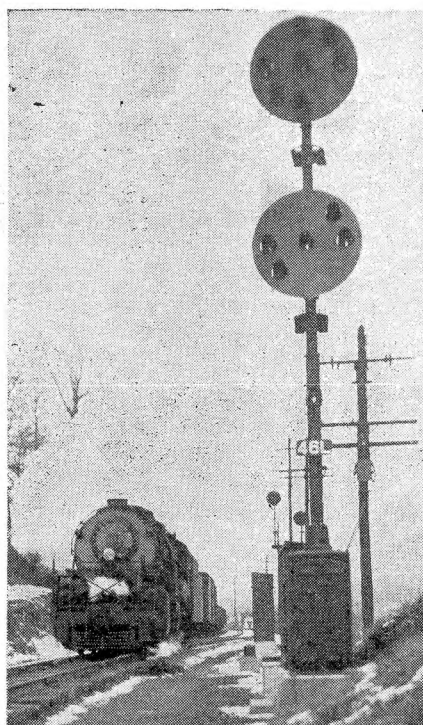


Southward signal at the north end of the siding at Buchanan, Va.



**Project on 107.8 miles of single track and 10 miles of double track reduces delays on busy line handling 45 to 55 trains daily**

# N. & W.

# Installs C. T. C.

## On Shenandoah Valley Line

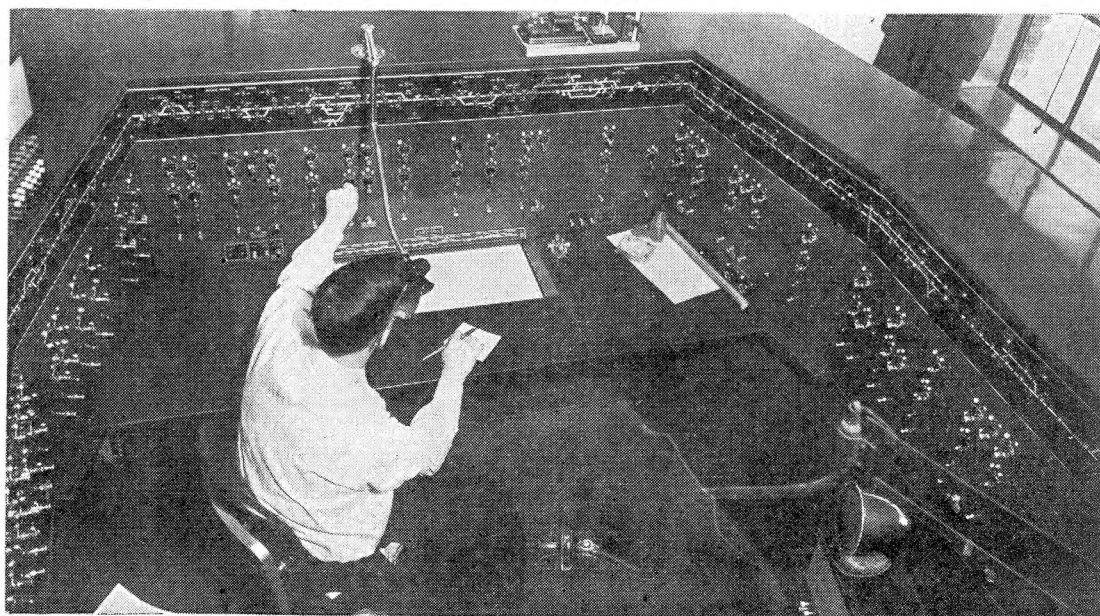
THE Norfolk & Western has recently completed an improvement program on the Shenandoah Valley District, including the construction of second track on 10.56 miles, and the installation of centralized traffic control on this new section of double track as

well as on 107.8 miles of single track. The purpose for these improvements was to reduce train delays and to increase the operating capacity approximately 30 per cent.

This Shenandoah Valley line extends 238 miles in a generally north-

and-south direction between Roanoke, Va., and Hagerstown, Md. At Roanoke, connections are made with the east-and-west main line of the Norfolk & Western between Cincinnati and Columbus, Ohio, and Norfolk, Va., as well as with a line between Roanoke and Winston-Salem, N. C. At Hagerstown, connections are made with the Pennsylvania and the Western Maryland, at Shenandoah Jct., with the Baltimore & Ohio, and at Waynesboro with the Chesapeake & Ohio.

Prior to the war, this Shenandoah District handled two passenger trains and three through freight trains each way daily, in addition to local freight trains. In February, 1939, the last pre-war February, this district handled 91,213,000 gross ton miles. At that time, the freight traffic was mostly agricultural and manufactured products, with no coal except for local delivery. By February, 1942, the traffic had increased to 180,452,000



Control machine for the Roanoke to Stuarts Draft section is arranged in a "U" shape

gross ton miles, nearly double that for February, 1939. Next came the war and curtailment of vessel movements along the Atlantic Coast, which necessitated that much of the coal, which had been moved by coastwise vessels north from Norfolk, Va., be handled by rail. As a result, the traffic on the Shenandoah District increased to 558,557,000 gross ton miles in February, 1943, more than six times the pre-war figure.

This traffic included 22,591 loaded cars and 1,139 empty cars out of Roanoke northbound, 16,201 of the loaded cars being coal, and 5,472 loaded cars and 13,736 empty cars into Roanoke from the north. The peak day was February 23, 1943, when 1,223 loads and 62 empties were moved north from Roanoke, and 276 loads and 715 empties arrived at Roanoke from the north. During the last few months traffic has decreased slightly, a total of 42,117 cars, counting both out of and into Roanoke over the Shenandoah District, being handled in February, 1944, as compared with 42,938 in February, 1943. The traffic in February, 1941, included an average of 14.4 trains daily as compared with an average of 33.3 trains in February, 1944. These figures include four passenger trains daily and a local freight train each way daily except Sunday, as well as return moves of light helper engines.

Prior to the recent improvements, train movements were authorized by timetable and train orders, with automatic block signal protection. As the traffic increased during 1942, the delays to trains became excessive. The

dispatchers could not issue orders fast enough, and as a result trains, in many instances, would wait in the yard for orders, or would be stopped at stations on the line to wait for orders. Inferior trains were required to clear the main line at least five minutes prior to the schedule time of superior trains. If some trains did not make the time anticipated, other trains would be delayed because there was no means for changing train orders soon enough to take advantage of the changed conditions.

Especially on the heavy grades, the trains lost a great deal of time when

miles of the single track in the sections where grades and curvature reduced the train speeds. One section of C.T.C. extends 85 miles between North Roanoke and Stuarts Draft, and the second section extends 34 miles between Shenandoah and Bentonville.

### Physical Characteristics of Line

The track consists of 130-lb. rail, good ties and crushed rock ballast, all of which is maintained in good condition. The maximum permissible speed for freight trains is 45 m.p.h.,



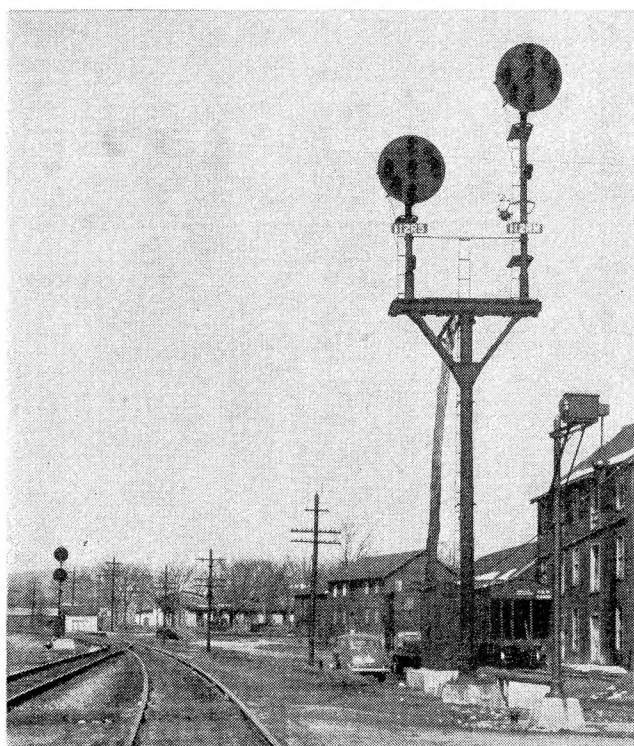
Equilateral turnout at the end of double track near Cold Spring, Va.

entering or leaving the passing tracks at which hand-thrown switches were in service. Therefore, a decision was made to construct second track on 10.5 miles of the heaviest grade between Vesuvius and Cold Spring, and to install centralized traffic control on this double track as well as on 107.8

and on grades, either ascending or descending, the limit is 30 m.p.h. The maximum speed for passenger trains is 65 m.p.h.

Between Roanoke and Buchanan the railroad passes over the divide between the Roanoke and the James rivers, the ruling grade southbound is 1.5 per cent for 3.5 miles between mile posts 221 and 225. On this grade there are three 4-deg. curves, one 5-deg., one 6-deg., and two 7-deg. The tonnage rating for Class Y-6 locomotive southbound up this grade is 2,650 tons. As the majority of southbound traffic consists of empty cars, the train length, rather than tonnage, usually determines the limit.

Between Buchanan and Glasgow, 19.2 miles, the line is near the James river and is mostly at river grade. Between Glasgow and Buena Vista, the line follows up the valley of the North river at water grade. Between Buena Vista and Stuarts Draft, 32 miles, the line passes over the divide between the James river and the Shenandoah river, the maximum grade northbound being 1.5 per cent for about 1.25 miles between M.P. 162.6 and 164, this being the ruling grade northward. The crest of this grade is at Lofton, and the ascending grade southward from Cold Spring to Lofton is about 1.5 per cent for nearly three miles. The curvature on this grade, however, is very light, so



Typical signals at the north end of Buena Vista, Va.

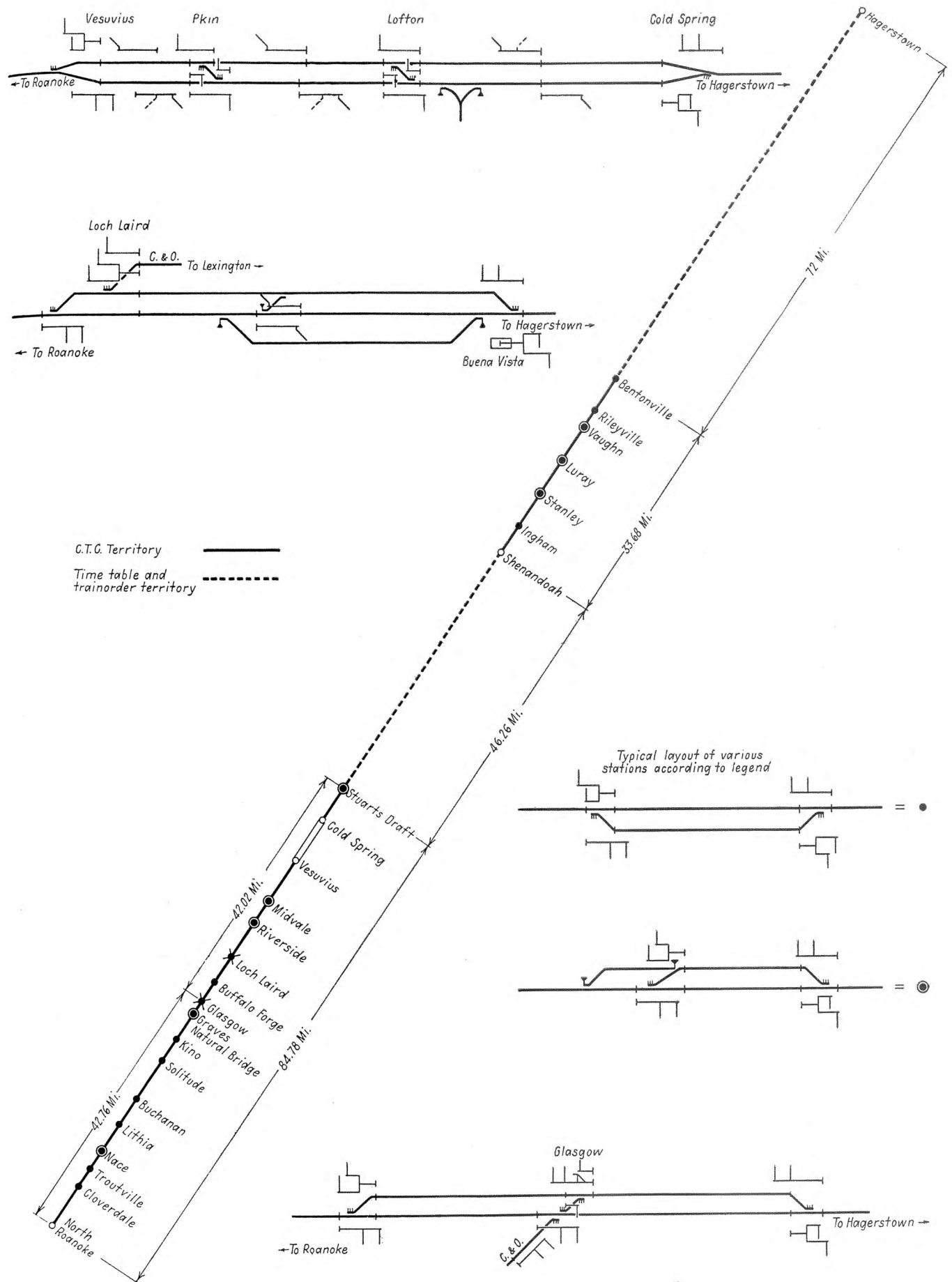
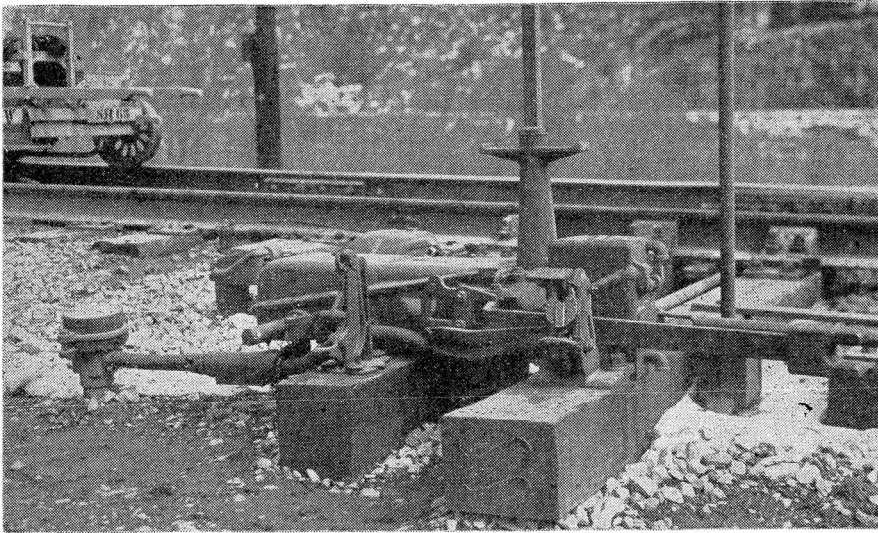


Diagram of the division showing the C.T.C. territories and typical track layouts





Hand-throw stand with an electric lock on an outlying switch in C.T.C.

that this is not the ruling grade southbound. The new section of second track extends throughout the heavy grades between Cold Spring and Vesuvius, 10.5 miles.

The Class Y-6 compound mallet locomotives, with 152,206 lb. tractive power simple and 126,838 lb. compound, are rated at 3,000 tons northbound between Roanoke and Shenandoah, this tonnage being determined by the ruling grade previously discussed. The operating practice is to handle about 6,000 tons in each train, with a Class Y-6 helper locomotive at the rear just ahead of the caboose. From 70 to 75 cars of coal, or about 100 cars of mixed freight, made a train of 6,000 tons. The helper locomotive is included in the train when it is made up in the yard at Roanoke and runs through the 76.6 miles to Lofton. After passing the crest of the grade at Lofton, the train is stopped with the rear just north of the wye switches. The helper locomotive is cut off and is turned on the wye, while the caboose drifts on down and is coupled to the rear of the train. Then after the train departs, the helper returns light to Roanoke. Thus for every tonnage train northward, there is an extra light-engine movement southward between Lofton and Roanoke, which was an additional consideration in favor of providing centralized traffic control all the way between Roanoke and Stuarts Draft, which is the first siding layout north of Cold Spring.

This C.T.C. includes power switches and semi-automatic signals at the ends of double track at North Roanoke, Vesuvius and Cold Spring as well as at 14 passing tracks. Within the limits of the double track there is a power operated crossover at Lofton and another at Pkin. Signaling is provided for train movements in either direction on both tracks of this section

of double track. Branch line trains of the Chesapeake & Ohio, one each way daily, use the Norfolk & Western main line between Glasgow and Loch Laird. The junction switches at Glasgow and at Loch Laird, as well as a crossover between the main line and siding at Glasgow, are power-operated and included in the C.T.C.

In the track layouts at the ends of double track at Vesuvius and Cold Spring, the switch points are 30 ft. long and the frogs are No. 20 with the divergence divided to make equilateral turnouts. Therefore, a train movement from the single track to either track of the double track or vice-versa can be made at normal speed. At these locations the freight train speeds are limited by the grades, but passenger trains are authorized to operate through these turnouts at normal speeds up to 65 m.p.h.

Between Stuarts Draft and Shenandoah the line is located in the valley of the Shenandoah river, the grade as well as curvature being comparatively light. In this section, train movements are authorized by timetable and train orders, with automatic signal protection, the same as previously.

#### The Shenandoah-Bentonville Section

Shenandoah, 135 miles north of Roanoke, is the sub-division point at which engine crews and freight train crews are changed. For the 105.7-mile sub-district between Shenandoah and Hagerstown, the ruling grade northbound is 1.5 per cent for about 0.9 mile between M.P. 99.7 and 100.6. This grade includes one 5-deg. curve and one 8-deg. curve. The ruling grade southward varies from 1.6 to 2.0 per cent for about 0.9 mile between M.P. 81.5 and 82.4. The Class Y-6 locomotives are rated to handle 2,750 tons

northbound and 3,000 tons southbound over these ruling grades between Shenandoah and Hagerstown. For trains handling more than the rated tonnage, helper locomotives are provided for northbound trains between Ingham and M.P. 98. Thus on account of the grades and extra helper locomotive moves, centralized traffic control was installed on the 34 miles of single track between the north yard switch at Shenandoah and the north passing track switch at Bentonville. These new facilities include semi-automatic signals and power switch machines at the north yard switch at Shenandoah and at the passing track switches at Ingham, Stanley, Luray, Vaughn, Rileyville and Bentonville.

#### C.T.C. Control Machines

The dispatchers' offices for the entire Shenandoah District are located in Roanoke. One dispatcher operates the C.T.C. machine for the North Roanoke-Stuarts Draft territory and handles the Stuarts Draft-Shenandoah section by train orders. A second dispatcher, in a different room, operates the C.T.C. machine for the Shenandoah-Bentonville section and handles the Bentonville-Hagerstown section by train orders.

The Shenandoah-Bentonville control machine consists of a panel 60 in. long, as shown in one of the accompanying illustrations. The Roanoke-Stuarts Draft control machine is made up of five panels arranged in a horseshoe shape, as shown in a picture herewith, the total length of the panel being 15 ft.

A special feature of the illuminated track diagrams on these machines is that a track occupancy lamp is provided to repeat each and every intermediate automatic block, this practice made it necessary to use longer sections of diagram to represent the portions of single track between towns. A result is that the levers are spaced farther apart in some instances than has previously been the practice with this type of panel. Also the diagram includes lamps to repeat occupancy of each passing track, as well as each OS switch detector section and section of main line opposite each passing track.

The switch levers and the signal levers are equipped with the conventional arrangements of indication



lamps. The C.T.C. system includes automatic time locking, including style DT-10 time-element relays. If a semi-automatic signal has been cleared, and is then "taken away" by lever control, the switch involved cannot be moved until the automatic time release has functioned, regardless of whether the approach track section is occupied. During the period when the time locking is in effect, all three indication lamps, on the signal lever involved, are extinguished, and as soon as the locking is released, the red indication lamp is lighted as information to the dispatcher so that he can save train time by sending out new controls for a different line up as soon as such codes would be effective in the field. If the dual control selection lever on a switch machine is operated from its normal position, an indication code is sent to the office which causes both the normal and reverse indication lamps above the corresponding switch lever to be lighted.

Each of the two C.T.C. control machines is equipped with a graphic train chart. Each morning, this chart is torn off on the line representing midnight, and this graph serves as the official record of train movements, the same as the ordinary train sheet for the sections where the timetable and train orders are in effect.

The panel also includes lamps which display indications when rock-slide detector fences are operated, when a-c. power is cut off of certain sections of the line, or when the air pressure at an electro-pneumatic switch is below a certain minimum.

### Signaling Arrangements

Prior to the recent C.T.C. program, the Shenandoah Valley District had been equipped for many years with straight a-c. automatic block signaling, using position-light signals, and the system included continuously-controlled three-aspect cab signaling.

When changing over to C.T.C., some of the intermediate signals were relocated and the controls were revised, this being made possible by the fact that C.T.C. obviated the necessity for opposing intermediates to provide head-on protection. The neutral a-c. track relays and polar line relays were retained in service. The absolute permissive block line control circuits include one wire in connection

with common for each direction, thus totaling three line wires, these circuits being continued in service. These wires are No. 10 Copperweld with weather-proof covering. In numerous instances the track relays and feeds were changed end-for-end to get the relay nearer to a C.T.C. field station, so that the length of line wire to be added to repeat the track occupancy of the intermediate automatic blocks, would be a minimum.

### Signals at Passing Tracks

The automatic signals at the ends of passing tracks were previously located properly for centralized traffic control, and, therefore, did not have to be moved, except at those locations where the passing tracks were lengthened. An accompanying picture shows the station-entering signal at the north end of Buchanan. When installing C.T.C., the lower unit was added on this signal so that the aspect of a horizontal row of lights over a diagonal row could be displayed, with the power switch reversed, to direct a train to enter the passing track. This aspect is track-circuit controlled on the passing track so that if the passing track is occupied, an aspect cannot be displayed for a second train to enter.

Another picture shows the northward station-departure semi-automatic C.T.C. controlled signals at the north end of Buena Vista. The two signals are mounted on a bracket mast located at the right of the main track and opposite the fouling on the passing track, identically the same as previous to the change over to C.T.C. The signal applying to the main track, 112RM, is to the right and has a higher mast than the signal 112RS which is to the left and has a shorter mast and applies for directing trains to depart from the passing track. Absolute signals are each so designated

by a marker lamp on the mast 6 ft. below the center lamp in the operative unit.

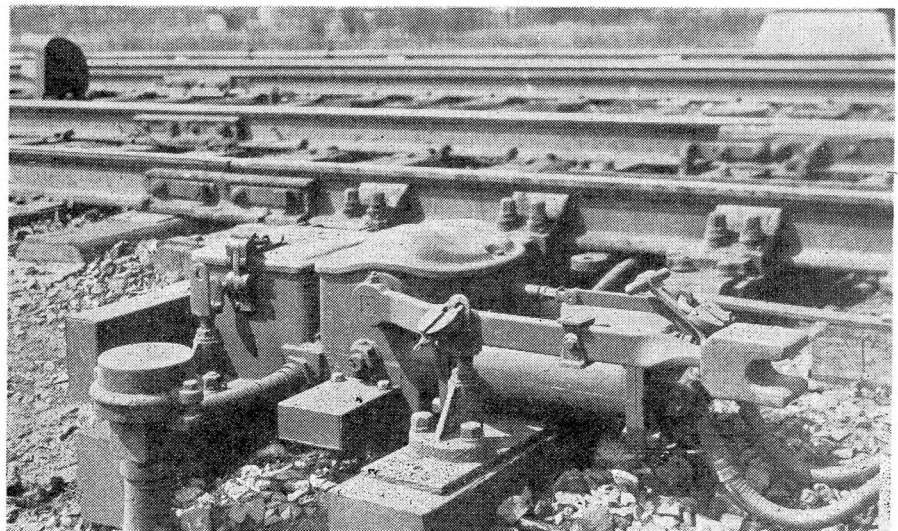
### Benefits of the Improvements

The benefits of the new improvements, including the new section of second track and the centralized traffic control, can be measured by the average reduction in train time on the road. The average time for through freight trains from yardboard to yardboard, North Roanoke to Shenandoah in February, 1943, was 7 hours 18 minutes, which was reduced in February, 1944, to 6 hours 4 minutes, a reduction of 1 hour 14 minutes. For southbound trains, between Shenandoah and North Roanoke, the average train time was reduced from 7 hours 54 minutes to 6 hours 5 minutes, a saving of 1 hour 49 minutes.

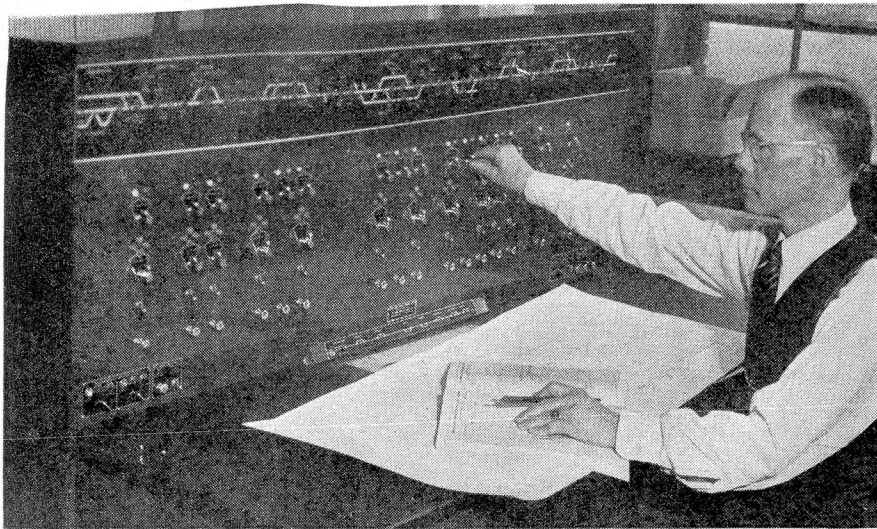
On the Hagerstown-Shenandoah district of 105.7 miles on which C.T.C. was installed on only 33.7 miles between Hagerstown and Bentonville, the average reduction in running time for northbound trains was 33 minutes, and for southbound trains the reduction was from 6 hours 4 minutes to 5 hours 4 minutes, a saving of 1 hour. Counting loaded as well as empty cars moved out of and into Roanoke over the Shenandoah district, the traffic handled in February, 1943, was 42,938 cars as compared with 42,117 cars in February, 1944, which was not much of a total reduction.

### Electro-Pneumatic Power Switches

Each of the power switches is operated by a Type A-20 dual control electro-pneumatic switch machine. When the selector lever is operated, the air supply to the switch machine is cut off, the valve control circuits are opened, and an indication code is sent to the dispatcher's office which



Dual-control electro-pneumatic switch machine on siding switch



The second C.T.C. machine for the control of section from Shenandoah to Bentonville

causes both of the indication lamps above the switch lever to be lighted. Each selector lever is locked with a standard switch padlock in order to prevent unauthorized movement of this lever. The hand-throw lever is, of course, also padlocked. Each switch layout is equipped with the standard arrangement of lock rods and a point detector which is set to operate if the switch point is open more than 3/16 in.

The compressed air for the operation of the switch machines is supplied by small-capacity motor-driven compressor sets. Duplicate compressors, each rated at 3.5 cu. ft. per min., are located at each single switch or crossover. The compressors are controlled automatically, the one in normal operation being set to cut in at 55 lb. and cut out at 70 lb., while the auxiliary compressor is set to cut in at 45 lb. and cut out at 60 lb. Each of the 3.5-cu. ft. compressors is driven by a 220-volt a-c. motor, rated at 3/4 hp.

#### Electric Locks on Hand-Throw Switch

At various places, as shown on the diagram, house tracks or spurs leading to industries are connected to the main line with hand-throw switches. At each of these locations, the previous switch stand was replaced with a T-21 hand-throw switch-and-lock movement including an electric lock which locks the operating lever in the normal position. These layouts include lock and point-detector rods which lock the switches in the normal position. In each instance, a Hayes derail, located at the clearance point on the turnout, is pipe connected to, and operated by, the T-21 hand-throw switch and lock movement.

A telephone is located near each switch. When one of these switches is to be used by a train, the conductor

telephones to the dispatcher. Where a switch with an electric lock is located within station limits, the lock is controlled by a lever on the C.T.C. machine. The electric locks on switches on single track between stations are controlled automatically by circuits on the same line wires that are the a.p.b. local line controls, these circuits being in effect the same as used on the various roads including the Chicago, Burlington & Quincy, as explained on page 203 of the April, 1943, issue of *Railway Signaling*. The point of interest is that no extra line wires are required to control these electric locks.

#### Coded Carrier C.T.C.

The two C.T.C. control machines are in adjacent rooms in the dispatchers' offices at Roanoke. The controls are sent out to the field stations, and the indications are returned by the means of Union Switch & Signal Company multiple time code system, multiple application, using only two new line wires between Roanoke and Bentonville. This project includes three separate arrangements of time code sending and receiving equipment, each with a capacity to handle a maximum of 35 stations. A point of special interest is that the system as a whole requires only two line wires throughout the Roanoke-Bentonville territory.

The controls and indications for the 44-mile section between North Roanoke and Glasgow are effected by conventional d-c. codes on the two line wires and similarly d-c. indication codes are transmitted on the same two line wires from the field stations in this section to the office at Roanoke.

The controls for the switches and signals between Glasgow and Stuarts Draft, 42 miles, are coded 20 kilocycle frequency which is transmitted over the same two line wires men-

tioned above and is received by carrier apparatus at Glasgow, and converted to conventional d-c. codes to be transmitted to the local field stations between Glasgow and Stuarts Draft. From these field stations, d-c. indication codes are transmitted to Glasgow where they are converted to 14 kilocycle carrier current for transmission to Roanoke.

The controls of switches and signals on the Shenandoah-Bentonville section are sent out from the Roanoke office as coded 18 kilocycle frequency to Stuarts Draft where they are converted to conventional d-c. codes for transmission to the various field stations in the Shenandoah-Bentonville section. Similarly d-c. indication codes from stations on the Shenandoah-Bentonville section are transmitted to Stuarts Draft where carrier current apparatus converts these codes to coded carrier of 12 kilocycles for transmission to Roanoke.

At the office and at the field stations, filters are provided to prevent interference between the d-c. codes and the high frequency codes, and, of course, there is no interference between the codes at the different high frequencies. For this reason the controls of the three different sections are independent and the line circuit can be used simultaneously for any two or all three of the sections.

The advantages of this utilization of carrier current equipment may be considered from various viewpoints. On a busy railroad such as this, if more than about 50 miles, including about 30 field stations, are controlled as a unit, there will be so many control and indication codes that there may be too much time delay for incoming indication codes. When meets and passes are being made on close timing, a few seconds may avoid stopping a train.

If the carrier current system had not been available, and if the controls were to have been separate for the three sections, one of several choices would have been available. There could have been three control machines, as for example, one at Roanoke, one at Glasgow and a third at Shenandoah. Or, with the machines as they are in Roanoke, with separate line circuits there would have been two additional wires from Stuarts Draft to Roanoke, 86 miles, and two additional wires from Glasgow to Roanoke, 44 miles. Roughly the



use of the carrier system saved about 260 miles of copper wire, or about 108,940 lb.

### Features of the Line Circuit

A particular feature of the line circuit on this installation is that it is arranged to accommodate a Type-H carrier telephone system on the same wires with the C.T.C. system including its carrier frequencies and the physical telephone circuit which is used mainly for maintenance purposes. The Type-H carrier telephone circuit has one terminal at Roanoke and the other at Shenandoah from which point it connects to a dispatcher's circuit for the territory between Shenandoah and Hagerstown. The line circuit is carried through a Western Union cable for a little more than one mile from the office at Roanoke. Suitable matching is provided for voice and carrier frequencies at the junction between the cable and open wire line.

There is a coded carrier repeater located at Glasgow which is normally inactive and may be brought in service at any time by the dispatcher sending a special code to the location. The coded carrier repeater is brought into service automatically in response to an open wire between Roanoke and Glasgow by making use of the field station disconnect arrangement.

Because of the length and high resistance of the wire in the Stuarts Draft to Bentonville section of the line circuit, most of which is No. 10 Copperweld 40 per cent conductivity, it was desirable to use the P-4 type impulse relay. The main reason for this was to economize in the size of line battery. This explains why a repeater of the impulse relay was used at Stuarts Draft. There was not the same requirement existing at Glasgow but a similar circuit was installed in the interest of uniformity.

### Details of the Carrier System

At the Roanoke office there are three separate line coding units. The one for the Roanoke-Glasgow section is connected to the line in the usual manner. The two line coding units for the Glasgow-Stuarts Draft and the Shenandoah-Bentonville sections are each connected to the line through the coded carrier apparatus. In order to simplify the statements, the following discussion will be confined to the carrier for the Glasgow-Stuarts Draft section.

At the office there is an oscillator which is capable of delivering 20,000 cycle energy by means of an electronic tube. The 20,000-cycle energy is normally suppressed by a reverse contact

of the TC relay which in turn is energized through contacts of the transmitter relay T. When a carrier code cycle is to be sent out, the T relay is energized for each impulse, which picks up TC, thus allowing an impulse of 20,000-cycle energy to feed over the pair of wires to the field station at Glasgow, at which point this energy is picked up by a receiving filter and is amplified to operate a C relay which is released at the end of the impulse. Thus the C relay at Glasgow follows the code impulses sent out by the TC relay at Roanoke.

The pair of line wires from Roanoke end at Glasgow, there being no physical connection between these wires and the pair that extends on north from Glasgow to Stuarts Draft.

Operation of the C relay at Glasgow causes conventional d-c. code impulses to be fed out on the pair of line wires north from that point to select stations and switches or signals in the conventional manner.

When an indication code is to be sent in from one of the field stations between Stuarts Draft and Glasgow, the apparatus at the said field station shunts the line circuit to increase and remove the shunt to decrease the line current in the conventional manner. This increase and decrease operates an impulse relay RL at Glasgow. RLP is a repeater of RL. A 14,000-cycle oscillator at Glasgow is normally suppressed by a normal contact of RLP. However, when RLP is reversed in response to an increase in line current, the 14,000-cycle energy is sent over the pair of line wires directly to Roanoke, where this energy is picked up by the office receiver filter and amplified to operate the OC relay. This delivers a pulse through the resistor and condenser to the upper winding of the office OR relay which is reversed. Thus the OR relay, in the office, follows the RLP relay at Glasgow, and the OR office relay causes indications to be displayed on the control machine in the usual manner.

Thus, insofar as the C.T.C. control machine is concerned, the operations are similar for both the ordinary d-c. line code section and the carrier section.

### Assembly of Carrier Equipment

The basic elements of each set of coded carrier equipment, including the oscillator and amplifier tubes, are mounted and wired in a standard sized sheet metal case. The panel of each set is equipped with scales and knobs for operating potentiometers for adjusting the voltage of outgoing codes and for adjusting the amplification of incoming codes. The front of

each case is enclosed with a glass door. These sets are identical and interchangeable with the exception that plug-connected coils can be changed to adapt the apparatus for operation on different frequencies mentioned previously. (See Fig. 1 page 314 next.)

The oscillator-amplifier unit operates from any 110-volt, 60-cycle source, and this source comes into the unit through plug connectors BX110 and CX110. This source is connected to the primary of a power transformer, and the unit takes about 40 watts. The power transformer has three secondaries. The secondary supplies the heater voltage for the 6C6 oscillator tube, the 42 amplifying tube for the oscillator, and the 2050 tube which is a hot cathode gas discharge type of tube. The 5V4G tube is a standard type rectifier having two plates for full-wave rectification. The high-voltage secondary winding has the outside ends connected to the plates 4 and 6 of the rectifier, and the center tap grounded. The heater or cathode of the tube is positive with respect to ground, which is minus d-c.

The rectified current is passed through a filter choke, and on the other side of the choke there is a condenser connected to ground. This choke and condenser take the ripple out of the rectified d-c., and the result is steady d-c. for supplying plate voltage to the oscillator.

The 6C6 oscillator tube has the primary of the oscillator coil connected in the plate circuit to No. 2 pin. A resistor connects + to the No. 3 grid. Grid No. 4 is tied to cathode No. 5, and these are connected to ground through a resistor. There is a feedback from the secondary of the oscillator coil through a resistor to the grid located on the cap of the tube. It is the inductance of the oscillator coil and the capacity of the associated condenser that determines the frequency at which the tube will oscillate.

### Operation of the Tubes

The No. 4 grid of the 42 tube is driven by frequency generated in the 6C6 tube. This grid can be driven as hard as desired by the adjustment of the potentiometer. When there is no grid potential, there is no change in the plate current which may be traced from plus d-c. through the primary winding of the oscillator output transformer, plate pin No. 2 on the 42 tube, through the 42 tube to cathode No. 5, thence to ground through a resistor. When the potentiometer is moved so there is a large voltage on No. 4 grid, the plate current changes by a large amount at the frequency of the oscillator, and this makes a large carrier current in



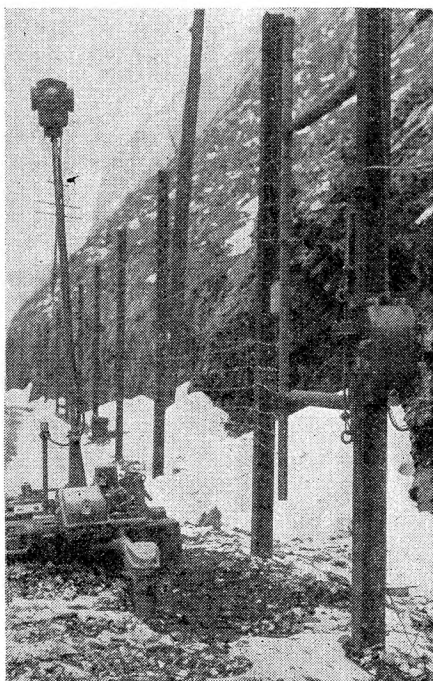


in operation is connected to the line through back contacts of an eight-point change-over relay, and the standby set can be placed in operation and connected to the line through the front contacts of this relay. If a failure occurs, the dispatcher can cut in the standby set by throwing a toggle switch on his desk which completes the circuit to energize the change-over relay. At Glasgow, for example, there is a change-over relay associated with each oscillator-amplifier unit, which can be energized selectively by throwing a toggle switch on the control panel and pushing a button to send out a control code. Once each week, the standby sets are cut into service as a test.

### Carrier Circuits in the Office

The Fig. 1, shows a schematic diagram of the circuits for a typical oscillator-amplifier unit of the coded carrier system. The 60-cycle energy feeds from commercial lines, which have several independent sources so that complete failure is practically unknown. If these sources all fail, however, the set can be fed from a tuned alternator which is fed from the local office storage battery, the change-over being automatic. Incidentally, this tuned alternator is the same unit which feeds the synchronous motor for operating the graphic train chart in the C.T.C. control machine in case of an a-c. power outage.

This circuit will function properly with approximately 6 volts coded on the line at Roanoke, this being reduced by line losses to about 2 volts



Rock slide detector fence alongside a hand-throw switch stand

when it arrives at Glasgow. This voltage range complies with those of carrier current systems used for telegraph and telephone.

time it is picked up. This relay repeats the operation of T in the office coding unit, and is energized from B16, terminal 24, front contact T-C3, back

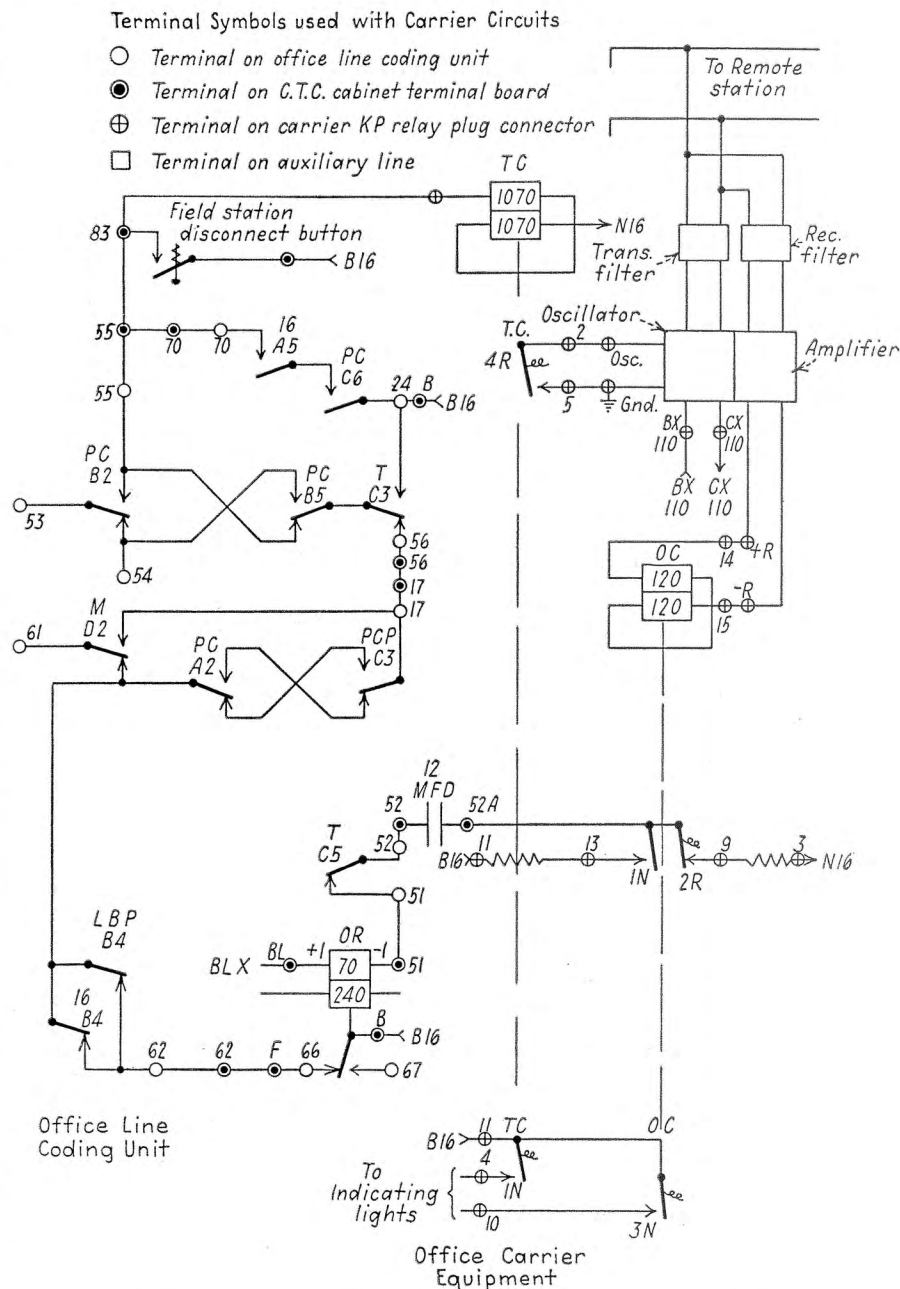


Fig. 2—Circuits in the office for the coded carrier control

At Glasgow, the feed for the oscillator-amplifier set is taken from transformers fed from the signal power distribution line. If this source fails, a power-off relay cuts in a battery feed for a tuned alternator which feeds the required 110-volt 60 cycles to the oscillator-amplifier.

### Office Circuit for Carrier

The Fig. 2 shows the circuits in the office for the coded carrier control. The TC relay is so named because it transmits a carrier pulse each

contact of PC, terminals 55 and 83 to the winding of the TC relay. Opening and closing T codes the relay TC which in turn codes the carrier output.

The OC relay at the office is the one that is connected to the amplifier and it responds to 14,000-cycle carrier frequency impulses sent in by the field. This relay is normally de-energized, and operates normal only when a 14,000-cycle carrier impulse is received by the amplifier. When operated normal, this relay causes relay OR to move to its reverse posi-

tion. The circuit is from B16 through a resistor, contact 1N of relay OC, condenser, back contact TC5 to the upper coil of relay OR. It is now

at the remote station in the same manner as 16 at the office drops PC at the beginning of the last step of the code. This is accomplished by send-

the winding of relay TC. This circuit is closed during the release time of relay PC.

### Release of the PC Relay

At the end of an indication code when 16 drops the PC relay, relay TC picks up momentarily to send a pulse of 20,000-cycle energy. The length of this 20,000-cycle pulse is, by design, of sufficient duration to insure the release of PC at the field carrier location (Glasgow).

For control codes, TC follows the code, and for indication codes OC follows the code. Contacts of these relays (1N of TC and 3N of OC) operate indication lamps. If for any reason the office should fail to follow so the LBP would release to drop the pole changer, the pole change relay at the field is dropped out due to the office sending an impulse of 20,000-cycle frequency from the time PC releases until PCP releases. In this manner the office can make a field station repeat a code.

### Carrier Circuits at Glasgow

The circuits at Glasgow are shown in Fig. 3. Battery for the remote line is located at Glasgow, also the limiting resistance, impulse transformer, impulse relay RL and its repeater RLP pole change relay PC and the pole change repeater PCP, normal repeater of RLP, NSA; repeater of NSA and PCP, NPCP; and a repeater of NPCP, NPCPP.

The impulse and carrier responsive relays are Style-KP plug-in relays located on top of the No. 1 oscillator-amplifier unit. The pole changer and pole change repeater relays are Style-L relays similar to corresponding relays in the office coding unit, and they are housed in a sheet metal case with plug-in top plate. This unit is known as the auxiliary line unit.

The remote line is equipped with filters, so that the line circuit is used also for telephone communication. A voice and Type-H carrier pass filter connects the two lines.

Battery is fed out on the line north from Glasgow exactly the same as if the office were located at that point, and the carrier responsive relay C opens and closes the battery just the same as if it were the office transmitter. This C relay is connected to the amplifier, and it is picked up whenever there is 20,000-cycle energy on the line. Since the relay C is nothing more than a carrier repeater of T at the office, it is apparent that control codes are sent by opening and closing the battery in accordance with the code, the same as if the office

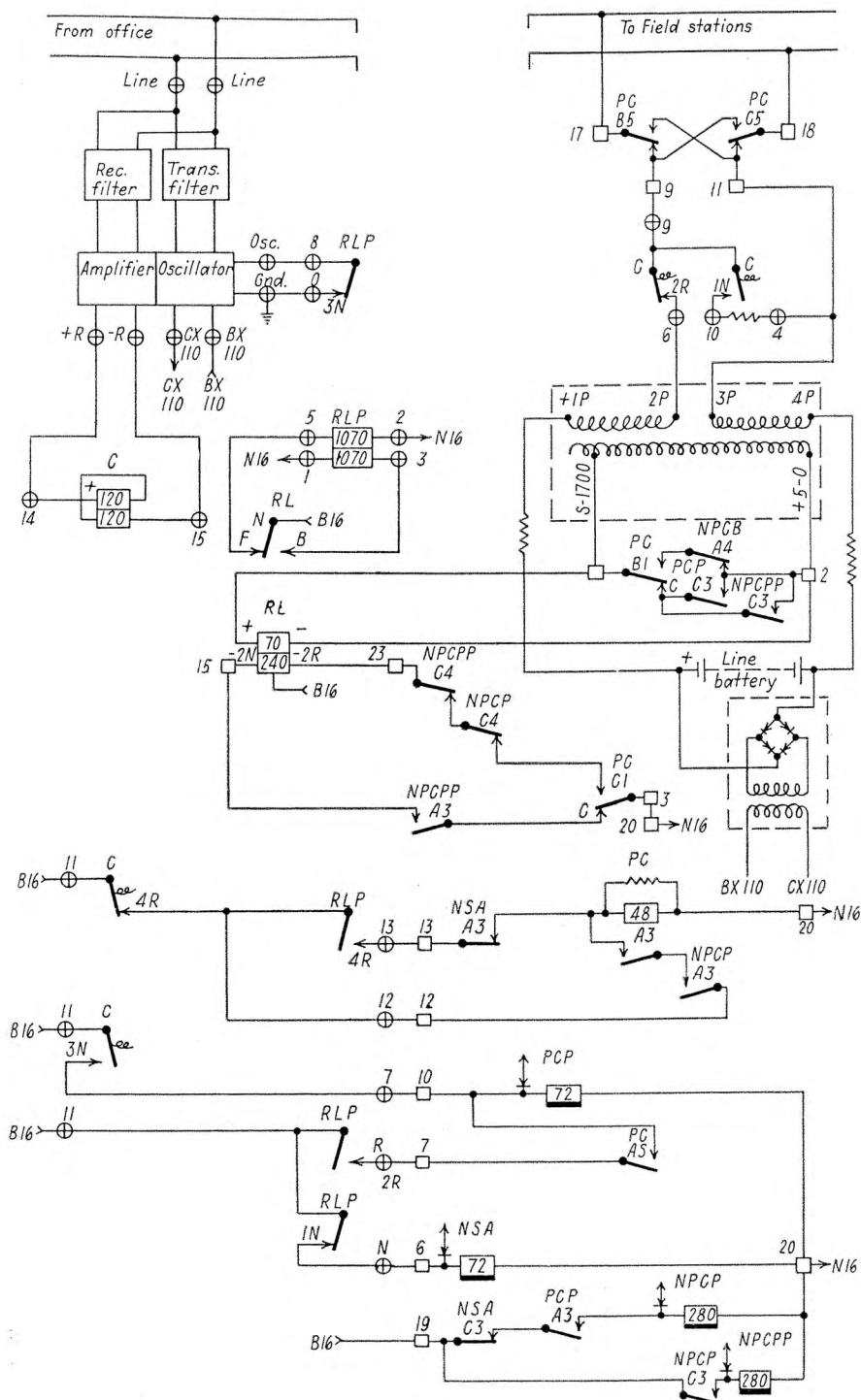


Fig. 3—Coded carrier circuits at Glasgow

apparent that OR will follow the same code as OC. On the first step of an indication code, OR reverses to pick up PC in the usual manner.

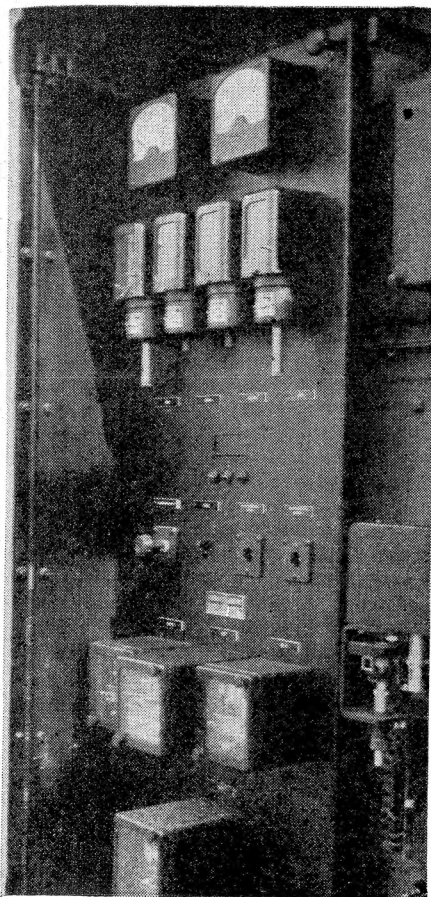
As will be pointed out later, there is a PC relay at the remote line location which remains up during an indication code the same as the PC relay at the office. Some provision must be made for opening the PC relay

ing one impulse of 18,000-cycle control frequency on the 16th step of an indication code.

### Feed for the TC Relay

The TC relay receives energy for picking it up momentarily from B-16, front contacts PC-C6, front contact 16-A5, terminals 70, 55, and 83 to





Automatic switching panel for the 4,400-volt a-c. signal power line at the Bueno Vista sub-station

transmitter were located at Glasgow.

When a field station on the Glasgow-Stuarts Draft section starts to indicate, it shunts the line in the regular manner to ask for a pole change. This shunt increases the current in the impulse transformer, and reverses the impulse relay to pick up relay RLP which picks up the pole changer relay. The pole changer relay both picks up and sticks over a reverse or de-energized contact on C, and for this reason an impulse of control frequency can break the pole changer any time during an indication code.

To prevent a false kick on RL when PC picks up, a PCP relay is provided to repeat PC. As soon as PC picks up, the secondary winding of the impulse transformer is short circuited by front contacts PC-B-1 and back contact NPCP-A4. This shunt remains on until NPCP picks up. Also, RL is guaranteed to be in its reverse position by a local circuit from B16, through part of lower coil of RL, back contacts of NPCP and NPCPP to N-16 over a front contact C1 of relay PC. This circuit is also broken when NPCP picks up.

Relay RLP normally suppresses the 14,000-cycle oscillator. When RLP is reversed in response to an increase in current, the suppression is

removed so 14,000-cycle energy goes out on the line to pick up the OC relay at the office. The OC relay delivers a pulse in the office to reverse OR. It is thus apparent that each time RLP is reversed in response to an increase in current, the OR relay in the office is made to reverse through the medium of OC carrier relay. Also each time RLP goes normal in response to a decrease in current, the OC relay delivers a pulse to position relay OR normal. In this manner OR is made to follow RLP for a complete indication code, after which the office sends out one impulse of 20,000-cycle energy to normal C and drop PC.

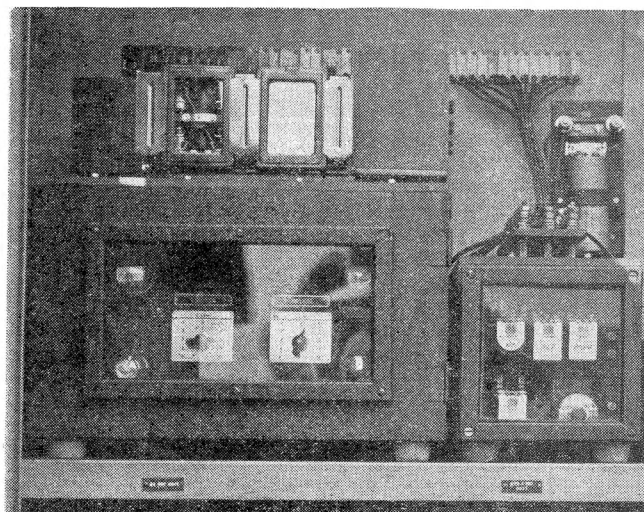
There is no M relay at the Glasgow location to shunt the impulse transformer during a control code. Each time the C relay opens and closes the line, there is a decrease and increase in line current which applies voltage to the top coil of RL. During a control code, it is necessary that RL stay normal so that RLP and PC do not pick up falsely. On the first step of a control code, when C operates normal, the current decreases and RL is given an impulse to position it normal. As it is already in the normal position, this impulse does no harm. However, when C reverses to close the line, the impulse is in the direction to reverse RL, and this reversal is prevented by PCP which is picked up each time C

controlled section to be returned to normal even though no reset pulse would be transmitted from the office. This is accomplished as shown in Fig. 3. During an indication code, relays PCP and NSA receive energy over the contacts of relay RLP, PCP being energized over the 2R contact and NSA over the 1N contact. Relay NPCP is controlled over front contacts of relays PCP and NSA in series. The slow action of these relays is selected so that relay NPCP will not release during any indication code.

It will be evident that in the event of no code being on the line and relay RLP stationary, either PCP or NSA will release. Either of these relays releasing will release relay NPCP. Note that the stick circuit of relay PC is carried over a front contact of relay NPCP and the pick-up circuit of PC is carried over a front contact of relay NSA. Relay PC will, therefore, become de-energized in response to relay RLP becoming stationary for a period somewhat greater than the length of the longest pulse of a normal code.

Relay NPCPP is a repeater of relay NPCP. The contacts of this relay are used in the disagreement circuits for the shunting of the secondary of the impulse transformer in response to changes in the position of relay PC and for the disagreement

The coded carrier equipment in the case at Glasgow



comes up on a control code. The circuit for holding RL normal is from B-16, to left through lower coil of RL, terminal 15, front contact PCP-A3 to NPCPP-A3 and back contact PC-C1 through terminals 3 and 20 to N-16.

#### A New Feature

The relay circuits within the auxiliary line units at Glasgow and Stuarts Draft have a new feature which permits the d-c. polarity of the carrier

circuits which energize the lower winding of the RL relay under this same condition.

#### Construction of the Project

This signaling project was planned and installed by the signal forces of the Norfolk & Western, under the direction of J. A. Beoddy, superintendent telegraph and signals. The major items of equipment were furnished by the Union Switch & Signal Company.