

The C.T.C. control machine at Denver is located on the sixth floor of the Denver National Bank building

Project on 123 miles of single track and 5 miles of double track includes automatic control of signals by normally-deenergized coded track circuits without the use of signal control line wires

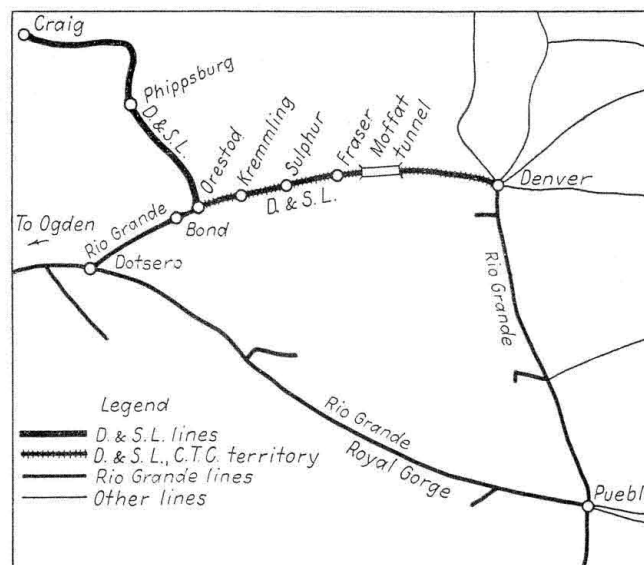
C. T. C. on 128 Miles

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

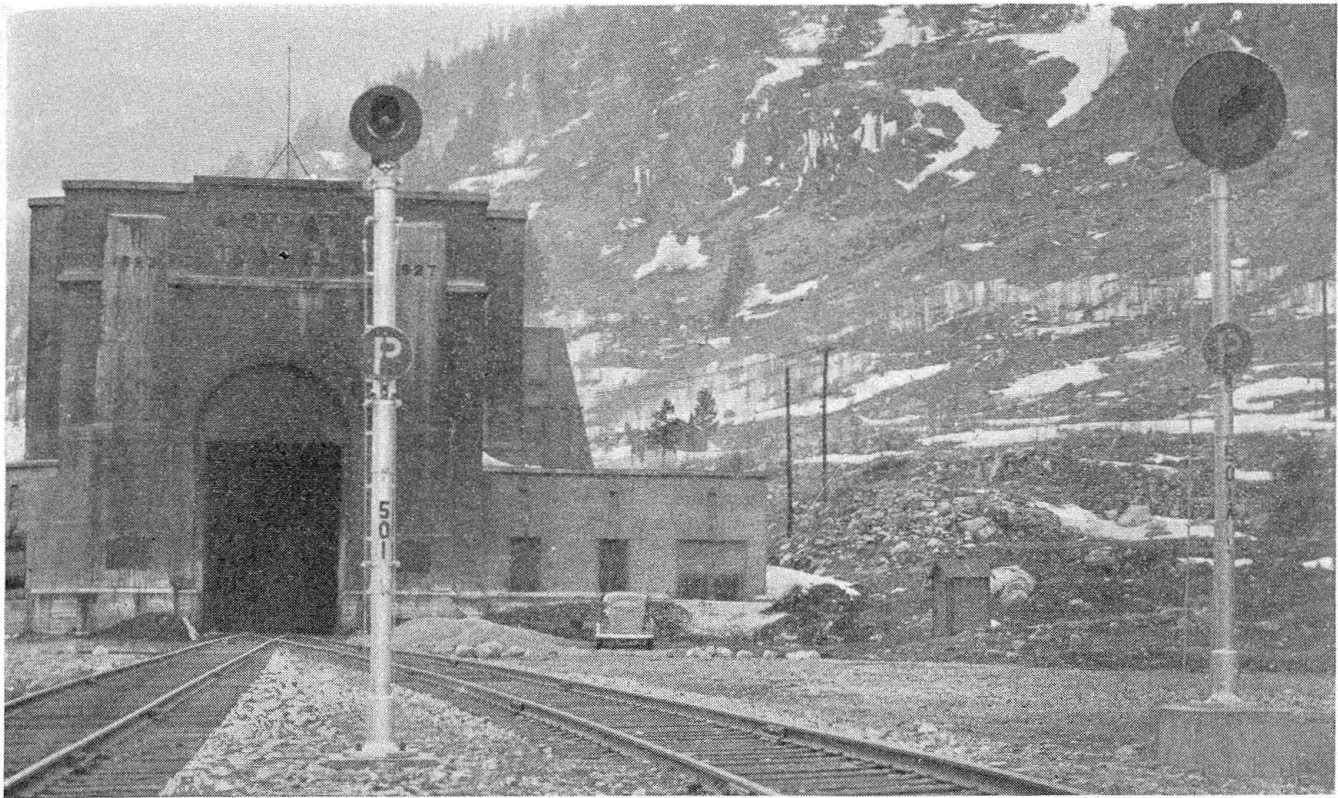
Craig. Also from Orestod, a single-track line of the Rio Grande extends south and west along the Colorado river for 39 miles to Dotsero, Colo., where a connection is made with the Rio Grande line between Pueblo, Colo., and Salt Lake City and Ogden.

THE Denver & Salt Lake has recently completed an installation of centralized traffic control on 122.5 miles of single track and 4.7 miles of double track between Denver, Colo., and Orestod, a total of 127.2 miles. The territory involved is shown in two accompanying maps.

The purpose for constructing the Denver & Salt Lake, 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



Map showing relationship of D.&S.L. lines to Rio Grande lines, as well as new C.T.C. territory between Denver, Colo., and Orestod on the Denver & Salt Lake



East portal of 6.2-mile Moffat tunnel at East Portal, Colo. Signals 501 and 501A are shown in the foreground

of Denver & Salt Lake

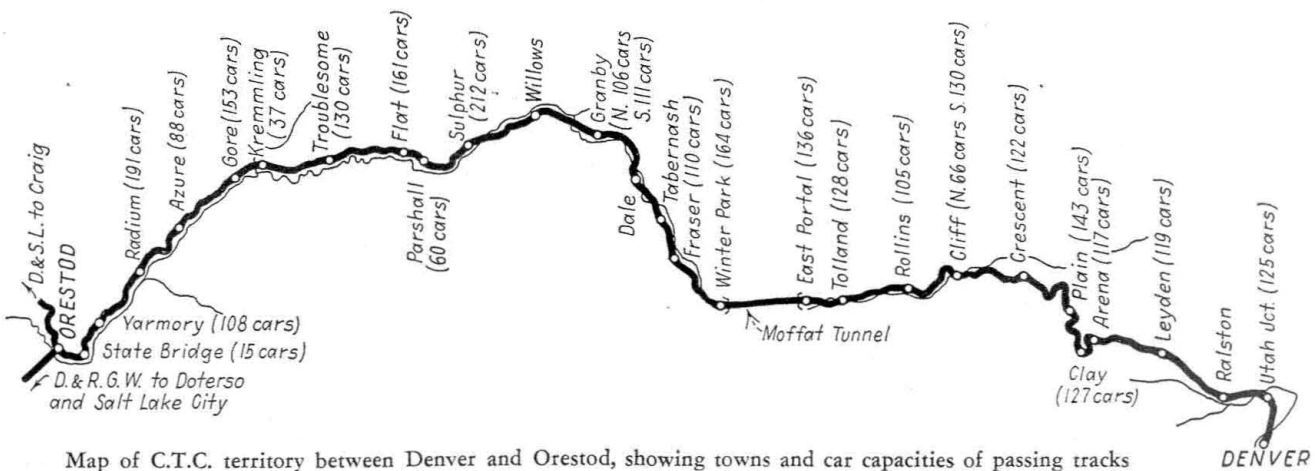
Utah. These lines are illustrated in the accompanying map showing the relationship of D. & S. L. lines to Rio Grande lines. Thus, in addition to trains of the D. & S. L., the line between Denver and Orestod is used jointly by those trains of the Rio Grande which are routed into and out of Denver for direct connections to or from western points.

The operating freight district for

the Rio Grande is between Burnham (Denver) and Bond, 131.2 miles. The Rio Grande uses the jointly operated track between Prospect, one mile west of Denver Union Terminal, and Orestod, 0.6 miles east of Bond. The operating freight district for the Denver & Salt Lake is between Utah Junction (Denver) and Phippsburg, 164 miles. Between Prospect and Endo, 1.4 miles, the line is single

track. Within this territory is Fox Junction where interchange is done between the Rio Grande, D. & S. L., C. B. & Q. and the C. & S. Two main tracks extend from Endo to Ralston, a distance of 4.7 miles.

The maximum grade westward from Denver to East Portal is 2 per cent compensated, and is a helper district. From Orestod eastward to the Moffat tunnel, the eastward ruling grade is 1 per cent, with exception of Tabernash to Winter Park with the maximum grade of 2 per cent, which is a helper district. The line rises 4,169 ft. and falls 2,539 ft. in 128.7 miles between Denver and Orestod. The maximum curvature in the line is 12 deg., with one exception, which is a short 15-deg. curve.



Map of C.T.C. territory between Denver and Orestod, showing towns and car capacities of passing tracks

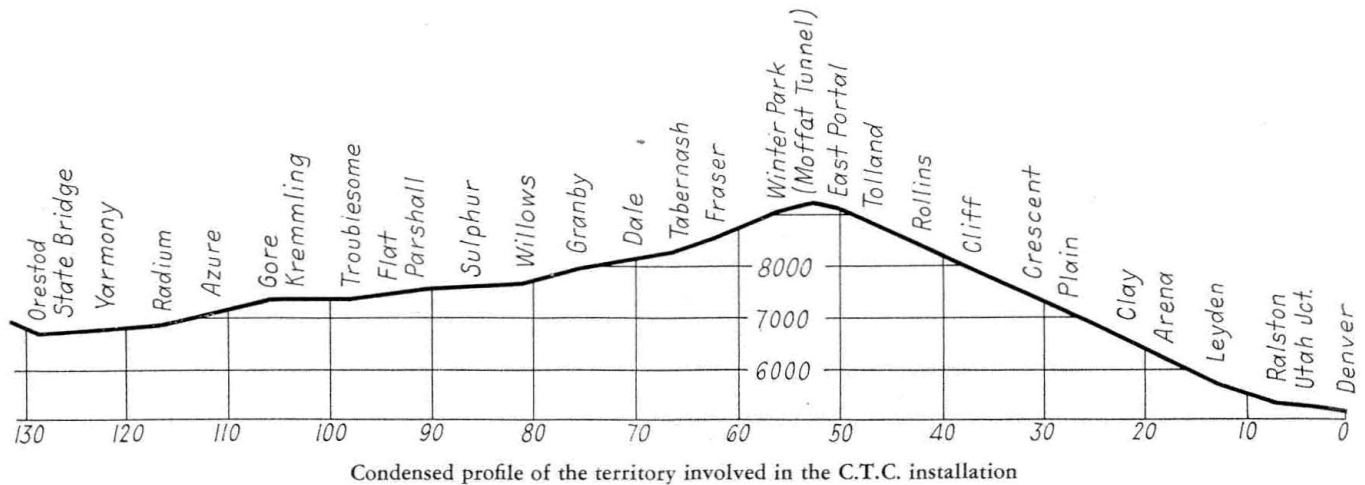
A condensed profile accompanies this article.

There are a total of 39 tunnels, ranging in length from 40 ft. to 6.2 miles, the latter being the Moffat tunnel. Other than the Moffat tunnel, 29 of them are located east of the Moffat tunnel and 9 west. East of the Moffat tunnel there is an average of one tunnel every 1.7 miles of line, and west an average of one every 7.8

In addition to the handicaps of grades, curvature and tunnels, train operation in this territory is all the more difficult during the winter months, with moderate snowfall, and temperatures as low as 50 deg. below zero. Furthermore, the topography is such that, from a practical standpoint, passing tracks can be located only at certain places, with the result that they are not equally spaced as to

automatic block system, and it became necessary to detour many Rio Grande trains via Pueblo and the Rio Grande Royal Gorge route, shown in the accompanying map illustrating the relationship of D. & S. L. lines to Rio Grande lines.

The increase in gross ton miles, compared with the first year of joint operation in 1935 was 44 per cent in 1936, 49 per cent in 1937, 77 per cent



miles. The track is well constructed, using 100, 112, 115 and 130-lb. rail and crosotied ties. Volcanic rock, broken rock, gravel or slag is used for ballast.

A typical lap siding at Cliff is shown in Fig. 1. Figure 2 shows the lay-

distance or train time. On the maximum grade, the passenger train speed is about 25 m.p.h. and the freight train speed about 20 m.p.h.

Because of the increasing importance of the Moffat route, a decision

in 1940, 127 per cent in 1941, and 214 per cent in 1942. In 1935 the total daily train movements over the line averaged 16.1. By 1938 this figure increased to 21.6; by 1941, 26.4; and by 1942, 33.5. During October, 1942, train movements averaged 41.7 trains daily, reaching 48 in April, 1943. Between June and September, 1945, the average number of train movements, exclusive of switching engine movements, between Denver and East Portal was 38 daily. Between Winter Park and Orestod the daily average was 30, the difference in figures being due to helper service. The percentage of Rio Grande car miles to the total car miles over the line between Denver and Orestod increased from 53.5 per cent in 1935 to 69.9 per cent in 1942.

The increased train density occurred notwithstanding a 52 per cent increase in the size of average Rio Grande trains. Loads were made possible by a 20 per cent increase in the size of locomotives. It was planned to further increase loads when locomotive capacities could be increased.

In spite of improved motive power and facilities in general, the adverse effect that increased train density had upon transportation efficiency is evidenced by the fact that since 1940 the average Rio Grande train speed on this line had been steadily falling, averaging 20 per cent less in 1942 than in 1940. The trend of gross ton miles per train hour likewise decreased, averaging 17 per cent less in 1942 than in 1940.

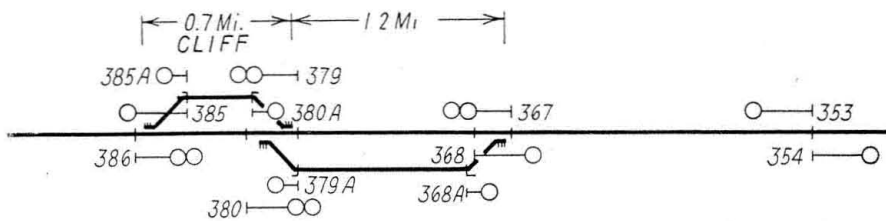


Fig. 1—Typical lap siding at Cliff, showing locations of signals

out at Sulphur with two power-operated crossovers between the main line and passing track, as well as an electric lock on a hand-throw main line

was made a few years ago to install A.P.B. signaling between Denver and East Portal and between Kremmling and Orestod. These installations

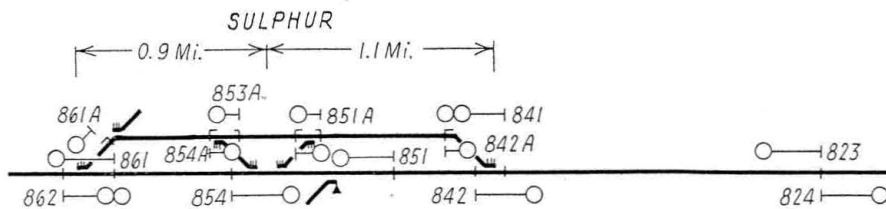
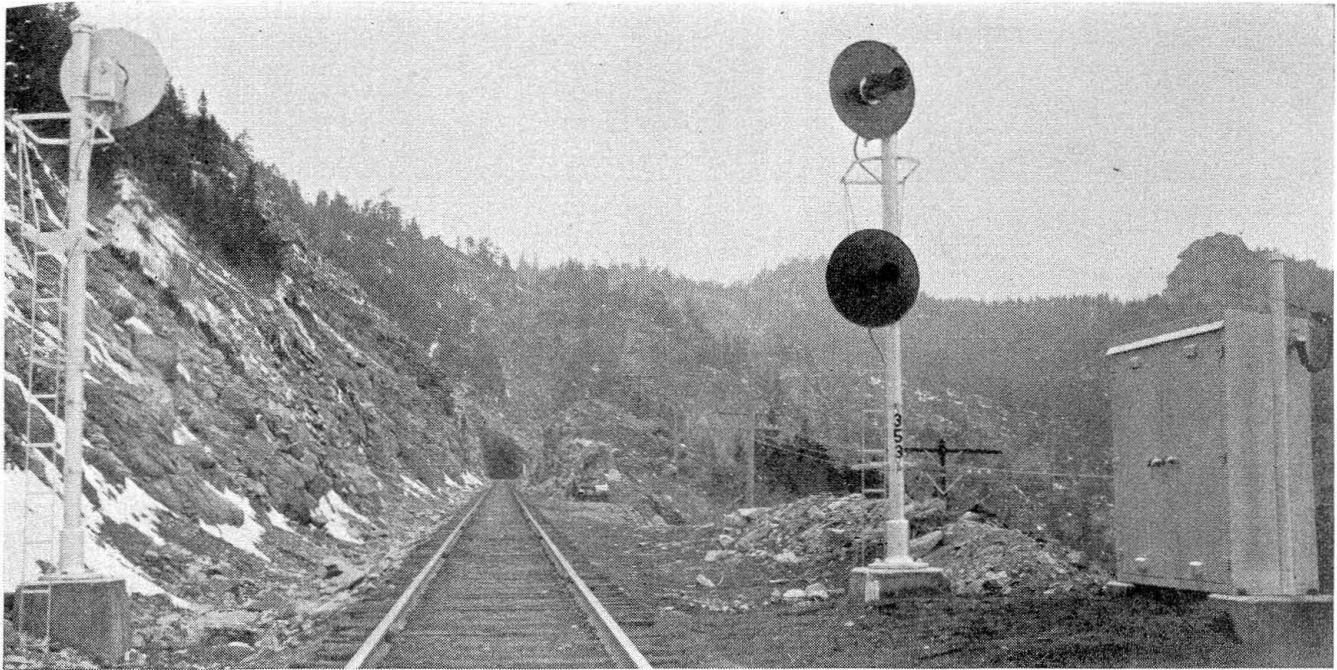


Fig. 2—Layout at Sulphur with two power crossovers between main line and siding

switch. The layout between Prospect (Denver) and Ralston is shown in Fig. 3. A typical single passing track location at Azure, and a typical single power-operated crossover between the main line and passing track at Radium, are shown in Fig. 6.

were completed in 1940 and 1943, respectively. However, the Rio Grande traffic over this joint line increased each year, and far beyond the original estimates. This taxed the line so that trains could not be handled efficiently by timetable, train orders and the



Westward intermediate grade signal 353 and eastward signal 354 between Crescent and Cliff. Tunnel 27 is in the background.

The increased traffic not only forced lengthening of schedules and an overall reduction in operating efficiency but also taxed the line to a point where train movements could not be maintained efficiently by timetable operation, as attested in 1942 by the necessity for detouring Rio Grande trains via the Royal Gorge route. Therefore, to increase track capacity, and improve performance, increase safety, the decision was made to install C.T.C. between Denver and Orestod.

C.T.C. Savings

With better dispatching control, C.T.C. has made possible fewer double and compound train meets, thus eliminating the need for certain additional facilities that would have been required by timetable, train order and automatic block operation. Two sets of train dispatchers were formerly located at Denver, one to handle train movements between Denver and Sulphur, 86.2 miles, and another set between Sulphur and Craig, 145.3 miles. C.T.C. operators are now located at Denver and Sulphur.

This installation has resulted in a considerable saving in total freight train hours daily, as well as a substantial gain in the average speed of trains. Combining principal, helper and light engine hours, the installation has resulted in a large average saving of engine hours daily, which in turn has stepped up the availability of motive power. It has also resulted in a daily saving in car hours, in turn releasing cars and increasing their availability for other service. Fur-

thermore, with a decrease in train stops, a saving is being made on wear and tear on locomotives and rolling stock, with a saving of water and coal. In addition, passenger train performance has been improved. Savings for stationery forms, office expenses and train order forms are substantial. Further economy results from less supervision, including time to check train delays and certain dispatching practices. By better control of train movements with C.T.C., the capacity of the Moffat tunnel has been increased by better distribution of trains through the tunnel. This is important and interesting in view of the fact that the tunnel was designed to handle 19 trains daily.

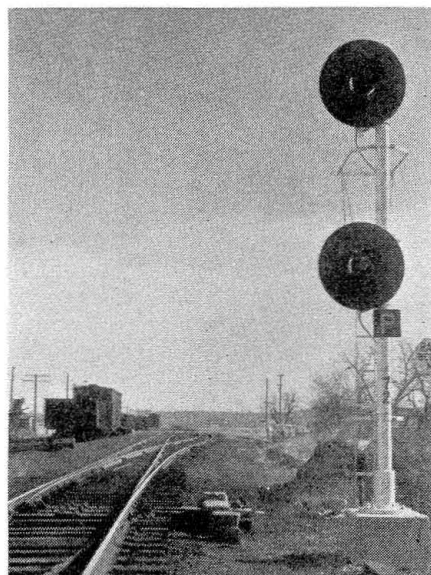
Due to increased train density and

the fact that Rio Grande trains were being limited in length because of sidings, considerable work on additional siding and main track facilities was included in this project, so that expected traffic could be handled. Included in the project were numerous track changes shown in the accompanying table. A total of 15 hand-throw switches were removed from the main track.

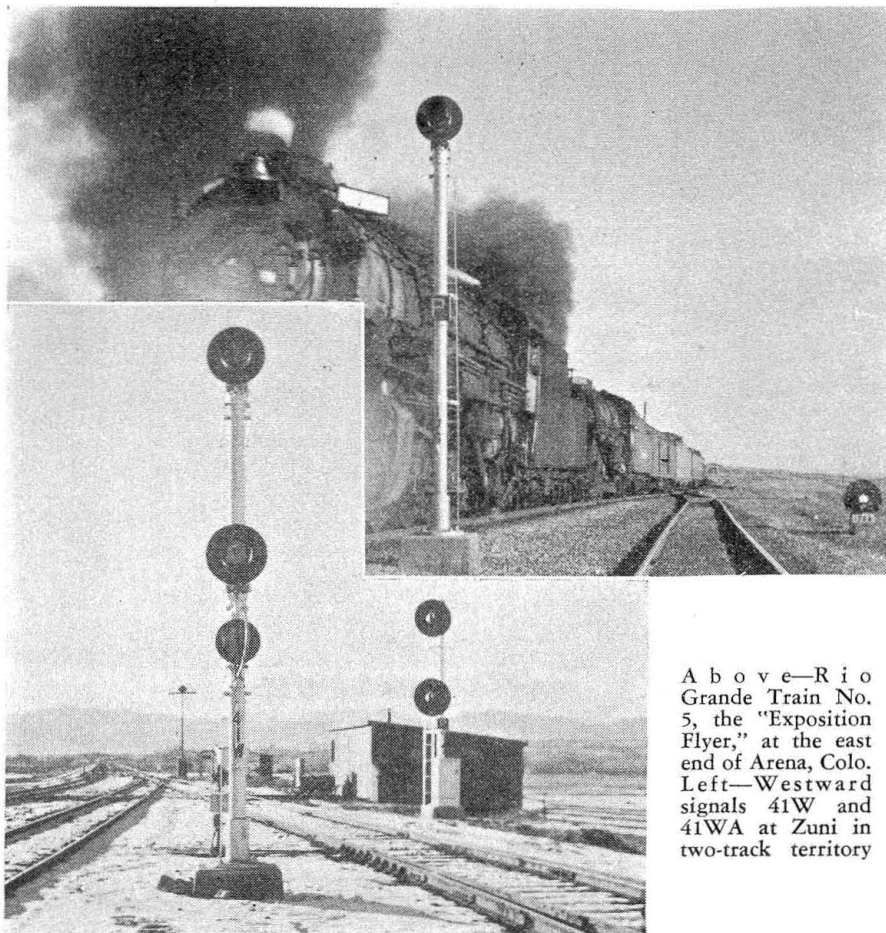
The majority of turnouts in this territory range from No. 10 to No. 18, with nine of the latter in service. Turnouts under No. 15 are being re-

Track Changes Between Denver and Orestod

Location	Change	Car Capacity Before	Car Capacity After
Clay—Extended	2,739 ft.	70	127
Plain—Extended	3,400 ft.	72	143
Crescent—Extended	2,400 ft.	74	122
Cliff—Extended	2,436 ft.	75	130
New lap siding 3,598 ft.			
		—	66
Tolland—Extended	1,305 ft.	99	128
Fraser—Extended	1,000 ft.	88	110
Tabernash—New main track	1.6 miles long		
	resulted in passing siding		
	2 miles in length		
Dale—Eliminated		62	—
Granby—Extended	743 ft.	98	111
New lap siding 5,280 ft.			
		—	106
Willows—Eliminated		98	—
Parshall—Eliminated as controlled siding		—	60
Flat—Extended	2,680 ft.	106	161
Troublesome—Extended	2,906 ft.	70	130
Kremmling—Extended	1,881 ft.	98	137
Gore—Extended	700 ft.	137	153
Orestod—Extended	735 ft. Running Lead		



Eastward signal 72 at Ralston



Above—Rio Grande Train No. 5, the "Exposition Flyer," at the east end of Arena, Colo. Left—Westward signals 41W and 41WA at Zuni in two-track territory

placed with that size, including Ramapo-Ajax curved points and Type-M switch clips, in a project now under way, which includes the installation of new 115-lb. rail in this territory. The speed limit over No. 10 turnouts is about 15 m.p.h., while that over No. 15 turnouts is about 32 m.p.h. In the new C.T.C. project, signals at turnouts to be changed out were located accordingly, in order to be in the proper positions when the new turnouts were installed. Power-operated switches were equipped with Model-5D switch machines, outboard magnetic brakes, and designed for operation from 24 volts, d-c. These, however, are operated at 30 volts to speed the movement.

Location of Control Machines

The control machine at Denver is in the dispatcher's office which is in the general offices of the D. & S. L. on the sixth floor of the Denver National Bank building, which is about one mile south of the D. & S. L. station. The control machine at Sulphur is in a new one-story brick building which was constructed for this purpose.

The machines are of the sectional type which permits changes or additions as may be required. The machine at Denver has seven sections

and one master unit to control from Denver to the east portal of the Moffat tunnel. The machine at Sulphur has seven sections and two master units, one to control eastward between Sulphur and Winter Park, and the other to control westward between Sulphur and Orestod. In the control machine at Sulphur there is a limited territory, shown in Fig. 2, near the control office which is controlled by unit-wire C.T.C.

From the top to the bottom of the control panels on both machines and in order, are the power-off—station indication cycle lights, sectionalizing lights, track diagram, switch lock levers, signal levers, switch levers, employee's call levers and start buttons. The power-off—station indication cycle lights are small red lights near the top of the control panels directly above each control location. The sectionalizing lights are opal lights in line with the power-off—station indication cycle lights, slightly to the left of the location to which they pertain. The track diagrams are engraved across the upper portion of the panel, and show the location and field numbers of signals, switches and electric locks controlled from the panels. The track is divided into sections, each containing its own track-occupancy light. Red lights are used for OS tracks, and opal lights for

approach tracks. All indication lights are normally dark.

The switch lock levers are the rotary type, mounted in a row under the control locations. They contain a button in the stem of the lever which is used in the execution of controls to the electric switch locks. Signal levers are the three-position rotary type, containing a light in the stem of the lever. They, likewise, are located in a horizontal row below the switch lock levers, directly below the signals on the track diagram with which they are associated. Employee's call levers are two-position, vertical operating, mounted in a horizontal row beneath the switch levers. The start buttons are self-restoring push-buttons located in a horizontal row beneath the employee's call levers. They are used to initiate code cycles to execute the controls set up by the switch and signal levers. Neither machine has traffic levers, traffic direction being established automatically with the manipulation of the signal levers.

The C.T.C. is known as the General Railway Signal Company's Class F, Type M-Duplex, 10-step system. The power-operated switches and signals are controlled by codes sent out from the office, and likewise indications on the control panel to repeat the operations of the switches and signals, as well as track occupancy, are sent into the office by codes. These codes are transmitted over three line wires by means of which control codes and indication codes can be transmitted simultaneously. The coding equipment on this installation can control as many as 32 single switch field locations or their equivalent, with 5 controls and 13 indications each.

Every code cycle contains a set of code elements for selecting the proper station and set of code elements for controlling the operation of the functions at that station. If two or more start buttons are pressed simultaneously, or in rapid succession, the corresponding codes are stored and are released successively in an arbitrary predetermined order.

Every indication cycle contains a set of code elements for identifying the calling station and a set of code elements for effecting the indications on the control panel. Indications are continuously responsive to changes in the field conditions, as whenever a change takes place at a field location, an indication code is automatically set up and transmitted to the control office.

The controls, whether they are stored or whether they are about to be transmitted in a control cycle already under way, may be cancelled by the operation of the cancellation switch on the control machine. Placing the cancellation switch on the master panel in the can-

cel position will cancel all control codes that have not been transmitted.

The Denver machine has 24 switch levers, controlling 22 turnouts and 2 crossovers; 4 spare switch spaces; 26 signal levers, controlling 96 signals; 2 spare signal levers; 25 code start buttons; 3 code start button spare spaces; 22 employee's toggle switches; and 10 lock levers. The Sulphur machine has 27 switch levers, controlling 24 turnouts and 3 crossovers; 1 spare switch space; 29 signal levers, controlling 107 signals; 1 spare signal lever space; 4 lock levers; 30 code start buttons; and 24 employee's toggle switches.

Automatic Train Recorder

Each control machine includes a G.R.S. automatic train recorder, in the center of the desk portion of the ma-

or counterclockwise 90 deg., preferably in the direction of traffic. To send controls, the signal and switch levers are turned to the position desired and the associated start button is pressed. Operation of the start button sends the controls to the field location, and the switches and signal, if contrary in the field, respond to the position of their respective levers. Secondary tracks, such as passing sidings, are not signaled, and signals may be cleared into such tracks regardless of occupancy.

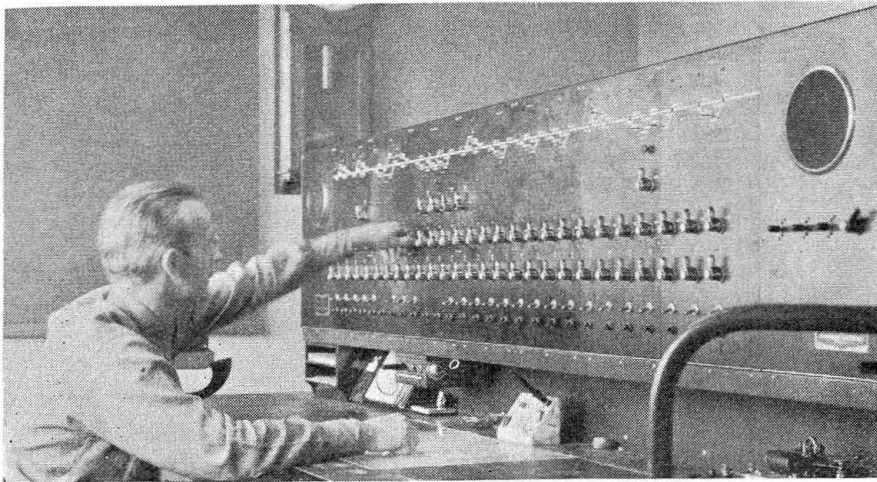
If a signal is cleared and then taken away by lever control, time locking is effective automatically.

Control of Electric Switch Locks

For a train to leave the main track over a hand-throw switch equipped with an electric lock, no operation is

leases the electric lock so that it may be operated to unlock the hand-throw switch. However, to unlock an electric lock to permit a train to enter the main track over a hand-throw switch, the adjacent signals governing movements toward the switch must be placed at Stop, the switch lock lever positioned in the direction in which the train is to proceed on the main track, and the push-button in the stem of the lock lever operated. Pushing the button in the center of the lock lever starts 75 or 180 coded track energy in both directions from the adjacent field control stations to the electric lock. This will, field conditions permitting, condition the electric lock, and, when the door of the lock is opened, will release the mechanism so that the lever in the electric lock in the field may be operated to release the switch. If the adjacent signals governing movement toward the switch have been cleared and restored to Stop, release of the electric lock cannot be made until the time locking has released itself, which normally is three minutes. The lock lever is never restored to normal, after using it in making a train movement, until the train for which it was used has completely passed the first OS track. The lock push-button is operated after the lever has been restored to normal.

To operate an employee's call light in the field, the corresponding employee's call lever on the control panel is placed in the upward or call position, the call lever on the master unit is held in the call position, and a code start initiated with the start button. The master unit call switch is released after the buzzer sounds for approximately two seconds. This illuminates a call light at the field location which will continue to burn until cancelled by placing the employee's call switch normal and again sending a call code



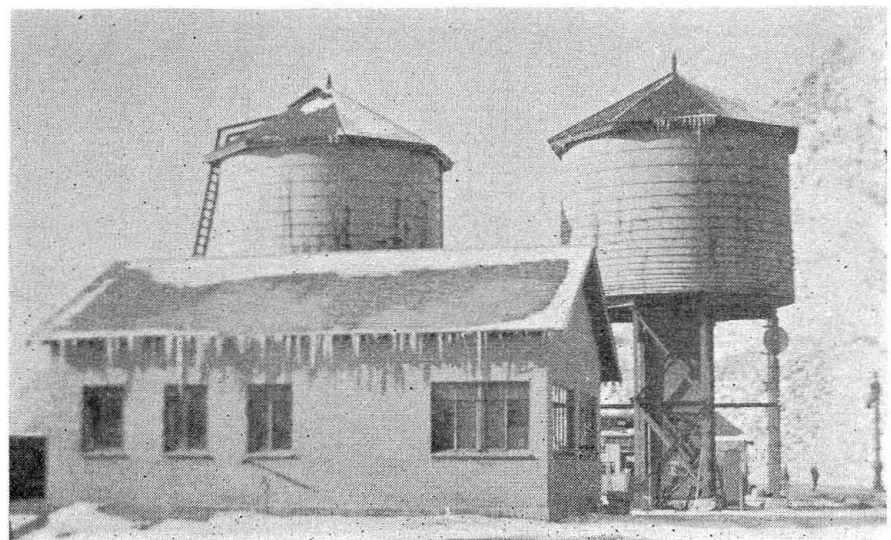
The C.T.C. machine at Sulphur controls the territory from Winter Park to Orestod

chine. This recorder has three styli to correspond with each of the OS sections in the field. One stylus is operated when a signal governing westward at the corresponding field location is cleared. The second stylus is operated when the eastward signal is cleared, and the third stylus is operated when the OS section is occupied. Thus the record on the chart shows which signal was clear before the train arrived. These charts are burnt by the styli and not inked. Charts, each 125 ft. long are moved 2 in. per hour by a 110-volt synchronous motor.

Manipulation of Control Machines

The signal levers normally point upward to control signals to the most restrictive aspect. To clear signals, the levers are rotated 90 deg. from the center position in the direction trains are to move. The switch levers point upward for the normal position of the switches, and are set for reversing a switch by turning the lever clockwise

necessary on the part of the control machine operator. The presence of the train on a short release circuit in advance of the switch, automatically re-



The control machine at Sulphur is located in a new one-story brick building

to that location in a manner similar to the initial call. The lamp is controlled by a magnetic stick relay.

Control Machine Indication Lights

When a line wire in the C.T.C. code circuit breaks, and the system becomes energized, the automatic sectionalizing terminates the line circuit, and illuminates the opal sectionalizing light marked SEC corresponding to the field location which is sectionalized. This indicates to the operator that the break has occurred at some point beyond the sectionalized location and the next location with automatic sectionalizing, and, at the same time, informs him that it is impossible to transmit controls or receive indications from stations beyond this location. Once sectionalized, the line circuit remains so until released by sending a re-check cycle to the sectionalized location. This is not done until the operator has been notified by a maintainer that the break has been repaired. After the line has been repaired, it is made operative by a re-check which cancels the stick feature. Automatic line sectionalizing locations are used in three places controlled by the Denver machine, namely, at Plain, Crescent and Cliff; and five locations controlled by the Sulphur machine, namely, Tabernash, Granby, Gore, Azure and Radium.

When the a.c. power fails at a field location, the red power-off—indication cycle lamp at each control location so affected is illuminated and will remain so until power is restored, except during a portion of all indication cycles originating at the location. This indication is not to be confused with the normal operation of this lamp due to indication cycles. Each indication cycle as it originates in the field illuminates the power-off—indication cycle light for its respective control location, and it continues to burn until the end of the cycle, at which time the lamp is extinguished and remains so until a new cycle is started or power-off condition arises. Practically continuous burning of one minute duration or more of one of these lamps, with only a short period of darkness at the end of each cycle, indicates that some faulty condition has arisen at that field location causing continuous cycling. If continuous cycling originates during a power-off period, it will be detected by the reverse of the foregoing.

Track indication lamps are divided into three classes, namely, OS or detector, block, and approach. The OS or detector lights are red, and, when illuminated, indicate a train between opposing positive signals which govern over one or more power-operated

switches. The remainder of the track lights are opal and are designated as block lights or approach lights, depending upon their functions. Where there are three lights between control points, the center one is the block light and the other two are approach lights. All single lights between control points are block lights. Track indication lights are normally dark, and, when illuminated, convey information to the operator, depending upon several conditions. They are illuminated and extinguished as the train proceeds over the track section they represent. As a train leaves a control point, the block light between that control point and the next control point is illuminated. The block light remains illuminated all the time the train is between the two control points, and is not extinguished until the train has completely cleared the OS circuit at the next control point.

Operation of slide detector fences due to slides is indicated on the control panel by flashing the approach and block lights corresponding to the track in the vicinity of the fence. If an approach or block light in one section remains illuminated after the passage of a train, it indicates generally either a broken rail or slide fence operation.

On the Denver machine a separate and special normally-dark opal indication lamp is flashed when the Colorado & Southern crossing between Endo

and Utah Jct., shown in Fig. 3, is in use by a Colorado & Southern train.

When an electric lock lever is positioned and the lock push-button operated, the block light in the track diagram between the two control points in which the lock is located is illuminated and remains so until the hand-throw switch is returned to normal, the operating lever of the electric lock returned to the locked position, the door of the lock closed, the lock lever on the control machine returned to normal (locked position) and the push-button again operated. Failure to return the electric lock in the field to its proper locked position is manifest by inability of the operator to extinguish the block light.

Broken rails or other block failures will not be detected if the break occurs while the system is at rest, that is, no signals are cleared or no train is in the block. Under these conditions no visible indication will be received at the control office, but when an attempt is made to clear signals over the territory in which the faulty condition is located, the signals will not clear.

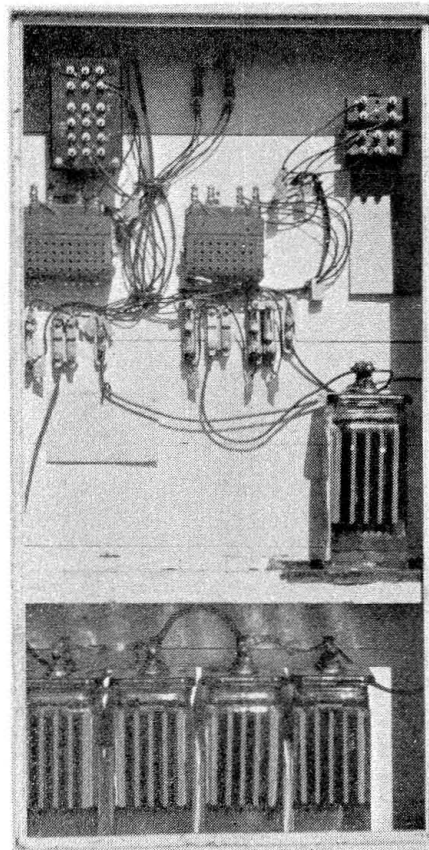
Signal indicating lights are opal and are located in the signal levers. When dark they indicate that all signals controlled by that lever are at Stop. When they are illuminated they indicate that the signals are clear in the direction in which the lever is turned. Switch correspondence lights are opal and are located in the switch levers. When illuminated they indicate that the lever on the machine is out of correspondence with the position of the switch points in the field.

Previous Automatic Signals

When A.P.B. signaling was installed between Denver and East Portal, and between Kremmling and Orestod in 1940 and 1943, respectively, certain features were provided so that the minimum expense was required in changing over to C.T.C. Such features included station-departure and station-entering signals, as well as track circuits being properly located. At OS sections, there are two track relays, one on the main track and one on the turnout to the siding. The signal circuits are controlled indirectly by both of these relays by means of a repeater relay. The advantage is that broken bonds or broken rails on the fouling section are detected, whereas an ordinary shunt fouling does not provide this feature of protection.

Spacing of Intermediate Signals

In determining the number and locations of new intermediate automatic signals, various factors were in-



Interior of instrument case at electric switch lock location

volved. The passing tracks are not spaced evenly on a basis of distance or train time. Braking distances for westbound 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 provide sufficient sighting distances. Figure 10, showing the territory between Arena, Clay and Plain, illustrates one intermediate section with no automatic signals and another with one set of intermediate signals. Figure 6 shows an intermediate section between Radium and Azure with two sets of intermediate signals.

Signals

The high and dwarf signals are the General Railway Signal Company's Type-SA, with compound lens assemblies, 250-ohm, 8-volt, d.c., operating coils and 8-volt, 13 + 3.5 watt double-filament lamps.

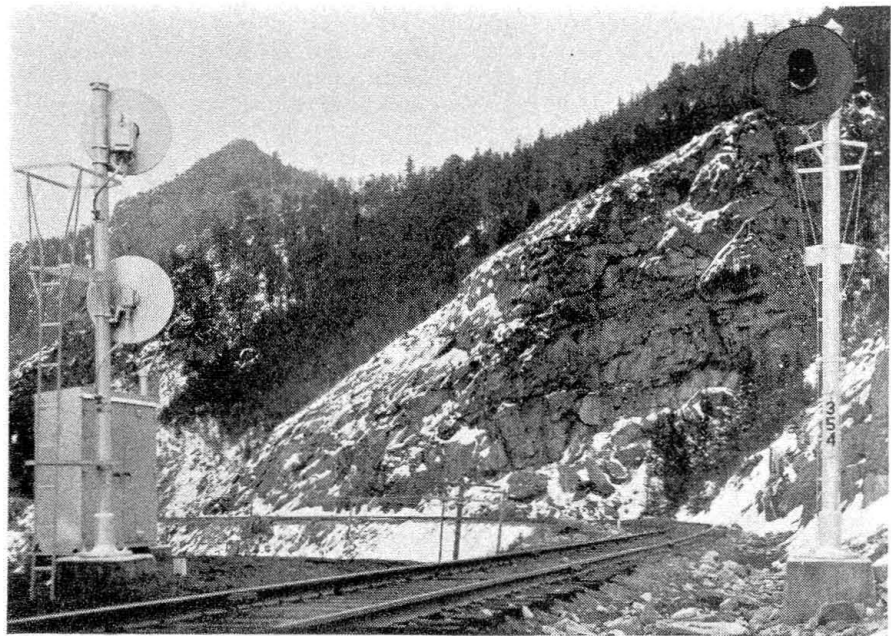
Where sufficient clearance permits, the high and dwarf signals are provided with full-size backgrounds. In



Dwarf signals 25 and 25A at Endo, showing full-size and small backgrounds

such instances, the high signals are side-of-the-mast mounted on the left side, and have standard ladders and platforms. Where signals are between tracks, the secondary tracks were moved to 18-ft. centers, and high signals of the top-of-the-mast type were used, with small backgrounds, straight ladders and no platforms. Single-“arm” signal units are mounted on masts 14 ft. above the rail level. Where second “arms” are in use, they are mounted 5 ft. below the top “arm.” On signals with side-of-the-mast mounted units, short pinnacles are used. Dwarf signals between tracks have small backgrounds, and those outside of tracks have standard backgrounds.

The majority of the signals have 20-deg. deflecting prisms on minor curves, and 70-deg. spreadlite lenses on major curves. All units have hot-spot lenses for close-up sighting. The signals are numbered by raised, black, metallic numerals and letters on an aluminum-painted metallic number plate. The absolute signals, such as station-entering and station-leaving signals, are designated as such by a



View of intermediate location between Crescent and Cliff gives a good idea of the terrain

reflectORIZED letter “P,” 8 in. high. All parts of high and dwarf searchlight signals are painted aluminum with the exception of the fronts of the signal units, fronts of the backgrounds and

train out and accelerate to normal speed, otherwise it would be necessary to run at reduced speed until he saw the next signal displaying a green aspect.

The intermediate automatic signals display three aspects, with the exception of grade signals and a few special signals. These aspects and indications include Stop-and-Proceed, Rule 291, and the Approach and Clear aspects, mentioned heretofore.

Special Signals

Approaching the two main tracks at Ralston, shown in Fig. 3, which are signaled for normal and reverse movement, eastward automatic signal 84 is capable of displaying four aspects: namely, Advance-Approach-Medium, Rule 281A; Approach-Medium, Rule 282; Advance-Approach, Rule 282A; and Stop-and-Proceed, Rule 291.

Westward signal 495, shown in Fig. 4, at East Portal, is equipped with a “Take-Siding” indicator, which consists of a G.R.S. Type-W marker unit as a third “arm,” which, when illuminated, outlines a letter “S.” Such an indication authorizes a trainman to operate the hand-throw switches on the crossover leading from the main track to the siding, after which the train movement is authorized by the Restricting aspect of red-over-yellow. A similar signal, No. 1281, shown in Fig. 5, is located at Orestod, to authorize train movements from the main line to the siding on the north side, this siding being equipped with hand-throw switches.

On account of the short sighting of westward home signal 1161 at the east end of Radium, shown in Fig. 6, due to the Tunnel 42 in approach

the numerals and letters of the number plates.

The intermediate automatic block signals are approach lighted through transformers from the a.c. power, but, if this supply fails, the signals are lighted from storage batteries. Positive signals at the ends of passing tracks are lighted continuously.

Signal Aspects

The station-entering signals display four aspects and indications, namely, Stop, Rule 292; Restricting, Rule 290; Approach, Rule 285; and Clear, Rule 281. The high and dwarf station-departure signals, all of which are single-unit, display three aspects; Stop, Approach and Clear. The use of three-aspect dwarf signals on the passing tracks, as compared with two-aspect, displaying only yellow when cleared, facilitates moves. Such a signal displays red normally, and, when cleared by the operator, will display green if two or more automatic blocks are unoccupied, or yellow if only one block. When a green aspect is displayed, an engineman can pull his

thereto, a two-“arm” repeater signal, 1161 (Rep.) was provided in approach to this signal. Signal 1161 (Rep.) is lighted only when signal 1161 is cleared for a train movement, and remains dark if signal 1161 is at Stop. In other words, if signal 1161 is cleared, signal 1161 (Rep.) repeats

The track circuits are of the coded type except the short release track circuits in advance of the hand-throw switches with electric switch locks, and the short OS track circuits through power switch layouts. In a station-to-station block, the coded track circuits are normally deener-

75 per minute controls the yellow aspect, and code at either 120 or 180 controls the green aspect. Receipt of 180 code at the entrance end of a station-to-station block, serves also to indicate that the station-to-station block is unoccupied.

Figures 7a to 7d, inclusive, show the

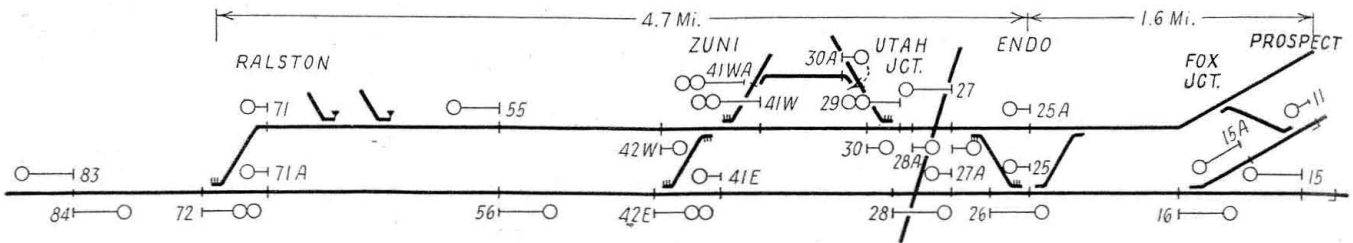


Fig. 3—Territory between Prospect (Denver) and Ralston. The end of double track is at Ralston

the indication, but if signal 1161 displays red-over-red for Stop, signal 1161 (Rep.) remains dark.

Grade Signals

Each intermediate automatic block signal on ascending grades is equipped with a grade signal. The Stop-and-Proceed aspect and the grade light authorize a following freight or pas-

senger train to pass the signal at a speed not exceeding 8 m.p.h., without stopping at the signal. The control of the grade signal is directional, i.e., for an opposing train the grade lamp is not lighted. This feature is ac-

gized, and when C.T.C. control is sent out to line up for a station-to-station move, the first action is to energize the track circuits in the station-to-station block to feed in the direction opposite to the train movement. Another feature is that the various rates of code, i.e., 75 and 120 or 180 per minute are used to control the signals to display the aspects and to accomplish directional control of

sequence of track codes in lining up to clear eastward signal A at station No. 1 for a train movement to station No. 2 through a station-to-station block with only one double pair of intermediate signals. Such a layout is typical of that between Clay and Plain, shown in Fig. 10. Figures 8a to 8e, inclusive, show the sequence of track codes in lining up for a train movement where there are two or more sets of intermediate signals under various conditions. Such a layout is typical of that between Granby and Sulphur. Figure 6 shows the layout between Radium and Azure in which there are two sets of intermediate signals.

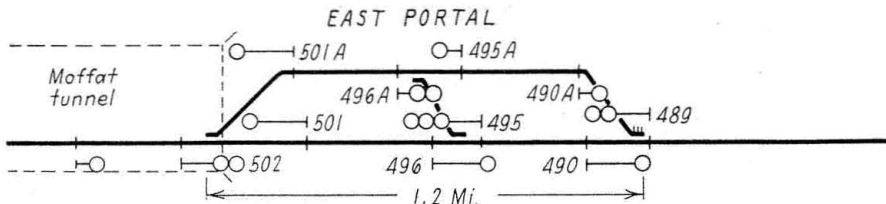


Fig. 4—Layout of track and signals at East Portal, showing signal 495

senger train to pass the signal at a speed not exceeding 8 m.p.h., without stopping at the signal. The control of the grade signal is directional, i.e., for an opposing train the grade lamp is not lighted. This feature is ac-

complished by extending the control through contacts of a directional stick relay. Absence of track circuit energy, steady energy, or improper code, sets the controls for a red aspect. Code at

sequence of track codes in lining up to clear eastward signal A at station No. 1 for a train movement to station No. 2 through a station-to-station block with only one double pair of intermediate signals. Such a layout is typical of that between Clay and Plain, shown in Fig. 10. Figures 8a to 8e, inclusive, show the sequence of track codes in lining up for a train movement where there are two or more sets of intermediate signals under various conditions. Such a layout is typical of that between Granby and Sulphur. Figure 6 shows the layout between Radium and Azure in which there are two sets of intermediate signals.

Circuits

The diagrams and following descriptions concern the circuits in which normally-deenergized coded track circuits control wayside signals without line wires for A.P.B. control. Figure 9 shows a typical station-to-station block with one set of intermediate automatic signals as is in service between Clay and Plain. The actual layout between Clay and Plain is shown in Fig. 10. Assume that all C.T.C. functions between Stations 5 and 7 at rest and that it is desired to clear signal 5RA for a train movement to the right. The usual lever manipulation is all that is required, no traffic levers being incorporated in this system. Signal lever 5 is turned to the right and the associated start button pressed. This creates a start for

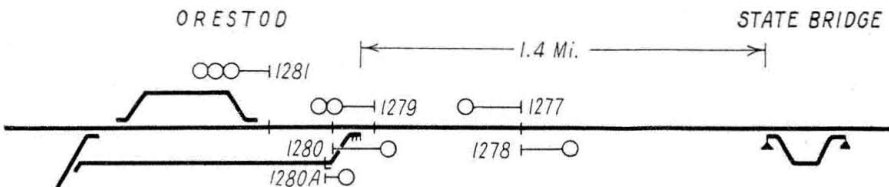


Fig. 5—Layout between State Bridge and Orestod, showing signal 1281 at Orestod

complished by extending the control through contacts of a directional stick relay.

Absence of track circuit energy, steady energy, or improper code, sets the controls for a red aspect. Code at

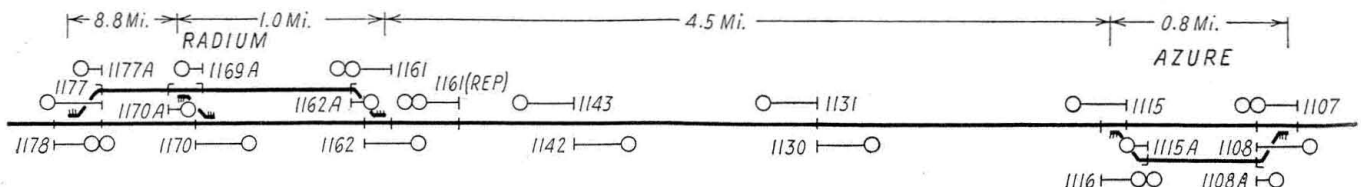


Fig. 6—Track and signals between Azure and Radium, showing signal 1161 (Rep.) near Radium

sending the control to pick up the 5RGZ relay in the field code equipment at Station 5, and also creates a start through the 7ACH slow-release control start relay in the control office, which picks up the 7LC code control application relay, also in the control office, for picking up the 2FZ traffic relay at Station 7. The 2FZ relay starts the coded track energy in the rails back towards signal location 5. The 5RGZ, 7ACH, 7LC and 2FZ relays are not shown here because they are incorporated in the standard C.T.C. line-code control operations. The 2FZ relay, at Station 7, controls the WCPR west code repeater relay at the same location, not shown, which, when operating, applies coded energy to the track, 75 or 180 code passing over a front contact of the 2FZ relay, depending upon the condition of the YGP relay for signal 7R, which relay likewise, is not shown here. If the YGP relay is energized, 180 code is fed to the WCPR relay over a front contact of the YGP relay, and, if the YGP relay is deenergized, 75 code is fed to the WCPR relay over a back contact of the YGP relay. In other words, if signal 7R is at Stop, the WCPR relay is fed 75 code. On the other hand, if signal 7R is at Approach or Clear, relay WCPR is fed 180 code. Similarly, the 1FZ relay controls the ECPR relay which controls the coding toward the right.

The track coding equipment and circuits beyond the WCPR relay at signal 7R, are identical to those for

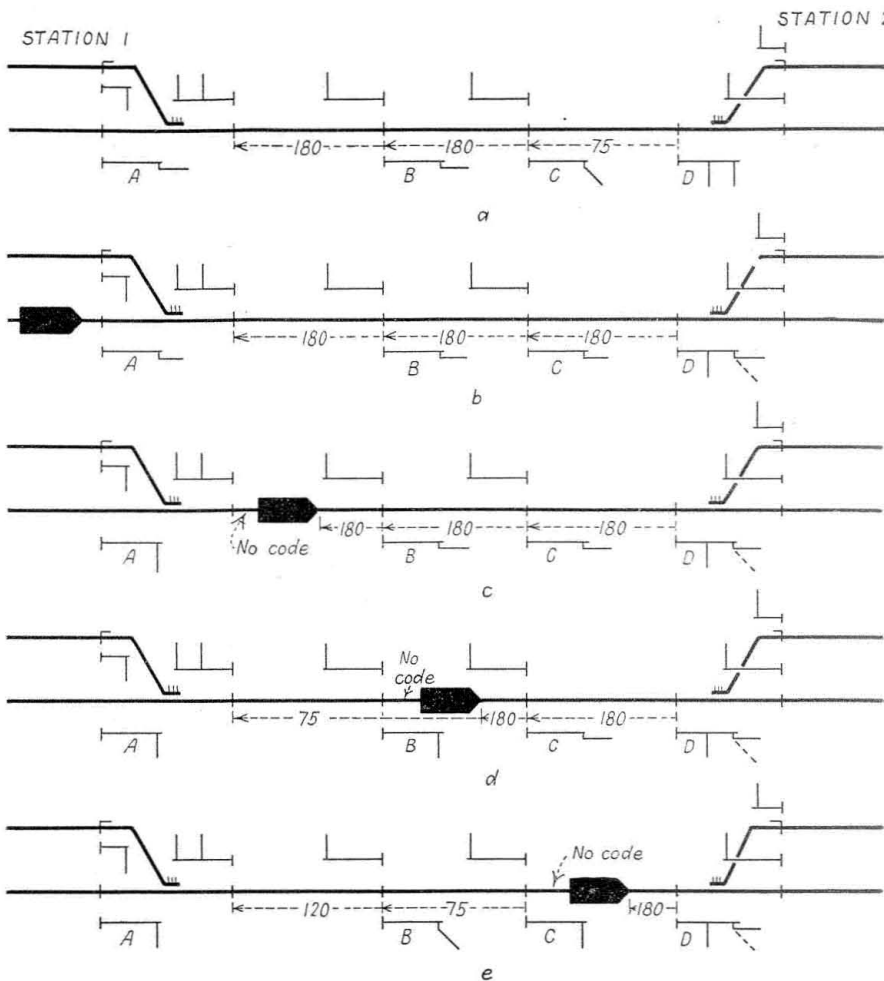


Fig. 8—Sequence of track codes with more than one set of intermediate signals

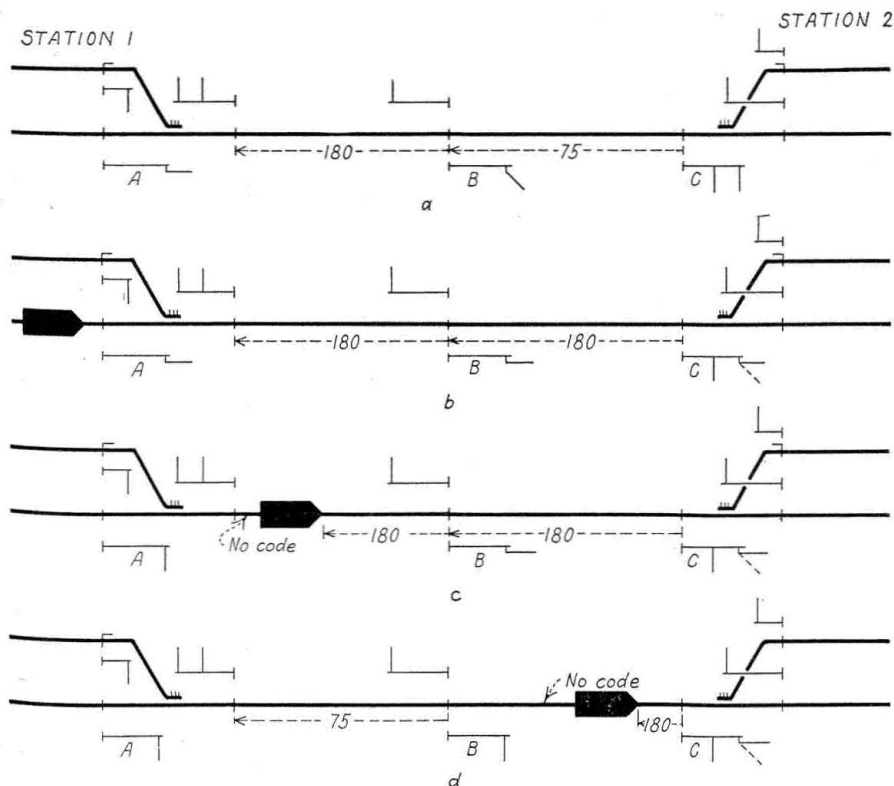


Fig. 7—Sequence of track codes with one set of intermediate automatic signals

track section WT shown in Fig. 11, representing a double intermediate location, except there is no WA approach relay and 5.9-ohm variable resistance at signal 7R. Referring to Fig 11, it will be noted that when the WCPR relay is deenergized, the west track relay WT is connected in series with a 1.35-ohm variable resistance to the rails and ready to receive code from the opposing direction. However, with the WCPR relay in operation, repeating either the 75 or 180 code transmitter, positive coded battery passes through the 0.65 current-limiting resistance and the coils of the west approach relay WA, through a 5.9-ohm variable resistor (this relay and resistor are cut out at signal 7R), through multiple front contacts of the WCPR relay, protected against arcing by a suppressor across the contacts, and thence to the upper rail. The track coding equipment at signal 5RA is identical. When the track relay ET at signal 5RA is energized with coded energy, the east front repeater relay EFP, not shown, is picked up, since it is connected over a front contact of the track relay. With the EFP relay energized, station-to-station traffic from Station 5 to Station 7 is set up, and signal 5RA will clear when its associated H and D relays also assume the energized position (not shown), because its GZ

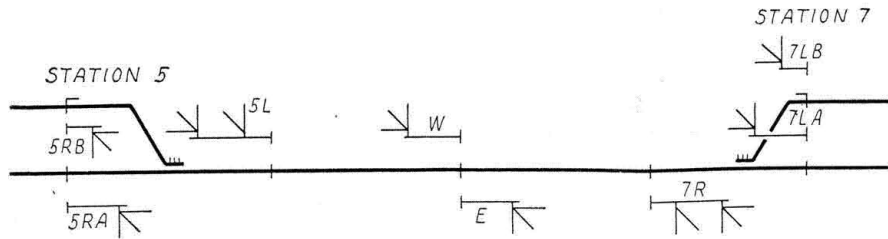


Fig. 9—Typical station-to-station block with one set of intermediate signals

relay was previously energized. The foregoing discussion covers the station-to-station track coding as though the section was continuous, but it should be understood that there are cut sections and intermediate signal

the control office. However, when the train gets entirely out of the station-to-station block and passed signal 7LA and a clear-out (180 code) is received at Station 5, an automatic start is created at signal 5 which drops

the control office and not shown, picking up as proof that the train has cleared the block, and signal lever 5 has been restored to the normal position. As long as lever 5 remains turned to the right, the automatic start is delayed. Lock-out protection between stations 5 and 7 is provided by the 5-7RFS right traffic stick and 5-7LFS left traffic stick relays located in the control machine, and not shown here. The RFS relay is energized when traffic is lined to the right between stations, and the LFS relay is energized when traffic is lined to the left. All positive signals are full-slotted, insuring that codes originating on

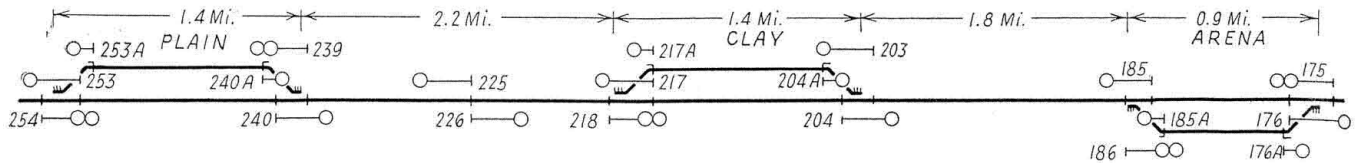


Fig. 10—There are no intermediates between Arena and Clay. There is one set of intermediates between Clay and Plain

locations where the track coding is repeated, but which were not mentioned, to simplify the discussion.

When the train accepts signal 5RA and moves through the block, the usual sequence of indications is received at

the 2RZ relay at Station 7, resulting in the release of the WCPR relay, which in turn results in cutting off of coded energy to the track at Station 7. The automatic start depends on the 5EBK, east block indication relay, in

clear outs will not again clear any signal. Signal control relays are responsive only to their own start buttons.

The indication circuits in the field are standard except for differences in block indication circuits to take care of several variables, as the number of intermediate signals and whether there is a slide-detection indication to be provided. For instance, for one set of intermediate signals between stations, such as between Clay and Plain, the east block indication EBK is obtained through the 18OD and EFP relays. For no intermediate signals between stations, such as between Arena and Clay, or over sidings, the EBK indication is taken only through the EFP relay. For more than one set of intermediate automatic signals, such as between Leyden and Arena, the EBK again is taken through the 18OD and the EFP relays. Where there are more than one set of intermediate automatic signals, a separate siding approach indication is given in addition to the block indication. For a train approaching a control station the approach indication is taken from the AP relay which is the repeater of a series relay in the ET track circuit feed. For a train leaving a control station the approach indication, which, in this case would be a leaving indication, is also taken through the AP relay, the AP relay being energized by means of a directional stick relay.

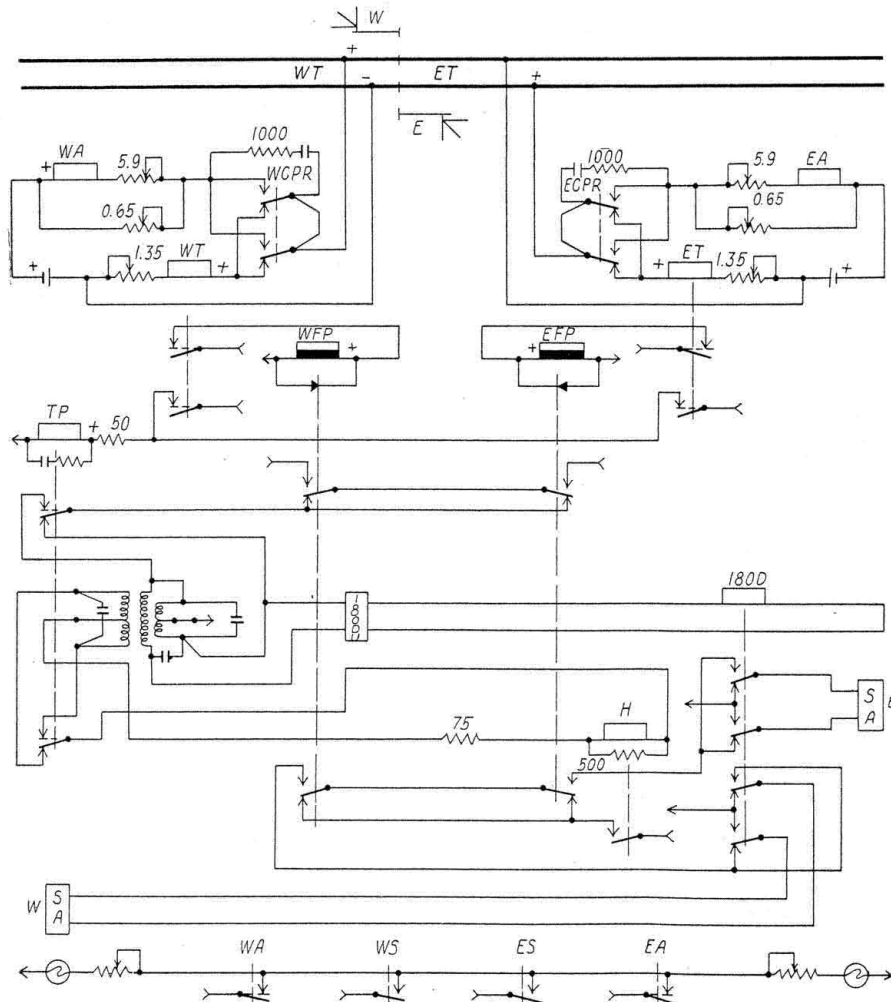


Fig. 11—Controls for A, T, TP, FP, D and H relays at double intermediate location

Slide-Detector Indication

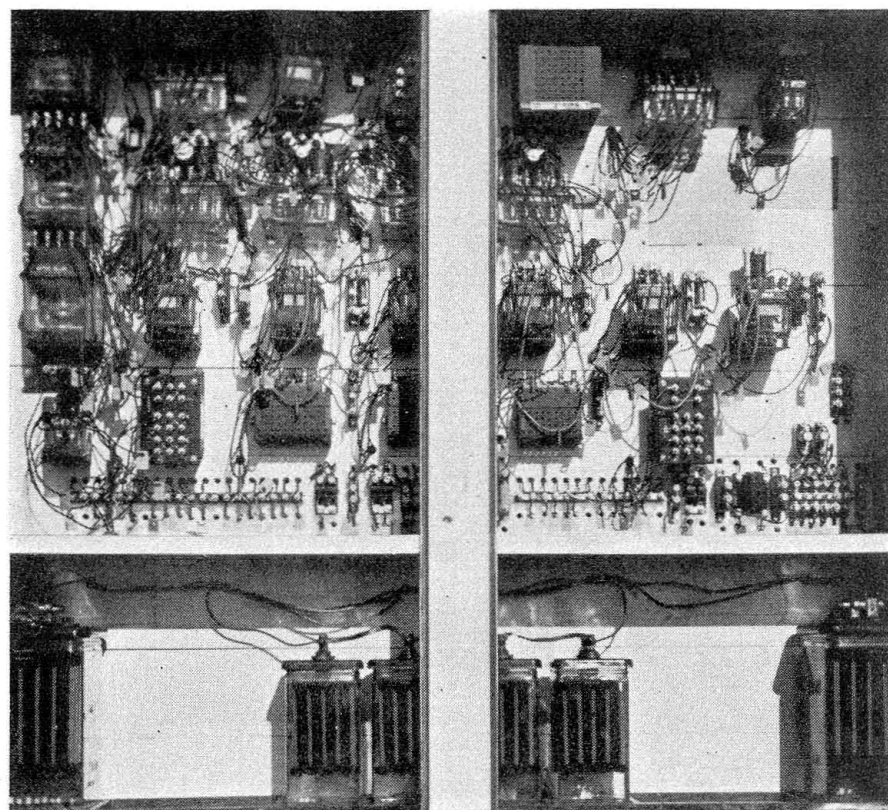
Generally speaking, slide indications from slide detectors are transmitted to the nearest control point. When a slide occurs, the slide detector functions, resulting in the release of the

SD slide detection relay, not shown, which further results in steady energy being applied to the track at the slide detection location. The steady energy results in the pick-up of the EFP relay, but not the EH relay. The SDK slide indication then goes into the control office directly when there is no siding approach indication and is combined with the siding approach indication when it is necessary to have both.

When the indications are received at the control office, the circuits are standard except for the block and approach indication selections. The traffic relays 5-7RFS and 5-7LFS, in conjunction with one of the BK block indication relays, determines when the block light is to be illuminated. This is necessary because normally the track circuits are deenergized. Only when the BK block indication relays are down and one traffic relay up, is it desired to display the block light. In combining block and slide detection indications, the block light is energized from a flashing energy source to indicate a slide. In addition, where an approach indication is given, the approach light is also flashed.

Control of Electric Switch Locks

Figure 12 shows the typical control circuits for an outlying electric switch lock. In obtaining the lock release, the safety selections are obtained from the coded track circuits. Coded track energy must be received at the lock location from each direction. This checks that no opposing signals are clear and that no train is approaching from either direction. The operator, in sending a switch unlock, checks to insure he has no opposing signals clear and that no train is approaching the lock location. He operates the switch lock lever left, or right, depending on the direction the train entering the main line is to move, then pushes the start button located in the stem of the lock lever. The switch unlock works with the ACH control start relays at the control office for each end of a section. Referring to Fig. 9, let it be assumed that an electric switch lock is located on the main line between Stations 5 and 7. When lock lever 6A is turned to the right and its push-button operated, the 7ACH relay in the control office starts a cycle to pick up the 2FZ relay at the 7 signal location. This establishes coded track energy for traffic direction toward the right from signal location 5. Another cycle is then started by the 5ACH relay in the control office to send a control to signal location 5 to pick up the 1FZ relay there. That, when conditions are right, will transmit coded track energy toward the lock against the



Interior of sheet-metal instrument case at an intermediate automatic location

traffic direction originally set up.

Referring to Fig. 12, the operation required by the trainman in the field to secure an unlock is shown. His first step is to call the dispatcher to get a release. He opens the door of the lock which drops the LP relay and stops the coded track energy from being transmitted past the lock location, and permits receipt of code from the other direction. Both the WFP and EFP front repeater relays will then be energized which will give an unlock.

At the lock location at which a slide detector indication is re-transmitted, an FBP front-back repeater relay is added on the side that the slide indication is received. Let it be assumed that a slide detector indication is being sent from right to left through the lock location. The slide detector energy (steady) will energize the EFP relay only, thus to insure that it is coded energy that is received from the east before an unlock can be given.

Intermediate Signal Control

Control of directional stick and code repeater relays at a double intermediate signal location is shown in Fig. 13. With the EFP and H relays energized positive battery checks contacts in the W signal at Stop, over contacts of the 18OCT code transmitter, started when the H relay is energized, over a front contact of the

EFP relay, two front contacts of the H relay, back contacts of the WFP and WS relays, through the coils of the WCPR relay, and thence to negative battery. Referring to Fig. 11, the WCPR relay in operation results in the repeat of 180 code from the ET track circuit to the WT track circuit. When a train enters the approach track section, the additional shunt current operates the WA relay. With the WA relay functioning, positive battery checks signal E, over a front contact of the WA relay, through the coils of the ES relay to negative battery. This relay remains energized as long as the WA functions or is stuck up over a back contact of the H relay when the latter relay is deenergized. For a train movement in the opposite direction, the relay and circuit operations are similar.

Code Transmitter Controls

The controls for code transmitters at a double intermediate signal location are shown in Fig. 14. At such a location only one set of code transmitters is used for both signals. The circuit arrangement is simple, and the transmitters are set into operation by positive battery passing over a front contact of either the WS west stick, ES east stick, or H signal control relay when energized. The accompanying circuit is used where there is only one set of intermediate signals. Where there are more than one set of inter-

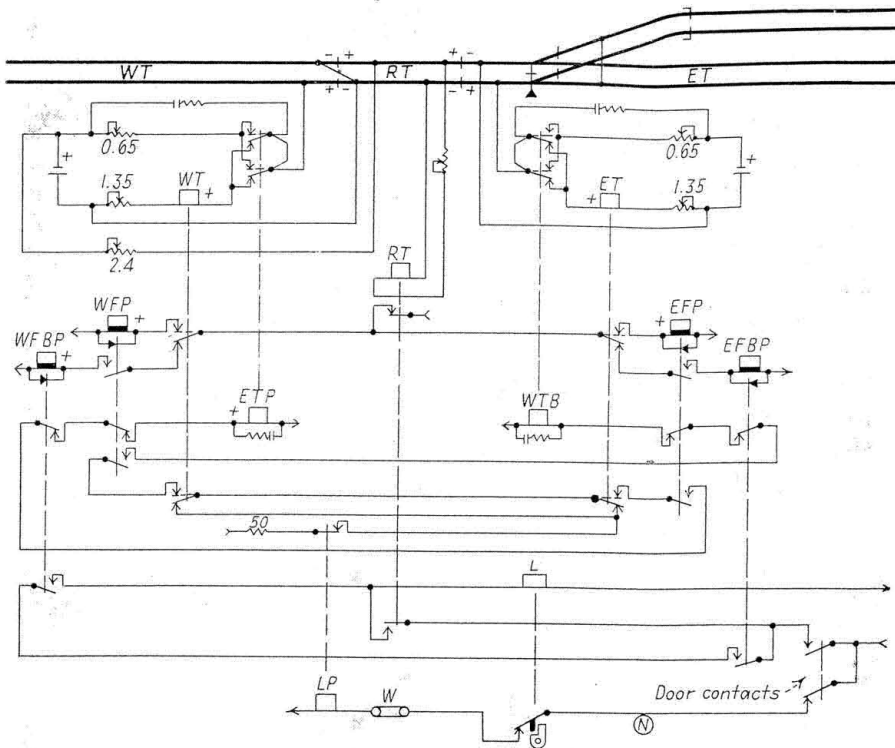


Fig. 12—Controls for electric switch lock on a hand-throw switch. The safety selections are obtained from the coded track circuits

mediate signals, an additional code transmitter with the rate of 120 per minute is used. Connection of the 120 code transmitter is shown by dotted lines at the right in Fig. 14.

Approach lighting control of signals is shown at the bottom of Fig. 11, representing a double intermediate location. No objectionable flashing is noted.

Power Supply

The Denver control office batteries are in a separate room across the hall from the room where the control machine is. The control battery consists of 90 cells of Exide BTMP-3 storage battery. The indication battery consists of 40 cells of the same type, while a third battery, the local control battery, consists of 12 cells of EM-7.

At Sulphur, all battery is kept in a separate combined battery and relay room in the new one-story brick building. In that the control machine at that location is the double-master unit type, two sets of indication and one control battery are provided. The control battery consists of 115 cells of BTMP-3 storage-battery, the east indication battery consists of 55 cells and the west consists of 80 cells of the same type battery. The local control battery consists of 12 cells of EM-11 storage battery. Since the local switch and signal facilities at Sulphur are unit-wire controlled, separate sets of local batteries are provided for these controls. The local switch control battery consists of 15

cells of DMGO-9 storage battery. The local signal control battery consists of two sets of five cells each of DMGO-9 storage battery.

At each controlled switch and signal location in the field one set of 15 cells of Exide DMGO-7 storage battery is

provided for the switches and local C.T.C. circuits. Another set of battery for signal and local relay circuits consists of five cells of EM-7. In the majority of cases each coded and OS circuit in the field where track leads are short, is fed by one cell of EM-11 storage battery which also drives the 5.5 ohm code transmitters. Where there are long track leads, two cells of the same type of battery in series are used due to the resistance involved. The storage batteries are on floating charge from dry-plate rectifiers. In one instance two cells of Edison 1,000 a.h. primary battery is used on track circuits at a cut section, where the pole line is not adjacent to the track.

Power Line

Power is received at locations in the field from the 550-volt, 60-cycle, a-c. power line. Where taps are made to this line, a G.R.S. air-cooled 550-110-volt, 60-cycle, transformer is mounted on the crossarm. The power circuit at such locations is protected by General Electric cat-head fuses and two Pellet type lighting arresters on the crossarm with the transformer. Supply service at 550 volts, 60 cycles, is received from various public utility companies at Leyden, Rollins, East Portal, Winter Park, Sulphur and Gore.

Where automatic block signals

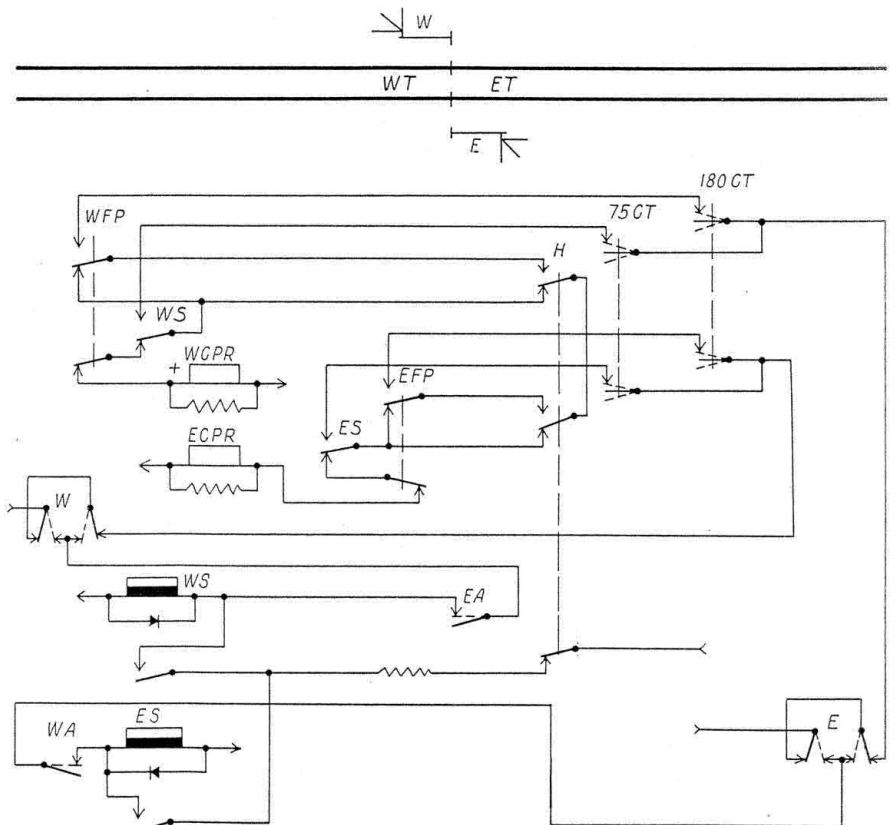


Fig. 13—Control of directional stick and code repeater relays at double intermediates

were in service previously between Denver and East Portal and between Kremmling and Orestod, the existing A.P.B. control and power wires on

ready in place, the C.T.C. coded control line is three No. 8 double-braid, w.p. insulated copper line wires. The supply circuit is on two No. 6 or

wires are divided into two quads, one quad being used at a time, and the other being reserved in case of an emergency, such as a cable failure. Two conductors in multiple are used for the line common, and a single conductor each is used for the line control and indication circuits. With this arrangement, a four-pole, double-throw knife switch is utilized at each end of the cable for switching purposes when required.

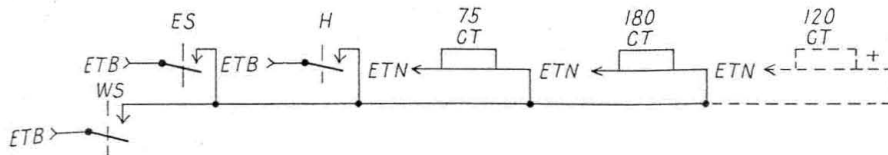


Fig. 14—Controls for code transmitters at double intermediate signal location



Portion of relays at Sulphur

the second crossarm of the telegraph and telephone pole line were used for the new C.T.C. system control and power circuits. Elsewhere where no such facilities were in place, a new 10-pin crossarm was installed on the existing telegraph and telephone pole line for the new C.T.C. line control and supply circuits. At the same time the crossarms were added, new poles were installed where required, the line reguyed where required to meet heavier loading conditions and in some locations, completely reconstructed. The poles on this line are cedar. Where existing pole line facilities were al-

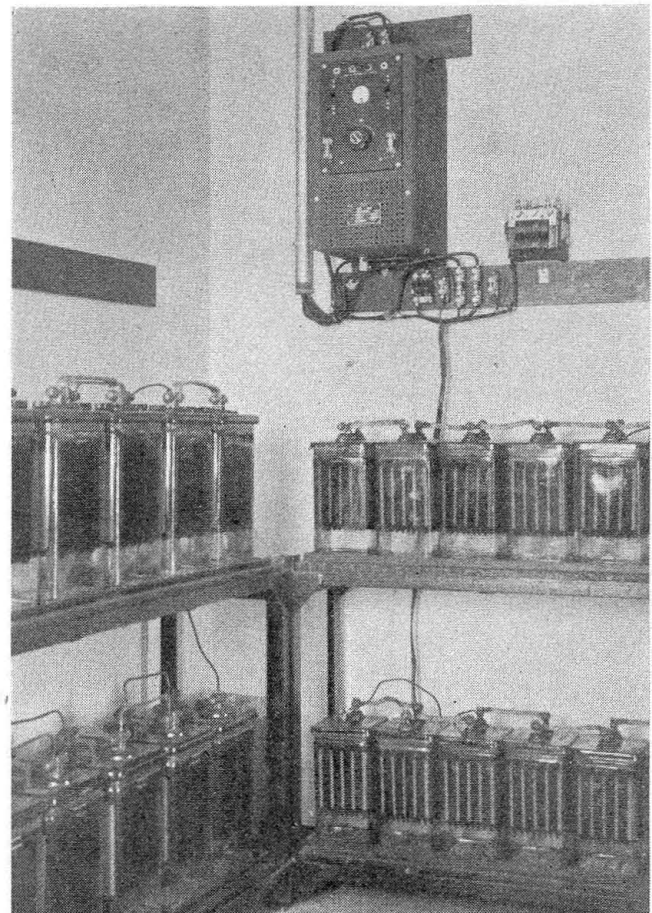
No. 4, double-braid w.p. insulated copper line wires transposed every 2 miles. Where new line was constructed, the C.T.C. line control circuits are on three No. 8 bare galvanized iron line wires, but the supply circuit is copper. The coded line wires are tied to Hemingray No. 42 clear glass insulators, while glazed brown porcelain insulators are used on the supply circuits.

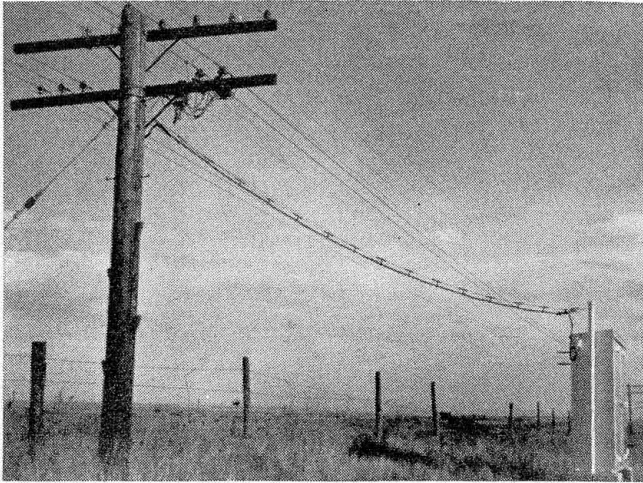
Telegraph Cable

Between the control machine in the Denver National Bank building in Denver and the junction pole at the railroad, eight wires in the existing underground telegraph cable were allotted to the signal department. This cable is the Western Union type with No. 16 paper impregnated conductors covered by a lead sheath. The eight

At line-tap locations the line wires are dead-ended on shackle-type dead-ends. Line drops are made with made-up cable from individual No. 14 solid, rubber-covered, braided, soft-drawn, copper conductors, supported on a solid No. 8 galvanized iron messenger with strain insulators by No. 14 wire ties. The cases and bungalows are wired with No. 16 flexible wires on low voltage local control circuits, and No. 10 on switch machine power circuits and battery leads. For ground connections, No. 6 bare wire is used in all cases, boxes and bungalows. At all locations a standard ground network is used employing three 6-ft. copper or Copperweld rods, with a total maximum ground rating of 25 ohms. The 550-volt arresters, cases, boxes or bungalows, anchor bolts and ground rods are all tied together in such a network. In the cases and bungalows the coded line circuits are

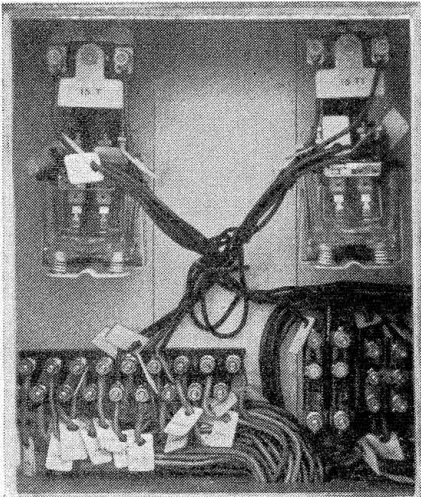
Portion of storage battery at Sulphur, showing a rectifier. All battery at Sulphur is in a separate combined battery and relay room in the new building sheltering the C.T.C. machine





Line drop at an intermediate automatic signal location, showing pole line and instrument case

broken through General Electric thyrte lightning arresters, and the 110-volt power circuit from the line and



Two track relays for a turnout

track wires, through G.R.S. carborundum-block lightning arresters.

The rails are bonded with American Steel & Wire mechanical type rail-head bonds. Bootleg connections are made with calsun-bronze bootleg bond wires with $\frac{3}{8}$ -in. plugs, using Raco bootleg risers. All insulated rail joints are of the Rail Joint Company's continuous type.

Sheet-Metal Bungalows

At the end of each passing track a 6-ft. by 8-ft. sheet-metal bungalow, which was received knocked down and assembled in field, includes the relays, rectifiers, field coding equipment and

Power-operated switches are equipped with Model-5D switch machines

storage battery. 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 department lock. At the intermediate signal locations, the relays, rectifiers and batteries are housed in large-size, 6-ft., 4-in. double-door, sheet-metal cases. The apparatus housings were wired at a central location by railroad forces.

Each bungalow is equipped on the outside with a special lamp, manufactured by the Lintern Corporation, and provided with a 360-deg. clear Fresnel lens and an 8-volt, 32 c.p., bayonet base automobile-type lamp. When one of these lamps is illuminated it is an indication to any employee, with the exception of an employee on a moving train, to call the train dispatcher immediately on the telephone.

Underground Cable

Underground wires between bungalows, cases, signals and switches are in Kerite bronze tape cable. Between

bungalows, relay and junction boxes at leaving-signal locations, 19-conductor cable, comprised of 6 No. 9 and 13 No. 14 conductors is used. Seven conductor No. 14 cable is used between bungalows, cases and signals. Between bungalows and switch machines a three-conductor No. 6 and a seven-conductor No. 14 cable is used. Between signals or between two or more units of signals, no wire or cable circuits are run directly. They are run to a terminal board in a case, box or bungalow and back.

Communications

A telephone, which can be connected to either the dispatcher or message telephone circuit by means of a small knife switch, is located in the booth section of the bungalows at absolute signal locations. At intermediate signal locations the dispatcher telephone circuit is brought directly into the apparatus case and terminated. Each maintainer carries a portable telephone, and if it is necessary for him to communicate with anyone he may do so by connecting his telephone to these terminals.

Construction

This installation was constructed and placed in service by the signal department construction forces of the Denver & Salt Lake under the direction of B. W. Molis, signal engineer. Construction was under the jurisdiction of O. H. Brown, signal construction engineer, B. M. Durland, signal supervisor, and A. H. Asnicar, signal inspector. Construction of all new signal pole line facilities was under the jurisdiction of S. V. Wirz, superintendent of telegraph and telephone. The major items of signaling equipment were furnished by the General Railway Signal Company.

