (after a stop has been made) and those which are positive and must not be passed until the signal indicates "clear". The term "clear" as here used means that the arm must go to either the forty-five degree or ninety degree position, while the light must change from red to either yellow or green before a train may proceed. The signal used is the General Railway Signal Company's Model #5 with motor mechanism. A direct connected movement is used. The motors for operating the signals are of the General Railway Signal Company's direct current type with a rating of ten volts and two and one half amperes under load. The blocks are of an average length of twenty two hundred feet, and trains are operated as fast as the blocks will permit. The freight and passenger traffic over this line is exceptionally heavy, there being about one hundred passenger trains daily, and about the same
number of freight trains, together with coach movements between the two cities. Four other railroads beside the Great Northern use these rails, which is a splendid test for the improved type of signals. The system operates very satisfactorily and there have been but very few failures.

Circuits

The arrangement of circuits provide control for the forty-five degree position through the track circuits and line circuit control for the ninety degree position. This arrangement has proven satisfactory and has the advantage of the signals working uninterrupted (in the horizontal to the forty-five degree position) through storms and other occasions when line circuits become broken down.

Construction and Equipment of Towers

The new tower buildings are of brick, steel and concrete fireproof construction and are very substantial. The towers are heated by hot water plants. The storage batteries are of the Chloride Accumulator and Westinghouse type, one hundred and ten of each and are located in the lower story of the tower along with the motor-generator sets. The current required to charge the storage batteries is obtained from the company's plant at the Dale street shops, from a twenty-four hundred volt sixty cycle three phase machine, current being carried to Mississippi street by a three wire system, which is used principally for lighting purposes. A ten to one transformer is used to step
**Automatic Block Signals**

From a point four thousand feet east of Bridge and Brookton, the Automatic Electric Semaphore Signals are being installed. Due notice shall be given at least 10 days prior to their installation.

- The line from Alders to Brookton (for east bound trains only) will be equipped with Automatic Block Signals. The equivalent Automatic Block Signals are at the J. J. Line east of the left switch. To ensure correct operation of East Bound Signal at Brookton Yard.

The block signals in all cases are located on the right hand side of the track, in operating arm being displaced to the right of the signal post, as seen from the center of the track.

- B incorrect arm of the signal will, in addition be shown by
- Red indicates "Stop".
- Yellow "Caution". Proceed under control prepared to stop at next signal in advance.
- Green "Proceed".

Bright signals do not effect the superiority of trains.

- Each switch in the Main track is equipped with a Switch Indicator which is to be used in the horizontal position. It indicates:
  - RED = Switches are not completed, or the track is blocked.
  - GREEN = Switches are completed, or the track is clear.

- Switches not to be opened until the signal is CLEAR.

**Interlocking Signals**

- Switches are provided to govern the best use of tracks and to control movements either to or from any tracks in storage or industry tracks.

A signal arm and signal light Home and Distant signals are provided in use at certain interlocking points on territory protected by the Automatic Block System.

1. **Bridges**
   - Line crossing from J. J. Line to Brookton (for west bound trains only) will be equipped with Automatic Block Signals. The equivalent Automatic Block Signals are at the J. J. Line west of the left switch. To ensure correct operation of East Bound Signal at Brookton Yard.

2. Bright signals in all cases are located on the right hand side of the track, in operating arm being displaced to the right of the signal post, as seen from the center of the track.

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down the voltage.

The motor generator used is a sixty cycle two hundred and twenty volt single phase eighteen ampere motor with a rated speed of eighteen hundred revolutions per minute. The direct current side is built for a charging rate of twelve and one half amperes and one hundred and fifty volts. The storage batteries are one hundred ampere hours capacity, and when charged, provides power sufficient to operate the interlocking plants for periods varying from seven to eleven days; which makes the cost of power very reasonable. There is a total of two hundred and forty-two levers in the six towers, an average of forty per tower.

Maintenance

Five men are required for maintenance, three day maintainers, one night maintainer and a lamp man. The cost of maintenance is figured by the signal arm. The cost per year per arm is eighty-one dollars, this item is divided between supplies and labor, supplies twenty-nine dollars and labor fifty-two dollars. Putting this on a monthly basis they cost seven dollars per arm per month. The primary batteries call for renewals about once a year.

General Construction

The four tracks are laid with eighty-five pound steel Great Northern section, fitted with Weber joints, models one and three. Rails are bonded with number 8 E.B.B. iron wire fifty-six and forty-eight inches in length depending on the length
of the angle bar. Channel pins are used to keep the bonds in place. Electric bells are placed in the towers to warn tower-men of the approach of trains.

The signal poles are made of iron and set in concrete. Derails are installed only at grade crossings. Storage batteries are used for the electric interlockings and primary batteries for all track and line circuits. The operating batteries are connected in series and the track batteries in multiple. The number of cells per signal varies, as some signals have one, some two and others three track sections between them, but two cells in multiple on each separate section.
ELECTRIC TRAIN STAFF SYSTEM

Development

The Electric Train Staff System of the present time is a gradual development from a simple principle for the operation of railroads which was recognized in England as early as 1840; namely that to pass safely over a given section of single track, every train should have in its possession a tangible right to do so in the form of some specific article of which there is only one obtainable. The first train staff was a metal bar about two feet long, which had cast or engraved on it the name of the two stations between which it alone gave authority for any train to proceed. Unless trains moved alternately in opposite directions the staff had to be returned over the section by a special engine or in same cases by road.

To partially overcome the difficulty the staff and ticket system was devised, in which device the original staff became a key that would unlock a box at either end of the section and permit tickets to be taken therefrom. If it was desired to forward, say three trains from one station to another before one should proceed in the opposite direction, the ticket box was unlocked with the staff and a ticket given to the first and second trains, the third or last train receiving the staff.

Since the engineer or guard of any train when receiving a ticket was required to see the staff as well, this system while making head-on collisions impossible did not permit trains to enter a section from the end at which the staff did not happen to be.
To accomplish this result Mr. Edward Tyer in 1878 introduced his electric tablet apparatus which consisted of two instruments, one at either end of a section, each instrument containing a certain number of tablets, any one of which constituted the right of a train to pass over that section. The two instruments were electrically connected and synchronized so that the removal of a tablet from either instrument absolutely prevented any other being taken out.

In 1889 Mr. Webb, Chief Mechanical Engineer, and Mr. Thompson, Signal Superintendent of the Landon and Northwestern Railway, invented the Webb and Thompson Electric Train Staff, in which staffs were substituted for the tablets in the Tyer system and a permissive feature added whereby several trains could follow each other into a block section if desired, in a manner similar to that employed in the no-electric staff and ticket system.

The American rights for the Webb and Thompson system are owned by the Union Switch and Signal Company. This company has overcome many of the objectionable features of the Webb-Thompson system. The main objection being the size of the staff, which made it difficult to catch at high speed. To overcome this objection the above Company introduced in 1900 what is known as its High Speed Train Staff System, which, although based on the same general principles and method of operation as the Webb and Thompson, possessed the essential advantage of employing staffs only six inches in length, weighing six and one half ounces; as against staff twenty-two inches long, weighing four pounds, of
the Webb and Thompson system, thus greatly simplifying the problem of taking staffs at high rates of speed. This type of machine was installed on the Great Northern Railway through the Cascade Tunnel in Washington. The total length of the tunnel is three miles with a grade of one and one half per cent.

Operation

In the operation of the electric train staff the track is divided into blocks or sections of such length as best accommodates local and traffic conditions. A staff instrument was placed at the entrance and exit of the tunnel, the line wires making up the connections were strung on poles. The tunnel is controlled by two instruments one at each end, which for convenience in this description are referred to as "X" and "Y". Each instrument is equipped with a sufficient number of staffs to take care of traffic conditions, varying from ten to thirty-five per section. No train is permitted to proceed between "X" and "Y" in either direction unless the conductor or engineer has in his possession one of these staffs which is in effect a metal train order. The instruments at "X" and "Y" are electrically connected as shown and synchronized so that the withdrawal of a staff from either can only be effected by the joint action of the operators at "X" and "Y", and but one staff can be out of both instruments at any one time.

The following are the general instructions for the operation of staff instruments. The operator on duty will have charge of the staff instrument and will in all cases be held responsible
for the use and care of the same. The following is the Bell Code.

Bell Code

One- To attract attention. Five- Block is not clear.
Two- Acknowledgement. Six- Train has cleared block.
Three- Unlock my instrument. Seven- Previous signal in error.
Four- Train has entered block. Eight- Testing instruments.

To remove staff from machine:
First, Press bell key "A" once (1). Answer will be two (2) taps.
Second, Press bell key "A" three (3) times. The watch indicating current needle "F" until it deflects to the right.
Third, Turn preliminary spindle "E" to the right as far as it will go and then release it, permitting it to automatically return to its former position. A white disc will appear in place of the red one at "H". This indicates that staff is ready to be removed.
Fourth, Move end staff "E" up vertically slot into engagement with guard "N", this guard having been turned so that the staff will slip into the slot in the edge of the guard "N".
Fifth, Revolve guard "N" using staff as a handle and withdraw the staff through the opening at "M". This operation moves "staff indicating needle "G" from "staff in" to "staff out".
Sixth, Immediately upon withdrawal of staff press bell key "A" once. This is absolutely necessary.

The operator who aids in removing the staff, obeys the following instruction:
First, Upon receipt of one ring, acknowledge same by two pushes on the bell key "A".
Second, Upon receipt of three rings press bell key "A" and hold it so until "staff indicating needle" "G" moves from "staff in" to "staff out". The key "A" is then released as the operation is completed.

The following instructions must be followed in replacing the staff in the machine.
First, If the staff is divided join the two sections.
Second, Turn outer guard "N" to place and insert complete staff in the opening "M".
Third, Using the staff as a handle revolve guard "N" to the right and allow staff to roll down the spiral into place.
Fourth, Press bell key "A" according to signal (6) in the bell code.

The operator at the opposite end of the block follows these instructions. The signal (6) of the bell code must in every case be answered in order to place the machine in the proper condition for the withdrawal of the next staff. The staff machine must be operated with deliberation and care. Machine must be kept clean and free from obstruction.

Two attachments may be placed on the absolute staff instrument the "pusher engine attachment" and the permissive attachment. It can be readily seen from the foregoing description that supposing the traffic up grade and down grade is the same, and a pusher is required in going up grade, as from "Y" to "X". On arrival at "X" the pusher engine would necessarily have to receive a staff to return to "Y". In this way, the staffs would eventually arrive at the foot of the grade. To overcome these
difficulties, a pusher attachment is used. It contains a staff of special design which can only be released by the absolute staff, but unlike the permissive staff, it can be out of its receptacle at the same time as the absolute staff.
That the signaling in this country will continue to advance as in the past can be readily seen. Railroad Companies are beginning to realize that fast passenger and freight service depends largely upon the signal protection of the road. It has been proved by actual figures that signaling accelerates traffic in a remarkable degree. Railway signaling not only increases the protection of passenger and freight traffic, but actually increases the earning capacity of the road.