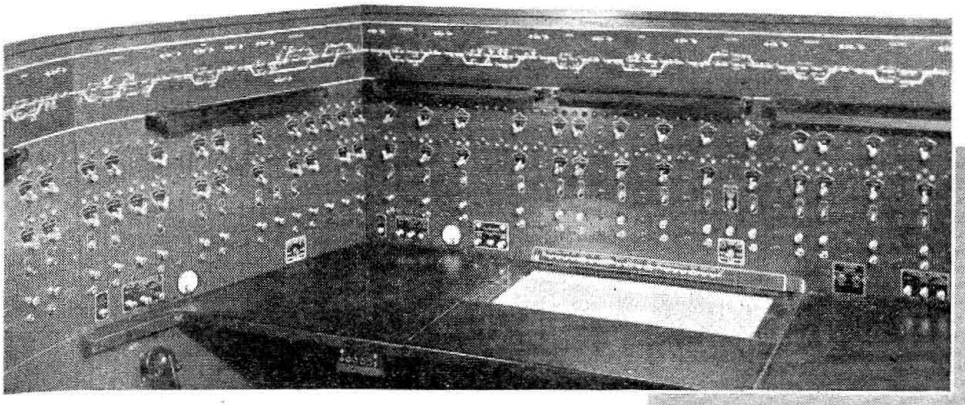
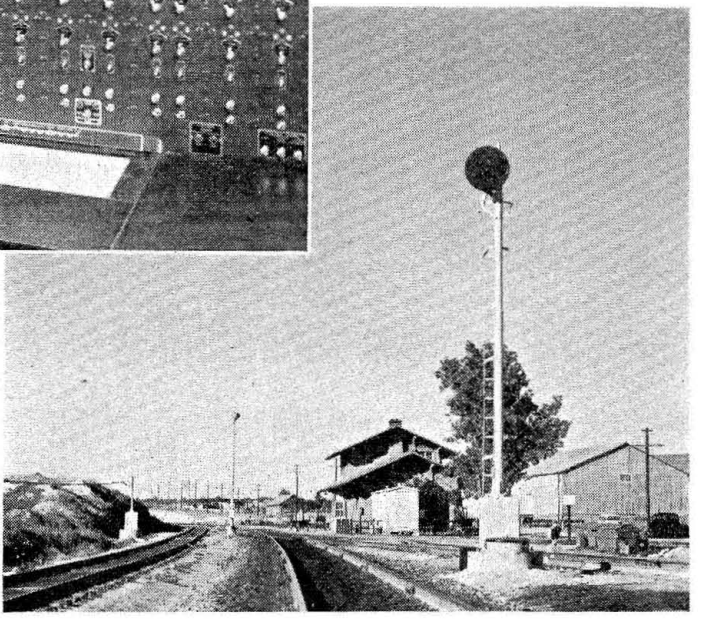


Left—C. T. C. control machine
Below—View of Mountainair passenger station looking west



Long sidings with signals permit freights to make non-stop meets almost as well as on double track

C. T. C. "West of the Pecos" On the Santa Fe

The Atchison, Topeka & Santa Fe has installed centralized traffic control on 105 miles of single track between Belen, N. M., and Vaughn, which is the Second district of the Pecos division. A second project, now under way, extends the C.T.C. on the First district between Melrose, N. M., and Joffre. These two projects comprising 202 miles of C.T.C., together with new double track between Clovis and Melrose and between Joffre and Vaughn, will provide continuous operation by signal indication between Clovis and Belen, 240 miles.

Between Newton, Kan., and Dalies, N. M., the latter being 10.3 miles west of Belen, the Santa Fe has two widely separated routes. The northern route, via La Junta, Colo., has heavy grades up to 3.5 per cent, and all but four of the through passenger trains between Chicago and California are routed that way. The southern route, via Amarillo, Tex., and Vaughn, N. M., has low grades except for one section of 1.25 per cent between Belen and Mountainair, and, therefore, the through freight traffic is handled on this route.

Another factor is that the Santa Fe line from Galveston, Houston, Ft. Worth and Dallas, connects with the east-west line at Clovis, N. M., 131 miles east of Vaughn, so that the Pecos division between Clovis and Belen handles traffic between points in Texas and California, as well as between Chicago, Kansas City and California.

The elevation above sea level is 4,806 ft. at Belen, 6,492 ft. at Mountainair, and 5,958 ft. at Vaughn. Going east from Belen Yards, the line rises constantly on a grade ranging from 0.5 to 0.6 per cent for the first 13 miles to Becker, and from there the grade continues to ascend at rates ranging up to 1.25 per cent for the remaining 26 miles to Mountainair. On this grade between Belen and Mountainair, the railroad is in the canyon of the Abo river for about 13 miles between Sais and Abo, and in this section there are seven 4-deg. curves and six 2-deg. curves. The locomotives assigned to through freight service are rated at 4,500 tons, and each eastbound train has a helper which is cut in at Belen and cut out at Mountainair.

From the summit west of the station at Mountainair, the grade descends eastward for 68 miles to Vaughn at varying rates between 0.3 and 0.6 per cent, except for 4 miles between Lucy and Silio where the grade ascends eastward at 0.1 to 0.6 per cent. Throughout the Mountainair-Vaughn territory, the railroad is in more or less open country, the curvature being very light, with no curves of more than 1 degree.

In the operating arrangement previously in effect, train movements were authorized by timetable and train orders, with single track automatic block signaling protection controlled on the overlap basis. Spring switches were in service at both ends of 14 sidings, and interlockings at both ends of 3 sidings. One siding had a capacity of 90 cars, five sidings a capacity of 110 cars, and 12 sidings a capacity of 130 cars.

The schedules included two

through passenger trains each way daily. A local freight train was operated each way daily except Sunday. Prior to the war, the remainder of the freight traffic was handled in two to three through freight trains each way daily. Thus the total traffic in the years 1930 to 1937 averaged from 12 to 16 trains daily, not including 2 to 3 light engine helper moves westward between Mountainair and Belen.

With the coming of the war, the number of passenger trains daily increased to an average of 3.2 eastbound and 5.7 westbound, and the freight traffic increased to a daily average of 762 cars eastbound and 812 cars westbound, totaling about 30 trains daily, in addition to about 10 light engine moves when helpers return from Mountainair to Belen. This increased volume of traffic caused serious train delays, especially on the grade between Belen and Mountainair. As a result, in this section the average speed of passenger trains was reduced to 31 m.p.h. westbound and 29.9 m.p.h. eastbound, and freight trains to 14.8 m.ph. westbound and 7.2 m.p.h. eastbound. Helper engines encountered serious delay in getting back down the hill to Belen, so that the number of locomotives assigned to this service had to be increased to an average of 6.9 daily. On the average, 3.8 freight crews were tied up daily on the 16-hour law.

What To Do About It

Faced with the necessity not only to expedite train movements but also to handle an ever increasing wartime traffic, a decision was made to lengthen the sidings and install centralized traffic control including power switch machines and signals for authorizing train movements, thus obviating the train stops and delays which were inherent in the timetable and train order method.

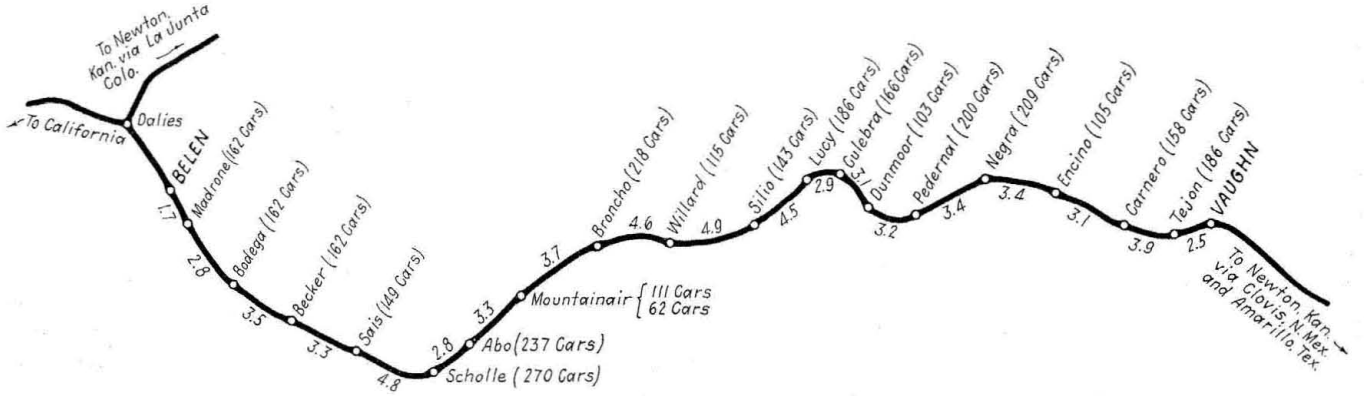


Fig. 1—Map of the general layout of the sidings on the C.T.C. territory

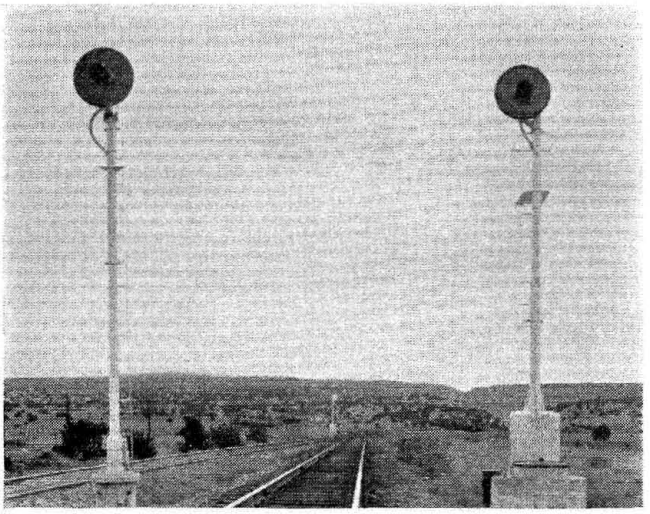
Long Sidings for Non-Stop Meets

The novel feature of this project is the use of very long sidings. At 13 stations the sidings were extended to 2 miles or more in length, and at 6 other stations the sidings range from 1.2 to 1.8 miles in length. In addition to a siding 3.4 miles long at Mountainair, there are also two other sidings, one with a capacity of 62 cars, and the other 111 cars. The distances between sidings and the car capacities of sidings, based on 55 ft. to the car, are shown on Fig. 1, and also in the accompanying table.

The purpose for lengthening the sidings was not to "hold" more trains but rather to provide track length for a train to keep moving while making a meet with an opposing train. On these sidings, the track is constructed and maintained to standards which permit trains to be operated safely at speeds up to 40 m.p.h. At many of the sidings, new No. 20 turnouts were installed to permit trains to enter and depart at speeds up to 40 m.p.h. As soon as materials are available, No. 20 turnouts will be installed at the remainder of the sidings.

All of these 21 sidings are equipped with track circuits which serve two purposes: (1) to control indication lamps on the track diagram on the C.T.C. machine so that the man in charge may be reminded of the presence of trains on sidings, and (2) these track circuits enter into the control of signals for directing trains to enter. When a switch has been reversed and a signal cleared for an approaching train to enter a siding, this aspect informs the engineman that the siding is unoccupied and, therefore, he can pull his train through the turnout and into the clear with promptness, rather than dragging along prepared to stop short of a train or a broken rail. Thus the train can use the turnout at the speed for which it was designed.

Having gotten his train into the clear on a siding, an engineman can reduce speed but keep moving. In the meantime the man in charge of the C.T.C. control machine can return the entering switch to normal and clear the signal for the opposing train to be met. At least eight times out of ten, the opposing train clears the far switch in time for it to be reversed and for the leave-



The west end of a siding showing a high leave-siding signal at the left

siding signal to be cleared so that the train on the siding need not stop, but can be accelerated and pull out promptly.

Another item of importance is that the leave-siding signals are the three-aspect type which display yellow if only one automatic block ahead is unoccupied, or green if two or more automatic blocks ahead are unoccupied. If the yellow were the best aspect on a leave-siding signal, an engineman cannot accelerate to maximum permissible speed until he sees the first intermediate signal, but, with the green aspect, an engineman can pull his train through the turnout at the speed for which it was designed and then promptly accelerate to the maximum permissible main line speed.

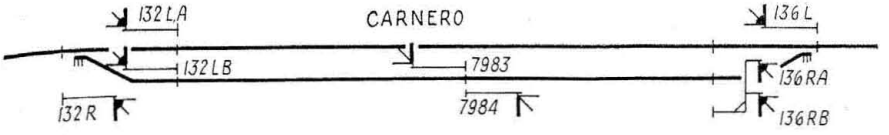


Fig. 2—Diagram showing signals on a siding

Can Hold Two Trains

As stated previously, the sidings were lengthened for the purpose of aiding in making non-stop meets, rather than to "hold" trains. On the other hand, in rare instances it is handy to double a train in on a siding behind a train of the same direction which is already occupying the far end. As applying to any one of the 13 long sidings with the intermediate automatic block signals, if the rear of the first train is beyond the intermediate automatic signal on the siding, the head-in signal can be cleared by C.T.C. control so that the engineman of the second train will know that the siding is unoccupied as far as the intermediate signal, and, therefore, this second train can be pulled in to stop short of the intermediate signal. If the intermediate signal were not provided, as is true with reference to the 8 shorter sidings, a second train would be stopped at the station-entering signal and then enter the siding under flag protection. The Fig. 2 shows the track and signal arrangement at Carnero, which is typical of the 12 long sidings.

Time-Distance Spacing Between Sidings

The possibility of making non-stop meets between opposing trains depends not only on long sidings but also on short time-distance between sidings, so that, with a better than average break, a train can be directed to move on over to the next siding and enter on short time, rather than being held back at the previous siding.

Train speed and distance are the factors which determine the time-distance between sidings. The maximum permissible speeds in this district are 90 m.p.h. for passenger trains and 50 m.p.h. for freight trains. Restrictions below these maximums are of course necessary on the grades as well as on some of the curves, the locations of which were discussed previously.

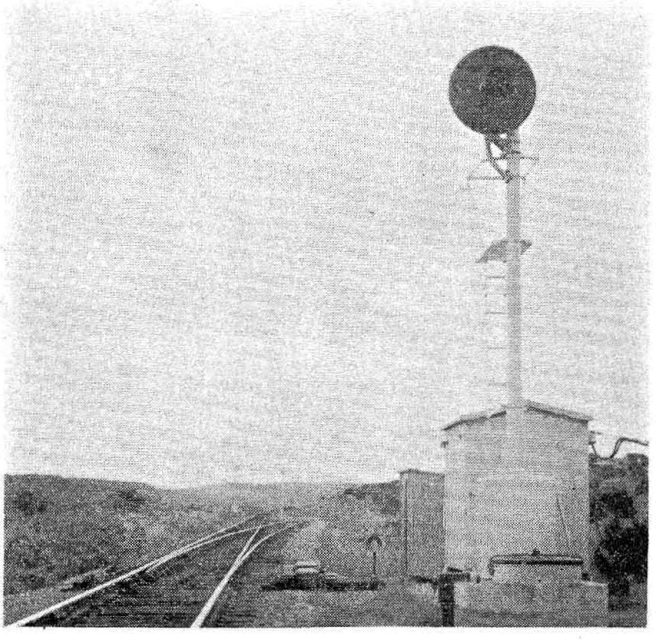
On this project the distances between sidings are comparatively short. As shown in Fig. 1, and in the table, the distance in miles from the west switch of one siding to the east switch of the next siding, ranges from 2.7 miles to 3.5 miles, with certain few exceptions. The outstanding exception is the 4.7 miles between Sais and Scholle. In this section, the grade is 1.2 per cent ascending eastward so that the speed is slow for eastward trains, thereby increasing the train time. This situation cannot easily be remedied because the railroad is in a canyon with no space available for another siding. Thus with these few exceptions, the time-distance between sidings on this project are short not only because of short distances but also because of the long turnouts and signals which permit trains to enter and leave sidings promptly.

Spacing of Intermediate Automatic Signals

In instances where the distance from one siding to the next varies from 2.5 to 4.5 miles, there is one set of intermediate signals, such a set including one signal for each direction. This arrangement applies in 15 of the 19 layouts between sidings. Between Silio and Willard, the distance is 4.9 miles and, therefore, two sets of intermediates are provided and the same arrangement provided on 4.6 miles between Willard and Broncho. Between Sais and Scholle, the distance is 4.7 miles, and furthermore the train speeds are slow on account of the grades and curves, therefore four sets of intermediate signals were provided in order to allow closer distance spacing between following trains when climbing the hill, or when going down the hill and around the curves at slow speeds.

Train Time Saved

These advanced practices in track layout with C.T.C. have proved to be advantageous as is indicated by studies of train operation before and after the project was placed in service on the section between Belen and Mountainair. Although the number of freight cars handled daily increased from 762 to 891 eastbound, and from 812 to 991 westbound, the average speed of freight trains increased from 14.8 m.p.h. to 24.5 m.p.h. westbound, and from 7.2 m.p.h. to 14.6 m.p.h. eastbound. On account of delays when returning



A station-entering signal and a power switch at the end of typical siding

from Mountainair to Belen, a helper locomotive and crew could be used for only one trip. Now the delays have been reduced so that a helper crew can help two, and sometimes three, trains up the hill and return to Belen. Counting road crews, as well as helper crews, the number of crews tied up on the 16-hour law was reduced from 6.9 to 0.1 per day.

Types of Signals Used

The automatic block signals previously in service on this division were the upper-quadrant three-position type. When changing over to C.T.C., the old semaphore mechanisms, spectacles and blades were scrapped. The masts were shortened and reused to mount the new searchlight type signal heads which are the H-5 type with quick-detachable plug-in mechanisms. These signals are equipped with 250-ohm operating coils for operation of 8 volts d-c. The signal lamps are the double-filament type rated at 8 volts, 13 + 3.5 watts.

In order that the aspects may be seen as far as practicable and without the possibility of interference locally, no dwarf signals are used, and, therefore, all signals on the sidings as well as on the main track are high signals. All signals are at the right of the track governed. Where practicable to do so, the sidings were thrown over to 18-ft. centers to allow clearance for a high signal on a mast. Where space was not available to throw the siding, the signals are on overhead bridges or cantilevers.

Fourth Aspect on Some Automatic Signals

With certain exceptions to be discussed later, each signal displays three aspects: red, yellow and green. In some instances the distance between signals at the two ends of a siding is less than maximum train stopping distance. As applying to such instances, as for example at Encino, as shown in Fig. 3, the automatic block signals 8011 and 8052 in approach to the station-entering signals are each equipped with a second "arm" which is one color signal lamp unit with an 8⅜-in. lens mounted on the signal mast 6 ft. below the center of the searchlight signal at the top of the mast.

Referring to Fig. 3, if signal 126LA is displaying the Stop aspect and signal 128L is lever controlled to line up for a westbound train with the switch normal, then the lower "arm" on signal 8011 would be lighted to display yellow under yellow in the searchlight unit. This yellow-over-yellow is the Medium Speed aspect which requires that the train be prepared to proceed at restricted speed at the next signal. Then the train will be traveling at a speed such that if the yellow aspect is still being displayed on signal 128L, there will be adequate space to stop in the distance between signal 128L and 126LA. A point of importance is that if the filament in either the searchlight unit or the bottom lamp on signal 8011 is burned out when supposed to be lighted to form a yellow-over-yellow aspect, no hazard thereby results because a single yellow is more restrictive than two yellows.

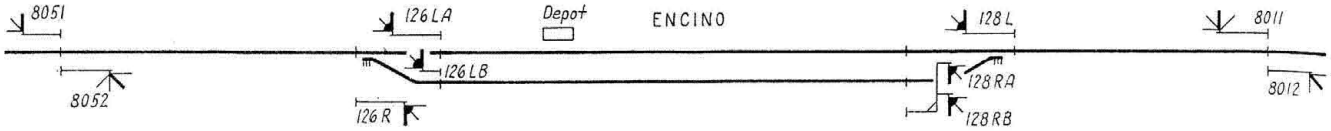


Fig. 3—Showing use of signals with fourth aspect

Switch Layouts

The power switch machines are the d-c. low-voltage type rated to operate in 14 seconds with 24 volts at the motor. In the No. 20 turnouts, the switch points are 30 ft. long, and, in order to prevent flexing of the points, a second operating connection is attached to a tie rod approximately 14 ft. from the point, with crank and pipe connections to the operating connection on the No. 1 rod. A layout of this type is shown in one of the views.

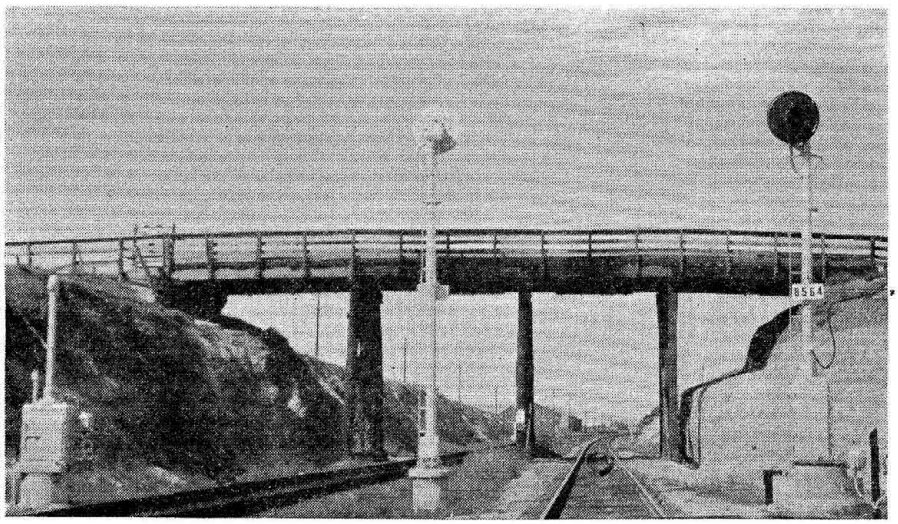
Insulated gage plates, 1 in. by 8 in., together with adjustable rail braces, are used on four ties, including the one ahead of the points. On two ties, the plates extend and are attached to the switch machine, thus preventing lost motion.

C.T.C. Control Machine

The C.T.C. control machine for the entire 105 miles of territory is located in an office on the second floor of the station at Mountainair. The center panel is 5 ft. long and at each side there are two panels which set at angles to form a "U" shape, the length of the five panels being 15 ft.

The illuminated track diagrams on these machines include a lamp to repeat the occupancy of: (1) Each OS switch detector section; (2) each passing track; (3) each section of main line opposite a passing track; and (4) each section of single-track main line between two passing tracks. The switch and signal levers, as well as the indication lamps above these levers are of the conventional arrangements.

Electric time locking is provided in connection with the signals at switches, i.e., if a proceed aspect is taken away by the lever control, electric time locking by time-element



Automatic signals on the siding located just west of Mountainair station

relays at the field location is effective in preventing operation of the power switch, as well as the clearing of an opposing signal until a certain time has elapsed. So that the operator will know when the time-element relay is operating, the red (Stop) indication light over the signal lever remains dark. Any attempt on the part of the operator to move a switch involved in the territory controlled by that signal will result in the loss of the code.

Traffic Direction Lamps

Below the levers, there are two rows of toggle type switches, one row of which controls the electric locks on the hand-throw main line switches and the other the maintainer's call lamps at each field location.

Above each portion of the diagram representing a section of main track between sidings there is a double-headed arrow with two lamps. When the machine controls are established to permit the clearing of a signal in a westward direction, the lamp to the left, which is green, is lighted. Or, when eastward, the right-hand lamp, which is yellow, is lighted.

Coded Carrier for C.T.C.

The C.T.C. system is the Union Switch & Signal Company's Type L, Form 506-A, time code for multiple line application, using biased polar line and starting relays. The transmission of control codes and return of indication codes are handled on two line wires throughout the project.

From the standpoint of the C.T.C. code line, the territory between Vaughn and Belen is cut into three separate sections. The code line west from Mountainair handles the 40.8 miles between Belen and Mountainair by conventional d-c. codes, this line being entirely independent from the code lines east of Mountainair.

The code line east from Mountainair to Culebra is handled by conventional d-c. codes, and also the line wires in this section handle 5 kilocycle carrier code which, at Culebra, is converted to conventional d-c. code for control of signals and switches on the 35.9 miles between Culebra and Vaughn. Similarly, the indications from the Vaughn-Culebra section are handled by d-c. code to Culebra where they are converted to 4 kilocycle carrier code on the line wires between Culebra and Mountainair. Thus controls can be sent to or indications received from the three sections simultaneously. The detailed circuits for coded carrier were explained on page 314 of *Railway Signaling* for June, 1944.

New Signal Pole Line

As a part of the project, a new pole line was constructed for the signaling line wire on the entire 105 miles except for 4.8 miles between Sais and Abo. This latter section 4.8 miles long is in the canyon of the Abo river where the terrain is so rough that the construction of a signaling pole line would have been very expensive. Therefore, in this section, the new signaling wires were installed on an arm on the Western Union-Santa Fe pole line.

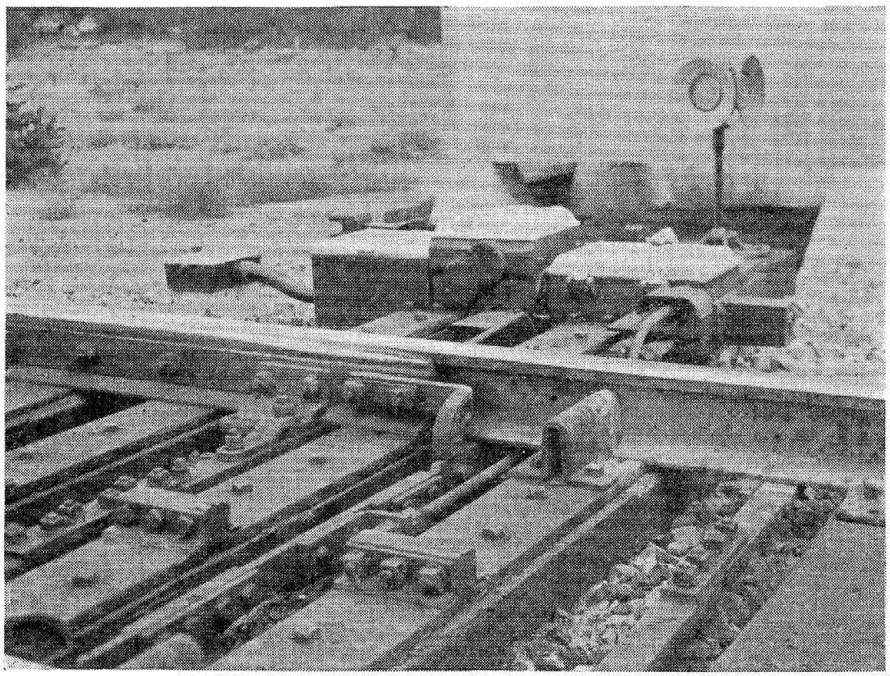
The 105 miles of new signal pole line was constructed with yellow pine poles, creosoted full length. The poles are 25 ft. high with a minimum of 8 in. at the top, and are spaced 35 per mile. H-fixtures were constructed at all the line transformer locations, such as at power switch locations and at intermediate signal locations. Where necessary to run a-c. to other locations, such as track circuit cut sections, these feed are at 120 volts on No. 6 wire on the lower crossarm. On long curves the poles are not set the same distance from the track to form a curve parallel to the track. About every fifth pole acts as a corner pole, and between two such poles the intermediate poles are in a straight line with the end corner poles. In this manner, guying is confined to the corner poles.

The gains are spaced 2 ft. A two-pin arm 38 in. long, in the top gain carries the two a-c. power distribution wires, and a 10-ft. 10-pin arm in the third gain carries the wires for the C.T.C. code, the local signal controls and the other line wires for the track-occupancy indication controls and for motor car indicators.

Power Distribution

The a-c. power distribution is at 60-cycle single-phase, supplied from commercial sources. The service feeding from Belen and Willard is at 4,600 volts, and from Mountainair, 2,300 volts. The line transformers rated at 4,600/115 volts and 2,300/115 volts are oil-immersed, crossarm mounted. These transformers at power switches are rated at 1.5 kva., and at intermediate signals at 1 kva. Between Sais and Abo, where the signaling wires are on the Western Union-Santa Fe pole line, the signal power distribution circuit is single-phase 460 volts. In this territory, the 460/115 volt transformers are rated at 250 V.A.

The two power distribution line wires are No. 6 bare copper. The two C.T.C. line wires are No. 8 Copperweld, 40 per cent, with weather-proof covering, and the same type of wire or else No. 8 galvanized iron with weather-proof covering is used for the two local signal line control wires.



The power switches have heavy gage plates and adjustable rail braces on four ties

Storage and Primary Battery

Storage batteries, Exide DMGO-9, are used for feeding the line code equipment, the power switch machines and the majority of signal

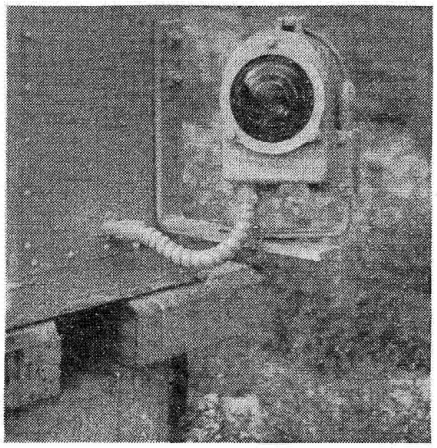
lamps, as well as some of the line circuits. Edison B4H storage batteries are used at some locations to feed signal lamps and line circuits, while at other locations the Edison 500-a.h. primary batteries, formerly in service, were re-used to feed line circuits. Each track circuit is fed from a set of four cells of Edison 500-a.h. primary battery connected in multiple.

The previous automatic block signaling included d-c. neutral track circuits, and two two-wire polar line circuits, one such circuit being for the control of signals in each direction. These line circuits were arranged on the overlap principle. In the new arrangement, the automatic signals are controlled on the absolute permissive block scheme. As a part of the C.T.C. system, only one of two opposing station-leaving signals can be cleared at any one time and, therefore, the intermediate signals need not be arranged to provide head-on protection. For this reason, the intermediate signals were entirely rearranged to provide protection for following moves and to serve as "distant" signals. As a result, the track circuit locations were changed in most instances, but the practice of using d-c. neutral track circuits was continued in the C.T.C. system. With 4-ohm relays, the maximum length of track circuits on main track is 3,500 ft. On passing tracks, the ballast may not be so clean and, therefore, the track circuits are limited to 3,000 ft.

Two-Wire Either-Direction Line Circuit

In the new arrangement, a circuit with only two line wires is used for the automatic controls of signals for one direction or the other, depending on the direction for which traffic is established when the C.T.C. code control is sent out from the office to clear a signal. The two-wire either-direction circuit is, in effect, practically the same as was installed on the Louisville & Nashville, as was explained in detail with circuit diagrams on page 420 of the August, 1943, issue of *Railway Signaling*. An important difference between the reversible line circuit used on the Santa Fe and that described for the L. & N. is that the Santa Fe uses positively-controlled switching to determine whether "battery" or "relay" is to be connected to the circuit at a control point while the L. & N. scheme employs automatic methods. The positive control makes use of a C.T.C. function relay (polar-stick Style-KP) to provide the directional selection, which is determined by the inter-panel wiring on the C.T.C. machine. Thus in clearing a home signal, codes are sent to both ends of the traffic block to properly select and set the direction of the two-wire circuit. Such a scheme permits the application of battery to both ends of the circuit to transmit a switch "unlock."

The intermediate automatic block signals between stations, for the direction of traffic established, are normally clear, i.e., the operating coil of the searchlight signal is energized to operate the spectacle to either the yellow or the green position. The lamps, however, are normally extinguished, being lighted when a train enters the block approaching the said signal. This approach control is done by a 40-ohm series line relay for each signal so that there are two such relays in series with each of the either-direction two-wire line circuits between any two given sets of intermediate signals.



A lamp-type motor-car indicator

Train movements through the signaled sidings are handled in the same manner as train movements from siding to siding in that opposing movements are positively blocked but following movements are permitted. A four-wire circuit arrangement is used in lieu of the two-wire scheme described above to avoid necessity for extra storage units at the field stations.

Block control of signals on the main track within station areas is accomplished by use of the reversible two-wire circuit as described for intermediate main line territory.

Lightning Protection

The lightning arresters on the 4,600-volt and 2,300-volt a-c. power distribution circuits are the G. E. Co. Pellet type and are mounted on the crossarms of the H-fixtures. The arresters for the C.T.C. code line and local signal line circuits are mounted in a wooden box on the crossarms. The connections to ground consist of 1-in. galvanized iron pipe from this arrester box down to and into the ground far enough to make a good low resistance connection. General Electric Company Thryite arresters are used on the C.T.C. code line circuits with a KX642 Westinghouse arrester across the battery end. On the signal line control circuits, otherwise known as traffic direction circuits, a General Electric Thryite arrester is connected across the coil of each of the searchlight signals, this coil being connected directly on the line when energized.

Motor Car Indicators

This project includes motor car indicators by means of which the men on motor cars can be informed of the approach of trains on those sections where curves and high banks reduce the sighting distances. Wherever a-c. power is available, these indicators are of the electric light type, each indicator consisting of a complete electric lamp and cast-iron case as previously used for electric lamps on the old semaphore signals. These indicators are mounted either on the signal cases or on short poles along the track, and are placed so that the lens is directed toward the track. Each indicator encloses a 3½-watt 13.5-volt lamp which is normally lighted when the track circuits, which are included in the control limits, are unoccupied. The lamp in each indicator is controlled through the front contacts of track relays for the extent of the control. Information to show the limits of control is given on the indicator. Semaphore type indicators are used at intermediate locations where no a-c. power is available to feed a light-type indicator. The semaphore indicators are equipped with 500-ohm coils which are controlled directly by line circuits.

The line circuits for the indicators are fed from sets of 16 cells of 500-a.h. Edison primary battery. Thus the battery and line circuits are entirely separate from the automatic signal and C.T.C. system. The line wire used for the indicator control is old second-hand galvanized-iron wire formerly used in the controls of the old semaphore automatic signals.

The track changes and centralized traffic control on this project were planned and constructed by the forces of the Atchison, Topeka & Santa Fe, the major items of the signaling equipment being furnished by the Union Switch & Signal Company.