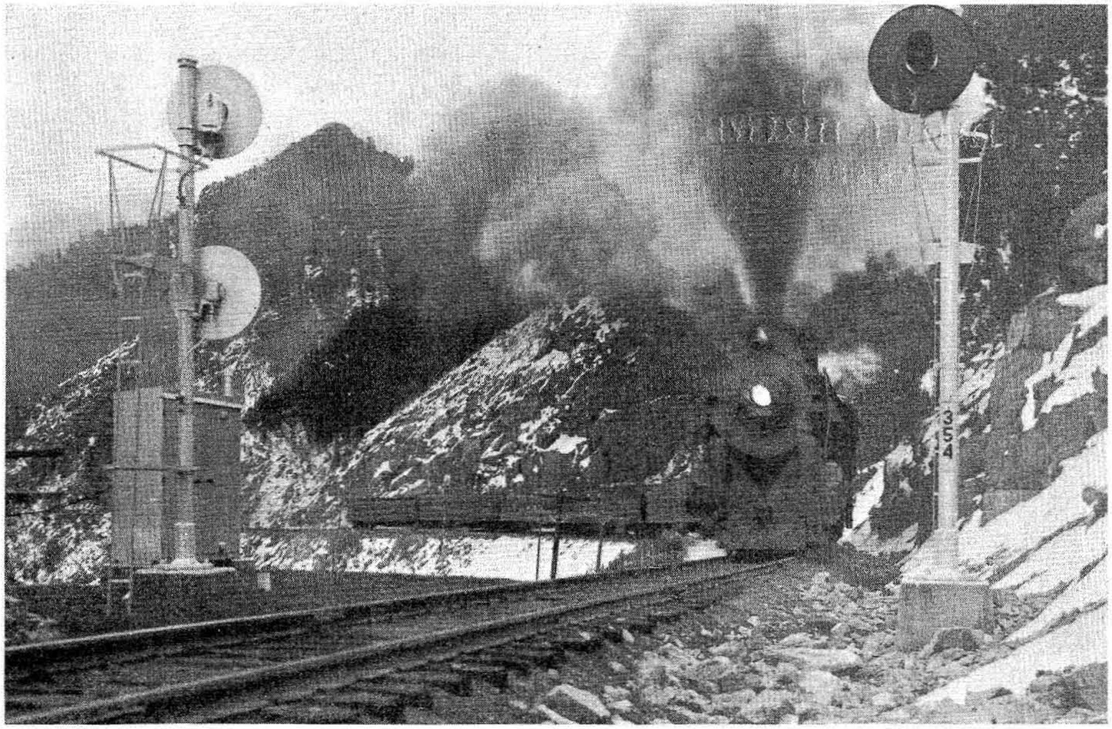
The "Exposition Flyer" westbound ascending the grade approaching signal No. 353 at left which is equipped with operative grade sign



Automatic Signaling and Tunnel Protection

On the Denver & Salt Lake

Coded track circuits, up to 11,180 ft. in length, and headblocks located properly for installation of C. T. C. later—Controlled manual block through 6.2-mile Moffat tunnel

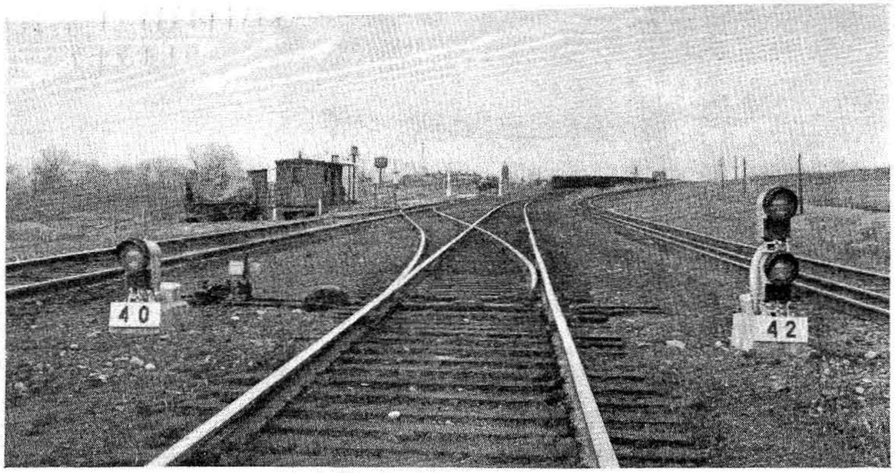
THE Denver & Salt Lake has recently installed automatic block signaling on 4.7 miles of double track and 47.7 miles of single track between Denver, Colo., and the east portal of the Moffat tunnel, and also, track-circuited semi-automatic signaling has been installed for the direction of train movements through the 6.2-mile single-track Moffat tunnel.

The primary purpose for constructing the Denver & Salt Lake originally, including the Moffat tunnel, was to provide a direct route westward from Denver through the Rocky Mountain continental divide to western Colorado, as well as to points beyond. The site of the Moffat tunnel was chosen because of minimum tunnel length under the divide, with portals at elevations which could be reached from Denver and from the west, with lines on which the ascending grade would not exceed 2 per cent, compensated for curvature. From the west portal of the Moffat tunnel, the Denver & Salt Lake extends westward 72 miles to Orestod and then 103 miles beyond to Craig. Also from Orestod, a single-track line of the Denver & Rio Grande Western extends south and west along the Colorado river for 39 miles to Dotsero, Colo., where a connection is made with D. & R. G. W. line between Pueblo, Colo., and Ogden, Utah. Thus, in addition to trains of the D. & S. L., the line between Denver and Orestod is used by those trains of the D. & R. G. W. which are routed into and out of Denver for direct connections to or from western points.

The territory which was recently signaled, extends from Denver to the west portal of the Moffat tunnel. The elevation of the Denver Union Station and various freight yards in that area is approximately 5,280 ft. above sea level, whereas the elevation of the east portal of Moffat tunnel is 9,192 ft. The mileage by rail between these points is 50, but the horizontal distance is only 38 miles. Starting at the west end of double track at Ralston, Colo., 7.15 miles from Denver and at an elevation of 5,258 ft., the single-track main line ascends westward at not to exceed two per cent, compensated for curvature, for 42.95 miles to the east portal. The 127 curves in this mileage represent a total of 5,708 deg. of central angle. The maximum curvature is 10 deg. Between Arena and Clay, there are two 10-deg. horseshoe curves. In addition to the main tunnel through the divide, 29 shorter tunnels, ranging from 300 ft. to 1,700 ft. in length, are located between M.P. 23 and the Moffat tunnel.

Difficulties of Train Operation

In addition to the handicaps of grades, curvature and tunnels, train operation in this territory is all the more difficult during winter months, with moderate snowfall, and temperatures as low as 40 deg. below zero F. Furthermore, the topography is such that from a practical standpoint, passing tracks can be located only at cer-



Dwarf signals 40 and 42 at Zuni where D. & S. L. freight trains enter and leave the main line tracks

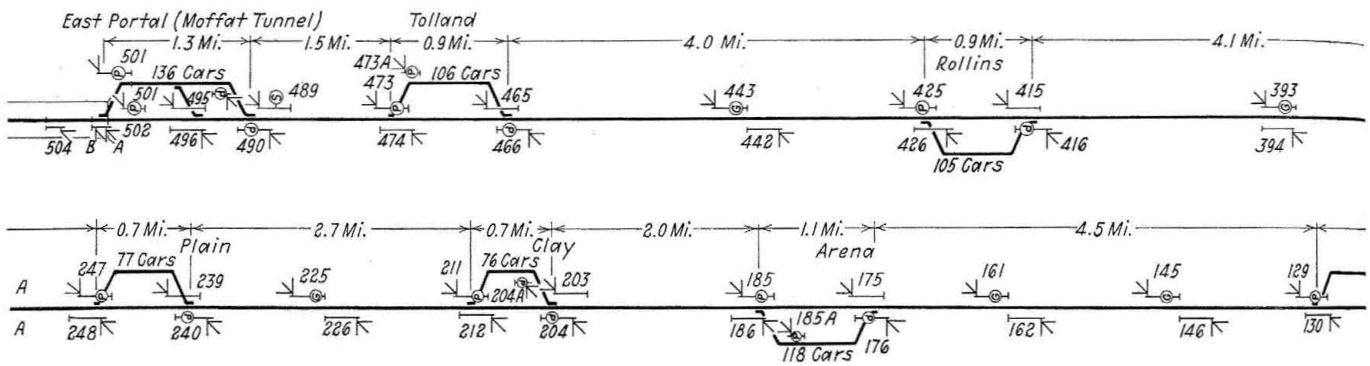


Fig. 1—Track and signal plan of the territory betwee

tain places, with the result that they are not equally spaced as to distance or train time. The locations of the passing tracks and the capacities in terms of freight cars are indicated on the plan. During a 24-hour period, opposing trains are scheduled to make eight meets, and in one instance a westward local passenger train takes siding for a through westward passenger train, in the same direction, to pass. The operation of extra trains increases the number of meets to be made.

On the ascending grades, the passenger train speed is about 25 m.p.h. and the freight train speed about 20 m.p.h. Between Cliff and Plain, passenger train speed is limited to 25 m.p.h. and freight train speed to 20 m.p.h. On the 128.6-mile territory between Denver and Orestod, a total of 8 passenger trains and at least 12 freight trains are handled daily. During the peak season of September and October, as many as 35 trains have been handled daily. Helper locomotives are usually required on ascending grades for freight trains, and, in order to equalize power, the operation of light helper locomotives down the grades increases the number of moves to be handled. The periods of maximum train congestion usually occurs during the forenoon and night. For example, between 10:00 a.m. and 11:30 a.m., there are four scheduled passenger trains and usually two freight between Denver and East Portal. The Ute, a fast westbound Rio Grande freight train, usually takes siding at Cliff to meet the eastward passenger train No. 6, while westbound passenger trains No. 5 and No. 1 are closely following.

Decision to Install Signaling

On account of the increasing importance of this Moffat Tunnel route, a decision was made to install signaling, the first section being between Denver and the west end of Moffat tunnel. For the most part, this installation is automatic block signaling, but certain features were provided so that minimum expense will be required later when changing over to centralized traffic control. The station-entering, station-departure signals and track circuits are located properly for future C.T.C. Future OS sections are provided with one track relay on the main line, and a second track relay on the passing track. The signal circuits are controlled indirectly by both of these relays by means of a repeater relay. The advantage of this arrangement is that broken bonds or broken rails on the fouling section will be detected, whereas an ordinary shunt fouling does not provide such protection. The switch circuit controller on each passing track switch does not shunt the track circuit, but contacts in the controller are connected to operate a switch repeater relay.

The signals on this project are of the searchlight type, using the standard color aspects, red, yellow and green. The 250-ohm d-c. operating coil of each searchlight signal is line controlled, thus obviating the use of a signal control relay. Except for unusual instances, to be explained later, the automatic signals are controlled by the conventional A.P.B. system to display positive Stop aspects for opposing station-to-station train moves, and permissive aspects for following train movements. Each station-leaving positive signal which displays the Stop aspect, Code Rule 292, is so designated by a reflectorized sign, displaying the letter "P," this sign being mounted on the mast below the operative signal unit.

The automatic signals are line controlled in the usual manner, using one control line wire in each direction, in connection with a common control line wire. The short track circuits at detector sections at switches are of the conventional d-c. neutral type. The remainder of the track circuits, with certain exceptions, are the d-c. coded type, using codes at the rate of 75 per minute. One reason for using coded track circuits was to minimize the number of track circuits; the lengths of these coded track circuits range up to 11,180 ft. A second advantage of the coded track circuits is that, in the future when converting this project to centralized traffic con-

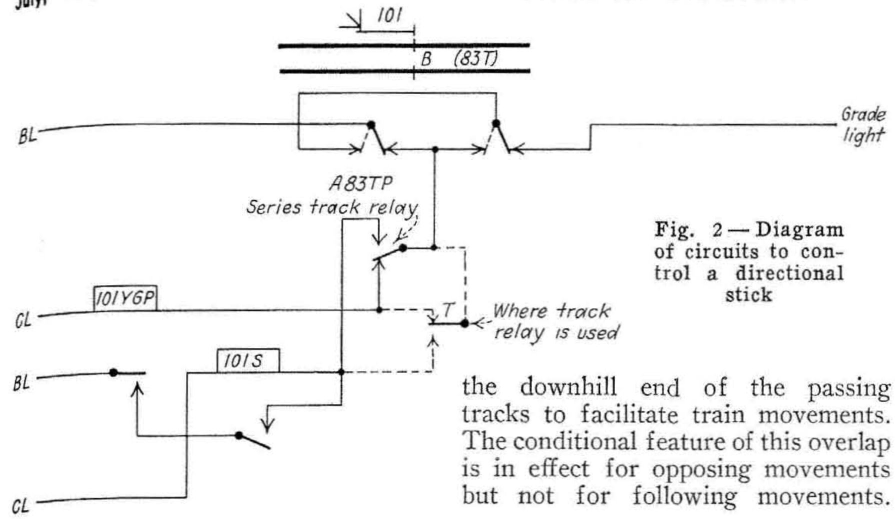
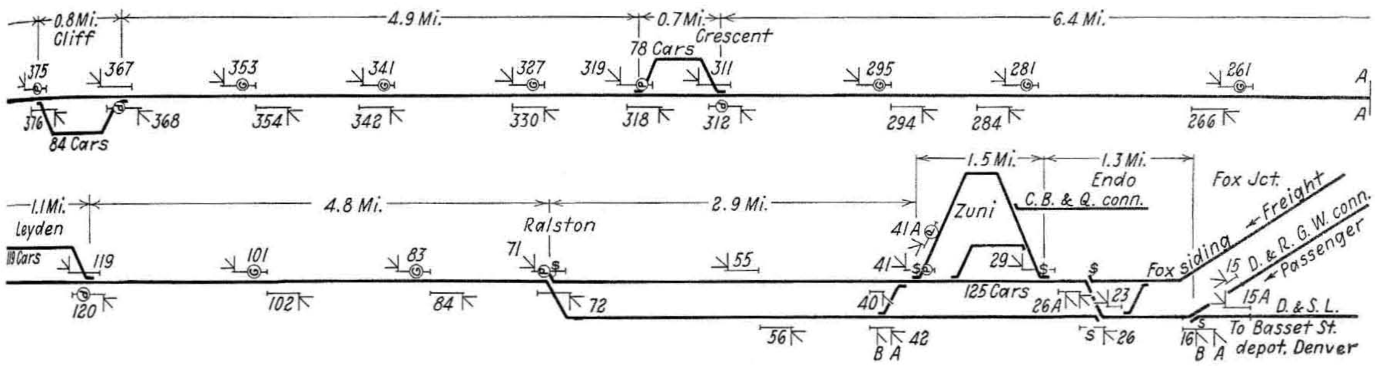


Fig. 2 — Diagram of circuits to control a directional stick



Denver and the east portal of Moffat tunnel

trol, the automatic control of the signals can be accomplished by track circuit code equipment exclusively, and the three line wires, now used for line circuits, will be utilized for transmission of control codes and indication codes as applied to C.T.C. The automatic control of the signals will require additional track circuit code equipment.

Approach and Successive Approach Aspects and Down-Hill Overlaps

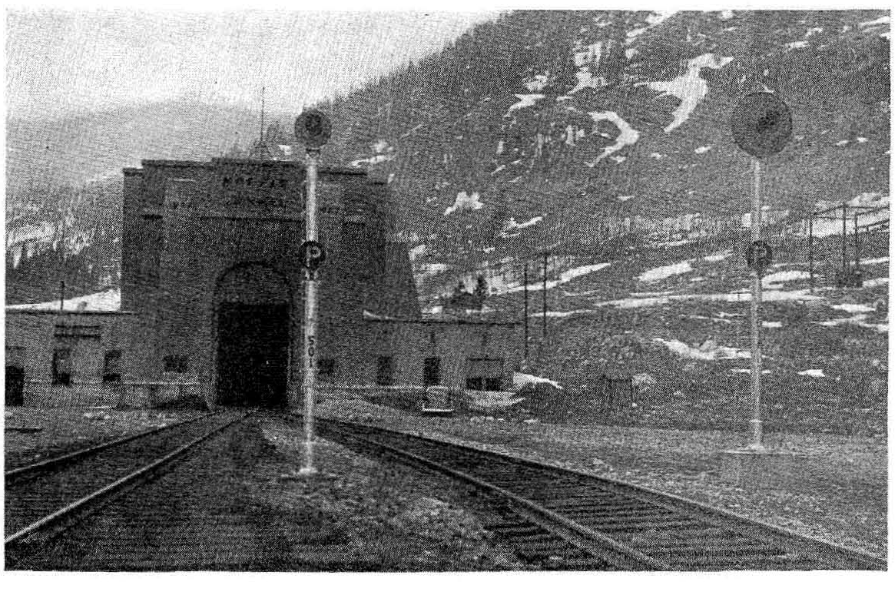
For following train movements, the signal in approach to one which is displaying the "Red" aspect, displays the "Yellow" aspect, "Approach." For opposing trains, approaching a passing track, however, two successive signals display the "Approach" aspect, in approach to a station-departure signal which is displaying the "Stop" aspect. In the territory involved, the grade is descending eastward and the eastward station entering signals are normally overlapped on the downhill side. This overlap is conditional and is on the downhill end of the passing tracks to facilitate train movements. The conditional feature of this overlap is in effect for opposing movements but not for following movements.

Control of Intermediate Stick Relays Save Contacts

A circuit, designed to reduce the number of contacts required, was used for the pick-up and hold-up of the stick relays required in the directional control of the A.P.B. system. As shown in Fig. 2, the pick-up circuit for 101S stick relay starts with BL which feeds through contacts in the searchlight mechanism, which are closed when either the yellow or green aspect is displayed, then through a front contact of A83TP, a series approach track relay, to the coils of 101S and to common CL. When the 120 yellow-green repeater relay is released, as a train passes the signal, the holding circuit is through a back contact of YGP, a front of the stick relay, the coil of 101S and to CL. This circuit obviates the use of contacts in various relays as required in the conventional stick relay pick-up and hold-up circuit.

Variations in Arrangements of Intermediate Signals

Various factors were involved in determining the number and exact locations of the intermediate automatic signals. As mentioned previously, the passing tracks are not spaced evenly on a basis of distance or train time. Braking distances for west-bound trains on ascending grades are entirely different from braking distances for eastbound trains descending the grade. Furthermore, on account of the mountains, curves and tunnels, intermediate signals had to be placed at certain locations to



View of the east portal of Moffat tunnel with signals 501 and 501A provide sighting distances as long as possible.

The distance between the west switch at Plain and the east switch at Crescent is 6.5 miles, and three intermediate signals are provided for each direction. The distance between the west switch at Leyden and the east switch at Arena, 4.7 miles, and two intermediates are provided for each direction. The distance between the west switch at Clay and the east switch at Plain is 2.9 miles, and one double intermediate location is used. The distance between the west switch at Arena and the east switch at Clay is 10,600 ft., and no intermediate signals are used. Where three or two intermediate signals are provided for each direction between passing trucks, the controls are conventional. Where only one set of adjacent intermediate signals is provided between passing tracks, the green indication of the station-departure signal is conditionally over-lapped through the track circuits in the limits of the next station layout.

As shown in Fig. 3, the control of the coil for the westward station-leaving signal 211 at Clay extends through contacts of the pole-changer relay of the intermediate signal 225. The control of this 225PC extends through front contacts of the track relay in the station limits at Plain, which constitutes the station overlap. Thus an eastward train when occupying this overlap at Plain causes westward signal 211 at Clay to display the Approach aspect. On the other hand, when a westward train occupies the station overlap at Plain, a directional stick relay shunts out the overlap contacts so that signal 211 displays the green aspect in the usual manner for following trains. The stick relays required for this arrangement include an eastward stick at the east end of Plain to cut out the green overlap of signal 211, and a westbound stick at the intermediate signal to shunt out the front contact on the YGP relay so that signal 211 displays the yellow aspect in the usual manner for following moves.

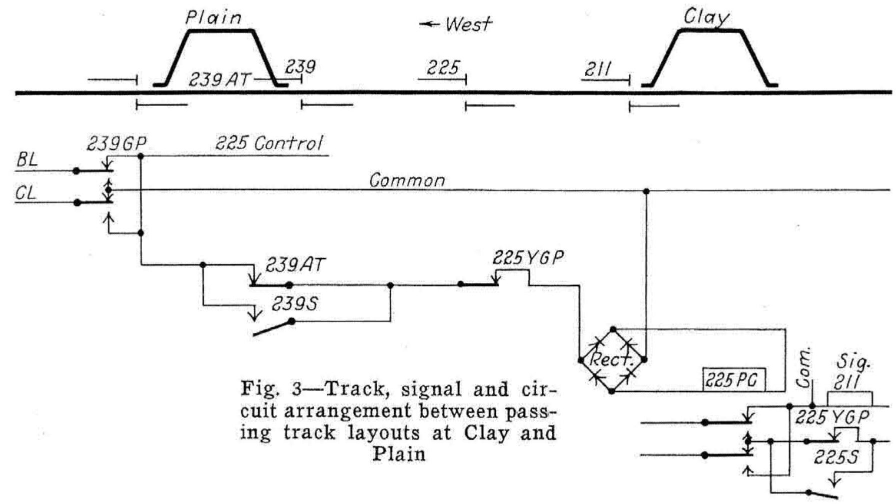


Fig. 3—Track, signal and circuit arrangement between passing track layouts at Clay and Plain

With no Intermediates

Between Arena and Clay, where no intermediate signals are used, special signal arrangements are provided, as shown in Fig. 4. The main line within signal limits at Arena is cut into two track circuits, 175BT being the one to the west. Opposite this cut section location, and to the right of the track, is a sign reading: "Signal Overlap Limits," and rules provide that westward trains which are to hold the main line for a meet at Arena are to stop short of this sign, and wait for the other train.

If a westbound train passes this sign and cut section, the eastward station-leaving signal 204 at Clay is set to display the Stop aspect. On the other hand, when an eastbound train passes signal 204 at Clay, the westward signal 185 at Arena is set to display the Stop aspect. Likewise, if an eastbound train on the passing track at Clay throws the switch and clears the eastward leave-siding dwarf 204A, the signal 185 at Arena displays the Stop aspect.

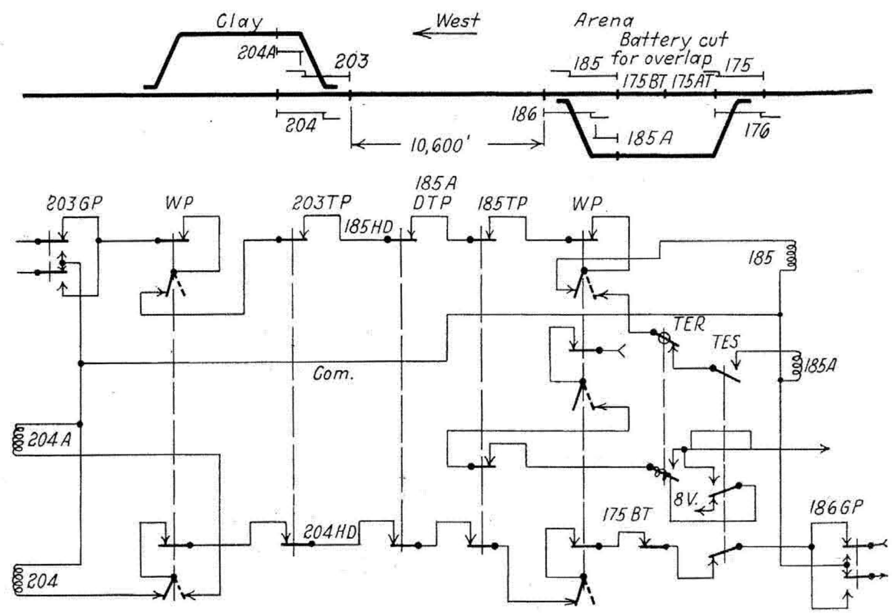
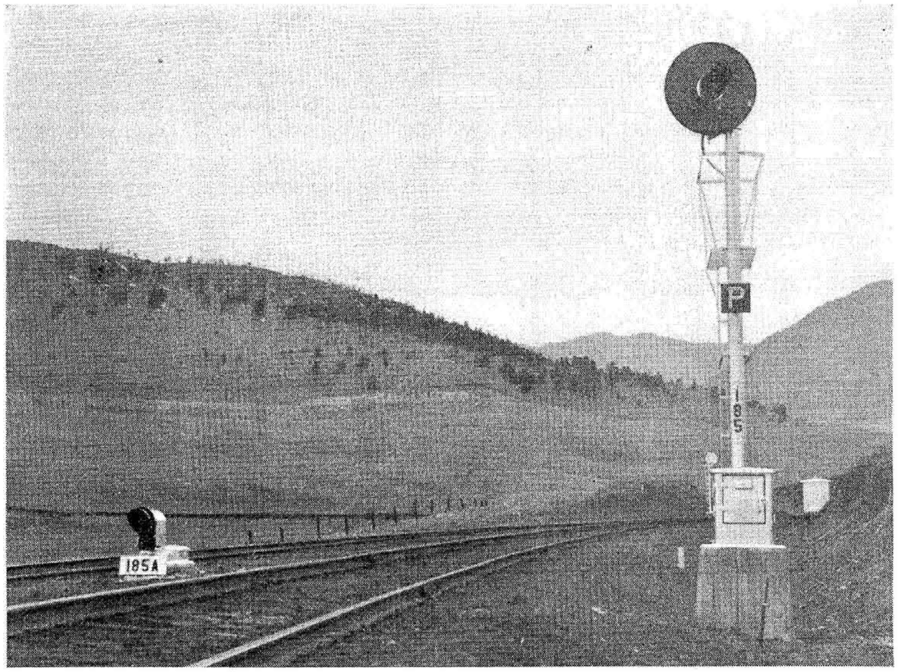


Fig. 4—Track layout and circuits between Clay and Arena

Operation at Arena

This arrangement presents a problem in getting a westbound train out of the passing track at Arena. Since there is no track circuit on the passing track, an overlap into this track for the control of signals 204 and 204A cannot be used. If a westbound train on the passing track at Arena has rights by time-table or train orders to depart, a trainman reverses the switch, which causes eastward station-leaving signal 204 at Clay to display the Stop aspect and signal 204A cannot be cleared. Time locking is provided so that the westward leave-siding dwarf signal at Arena will not clear for 45 seconds after the switch is thrown, which would allow adequate time for any eastward train which may be approaching signal 204 at Clay to stop short of that signal, or, if the train overran the signal, then the controls of westward signals 185 and dwarf 185A at Arena would be opened by track occupancy.

Under the circumstances explained, when the switch at Arena is thrown, 10 seconds are required to heat the thermal coil of a relay, after which a time-element stick relay is energized and opens the heating coil. Thirty-five seconds is required for the heat-



High signal 185 and dwarf 185A at west end of Arena

ing coil to cool and close the check contacts. Then the westward dwarf signal 185A will clear.

Grade Signals Controlled Directionally

Each of the westward intermediate automatic block signals on the 2 per cent ascending grade is equipped with a "grade" signal, which consists of a normally-extinguished lamp unit, with a standard sized background, mounted on the mast 6 ft. below the main searchlight signal unit. The cover glass of this "grade" signal has the letter "G" etched in the surface, and, when operative, displays a yellow light to outline the letter "G". A grade signal is lighted only when a westbound train is occupying the block controlled by the signal, and when the main unit is displaying the Stop-and-Proceed aspect. The "Stop-and-Proceed" aspect and the grade light authorize a following westbound train to pass the signal at a speed not to exceed 8 m.p.h, without stopping at the signal. This rule applies to passenger as well as freight trains. The control of the grade signal is directional, i.e. for an opposing train, the "grade" lamp is not lighted. This feature is accomplished by extending the control through contacts of a directional stick relay.

Advance Train-Order Signals

At some layouts, such as, for example, Cliff, the train-order office is located a considerable distance from the east switch of the passing track. Between the switch and the office, the track curves around a bluff so that the train-order signal cannot be seen by the engineman of a westbound train until he is within a few hundred feet of the office. When the operator has orders for an approaching westbound train, and sets the train-order signal accordingly, a yellow lamp is lighted to outline a letter "T" in a normally-extinguished signal unit which is mounted on the mast of the west-bound station-entering signal at the east switch. The "T" aspect will not be lighted unless the main signal unit is displaying a yellow or a green aspect. When the westbound "advance train-order" signal is lighted, the eastbound entering signal automatically goes to stop. When this "T" aspect is displayed, the engineman of a train has advance information that he is to pick up orders at the station and may hold the main line. Thus these "advance" train-order signals which are used at seven locations, are an important factor in reducing unnecessary train delays. An important point, with reference to the advance train-order signals, is that they are mounted 6 ft. below the automatic signals, so that there can be no confusion between the aspects of automatic and the train-order signals.

At most train-order offices, indicators are provided to warn the operators of the approach of trains from either direction. Three indicators of the enclosed disk type are provided in each office. One indicator displays a red spot aspect when a train is occupying the track circuit in approach to the westward station-entering signal, and a second indicator displays a red spot aspect when a train is occupying the track circuit in approach to the eastward station-entering signal. These track circuits range from 1.5 to 1.75 miles in length. A third indicator in each office can be connected to either east or west signal control through a double-pole, double throw switch, operated by the operator. When this indicator displays the red spot aspect, the operator knows that a train has passed the station-departure signal at the next town adjacent to him. The indicators at each office are fed from a set of five cells of 500 a.h. primary battery.

Operation of Coded-Track Circuits in Automatic Signaling

The code for each track circuit consists of impulses 0.4 seconds long of direct current fed through a series resistor from one cell of storage battery. The coding is accomplished by an oscillating type code transmitter, which is a device constructed somewhat on the principle of the balance wheel of a watch. On a vertical shaft, there is an arrangement of weights and a coil spring such that the shaft rotates back and forth 120 deg. of revolution, with 75 operations clockwise and 75 operations counter-clockwise each minute. Normal variations in the voltage of the operating battery do not affect the period of oscillation of the code transmitter.

Each code transmitter is in operation normally, motion being initiated and continued by energization from the 8-volt coil of a magnet which rotates the shaft to the extreme clockwise position, at the same time winding the coil spring. When in the clockwise position, contacts are closed to feed the current impulse to the rails, and likewise the circuit for the operating coil is opened so that the coil spring takes effect and rotates the shaft to the counter-clockwise position, at which location contacts shunt the track circuit for 0.4 seconds. In the meantime, the contact in the operating coil circuit has been closed, and, as soon as the force of the spring is spent, the force of the magnet swings the shaft again to the counter-clockwise position.

The rail joints are bonded with railhead bonds. On about half the mileage, Raco mechanically applied bonds are used, while on the remainder of the territory the Cadweld welded bonds are used. At the relay end of each coded track circuit, a 0.1-ohm relay is connected to the rails. A two-point relay is used where track circuits do not exceed 7,000 ft. in length and a one-point relay with a two-point 140-ohm code-repeater relay is used on longer track circuits. When the track circuit is not occupied, the track relay is energized and released 75

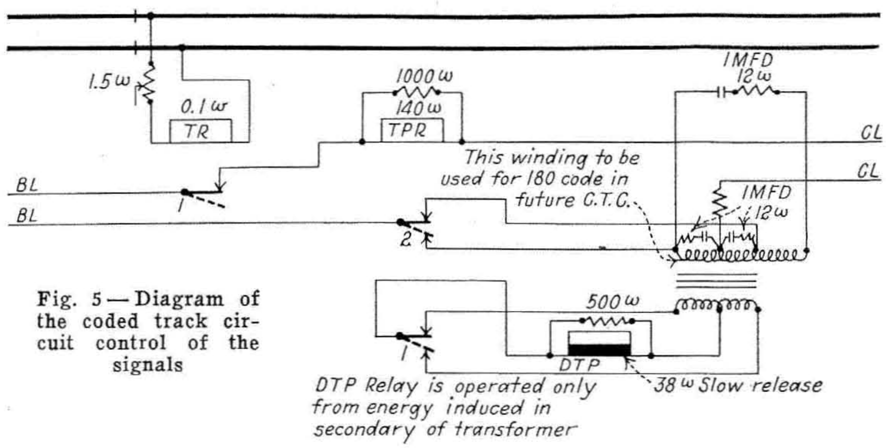


Fig. 5—Diagram of the coded track circuit control of the signals

times each minute to follow the code. A front contact of this TR relay completes a circuit for the coil of a repeater relay TPR, rated at 140 ohms. As shown in Fig. 5, the "upper" finger in the TPR relay feeds direct current to first one and the other of the two primary coils of a transformer, at the rate of 75 per minute. The "bottom" finger of relay TPR acts as a mechanical rectifier to take the energy from the secondary of the transformer and produce uni-direction impulses of direct current at the rate of 150 per minute, which serve to pick up and hold the 38-ohm DTP relay in the energized position, so long as code is being received at the rate of 75 per minute by the code-following track relay TR. The signal circuits check the contacts of relay DTP, in the usual manner. Steady current to hold relay TR energized, will not result in relay DTP being energized because of the arrangement of connections to the transformer.

Capacitors as well as resistors are connected across the primary coils of the transformer, to reduce arcing and radio interference at the contacts of relay TPR. Also, resistances are used across the coils of relays TPR and DTP.

Traffic Direction Signaling Through the Moffat Tunnel

Formerly the train movements through the single-track Moffat tunnel were directed by absolute manual block, between the office at East Portal and the office at Winter Park, which is 3,000 ft. west of the west portal. The operators at these stations worked under the direction of the dispatcher when clearing their respective manual block signals to authorize trains to enter the tunnel. In the new signaling arrangement as shown in Fig. 6, searchlight type signals direct trains to enter and use the tunnel. These signals are controlled automatically by track circuits throughout the length of the tunnel and also manually by cooperation on the part of the operators at East Portal and Winter Park.

The switch at the west end of the passing track at East Portal is operated by a lever in a mechanical interlocking machine, and a second lever is used to operate a facing-point lock on this switch. Signal 501 controls westward moves on the main line from this signal through the tunnel to Winter Park. If the switch is reversed, signal 501A controls westward moves from the passing track through the tunnel. At Winter Park, the switch at the east end of the passing track is hand-thrown. The eastward signals are 566 and 566A to control moves through the tunnel to East Portal.

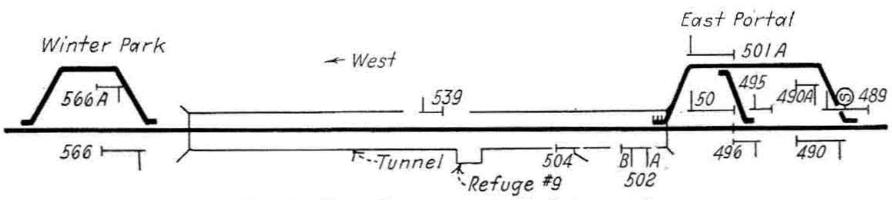
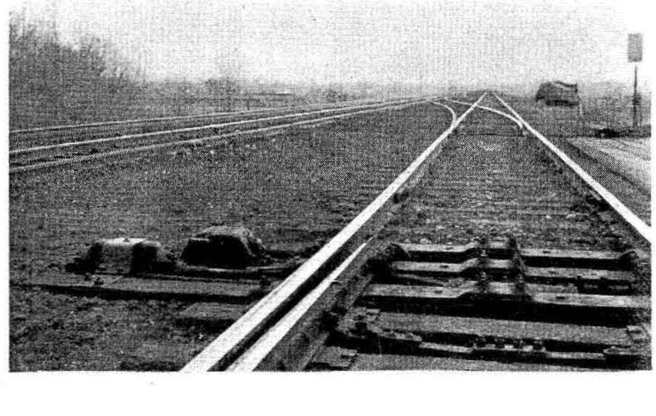


Fig. 6—Signaling through Moffat tunnel

The signaling is arranged to handle one train movement at a time through the tunnel. The operation of two trains in the same direction in the tunnel at the same time is not practical, not only on account of the effects of locomotive smoke on engine crews but also due to the fact that enginemen could not, under all conditions, see the signals due to the density of smoke and fog. The signaling, therefore, is set up for a full length, track-circuited control, absolute block, East Portal to Winter Park, or Winter Park to East Portal.

Operation of the Control Machines

A miniature-lever control machine is provided at each of these offices. By means of a buzzer code, the two operators can coordinate their controls when a train is to be operated through the tunnel. The buzzer controls are on a special simplex circuit which was superimposed on the existing telephone line circuit. For example, if signal 501 is to be cleared for a westward train, both operators set their respective "Traffic" levers to the westbound position. The result is that code is fed to the track at the west end, Winter Park, and is repeated through from one track circuit to another to decoding equipment at East Portal, thus energizing a relay which lights a lamp to indicate to the operator that traffic is established westward. Then he can operate his signal lever to clear westward signal 501, and the signal will clear, providing the coded control from the west end is still being received at East Portal. On the other hand, if traffic is to be established eastward, both operators set their traffic levers in the eastbound position, and code is fed from East Portal



A spring switch layout showing the plates and the rail braces

through the track circuits to Winter Park, so that an eastward signal, 566 or 566A, can be cleared by the operator at Winter Park.

Normally, the track coding equipment is not in operation, and can be set in operation to be effective to clear

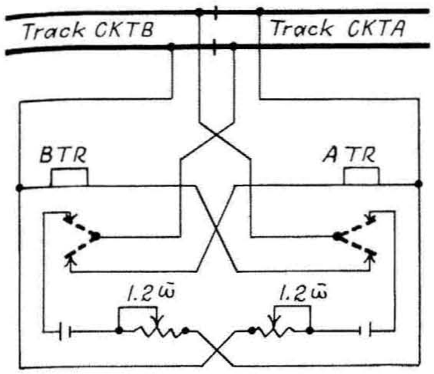


Fig. 7—Cut section in tunnel

a signal, only when fed all the way through from one end of the tunnel to the other. Thus the two rails, when not occupied by a train, are used as conductors to transmit coded energy. With any track circuit occupied, no signal can be cleared to authorize a train to enter the tunnel at either end.

As shown in Fig. 7, each of the code-following track relays is normally de-energized, and the coils of relay B, for example, are connected through back contacts of relay A to the rails of track circuit B. When coded energy comes in from the west on track circuit B, relay B is energized and released to follow the code, but relay A remains de-energized. Energy from a set of two cells of primary battery in multiple feeds through front contacts of relay B to send impulses of energy on eastward over track circuit A. If relay A is operated by code coming in on track circuit A, the reverse operation takes place. Thus two relays and two sets of battery are required at each repeater track cut location.

Low Ballast Resistance

Except where insulated joints are required, the rails are welded together throughout the length of the tunnel. For this reason, bond resistance is not a factor. However, due to the dampness, locomotive smoke, cinders and salt brine, the ballast resistance is extremely low, ranging from 10 to as low as 0.5 ohms per thousand track feet. For these reasons, the track in the tunnel was cut to make 10 coded track circuits, maximum length 4600 ft. On account of the low ballast resistance, when the energy of a code impulse is cut off, the collapse of the magnetic flux in the coils of a code-following track relay induces a current to flow through the coils and the ballast. This action retards the release of the relay. This effect, however, was overcome by using code that is effective for only ½ sec. to energize a relay, and is cut off for 1½ sec. to permit release of the relay. The code transmitters are of the oscillating type, and operate 60 times per minute. The producton of code, which is feeding for ½ sec. and off for 1½ sec. is accomplished, as shown diagrammatically in Fig. 8, by a code transmitter and two code-following relays.

The code transmitter CT, swings to the right for ½ sec., and then to the left for ½ sec. Relay CT1 picks up with the first right swing of the code transmitter. With CT1 up, the first left swing of the code transmitter causes relay CT2 to be energized. With CT2 up, the next right swing of CT shunts the 125-ohm resistor in the CL lead of relay CT1 and the relay drops. On the next left swing

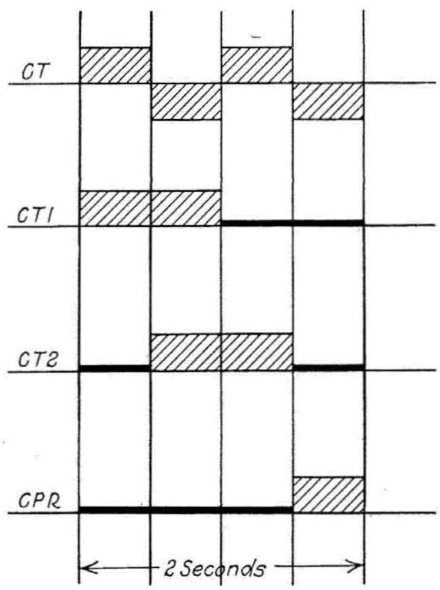


Fig. 8—Code production

of CT, CT2 drops and CPR picks up, energizing the track for ½ sec. On the next right swing of CT the 2-sec. cycle starts over again.

As this code is repeated through the track circuits and cut sections, the effect of the ballast resistance to increase the release time of a relay brings about a total effect that, in half the distance through the tunnel, the code is converted to about 1 sec. on and 1 sec. off. At the mid-point in the tunnel, i.e. the apex, there is a decoding and recoding station. The incoming track code to the apex station operates a code-following track relay, as shown in Fig. 9. When this relay is energized by the first incoming impulse, a relay FP, "front contact" repeater, is energized, and due to its slow-release characteristics it remains energized as long as it gets an impulse of current every two seconds. When the code-following track relay releases, with relay FP up, a circuit is closed to energize "front-back" repeater relay FBP, which likewise has slow-release characteristics so that it remains up as long as it gets an impulse once in every period of two seconds. With both FP and FBP picked up, a circuit is closed from battery to operate an oscillating code transmitter which, in combination with a set of CT1, CT2 and CPR relays, as explained previously, causes coded energy, ½ sec. on and 1½ sec. off, to be sent out on the rails to be repeated through the track circuits and cut section repeaters to the far end of the tunnel. The one code transmitter at the apex station produces a code for either direction, depending on the controls established by the code coming into this location.

This code transmitter as well as all the relays are normally de-energized. At each cut section, as well as at the apex location, a set of two 500-a.h. primary cells in multiple provide energy to feed direct current for the coded impulses to the track in each direction. The code transmitter and various control relays at the apex location are fed from a set of 16 cells of 500 a.h. primary battery. Thus all of the electrical energy required inside of the tunnel is supplied from primary batteries, so that no power distribution circuits are required. Therefore, the only wiring for the signaling system inside the tunnel includes connections from the rails to instrument cases and battery boxes, as well as wiring inside

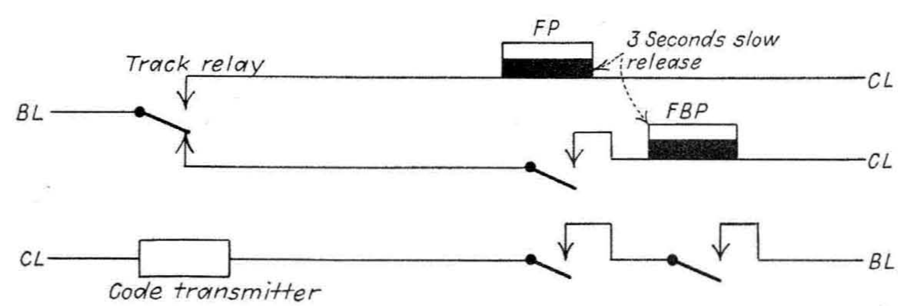


Fig. 9—Decoding at apex in the tunnel

these housings. Cast-iron relay cases were used, and were coated with pitch to minimize corrosion.

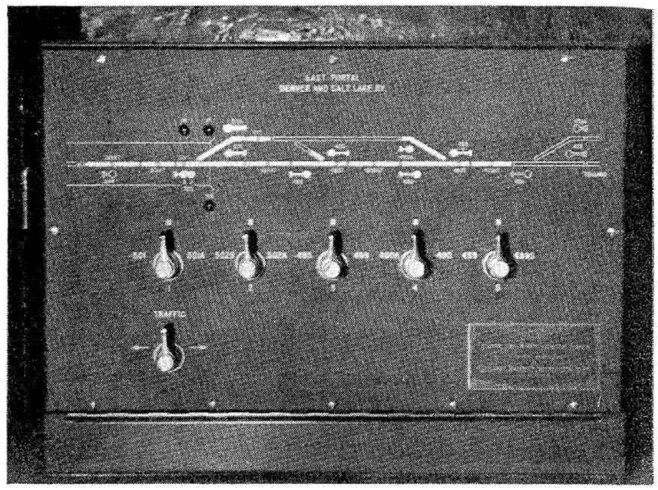
Signals in the Tunnel

Inside the tunnel the grade ascends at 0.3 per cent from East Portal to the center of the tunnel, and from there the grade descends westward at about 0.8 per cent to the West Portal. Helper locomotives are not required in the tunnel for westward trains, but a helper, usually coupled at the rear, is required on each eastward tonnage freight train, between Winter Park and the apex of the tunnel. After passing the apex, the train is stopped, and two minutes are allowed for uncoupling the helper, then the train proceeds.

From the controls explained previously, obviously no second eastward train could get a signal to enter the tunnel until both the helper and the leading eastward train have departed from the tunnel signal limits. Thus, a westward dwarf signal at the apex location, to authorize the helper locomotive to return from the apex to Winter Park can be controlled separately from the over-all end-to-end tunnel control. After an eastbound train with a helper on the rear has departed from Winter Park, the operator sets his traffic-direction lever at the westbound position, which causes the code to be sent out on the rails eastward toward the rear of the departing train.

As shown in Fig. 10, when the head end of the train occupies the last track circuit in approach to the apex location, the code sent westward from East Portal causes an AR relay, in series with the battery being fed to that track circuit, to be coded, which picks up an "AR" stick relay, and this relay sticks up through a back contact of the FP relay, which is one of the decoding relays for a westbound code from East Portal and is de-energized as soon as the head end of the train passes the apex. When the helper passes beyond the apex, the FBP relay for the eastbound code from Winter Park picks up, and in turn picks up a GR relay which causes the westward dwarf at the apex to display a yellow aspect. This authorizes the helper to return to Winter Park. This dwarf signal is normally extinguished for through westward moves, and displays a "yellow" aspect only under the circumstances explained previously.

Eastward dwarf signal 504, located 900 ft. from eastward signal 502AB, provides "distant" signal aspects for signal 502A. Signal 504 displays a green aspect only if 502A is yellow or green, and 504 displays yellow if 502A is red. Signal 504 does not display a red aspect. As a warning to enginemen of trains in the tunnel, that they are approaching a portal, a special dwarf signal is located 1,750 ft. from each end. Such a signal is controlled to flash a white light 30 times per minute as a train approaches. This control is accomplished through the track circuits explained previously by use of a relay in series with the track feed.



Panel of control machine in office at East Portal

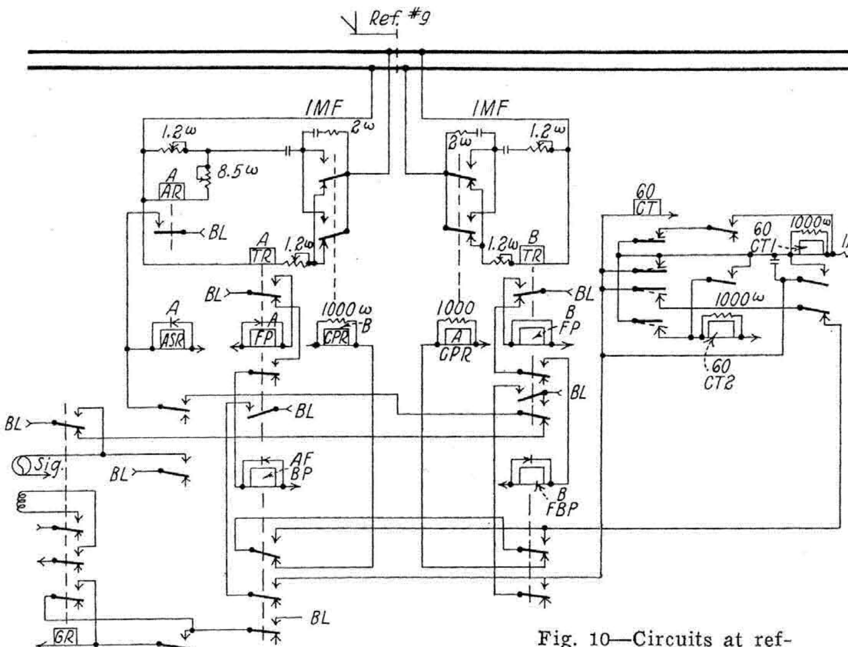


Fig. 10—Circuits at refuge 9 in the tunnel

The switch at the west end of the passing track at East Portal is operated by a two-lever mechanical interlocking machine. As explained previously, a miniature lever machine in the East Portal office controls the traffic direction as well as the two westward tunnel entrance signals 501 and 501A. This same machine also controls the eastward two-arm dwarf signal 502AB, which is just inside the tunnel, for directing eastward trains on the main line or into the passing track.

The switch at the east end of this passing track as well as the crossover between the main line and this passing track are all hand-thrown. The westward signals for the main line and for take-siding at the east end of the passing track are controlled by the miniature lever machine in the East Portal.

Ralston, West End of Double Track

The switch at the west end of Ralston, which is the west end of double track, is equipped with an oil-buffer spring mechanism. Eastward signal 72, normally displays a green aspect to govern train movements on the diverging route over the No. 18 turnout to the righthand eastward track, the spring switch being set normally for this route. Westward automatic signal 71 normally displays the green aspect for the Ralston-to-Leyden overall block for opposing moves, or a permissive aspect for following westbound train movements.

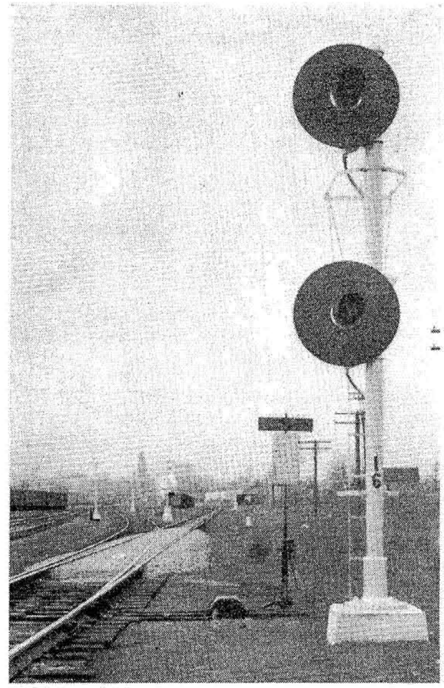
At Zuni, a turnout equipped with a spring switch mechanism, extends from the westward main track to the D. & S. L. freight yard. This lead is used by freight trains of that road when entering or leaving the main line. The westward main line signal 41 is normally clear. When the operator at Zuni wants to line up for a westbound D. & S. L. freight to depart from the yard, he throws a knife switch, which causes signal 41 to display the Stop aspect, and signal 41A to clear, if the track ahead is unoccupied. Eastward two-arm dwarf signal 42A-B normally displays a green aspect in the top arm. When an eastbound D. & S. L. freight train is to move into the yard, the crossover is reversed, and the dwarf 42A-B displays an aspect of red-over-yellow, while at the same time, signals 41 and 41A display the Stop aspect.

At Endo, which is the east end of double track, both switches of the crossover are equipped with oil buffer spring mechanisms, and the switches are lined normally for a westbound train to be diverted from the single track to the double track. The tail track, which is an extension of the westward track to the east, is the lead used by Rio Grande freight trains when entering the westward main track. Signal 26 and signal 23 at Endo normally display proceed aspects on automatic control.

The east end of the new installation is at Fox Junction, located about 1.5 miles west of the Denver Union Station. The switch at Fox Junction is equipped with a spring buffer operating mechanism, and the switch is lined normally for the diverging route to the left, as approaching from the west, this being the track lineup used by Rio Grande passenger trains enroute from and to the Union Station. The straight track, from Fox Junction eastward, leads to the D. & S. L. passenger station. Normally the signals 15 and 15A, as well as the top arm of 16A-B, display proceed aspects. All westbound trains of both the D. & S. L. and the Rio Grande stop for orders at Prospect, one-half mile east of Fox Junction. As a westward train, for example, on the D. & S. L. approaches Fox Junction, approach track circuits are shunted which set signals 16A-B as well as 15A at the Stop aspect. Likewise, a Rio Grande westbound train would set 16A-B and 15 at the Stop aspect. When an eastbound train approaches Fox Junction, signals 15 and 15A are set to display the Stop aspect.

Power Supply and Pole Line

A new crossarm was installed on each pole of the existing pole line. This arm carries three No. 8 wires for the control of signals and two No. 4 wires for the 550-volt, single-phase, 60-cycle, power distribution. The wires are hard-drawn copper with weatherproof covering. At each location, a 0.25 kv.a. 550-110 volt transformer is mounted on the cross-arm. Low-voltage transformers in the instrument housings provide voltages for feeding the signal lamps normally and for operating rectifiers for charging storage batteries, which are rated at 80 a.h., and are the Exide Type DMGO-9. Four such cells are provided at each signal and one cell feeds each track circuit. The primary battery used to feed the indicators at the train-order offices, and also the primary cells used in the tunnel signaling, are rated at 500 a.h. Edison primary cells are used with the exception of those on the track circuits in the tunnel which have AR relays in series, LeCarbone 619-A air-depolarized cells being used on these circuits.



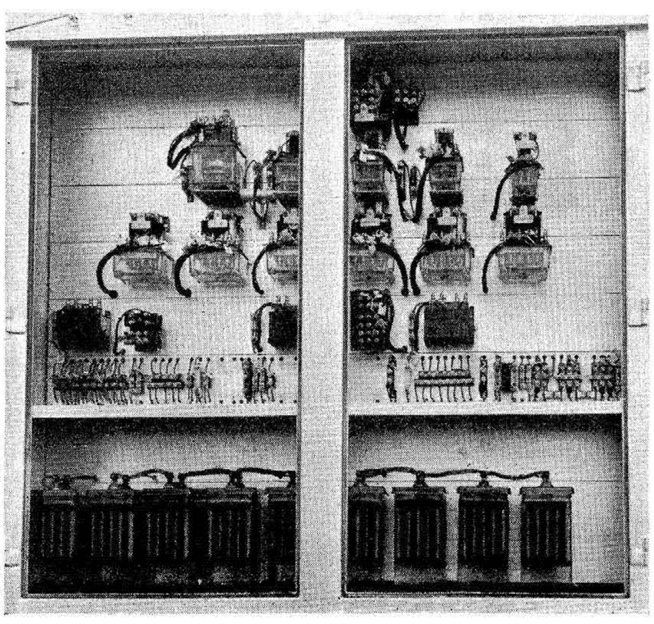
Signal No. 16 at Fox Junction

The automatic block signals are normally lighted through transformers from the a-c. power, but, if this supply fails, the signals are lighted from the storage batteries, using approach control circuits. Various approach lighting schemes are used, such as, contacts in track relays, series line relays and series track relays. With a train on a passing track such as at Leyden, the ordinary approach control lighting would not be effective to light signal 129. In such instances, the equivalent of approach lighting is effected by a small switch in the telephone booth, which is operated by a trainman when the train is ready to depart. The grade signals are fed from battery, with a control circuit as shown in Fig. 2.

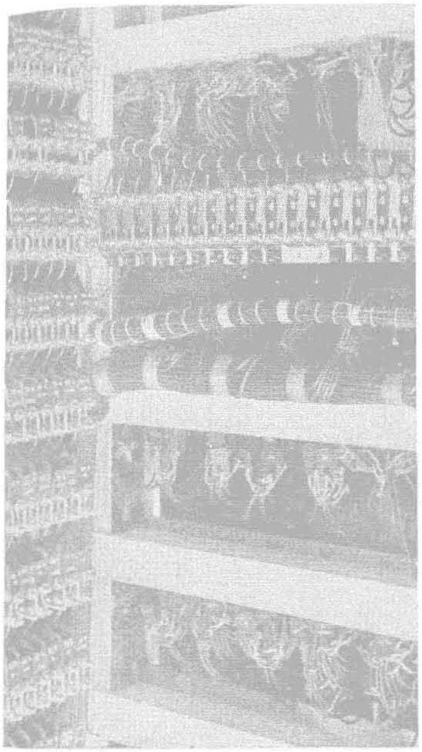
Instrument Houses

At each end of each passing track, a 6-ft. by 8-ft. welded sheet-metal house includes the relays, rectifiers, batteries and other equipment. Adequate space is provided for additional relays and batteries when C.T.C. is installed. The outer door of each house leads to an entry way, with a second door leading to the interior of the house. This entry way serves as a telephone booth, the outer door being locked with a switch padlock and the inner door with a signal lock. At

(Continued on page 367)



At the intermediate signals the relay and batteries are housed in big sheet-metal cases inating "flipping," false closed and open contacts and other trouble, the main reason for which this type of relays were provided in this installation. The track relays are of the 4-ohm, PN-50 type, with four front-four back and eight front-eight back contact combinations. The line relays are 550-ohm, PN-50 type with the same contact combinations as the track relays. The polar relays are of the PP-51 type, 800 ohms, with eight normal and eight reverse contacts. The thermal relays are of the 10-volt, PT-52 type, with one front and common contact. Other relays used on



Wiring at rear of relay panel

this installation, a few of which are also located in the house, include DN-11 track, DP-20 track, DN-18 line, DX-13 line, DT-10 line, ANL-40 power off and DN-22-P power off relays.

All of the underground cables entering the house, which are Kerite parkway with mummy finish and no metallic content, are terminated on a terminal board behind the relay rack. Each cable is pot-headed and the individual conductors extend to standard Raco terminals, from which point other conductors are distributed to the relay sockets where they are soldered in place.

Power Supply

Commercial power at 110 volts, 60-cycles, a-c., is received at the crossing. The main operating battery at the crossing for relays, signals, etc., consists of eight cells of Edison A4H, nickel-iron-alkaline, rated at 12 volts, 160 a.h., on floating charge from a Union RT-42 copper-oxide line rectifier. Track circuits on the Nickel Plate are straight primary battery fed by three cells of Edison Type 1002, 1000-a.h. primary battery in multiple. Track circuits on the D. T. & I. are a-c. primary, fed by three cells of Edison Type 1002, 1000-a.h. primary battery in multiple, across which is wired an RT-5 track rectifier. The rails on both roads are bonded with Thermet-Weld bonds. Connections to the rails are made with Union Type-U bootlegs and single-cable bootleg connections welded to the rails.

Construction by Railroad Forces

This installation was installed and placed in service by the D. T. & I. under the supervision of T. W. Burns, signal foreman, under the direction of P. L. Forbes, superintendent of telegraph and signals and W. G. Clinton, signal engineer. The Nickel Plate distant signals were installed by the forces of that road. The circuits, plans and major items of signaling equipment were furnished by the Union Switch & Signal Company.

Signaling on the Denver & Salt Lake

(Continued from page 361)

the intermediate signal locations, the relays and batteries are housed in large-sized, double-door, sheet-metal cases. The terminals, fused cutouts, bootleg outlets and various other accessories on this installation were furnished by the Railroad Accessories Corporation. The insulated wires and cables are of Kerite manufacture, outer covering of the underground cable is of the mummy type, with no metal. Sections of 4-in. fiber conduit were installed in the concrete foundations when they were poured in place. The cables are brought up through these conduits into the cases or houses. At signals, the cables extend up through the masts, and, near the top, out through fittings to the searchlight units.

The rail through this territory is 100 lb., and Rail Joint Company armoured type insulated joints are used. Each hand-throw switch is equipped with one 1-in. by 8-in. insulated gage plate, with adjustable rail braces, and each spring switch is equipped with three insulated gage plates and adjustable rail braces. The switch circuit controllers are equipped with spring devices which, in case the connecting rod becomes disconnected, will operate the controller to the center position. The cables from a switch circuit controller extend through a section of discarded air hose and down into the ground. A special fitting is provided on the case of each switch circuit controller so that the end of the air hose can be clamped in place.

Switch-Position Protection

At the passing track switches, all of which are hand-operated, the contacts in the switch circuit controller operate a switch-repeater relay. At outlying spur tracks, the contacts in the switch circuit controllers shunt the track circuits. At each of the five switches, which are equipped with spring switch mechanisms, two switch circuit controllers are used, one connected to each of the two switch points. The circuit for the control of the switch relay controlled through contacts of these two switch circuit

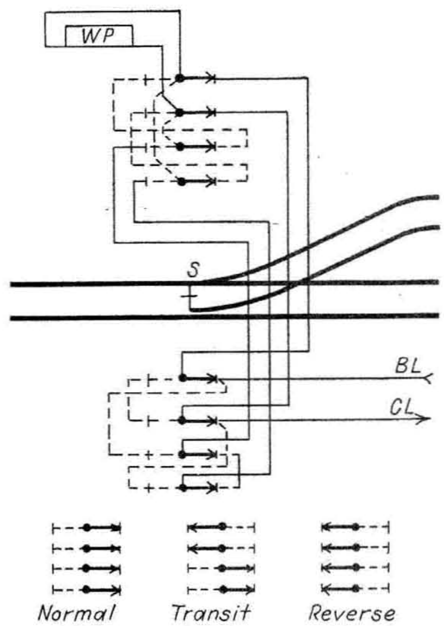


Fig. 11—Controller connections at a spring switch

controllers is shown in Fig. 11. If the normally-closed switch point is open more than ¼ in. or if the normally-open switch point is open less than 3-in., the relay is released. In order for the relay to be energized to repeat the reversed position of the switch when hand-thrown, the normal point must be open at least 3 in., and the reverse point must be closed within ¼ in. of the stock rail.

This installation was installed by the D. & S. L. forces under the jurisdiction of B. W. Molis, signal engineer. The major items of signal equipment were furnished by the General Railway Signal Company.