B. & M. Installs

Either-Direction Signaling

in Hoosac Tunnel

Extensive rearrangement program carried out to expedite traffic through electrified five-mile tunnel

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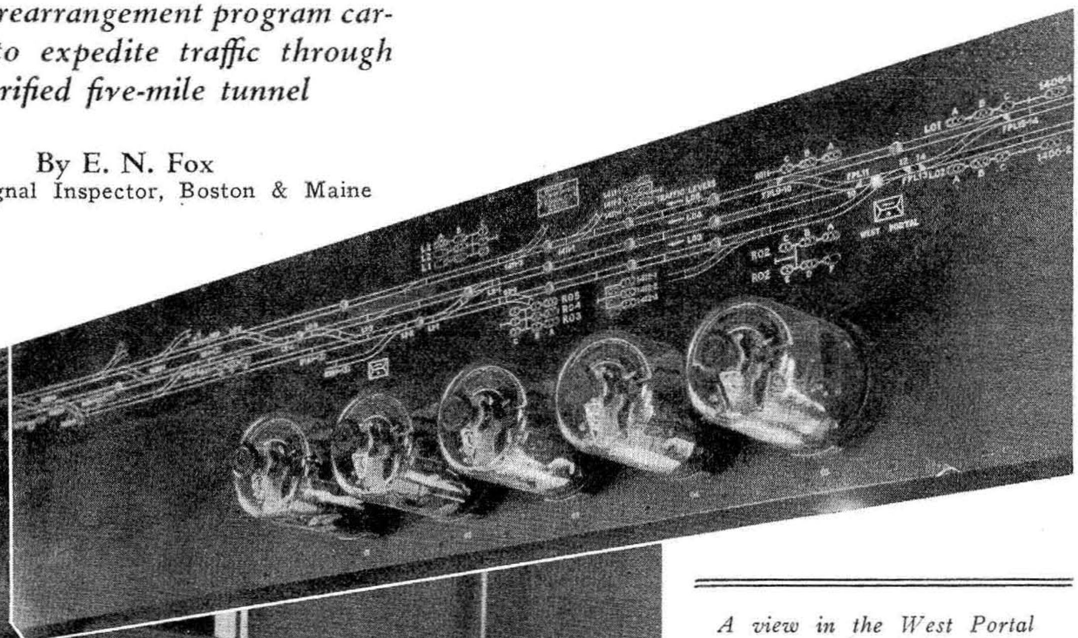
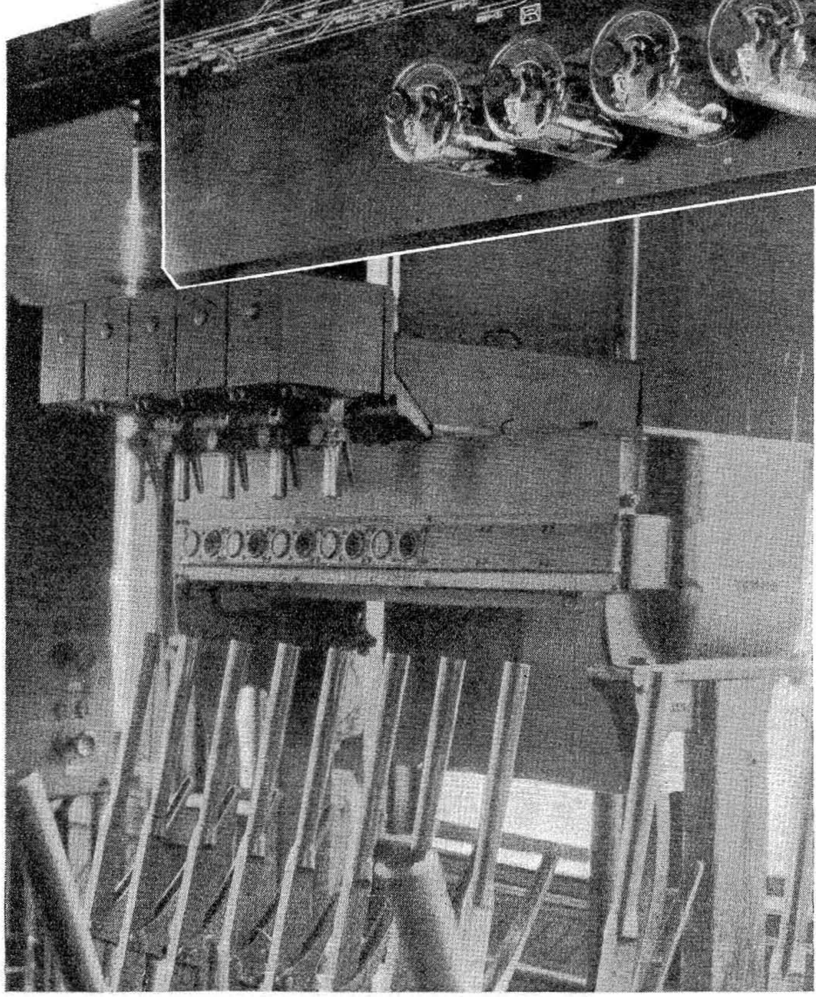




A view in the West Portal tower

IN order to expedite train movements, the Boston & Maine has recently installed a new signal system through the Hoosac tunnel. Trains are now operated by signal indication, in either direction, on each track through the tunnel and also in either direction on the tracks in the electrified territory adjacent to the tunnel. The Hoosac tunnel is located 136 miles west of Boston, Mass., on the main line of the Fitchburg division, which extends from Boston to the western gateways of the Boston & Maine; namely, Troy, N. Y., Mechanicville and Rotterdam. The double track extends through the tunnel, which is nearly five miles long. The Hoosac tunnel was, until comparatively recently, the longest tunnel in North America, and is exceeded in length only by the Connaught tunnel on the Canadian Pacific, the Moffat tunnel on the Denver & Salt Lake and the Cascade tunnel on the Great Northern.

The tunnel was first conceived and seriously proposed in 1819 as part of a canal route to connect the Connecticut river with the Erie canal. A canal through the Berkshire mountains was rather an ambitious project, particularly so when it is realized that the railroad, in following the proposed canal route from Greenfield, Mass., to the east portal of the tunnel, rises 572 ft. in the 30 miles.

Excavation of the tunnel, as a railroad project, was started in 1851. Mining and boring methods in those days were crude in comparison with present day methods, and the progress through the solid rock was necessarily slow. Consequently, it was 23 yr. later, on November 27, 1874, when the east and west headings met. The error in levels between the two headings was only $\frac{9}{16}$ in., a remarkable feat of engineering. The first train passed through the tunnel on February 9, 1875.

The tunnel is level for about 1,650 ft. in the vicinity of the central shaft. Approaching this level stretch from either portal, there is an ascending grade of 0.5 per cent. The track at the center is 66 ft. higher than at East Portal and 56 ft. higher than at West Portal. The dimensions of the central shaft are 15 by 27 ft., with a depth of 1,028 ft. It is now used for ventilation, a large electric fan operating at the head of the shaft. The depth of the central shaft does not represent the greatest depth of the tunnel, as the height of the eastern summit of Florida Mountain is 1,429 ft., and the western summit 1,718 ft. above the tunnel.

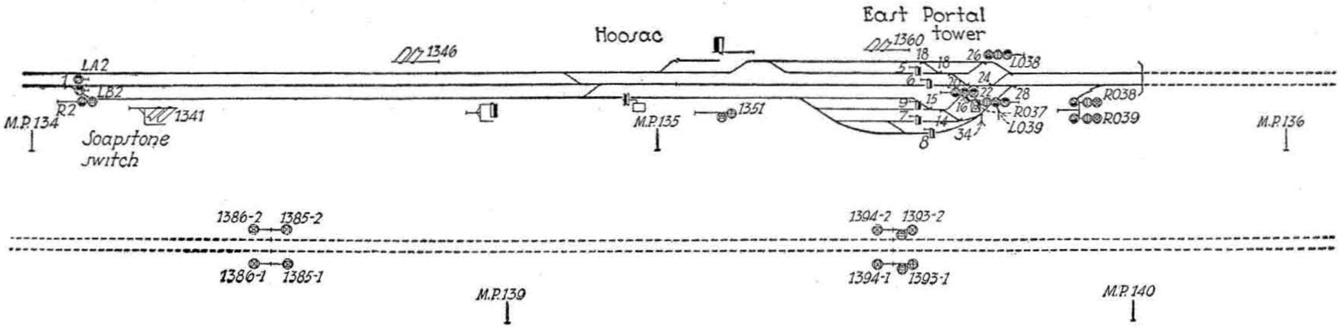
Until 1910, all trains were pulled through the tunnel by steam locomotives. As the first 2¼ miles inside the tunnel in either direction was 0.5 per cent up grade, the tunnel was usually thick with smoke, gas, and steam, and a ride through it was an event to be remembered for more reasons than one. Train operation was by means of manual telegraph block. A telegraph operator was stationed midway at the central shaft, not a particularly desirable job.

During 1910, the tunnel was electrified, together with 1.04 miles of road east of East Portal and 2.04 miles of road west of West Portal. The system uses an overhead trolley, carrying 11,000 volts 25 cycle single phase. The electric locomotive hauls the entire train, including the steam locomotive, the fires of which are banked before entering the tunnel.

Previous Signaling Combined with Staff System

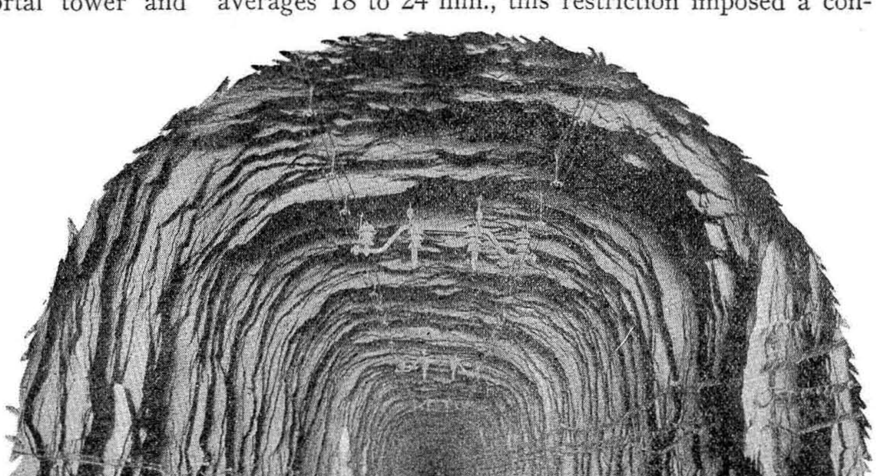
Along with the introduction of electric propulsion, a 60-cycle a-c. signal system was installed, color-light signals being used within the tunnel, and two-arm home and distant semaphore signals outside. Trains were operated as with any automatic block signal system, except that before a train could pass a "stop" signal within the tunnel, the engineman was obliged to telephone the train director at West Portal tower and receive permission to do so. In case of a power failure, or of necessity to operate the tunnel as single track, train movements were handled by means of an electric staff block system. Electric staff machines were located at East Portal tower and at West Portal tower. The control wires connecting these staff machines were not run through the tunnel, but instead were carried on a pole line over the mountain. Possession of a staff conferred upon the engineman the absolute right over all trains, regardless of the indication of the manual-controlled tower signals at the entrance to the tunnel and the automatic block signals within the tunnel.

This method of operation proved satisfactory until the increasing volume of traffic in recent years resulted in the tunnel becoming the "bottle neck" of the division, causing numerous train delays. These delays were occasioned by the fact that the trains, before entering the tunnel, had to stop to have the electric locomotives attached, air brakes tested, and, upon leaving the tunnel, to stop again to have the "motor" cut off. They were further aggravated by the custom of running trains in "fleets," that is, three or four through freights following each other closely. Approaching the tunnel in each direction, there is a third track, which enables the "motors" to be attached and air tested on two trains at the same time. The result of all this, however, was that frequently two or three westbound trains were waiting for an opportunity to run through the tunnel on the westbound track, while the eastbound track was entirely clear of traffic, or vice versa. Similarly, a westbound freight train which did not have quite enough time to get through the tunnel ahead of a westbound passenger train would have to wait 30 min. at the East Portal, whereas, if the eastbound track was clear, the passenger train could have been run around the freight train. The answer was to install either-direction signaling on each track.



Track and signal plan showing interlockings and signaling

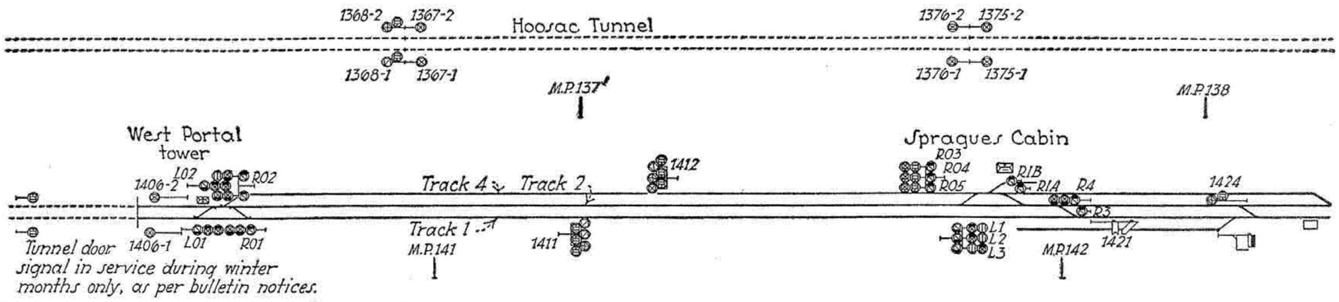
Another reason for either-direction signaling was the necessity of operating for considerable periods of time with only a single track, owing to a train breaking down on one track, or to the periodical inspections of the tunnel roof for loose stones and of the insulators supporting the 11,000-volt trolley wires. This meant, with trains running against the current of traffic and, therefore, using the staff system, that only one train at a time could proceed between the portal towers. As the running time for a freight train through the tunnel averages 18 to 24 min., this restriction imposed a con-



Interior of Hoosac tunnel

siderable handicap on an operating department working hard to speed up traffic.

To install improved signaling merely through the tunnel would have been only half the job, as the trains, once through the tunnel, must be quickly moved away from the portal towers. To accomplish this at the west end, the three tracks between West Portal tower and Sprague's Cabin have all been signaled for traffic in either direction. At East Portal tower certain interlocking changes have already been made, but the changes that will most facilitate starting traffic away from there, are to be made in connection with the centralized dispatcher's control system about to be installed between East Deerfield and East Portal, a distance of 34 miles. One factor which aids quick starting upon leaving the tunnel is the fact that there is an appreciable down grade upon leaving the tunnel in either direction.

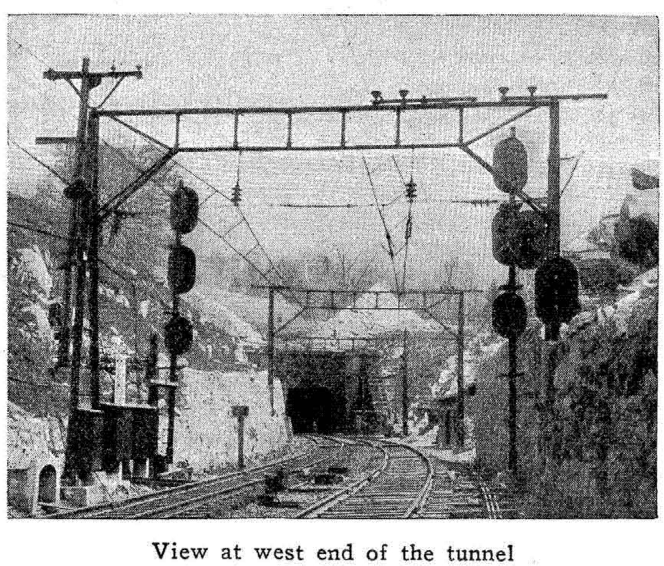


in the territory from Soapstone switch to Sprague's Cabin

Volume of Traffic

The traffic through the tunnel consists of 6 passenger and about 13 freight trains per day each way, the best known passenger train being the "Minute Man," running between Boston and Chicago via the B. & M. and N. Y. C. The major portion of the traffic consists of fast freight trains. Eastbound the principal shipments consist of coal, cement, raw wool and cotton, automobiles, furniture, leather hides, flour and milling products and perishables, such as fruits, vegetables, meat and dairy products. Westbound it is chiefly manufactured articles, boots and shoes, textile products, paper, lumber, sand and gravel. The normal and maximum volume of traffic is shown in the accompanying table. The term "maximum" refers to the traffic on an unusually heavy day or hour, not, however, to the very highest traffic ever handled.

In speaking of maximum traffic handled through the Hoosac tunnel, reference should be made to the remarkable performance of the Fitchburg division operating department in handling traffic following the memorable flood of November 3 and 4, 1927. West of North Adams, the line was completely washed out, and, until a single-track service was restored on November 7, freight cars were constantly accumulating at our western gateways. As soon as the line was open, it was imperative that these cars be handled as rapidly as possible. In addition to this, Boston & Albany freight traffic was also being detoured over our line from North Adams, Mass., through the tunnel to Springfield, via Greenfield. In one week, a total of 16,462 cars were moved through the tunnel, with the peak occurring on November 14, when 2,214 eastbound and 1,026 westbound cars were handled.



View at west end of the tunnel

Before commencing a detailed description of the signaling, it is desirable that the method of train and electric locomotive operation be thoroughly understood.

Movements Through Hoosac Tunnel

	Westbound			Eastbound		
	Per Day		Per Hour	Per Day		Per Hour
	Average	Maximum	Maximum	Average	Maximum	Maximum
No. of passenger trains	6	6	1	6	6	1
No. of freight trains	13	19	2	12	18	2
No. of light engines	5	9	4	6	7	1
No. of freight cars	1,038	1,375	186	717	1,237	185
Total freight tonnage	28,847	36,901	4,563	33,096	59,898	4,800

A westbound freight, providing the main track at Hoosac tunnel station is clear, or that it is not encroaching upon the time of a superior train, will keep on the main track, coming to a stop sufficiently clear of signal *R037* (see accompanying track and signal layout), so that when the electric "motor" is attached to the train it will be in front of the signal ready to accept it. As soon as the steam train has come to a stop, the "motor," which has been waiting on the siding back of signal *6*, proceeds through crossover *20* and then backs to the train. If it is not desirable to have the freight come up the main track, it takes track *3* at the Soapstone switch remote control, and proceeds to whichever dwarf signal at East Portal the towerman decides to advance it.

The train can then be sent through the tunnel on either track, in accordance with the instructions of the train director, located at West Portal tower. Upon arrival at that tower, if there is an eastbound train waiting, or expected, on tracks *2* or *4*, the westbound freight is stopped at signal *L01*, and its "motor" cut off and moved over to the proper track, so as to couple on to the eastbound train.

The steam train then proceeds under its own power without again having to stop in the electric zone. However, should it be necessary to return the "motor" eastbound by pulling a passenger train or running light, the director would not stop the freight train at West Portal tower, but would instead send it down on either

View at Soapstone switch, looking west

track *1*, *2* or *4*, as he deemed best. The train would then stop at signal *L3*, *L2* or *L1*, respectively, at Sprague's Cabin, while the locomotive cut off and crossed over out of the way.

A westbound passenger train scheduled to stop at Hoosac Tunnel station has the "motor" attached there, while it is making its station stop; otherwise the "motor" is picked up at the tower. The motor then hauls the train to North Adams station, where it cuts off and crosses to the eastbound main via the crossover just west of State street.

Eastbound freight trains proceed under steam on tracks *2* or *4* to signal *Ro2* at West Portal tower where they are connected to a "motor." They are then routed through the tunnel on either track, and stop at either signal *Lo38* or *Lo39* to cut off the "motor." For eastbound passenger trains, the electric locomotive waits just beyond signal *1442*, and then backs to the train while it is making the North Adams station stop. The motor is cut off again at Hoosac Tunnel station, using the crossovers just east of there to get into clear. To protect this move, mechanical signals are now in use, but these will be replaced with interlocking protection upon the completion of the dispatcher's control system.

Train Movements Directed from One Point

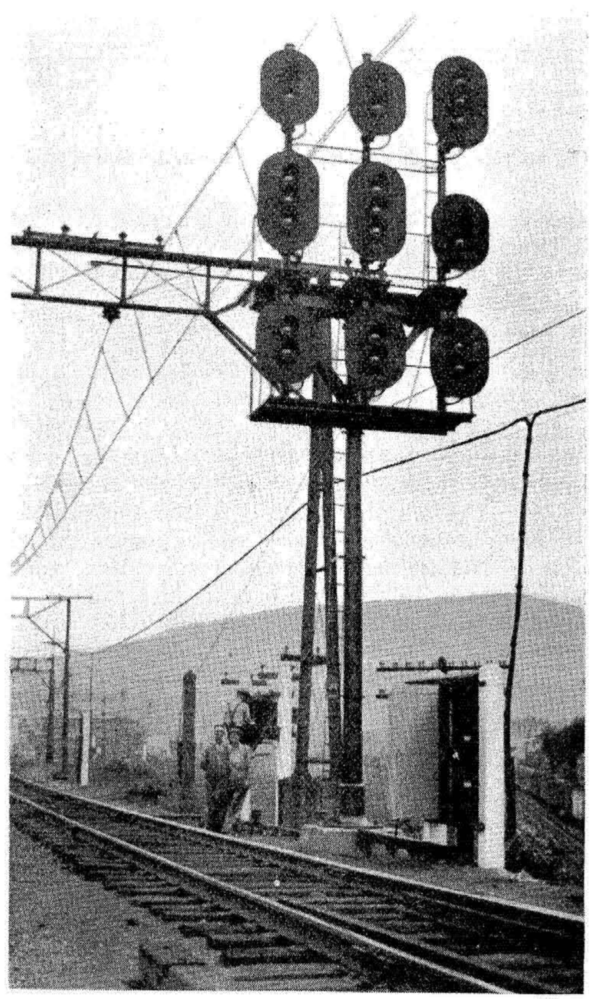
All traffic between East Portal tower and Sprague's Cabin is under the control of the train director at West Portal tower. The towerman at East Portal operates the switches and signals at that location, as well as the remote-control switch and signals at Soapstone switch. He also operates signals *Ro38* and *Ro39*, allowing west bound trains to enter the tunnel, but he cannot clear these signals, unless the traffic levers at West Portal are in the proper position. Once a direction of traffic is established on either track in the tunnel, the director at West Portal cannot change his traffic levers to reverse the traffic direction until the following conditions prevail:

1. All opposing signals at East Portal tower must be in the normal (stop) position.

2. The traffic lock lever at East Portal must be in normal position and all track circuits (on the track affected) from the opposing signals at East Portal tower through the tunnel to West Portal tower must be unoccupied.

The director at West Portal handles the switches and signals at that location, as well as signals *Ro3*, *Ro4*, and *Ro5*, which permit eastbound movements from Sprague's Cabin, thereby giving him direct traffic control in either direction between these two locations. The switches at Sprague's Cabin are hand switches operated by a ground switchman stationed there. A table interlocking machine has been provided in his cabin, giving him control over signals *L1*, *L2*, *L3*, *R1*, *R3*, and *R4*.

The switches at the two interlocking towers are operated mechanically from existing interlocking machines, but all of the signals throughout this installation are new, and are the Union Style-R color-light type. All home interlocking signals are of the three-unit type, that is, they have a top "arm," middle "arm," and bottom "arm." Shortly after the work of installation had



Signal "L" near Sprague's Cabin

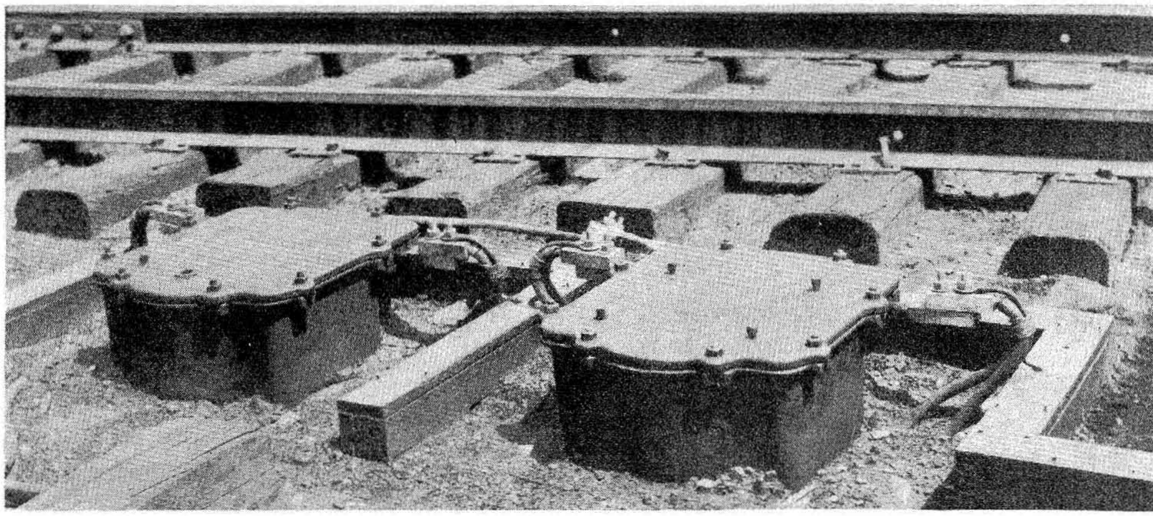
commenced, a new system of aspects was adopted for all color-light signaling, using three colors when desirable, red, yellow, and green, for the top and middle units, instead of the former two-color (red and green) units. This system was adopted to permit use of intermediate cautionary signals, as well as to give an approach-medium indication.

At the same time, a new standard was adopted for automatic block color-light signals used in approach of home interlocking signals. A two-unit signal is used, the lower light being staggered about 13 in. to the right of the upper light, thereby providing the engineman a distinctive indication that he is approaching an interlocking plant. For a clear signal, green over green has been employed instead of the frequently used green over red. This does away with the use of red at a clear automatic block, and, as red has greater visibility than green, eliminates, in high-speed territory, the undesirable liability of the engineman seeing a red signal before he can see the green light when he is approaching a clear signal. The other aspects used are yellow over green for approach-medium, yellow over red for approach, and red over red for stop-then-proceed. Light-out relays are used to prevent a less restrictive indication being given in the event of the failure of one a purely mechanical to an electro-mechanical plant.

Under the new layout the machine scheme for the S. & F. machine is as follows:

9 levers for 9 mechanical dwarf signals
10 levers for 15 mechanical switches
11 levers for 15 F. P. locks
2 levers for 2 traffic locks
—
32 working levers
8 spare levers
—
40 lever machine.

The three Style-S8 units control five color-light signals having 11 operative units and four inoperative units.



The impedance bonds are located at the side of the track, rather than between the rails

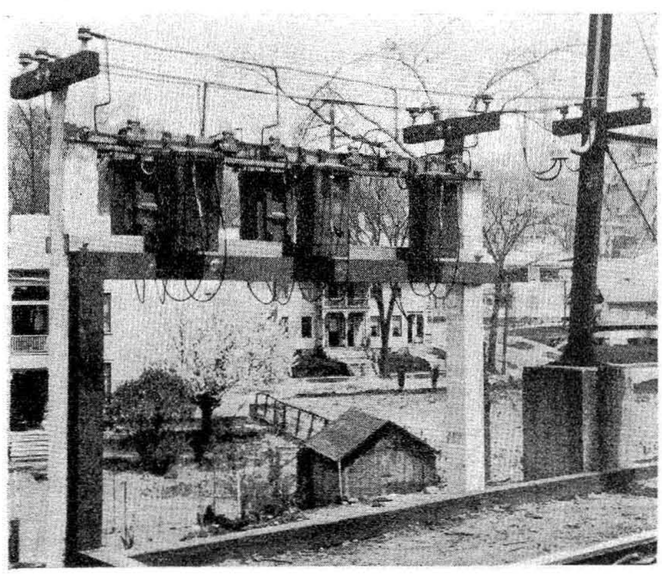
of the two lights, although it is questionable, in view of the powerful headlights in use at present, whether such a precaution is necessary.

The Soapstone switch remote-control installation is actually a detached unit apart from the major project. However, its primary purpose is the same, namely, that of speeding up traffic and reducing operating costs. Before it was placed in service, a ground switchman was stationed there to route the trains in accordance with instructions given by telephone from West Portal tower. The switch and signals are controlled by a standard eight-wire circuit scheme, operated by two table interlocker levers located in West Portal tower. The signals are of the color-light type. The U. S. & S. Style-M switch movement is operated by 12 cells of Type-DMG09 Exide storage battery, the latter being kept on floating charge. A telephone and a switch operating crank are located here so that, in event of a battery power failure, the switch can be cranked over by hand by the train crew after receiving authority to do so from the towerman at East Portal. Removal of this switch crank from its case opens the circuit of the switch control relay, thereby preventing the towerman from moving the switch during hand operation. Standard approach and electric detector locking are provided. The control wires within the electric zone are in cable attached to the electrification struts, while outside of the zone open wiring is used.

East Portal Tower

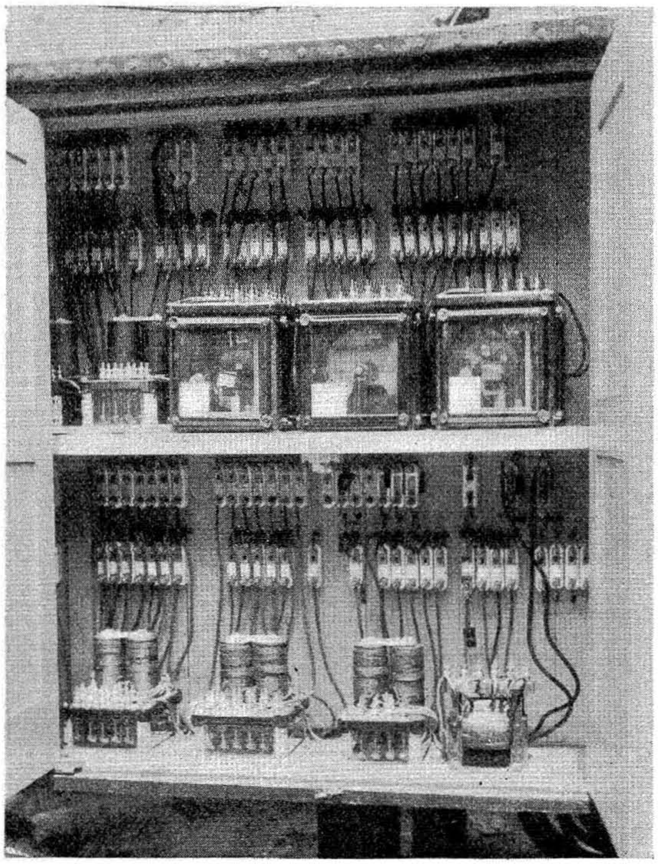
This tower is located about 1,400 ft. east of the East Portal of the tunnel, and was originally placed in service in 1911, replacing an earlier tower that had been destroyed by fire. It houses a 40-lever S. & F. interlocking machine, to which has since been added three Style-S8 units, thereby changing the interlocking from

For all bridge and bracket signals, the standard is to have a uniform vertical distance of six feet between the center lines of the red lights of the units on any signal. This is to assure, where two or three signals are side by side on the same bridge or mast, that the corresponding lights in the corresponding units of different signals, are in the same horizontal line, thereby presenting a symmetrical appearance. On ground signals, which, of course, stand alone, the standard is to have four ft. between the center lines of the two nearest lights in adjacent units, this spacing being considered the minimum to prevent blending when seen from a distance.



An outdoor sub-station for power used for signals and interlockings

Electric detector locking was provided on all switches using Model-12 electric locks to lock the lever latches. This permitted removal of all detector bars. The original plunger type facing point locks were left in service, and four of these facing point lock levers, No.'s 19, 23, 25, 30, were used as master levers to lock other facing point lock or switch levers, and thereby simplify the route and mechanical locking. Electric approach locking is effective from one track section in the rear of the approach signal for the respective home signal. An illuminated track model board has been installed, indicating whether or not the track circuits within the tower limits, also approach circuits, are occupied. This board also has a direction indicator light in each direction for each track in the tunnel, so that the towerman can quickly tell in which direction traffic is established.



One unit of a three-section relay box at signal LO1

Steel relay cabinets located on the ground floor of the tower house 23 relays, together with the necessary terminals, transformers, and rectifiers. A five-cell storage battery is located adjacent to the cabinets. Five relay boxes within the interlocking limits house a total of 41 relays, four lighting and two insulating transformers, six rectifiers, and 17 lamp resistance units. This does not include the housing existing prior to these changes for the apparatus already in service.

Hoosac Tunnel Signals

Under the old signal layout, the tunnel territory was divided into three blocks, there being only two signals actually in the tunnel for each track. These consisted of two unit color-light signals giving the same aspects as the night aspects on our two-arm Style-B automatic block signals. With the new signaling, the tunnel is divided into five blocks, there being four signals within the tunnel each way for each track, making a total of 16 signals. This of course permits closer spacing of trains through the tunnel. These signals are of a tunnel type, mounted on the side of the wall, and back to back to provide for reverse running. For trains running against normal current of traffic, the signals are at the left side of the track, but owing to the type of cab on the electric locomotives, the visibility is practically the same. The signals are a single unit three-color type, except for the last signal each way before leaving the tunnel. These latter signals have two units, similar to our standard approach signal previously described, except that due to clearance limitations it was not possible to stagger the lights. They act as the approach signals for the home interlocking signals at the portal towers.

During the winter months it is much warmer within the tunnel than out of doors. Hence, on account of this and the prevailing westerly winds, it has been found necessary to put doors on the West Portal from December to March to prevent winds of hurricane intensity traversing the bore. The doors are kept closed all of the time, except for the entrance or exit of trains. During these months, color-light signals, located 1,000 ft. within the tunnel, are placed in service, indicating "red" if the door is closed and "green" if open.

General Description of Signals

Each signal light unit has two 110-volt, 18-watt lamps per indication. A flashing white gas light is used as a marker light at each signal location, in case of power failure or burned out lamps. The power for the entire installation is obtained at North Adams, at a substation just west of the Little Tunnel. From there to West Portal the power line, 3-phase, 2,200-volt 60-cycle, comprises three wires, No. 5 B. & S. gage, run in open line, except through the Little Tunnel, and in the electric zone these wires are supported on crossarms attached to the top of the trolley struts.

Thrugh the tunnel, this line is in a three-conductor No. 5 B. & S. gage wire lead-covered cable. From East Portal it is again run in open wire to the end of the territory. To prevent lightning burnouts in the cable, a three-phase 22-kva., 2,200/2,200-volt insulating transformer is located at West Portal where the line goes from open wire to cable. An oil switch, horn gap arresters, fuse plugs and wire fuses are also located here. A similar installation is in service at East Portal, except that the transformer is five-kva. capacity. The above described power service was in use on the old layout, and it was found to have sufficient capacity for the new work, except for the three-phase five-kva. insulating transformer at East Portal. To provide the desired capacity, the secondary side of the three-phase transformer was disconnected, except for phase B-C, and the transformer operated single-phase. An additional 7.5-kva. single-phase insulating transformer was installed here, tapped on to each side of phase A-C. This resulted in a three-wire two-phase system east of East Portal of sufficient capacity for our needs.

The former signal circuits through the tunnel were in a seven-conductor lead-covered cable. This was retained for some of the new circuits, and in addition a new 14-conductor lead cable was installed. All cables are supported in the tunnel from Monel metal messenger wires, this metal having been found from experience to withstand the highly corrosive action of the gases and moisture. Wherever it has been necessary to tap into the 2,200-volt cable, Noark junction boxes have been used.

New transformers, relays, and relay housings were used inside of the tunnel. Old material taken from the tunnel, which was in serviceable condition, was used on the outside work so far as could be done. The 2,200-110-volt transformers are fused for 1 amp. on the primary side and for 20 amp. on the secondary side. Insulating transformers (110-volt) and track transformers (110-volt) are fused for 10 amp. on the primary side.

Track circuits within the tunnel extend the length of the block, about a mile, and all are center fed. Track relays are 2-position 2-element centrifugal 60-cycle frequency type, having 6 front and 4 back contacts. Owing to afford better return propulsion current facilities. It was not felt desirable to bond them at every location, on account of the liability of loss of broken rail protection at times when the ballast resistance was comparatively high.

The relays are housed in special wooden boxes, built into manholes or niches excavated in the side of the rock wall. The upper two shelves hold the vane-type a-c. line relays and transformers while the lower shelf contains the centrifugal track relays. These boxes

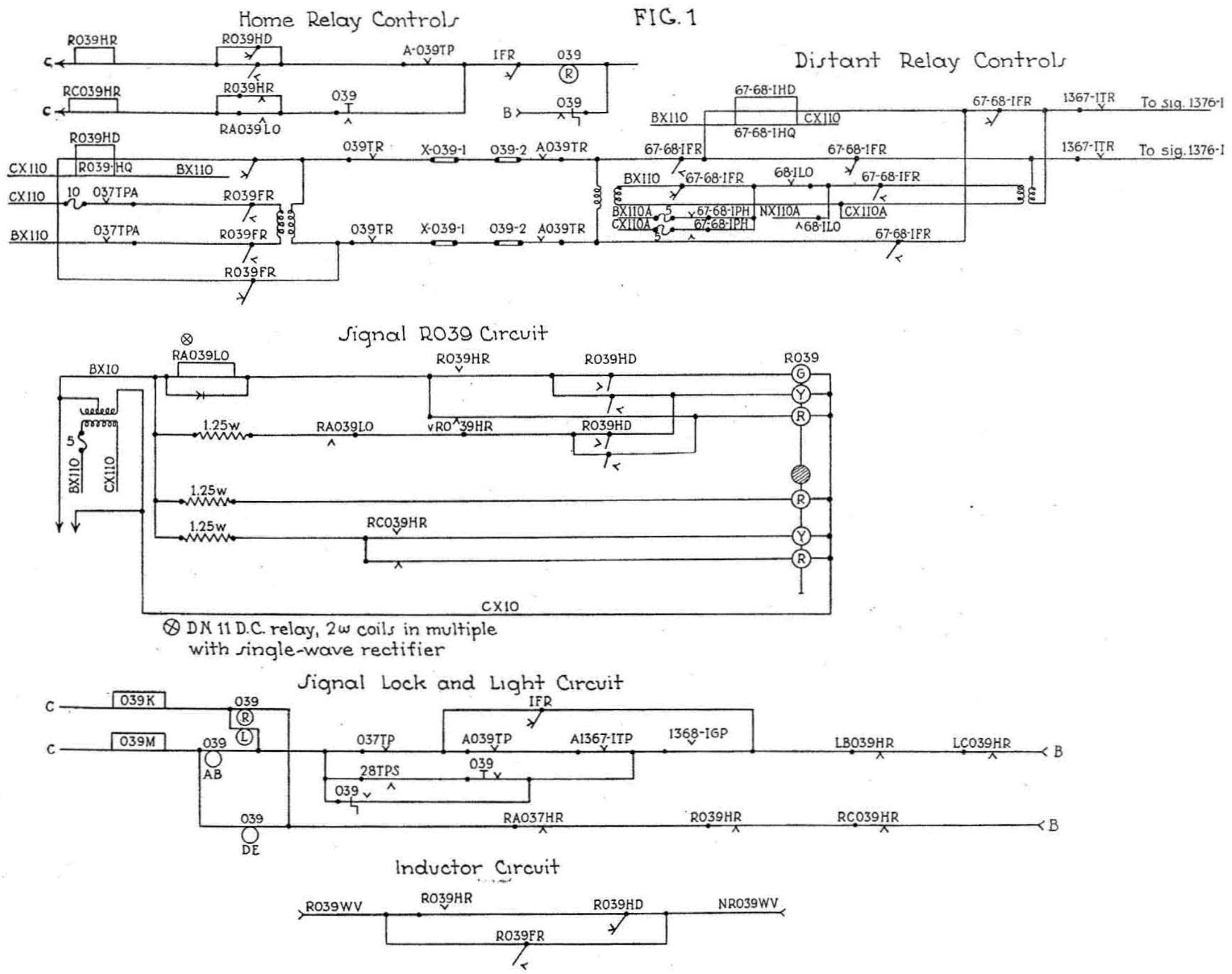


Fig. 1—Major control circuits for signal *R039* which is the westbound entrance signal to the tunnel on track *1*

to wet ballast conditions within the tunnel, particularly at certain seasons of the year, the ballast resistance drops very low, and a careful track circuit study had to be made to assure against signal failures.

The former impedance bonds were located between rails, but for the new work all impedance bonds have been placed between tracks. Provision had to be made to handle fairly heavy current through these. A heavy freight train, drawn by two electric locomotives, might pull a maximum of 5,000-kw. at 11,000 volts, 25 cycles, 0.85 power factor, for 9 to 12 min. This would result in a return current of over 500 amp. per track or 250 amp. per rail, if all the current returned on one track, which would be the case if both rails on the opposite track were out for relaying or other track work. The connections from the bonds to the rails are of stranded No. 0000 cable. The impedance bonds are cross bonded in the tunnel at every other location are all provided with electric lights, as well as receptacles for portable lights, so as to afford all possible assistance to the maintainer in making inspections and repairs. Relays and terminals have been placed so that similar apparatus will occupy corresponding positions in all boxes.

Circuit Features

The circuits for the installation are interesting, but they are too intricate to attempt to reproduce them in an article of this nature. Certain detail circuits fairly typical have been singled out of the circuit structure and are reproduced here.

Figure 1 shows the major circuits for signal *R039*, which is the westbound entrance signal to the tunnel on track *1*. The *R039HR* relay takes d-c. battery through *R039HD* poled normal or reverse, through *A-039TP* closed (an a-c. relay repeating both ends of

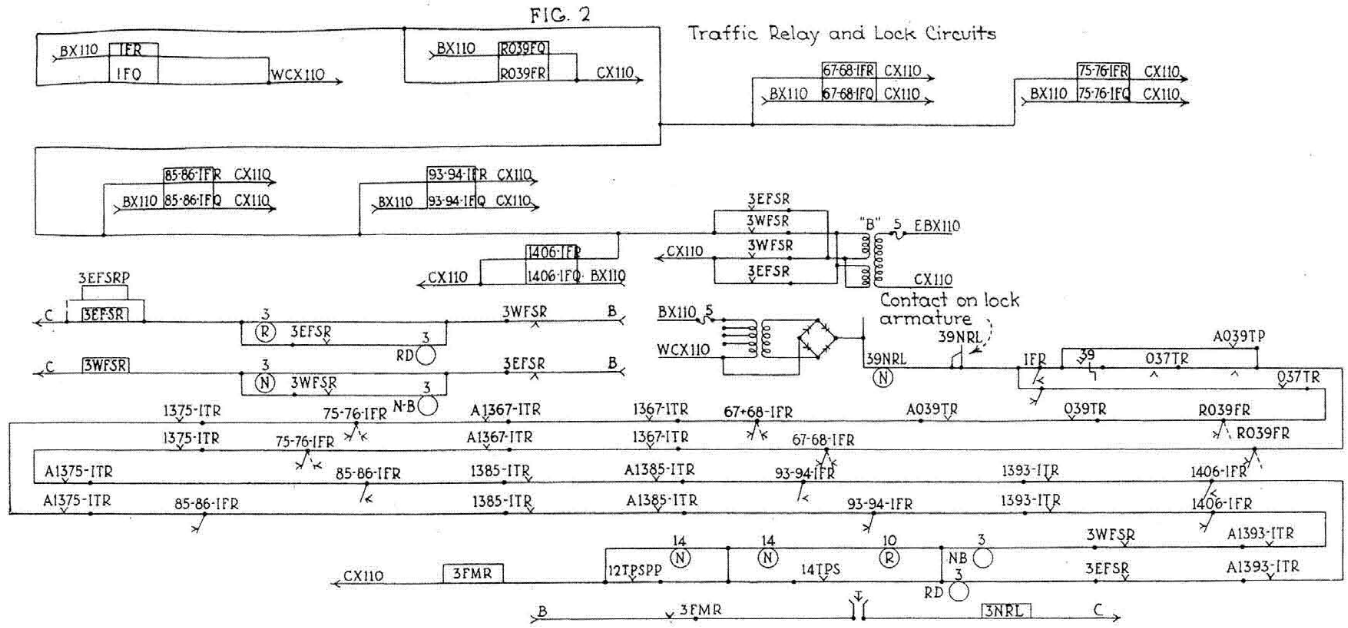


Fig. 2—Principal traffic locking circuits for track *1*

the center-fed track circuit between signals *R039* and *1367-1*), through *1FR* traffic relay poled for westbound traffic on track *1*, through the *R* band on lever *039*, and through time release *039*. The *RC039HR* relay is picked up through, either *R039HR* de-energized or through the *RA039* light-out relay de-energized, then through *039* push button closed, *1FR* track relay, etc., to battery. *R039HD* is a 110-volt double-element polarized a-c. relay. It receives energy through *R039FR* traffic relay poled westbound, through the track relays *039TR* and *A039TR*, through the switch boxes on a hand-operated switch and derail, through the 110/110-volt insulating transformer at signal *1367-1*, through traffic relay *67-68-1FR* poled westbound, then it establishes the polarity of the circuit by going to *BX110A* if *67-68-1HP* is energized, or to *NX110A* if *67-68-1HP* is de-energized. The wire from the other end of the transformer primary goes to *CX110A*. *67-68-1HP* is a slow-acting relay which is energized when relay *67-68-1HD* is poled either normal or reverse. A study of this circuit will reveal that when traffic relays *67-68-1FR* and *R039FR* are poled for eastbound traffic, the same two wires will energize *67-68-1HD* relay, poled so as to take part in clearing signal *1368-1*. If the complete circuits were given, it would be seen that this same relay, *67-68-1HD*, when poled in the opposite direction, would function in clearing signal *1367-1*.

The wiring circuits for obtaining the various aspects are also shown. It will be noted that in connection with the upper unit, a d-c. light-out relay is used in multiple with a copper-oxide rectifier, with the result that in case of a burned out light in the upper unit, the next more restrictive indication will be given. No approach locking is necessary for signal *R039* as there is no diverging route ahead of this signal. The inductor circuit is very simple. When traffic is set up eastbound, the *R039* inductor is maintained closed through a polarized contact on *R039FR* traffic relay, which bridges around the *HR* and *HD* relays.

Figure 2 shows the principal traffic locking circuits on track *1*. Lever *3* in West Portal tower is the traffic lever for this track. In the normal position it picks up a d-c. stick relay, *3WFSR*, to establish westbound traffic. When reversed, it picks up relay *3EFSR* to establish eastbound traffic. These two relays form a pole-changing combination to establish the polarity of the *3F* circuit, which is an a-c. circuit extending from West Portal tower to East Portal tower. At each signal location, a two-element vane-type relay is tapped across this line, thereby establishing a uniform traffic direction at the various signals.

The locking of lever *3* is controlled by *3NRL*, which in turn is controlled by a Model-13 d-c. relay *3FMR*. This relay circuit takes battery at East Portal through a rectifier, and then breaks through traffic lever and lock *39* normal. With *39* lever at East Portal normal, all signals for routes leading to signal *R039* are mechanically locked in the normal position. The *3FM* circuit now splits into two circuits extending the entire length of the tunnel. Both circuits break through every track relay on track *1*, and one circuit breaks through all signal traffic relays poled for westbound traffic, while the other circuit breaks through all signal traffic relays poled eastbound. The westbound circuit also breaks through *3WFSR* relay and lever *3* in the *NB* position at West Portal, while the eastbound circuit breaks through *3EFSR* and lever *3-RD*. From that point, both circuits unite, and break through the track relays between West Portal entrance and the eastbound home signal, except that these relays are bridged out by bands on the mechanical interlocking switch levers when set for routes not leading to track *1*.

This above described circuit functions as (1) detector locking to prevent traffic levers from being reversed unless all track circuits are energized, and also as (2) indication locking to assure that all polarized traffic relays have reversed to establish proper traffic polarity. It should be remembered that to be able to throw electric lever *R039* at East Portal to clear signal *R039* for a westbound move on track *1*, that the mechanical traffic lever *39* must be reversed, and this can only occur after the towerman at West Portal has established westbound traffic by having his lever *3* normal. If the West Portal towerman desires to reverse traffic to eastbound, lever *39* at East Portal must first be placed normal, thereby locking the opposing signals leading to *R039*. Once traffic is reversed to eastbound, lever *39* is locked normal, as *39NRL* circuit (not shown) is made through traffic relay *1FR* poled for westbound traffic. Also, with traffic lever *39* reversed for a westbound move, the lever is kept locked in the reversed position by the occupancy of the track circuits until signal *Ro39* is passed by the entire train.

West Portal Tower

This tower is located about 650 ft. west of the tunnel, and, like the East Portal tower, was built in 1911. The switch and signal layout handled at this tower is, however, considerably smaller. The present equipment consists of a 20-lever S&F interlocking machine, to which has been added 5 Type-S8 electric levers. The new machine scheme for the mechanical interlocking machine is as follows:

3 levers for 5 switches
4 levers for 5 F. P. locks
2 levers for traffic in tunnel
—
9 working levers
11 spare levers
—
20 lever machine

The 5 Type-S8 units operate 8 color-light signals, having 23 operative units and 1 inoperative unit. The three signals adjacent to the tower controlling normal direction traffic were originally mechanical signals handled by levers in the mechanical machine, thus accounting for the present large number of spare levers therein.

As at East Portal, electric detector locking has replaced detector bars. Facing point lock levers *13* and *15* are used as master levers to effect route locking. The five electric time releases required by the circuits have been mounted on the lower part of the steel casing forming the front of the illuminated model board. As shown in the heading photograph, the model board covers the territory from within the tunnel to and including the Sprague's Cabin layout and the approach thereto. A careful inspection of the photograph will reveal two block indicator lights. These are lighted when conditions permit the reversal of the West Portal traffic levers, namely, when the track is unoccupied between the home signal at West Portal governing entrance to the tunnel and the opposing signal at East Portal, and the East Portal traffic lever is in the normal position to permit traffic reversal. No traffic direction lights are provided on the West Portal model board as that information is given by the position of the traffic levers in the tower.

Five single-stroke bells, two westbound and three eastbound, are provided, which announce a train as it enters the approach circuit for the first home signal on each track.

Levers *o3*, *o4* and *o5* are used for traffic locking between West Portal tower and Sprague's Cabin on tracks *4*, *2*, and *1*, respectively. When thrown to the right, they clear signals *Ro3*, *Ro4*, and *Ro5* at Sprague's Cabin, providing the route is clear, and through mechanical locking prevent opposing signals *Lo1* and *Lo2* being cleared. When thrown to the left, they release levers *Lo1* and *Lo2* and hold all opposing traffic at Sprague's Cabin. These levers also control polarized traffic relays located at all intermediate signals. The circuit for traffic relay *o4* is shown in Fig. 3.

Figure 3 also shows the locking circuit for lever *o4*, and it will be noticed that this circuit provides a combination of approach locking and traffic locking. Lever *o4* cannot be restored to normal position from either *L* or *R* with a train in the approach circuit for signal *Ro4*, or with a train anywhere between signal *Ro4* and either signal *Lo1* or *Lo2*, except by use of a time release. Thus once a train enters the territory between these signals complete traffic locking is provided until it leaves the same. Signals *Ro3*, *Ro4* and *Ro5* are semi-automatic non-stick signals, and it is the intention to keep these levers set in the position for normal traffic and not place them normal after the passage of each train.

The photograph of the West Portal of the tunnel (p. 337) shows a real view of signals *Lo1* and *Lo2* and a face view of automatic signal *1406-2*. Just below and to the right of signal *1406-2*, a temporary signal is seen mounted on the strut, while at the left of *Lo1*, the former two-arm westbound mechanical signal can be seen. Both of these signals have since been removed. The pile of loose rock above and slightly to the right of the portal was removed from the tunnel about a year ago, when the floor of the tunnel at the west end was lowered about a foot to permit the passage of large sized freight cars through the tunnel. Before this was done, many cars had to be re-routed on account of close clearances. In the background is Florida Mountain through which the tunnel passes.

Between West Portal and Sprague's, there is one set of automatic block signals, subject of course to traffic control, in each direction. These signals are of the staggered two-unit type now standard for approach signals to home interlocking signals. Signals for all three tracks at a given location are mounted on a bracket mast erected at the right of the outside track. This type of construction was adopted on account of the trolley struts being too light to support the signals. To have installed heavier bridges, would have entailed extra expense and delayed the work.

The three-unit home signals located at Sprague's are upper two units on signals *L1*, *L2*, and *L3*, have been changed since the photograph was taken to provide aspects as shown on the track and signal layout. Like the famous cow which hid the town from travelers on

FIG. 3

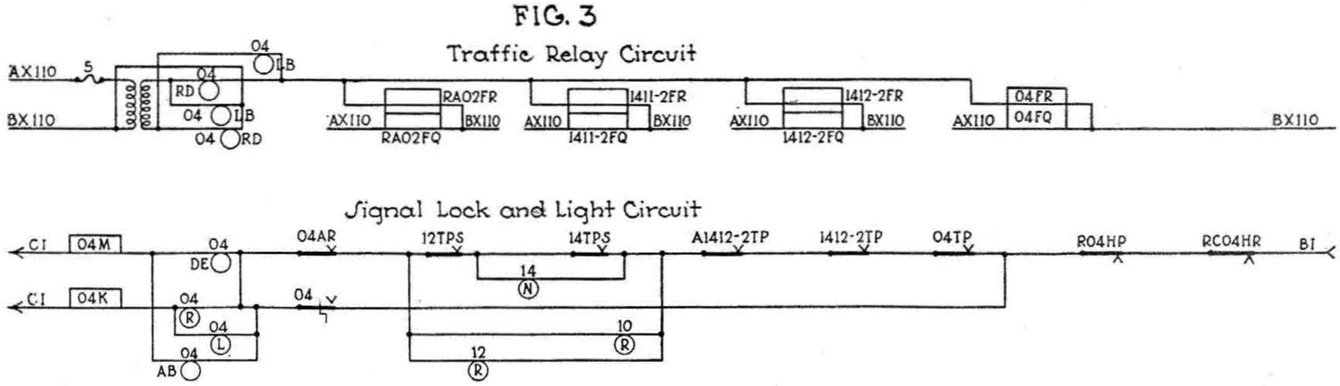


Fig. 3—Circuit for traffic relay *04* which controls signaling between West Portal tower and Sprague's Cabin—Also the locking circuit for lever *04*

a passing train, Sprague's Cabin is hidden by the two electric locomotives. Another picture taken at this signal, shows in detail the mounting of the 2,200-volt line and track transformers, as well as the method of bringing the 3-phase high-tension wires down the side of the strut in conduit.

The track circuits in this territory have much higher ballast resistance, and are all end fed. Until the new work was installed, track *4* had no signals, and this track was used for grounding the struts. A separate ground wire has now been installed, each strut grounded to it, and this wire in turn is tapped to each impedance bond where it passes the same.

Sprague's Cabin

The crossovers and switches at Sprague's Cabin are all hand operated by a ground switchman, who lines them up for the various routes in accordance with instructions received by 'phone from the West Portal train director. A four-lever table interlocker located in his cabin affords complete signal protection over the crossovers. Provision has been made for a future crossover to permit traffic to be routed by signal *R4* from track *2* to track *1*. Complete route and approach locking is provided by the table interlocker. The signals are also broken through "KR" relays, which repeat the position of the crossover switches. As this marks the end of the reverse running territory, the westbound track-circuited units on the home signals all route to track *1*, and the only high signal needed for eastbound movements is signal *R4* on track *2*.

At first glance, automatic approach signal *1424* appears unnecessary, but its purpose is to permit the electric locomotives to stand slightly in advance of it, while waiting for the passenger train which they are to pull into North Adams station, whereupon they can back on to the steam locomotive without waste of time. If it were not for this signal, they would have to wait in advance of signal *R4,* in order to prevent the passenger train from being stopped at signal *1428*. A few further signal changes are about to be made to provide better protection for switching movements between the Little Tunnel and North Adams station, but these will not be considered in this article.

All aerial cables conform to A. R. A. specifications, and, where new messenger wires are used, these are 3/8 in. copperweld. All signal wires have Kerite insulation. Alternating-current mains are No. 6 B. & S., d-c. mains are No. 6 and No. 10, all track transformer and track relay lead wires are No. 9, and switch and signal control wires are No. 14. For relay wiring No. 14 flexible lamp cord is used. Wood conduits and trunking are yellow pine, dipped. Insulated rail joints are 100-lb. continuous type. Although the circuits are mainly a-c., 10-volt Exide storage batteries are provided at the three interlockings for the circuits for which d-c. is used.

Automatic Train Stop

In connection with this project, the seven electric locomotives which handle the tunnel traffic have been equipped with automatic train stop of the G-R-S inductive intermittent type. Before adopting the intermittent type, one locomotive was equipped, and careful tests were made to insure that the heavy 25-cycle return propulsion current would cause no interference with the proper operation of the train stop device. All tests of this nature were successful, no interference being noted. Further tests were conducted to ascertain the maximum permissible air gap between the receiver and the inductor, as well as the "maximum" slow speed at which an engine could pass a stop inductor without receiving a restrictive indication. Tests proved that a failure to receive a restrictive indication would not be obtained until the speed was less than 3/4 mile per hour.

The locomotives are all double-end control, and, hence, had to be equipped with train stop apparatus for reverse running, each cab being provided with all necessary control equipment. A receiver is mounted at the forward right side of each cab, and the proper receiver is automatically cut in, depending upon whichever direction the locomotive is operating. Most of the apparatus is of the same type as used on steam locomotives, although certain modifications had to be made to suit the electric locomotive conditions and type of air brake.

One of the changes in the equipment was to provide for a 6 sec. delay time between the receiving of the restrictive indication and the actual start of the brake application. During an automatic brake application, operating power is automatically cut off of the motors. This is accomplished by breaking the proper power control wire through the 6 sec. delay relay and providing a sealed cut-out switch for bridging around this relay point. This sealed switch is located on the outside of the relay box. The reset device is also located in the cab. The wayside inductors are located about 16 ft. from the insulated joints. Each inductor is placed 2½ in. above the top of the rail, and 21 in. from the gage of the rail to the center line of the inductor. The train stop system is not installed throughout the electric zone, but only from East Portal tower through the tunnel to West Portal tower.

Construction Procedure

With the exception of the train stop apparatus, materials and apparatus for the entire signal installation were furnished and installed by the Union Switch & Signal Company. As the tunnel is a quite hazardous working place for men unfamiliar with it, the construction company took over our leading signal maintainer in that territory, for the duration of the construction work. He served with them in the nature of a guide and pilot, and in turn was enabled to familiarize himself with the new installation far better than if he had remained maintaining the old signals.

All motor car movements through the tunnel are made under authority of the train director, who specifies between what points and time the car may use the track. Telephones are located at each signal, and at certain locations, niches have been cut in the tunnel wall to provide take-offs for motor cars. Needless to say the tunnel is not lighted.

The new work extended over so much territory, and was of such a complicated nature, that it was not feasible to cut it all over from old to new at once. The first change consisted of discontinuing the old automatic block signals in the tunnel, and placing the new ones in service for normal direction of traffic only. The second step consisted of the changes at East Portal tower. As this involved a very extensive change in locking, it was found best to take the tower out of service while this change was being made. During this time, the switches were thrown by hand on the ground, and traffic handled under the direction of a trainmaster. The third change was an extensive one, and included the changes at West Portal tower, the cutting in of the reverse traffic signals in the tunnel, and all of the signals from West Portal to Sprague's. The fourth stage consisted of the work at Sprague's Cabin, together with the approach signals, and this completed the installation.