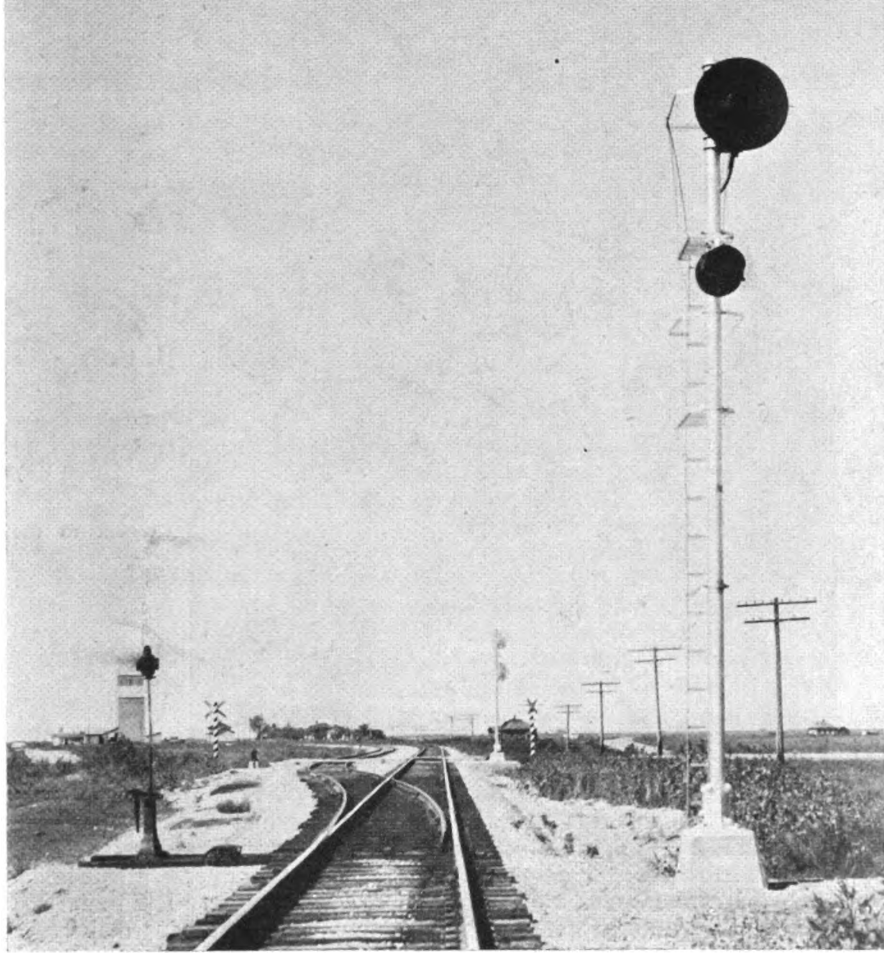
Right—Typical layout at the end of a siding, the letter "S," when displayed in the lower signal unit, indicates that the head brakeman is to throw the hand-throw switch stand, and that the train is to enter the siding and stop



Normally deenergized coded track circuits with signals at sidings under control of dispatcher to authorize train movements

Milwaukee Installs Block System on 98 Miles

THE Chicago, Milwaukee, St. Paul & Pacific has recently completed the installation of a system, termed controlled automatic block, on a complete engine district of 98 miles of single track between Aberdeen, S.D., and Mobridge, S.D., which was formerly manual block territory. In brief, the new installation is controlled automatically by track circuits throughout on all main track, and, in addition, the signals at the sidings are manually controlled from the dispatcher's office, so that train movements are authorized by signal indication. With the exception of one siding and one yard lead switch where power machines were installed, and one siding switch equipped with a spring switch mechanism, the main-track switches are operated by hand-throw stands the same as previously.

An important advantage of this system of controlled automatic block is that the train movements are authorized by signal indication, thus superseding timetable and train order operation. The expense for attaining this objective, over and above the cost of conventional automatic block, was offset to a large extent by: (1) using a minimum number of intermediate signals; (2) by the elimination of local signal line control circuits and power distribution circuits; and (3) by superimposing the code line controls and indications on the existing telephone train dispatching circuit.

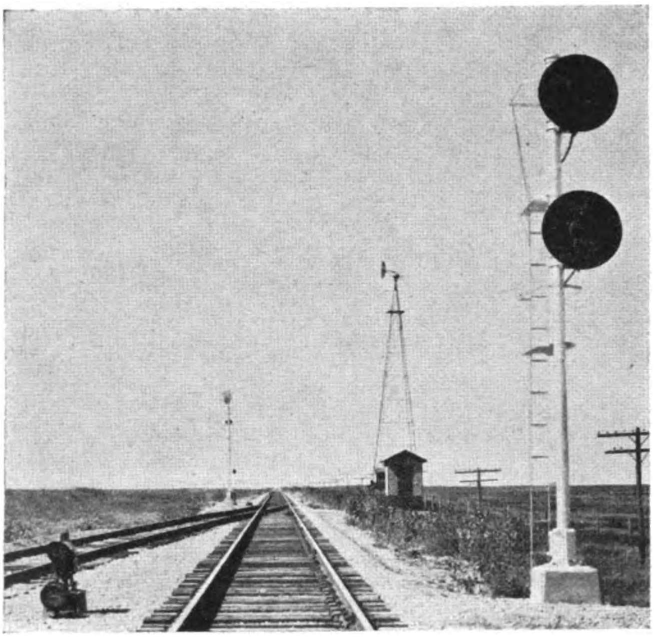
Medium Number of Trains and Signaling Accordingly

In addition to the Olympian, operated in two sections each way daily, there is a local passenger train each way, thus totaling six passenger trains daily. A local freight train is operated westbound daily except Sunday. Two time freight trains on fast through schedules are operated each way daily, and extra trains are operated as the traffic requires. For example, when live stock is moving eastward in the autumn, as many as 10 stock trains may be operated daily. Therefore, the number of trains operated daily may range from a minimum of about 14 to a maximum of up to about 25.

Thus the problem was to design a signaling system that could readily be justified economically by a medium number of trains both passenger and freight, operated on fast through schedules. The requisites for a signal system, therefore, were not only safety but also train operation by signal indication as a means of saving train time as well as reducing operating expenses, as compared with timetable and train order operation.

Character of the Line

This district is a part of the Milwaukee's through route between Chicago and Seattle-Tacoma, 2,189 mi., Aberdeen, the east end of the new project, being 706 miles west of Chicago. Between Aberdeen and Mobridge the line crosses rolling prairie. From Aberdeen to mile post 66, between Almo and Java Jct., the grade is very light, ascending gradually from 1,298 ft. elevation at Aberdeen to 2,132 ft. at M.P. 66. Also on this 66 mi. the curvature is light with long sections of tangent, ranging from 7 to 10 mi. in length. West from M.P. 66, the line descends



When a train is to leave a siding, the "S" unit is lighted below the searchlight dwarf signal, and when the head brakeman throws the switch, the dwarf displays a proceed aspect to the train

to the Missouri river at Mobridge, elevation 1,653. In this 33 mi. there is a considerable number of curves, but none to exceed 1 degree. From M.P. 96, three miles east of Mobridge, the grade ascends eastward for about 30 mi. to M.P. 66, at a maximum of about 0.5 per cent. Within the last year the track on 88 mi. of this subdivision has been rebuilt, using new 112 lb. rail, new ties and ballast. In addition, several major line changes have been carried out in order to reduce the maximum curvature to one degree. The alinement, grades and the improved track all contribute to the practicability of operating trains at high speeds on this subdivision.

The tonnage rating westbound of the Class S-2 freight locomotives is 3,800 tons, and the L-3 locomotives 2,900 tons westward from Aberdeen to Java junction, and 7,000 tons and 5,500 tons, respectively, for the two types of locomotives from there on down to Mobridge. Eastbound from Mobridge to Roscoe the S-2 locomotives are rated at 4,800 and the L-3 at 3,700. With a helper locomotive eastward up the grade from Mobridge, to Alamo, the tonnage can be increased to 5,000 tons for either the S-2 or the L-3 locomotives. From Roscoe eastward to Aberdeen the grade descends gradually so that the S-2 locomotive can handle 9,000 tons and the L-2 locomotive 8,000 tons. These figures represent maximums with normal weather conditions, the tonnage being reduced when conditions are adverse. Scheduled time freight are given less than maximum tonnage so they can make fast time. In instances where light tonnage through freight trains lose no time in making meets, they can make the run in either direction in about four hours. The through passenger trains make the run in about 2 hours 10 minutes.

Layout of Sidings

On this subdivision there are 12 stations with sidings which are intended for use regularly in the passing and meeting of trains. Confining consideration to the 95 miles between the west yard switch at Aberdeen and the east yard switch at Mobridge, the 12 towns with sidings are spaced an average of 7.6 miles. Roscoe is a coal and water station as well as a junction with two branch lines, one to the north and the other to the south. At Glenham, when making grade revisions on a new alinement, a section of the old line, about 1.5 miles long by way of the station, was left in service to be used by local passenger trains and way freights. Power switches are provided at each end of the Glenham siding. This track can be used also as a siding by other trains which can negotiate the grades. The east end of this Glenham track is only 2.5 miles from the west end of Sitka, and the latter is used by trains which could not negotiate the grades at Glenham. The sidings at Fife, Mina, Craven, Roscoe, Gretna, Bowdle and Selby will hold 112 to 115 cars; at Ipswich, Beebe, Alamo and Java, 83 to 87 cars; at Sitka, 97 cars; and at Glenham, 155 cars.

Signaling Arrangements

At each siding switch there are three signals located as shown in the accompanying Fig. 2. Eastward high signal No. 2 has a color-light searchlight unit as the top "arm" and an "S" unit as the lower arm. This "S" unit consists of a cast-iron housing, a reflector, a lamp and a clear ground glass roundel 10 in. in diameter, the lamp being normally extinguished, but, when controlled by the dispatcher, the lamp is lighted which causes a black letter "S" on white background, to be displayed on

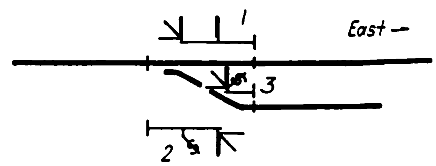


Fig. 2—Signals at a siding switch

this ground glass roundel. When the dispatcher sends out controls to establish aspects to direct an approaching train to enter the siding, the signal No. 2 displays red in the top "arm" over "S" in the lower "arm," and at the same time the distant signal displays the Approach aspect, yellow. When the train arrives and stops short of the switch, the letter "S" directs that the trainman is to throw the switch and the train is then to enter the siding, after which the trainman places the switch normal.

The leave-siding dwarf signal No. 3, has a searchlight head with an "S" unit mounted below. When a westbound train on the siding is to be directed to depart, the dispatcher sends out a control which lights the "S" under the red, and this authorizes the trainman to throw the switch, after which the "S" is extinguished and the searchlight dwarf displays a proceed aspect, such as green if two or more blocks are un-

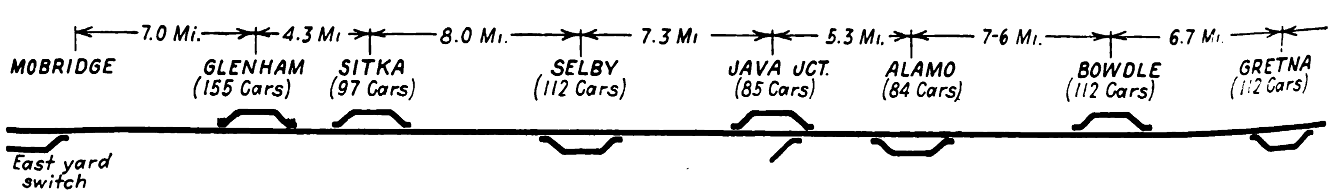


Fig. 1—Track and signal plan of the sidings on the

occupied, or yellow if a preceeding train is still occupying the second block. After the train is out on the main track, the rear brakeman returns the switch to the normal position.

For a train movement with the switch normal, the dispatcher controls signal No. 1 for a westbound train or the top "arm" of signal 2 for an eastbound train.

Derail and dwarf on a house track turnout

Derails and Signals on House Tracks

At towns, some main-track switches lead to house tracks or cattle pens. At the clearance point on each of these turnouts there is a color-light type dwarf signal with three lamp units in a vertical row, as shown in one of the pictures. Also on each turnout where grade conditions require, there is a hand-throw Hayes derail to which is connected a circuit controller. If a local freight train gets in the clear on one of the house tracks, the derail must be restored to the derailing position in order for the main-track signals to be cleared.

When the local freight train is ready to depart from the house track, the conductor uses the telephone to inform the dispatcher. If the dispatcher is ready for the local freight to pull out, he informs the conductor accordingly and also the dispatcher sends out a control to the station where the switch is located. Then

Fig. 3—At a house track turnout

the conductor pushes a push-button which closes circuits that, in combination with the control from the dispatcher's office, causes the letter "S" to be displayed in the bottom unit of the dwarf signal, the red being continued to be displayed in the top unit. The letter "S" authorizes the trainman to throw the derail to the non-derailing position, and/or to throw the switch. When this is done, the letter "S" and the red light are extinguished, and a yellow light appears in the second unit. This authorizes the engineman to move his train out onto the main track, after which the trainman places the switch and derail on the turnout in their normal positions.

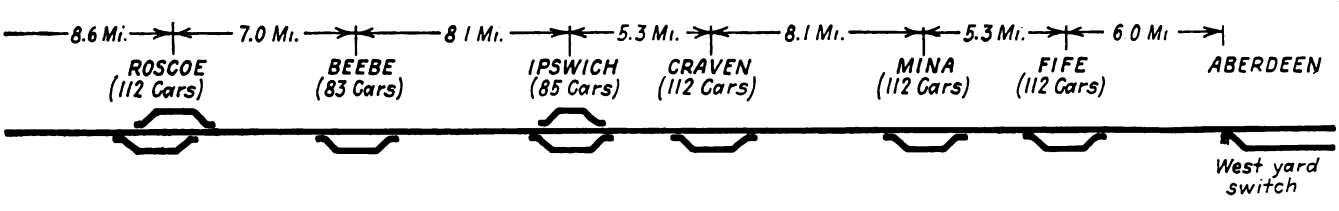
Hold-Out Signals

When making up trains at the east end of the yard at Mobridge, switching moves must be made out on the main track. In order that such moves may be made without holding westbound trains at Glenham, the next station to the east, a pair of absolute signals controlled by the dispatcher, is located 1,867 ft. east of the east yard switch, as shown in Fig. 4. When switching is under way, the westward signal 148L, controlled from Mobridge, displays the Stop aspect and at the same time westward signals can be cleared to advance a westbound train from Glenham. In the meantime, when the switching operations are cleared of the main track, the dispatcher at Mobridge can control signal 148L to permit the westward train to proceed. One purpose for the eastward signal 10R is to mark the limit for the switching moves. This signal is controlled by the dispatcher at Aberdeen.

Spacing of Intermediate Signals

As shown in Fig. 5, the distance from the west switch at Ipswich to the east switch at Beebe is 7.4 mi. The eastward intermediate signal 288 is located 10,054 ft. from the station-entering signal 54R at the west end of Ipswich, and the westward intermediate signal 325 is 9,462 ft. from the westward station-entering signal 52L at the east end of Beebe. This leaves 3.74 mi. between the two intermediate signals. In addition to serving as distant signals, these intermediate signals serve also to allow a second train to follow into the overall station-to-station block. For example, after the rear of a leading eastbound train has passed signal 288, then the eastward high signal 52RA or the leave-siding dwarf 52RB can be controlled by the dispatcher to direct an eastbound train to follow. On account of the comparatively few passenger trains, there will not be many instances in which a closer spacing of following trains will be of any advantage, and, therefore, no second eastward intermediate signal opposite 325 was warranted, and similarly no second westward intermediate signal was provided opposite 288. A point of interest is that this arrangement of only two intermediate signals, as shown in Fig. 5, can be used in a signal system such as this, because the head-on protection is provided by the station-leaving semi-automatic dispatcher - controlled signals, whereas with straight automatic block, opposing intermediates must be located twice braking distance to provide head-on protection. Therefore, the installation on the Milwaukee requires fewer signals than straight automatic block with a conventional arrangement of signals using an average of two-mile blocks. This saving in signals helps to offset the cost of the control machine and line code equipment to control the signals from the dispatcher's office.

Where the distance from the west switch of one siding to the east switch of the next was 4 mi. to 5 mi., the two intermediates were placed opposite, as a double location, as for example between Craven and Ipswich. In one special instance,



entire engine district between Mobridge and Aberdeen

between Sitka and Glenham, the distance is 2.5 mi., and in this layout there are no intermediate signals. The westward leaving signal at Sitka, for example, serves as a distant signal for the station-entering signal at Glenham.

Features of Control Machine

The control machine is in the dispatcher's office at Aberdeen, which is the east end of the new signaling. The illuminated track diagram at the top of the panel has lamps which are lighted to repeat automatically the locations of trains on all portions of main tracks. When a train enters a siding, the dispatcher flips a small toggle switch below the symbol for that siding, which causes a red lamp to be lighted in the corresponding portion of the diagram. This lamp is a reminder to the dispatcher in case the train is delayed for some time. When the train departs from that siding, the dispatcher places the toggle normal which extinguishes the lamp.

As explained elsewhere in this discussion, the siding switches are operated by conventional hand-throw stands the same as previously. Nevertheless, in the top row on the control machine, there is a "switch" lever corresponding with each passing track switch, these levers being used to establish selections for signal controls. For "straight" track through moves, the switch lever is left normal, the signal lever is positioned and the code-starting button pushed to send out the code to control the signal. When establishing a control to include a take-siding indicator or a leave-siding indicator, the first action is to throw the corresponding switch lever to the reverse position, then throw the signal lever left or right as required, and push the code sending button. No track circuits are provided on the sidings but a special new feature is that the circuits in the machine are so interconnected that, having established controls to direct a westbound train, for example, to take siding at the east end of a given siding, controls cannot be established to direct an eastbound train to enter the west end of that same siding.

Lamps above the switch levers repeat the position of the corresponding hand-throw switches, and lamps above the signal lever repeat the aspect displayed by the signals. The color-light dwarf signals, which control movements from house tracks to the main track, are controlled by special push-to-turn buttons which are mounted in a row near the bottom of the panel. Such a button is turned to the left if the train is to move to the west after entering the main track, or to the right if the move is to be eastbound. An automatic graphic train chart, located in the desk top of the control machine, has pens to record the passing of trains at each OS track circuit at the various switches.

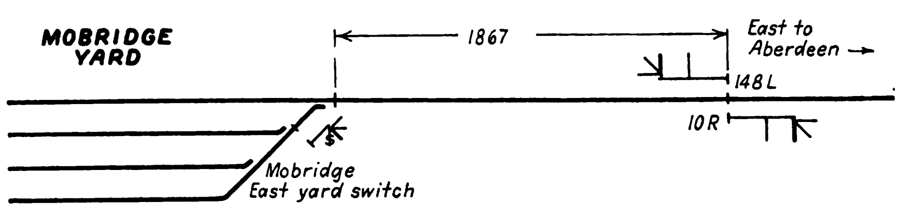


Fig. 4—Hold-out signals near Mobridge

Either-Direction, Normally-Deenergized Coded Track With No Line Circuits

This installation includes several modern features which assisted in adapting the signaling to the requirements of the traffic and, at the same time, aided in reducing the costs, as compared with conventional automatic signaling. In this respect, the first item is the use of normally-deenergized coded track circuits. One of these coded track circuits can be up to 10,200 ft. in length which is three times longer than ordinary d.c. track circuits used elsewhere on the Milwaukee, thus the use of coded equipment reduces the number of track circuits. A second feature is that different rates of code, 75 or 180 per minute, are used to control signals to either the Approach or the Clear aspect, thus obviating the need to install line wires on pole lines for line circuits. A third consideration is that these coded track circuits are normally de-energized, being "turned-on" when the dispatcher sends out a control to establish a line up for a train in a station-to-station block.

For this reason, the track circuits and intermediate signals can be, and are, supplied from primary batteries, which obviates the need to run an a.c. power distribution circuit through the territory. Finally the C.T.C. codes between the dispatcher's office and the field stations are superimposed on the previously existing line wires for the dispatcher's telephone circuit. This line circuit consists of two No. 9 bare hard-drawn copper wires which carry not only the dispatcher's phone and C.T.C. codes but also telegraph carrier and voice carrier for a phone circuit between Chicago and Seattle. Thus in the station-to-station blocks, no changes or additions to the pole line were required, this being an imporant factor as compared with a conventional single-track automatic block system requiring at least three line wires for line circuits, and two wires for a.c. power distribution, if available and justified.

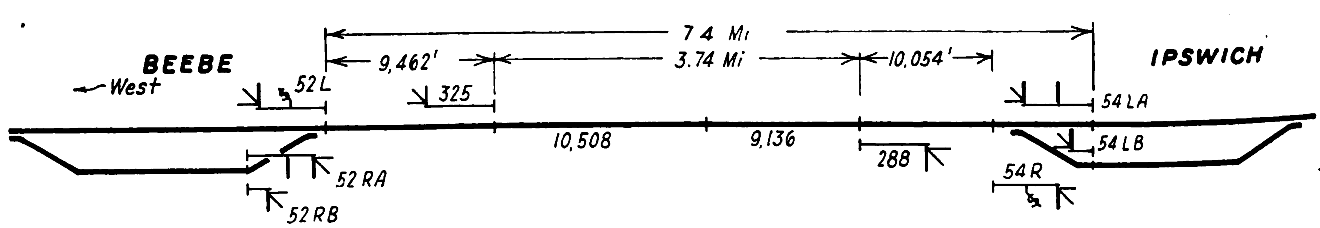
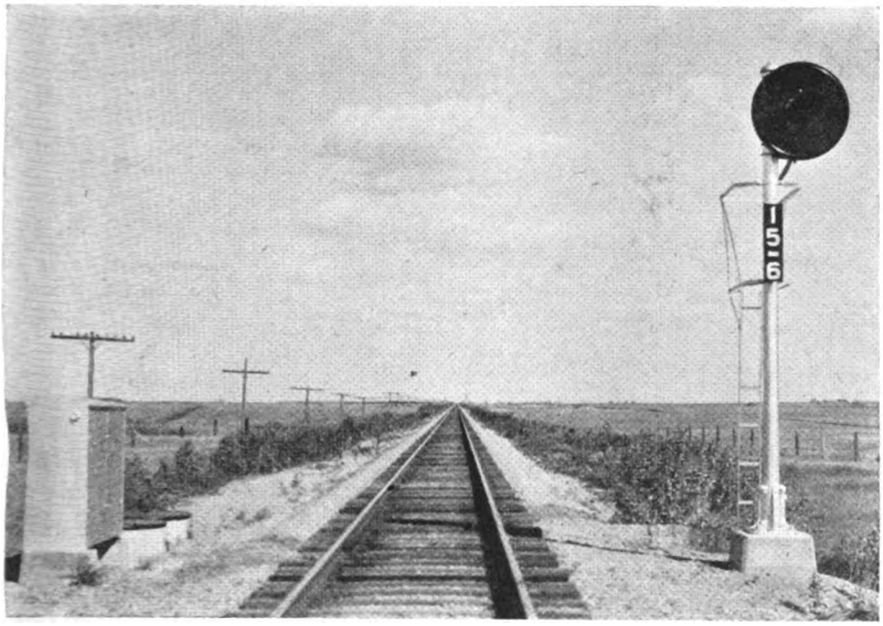


Fig. 5—Only two single signals between sidings

How Normally-Deenergized Track Circuits Work

In the station-to-station blocks the normally-deenergized coded track circuits are arranged so that either a relay or coded track battery can be connected to the rails at either end of any track circuit according to the direction in which traffic is being established by the control from the dispatcher's office, the direction of track circuit feed being opposite to that of the train movement to be made.

The diagram in Fig. 6 shows the basic principles of the circuits at one end of a typical track circuit in a station-to-station block. Normally the connection from the upper rail



One of the two single locations between Mina and Craven

extends through the coil of the track relay LTR, through the back point to contact finger 2 of left code transmitter repeated relay LCTPR, and then to the lower rail. In this condition, when any energy comes in on

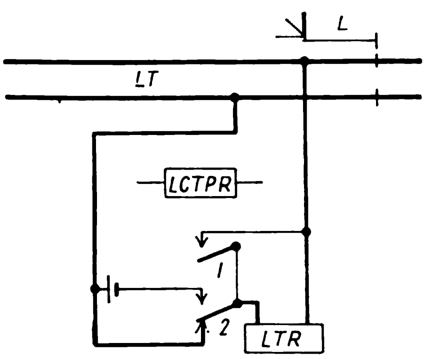


Fig. 6—Principle of coded track

the rails from the other end of the track circuit, the relay LTR is energized and deenergized 75 or 180 times per minute in accordance with the track circuit code being received. Contacts of this code-following track relay LTR, control circuits through a decoding transformer to energize relays to control the operation of searchlight signal L, as will be discussed later.

On the other hand, if track circuit code is to be transmitted to the left from the location shown, then the contacts of relay LCTPR are operated a certain number of times each minute, as for example, 75 or 180, as will be explained later. Each time the front points of the contacts of relay LCTPR close, as shown in Fig. 7, the battery feeds through the front point of finger 2, through the jumper connection and through finger 1, and out to the top rail. The negative side of the battery is directly connected to the bottom rail. Thus one impulse of energy is fed to the left on the track each time the front contacts of relay LCTPR are closed, and similar impulses are sent one after another at the rate then in effect.

An item to note in Fig. 7, is that when the front contacts of relay LCTPR are closed, the connections to contact 1 are a shunt across the coil of relay LTR, so that this relay is not energized by the track battery shown in this drawing. The track relays are polar biased so that they will not be operated by energy from the local track battery.

Referring now to Fig. 8, when a line up is being established westward from signal 54L at Ipswich to signal 52L at Beebe, the C.T.C. control from the dispatcher's office goes to

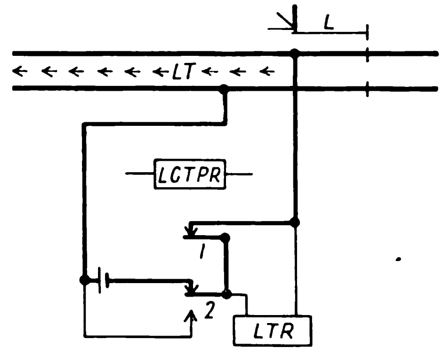
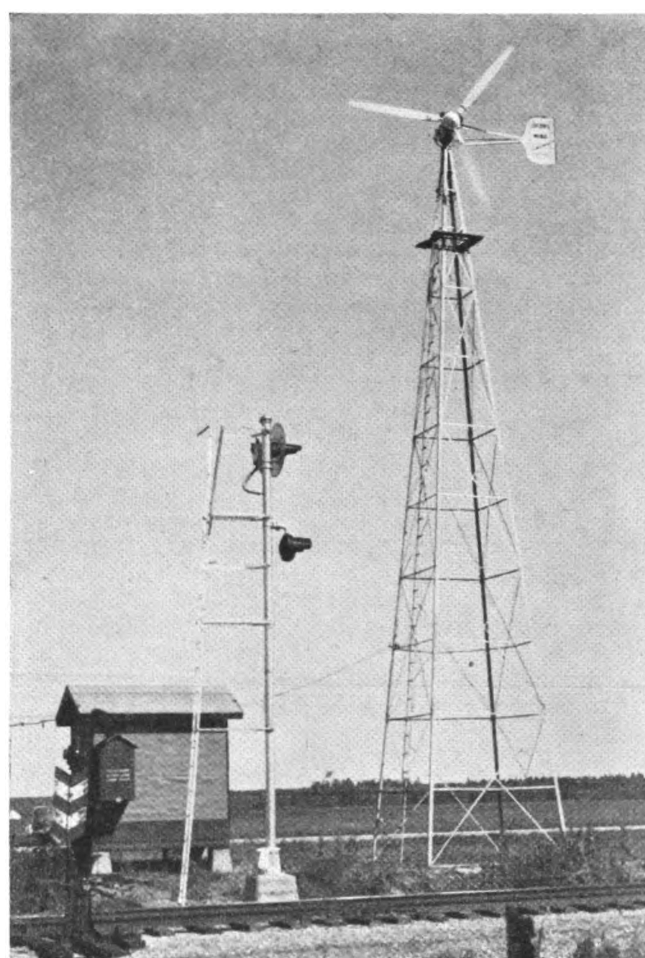
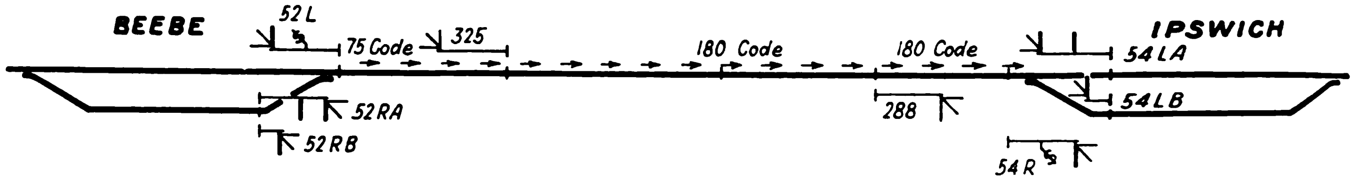


Fig. 7—With relay energized

Beebe to cause 75 track code to feed eastward from signal 52L to the intermediate signal 325 which causes the spectacle of this searchlight head

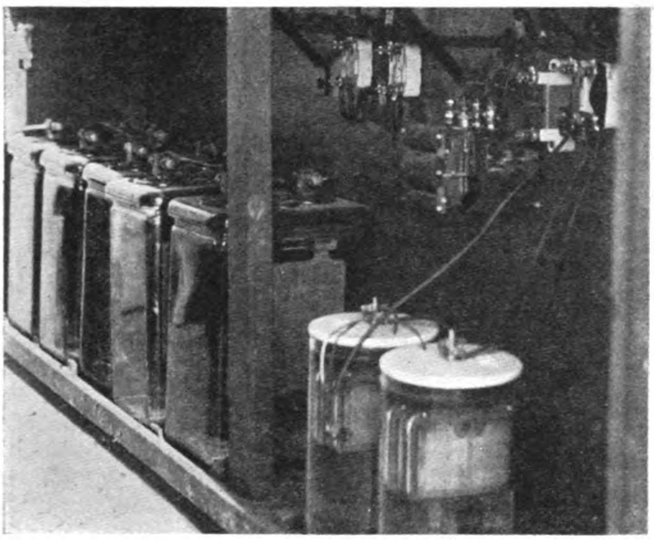


At sidings where no commercial a.c. power is available, the batteries are charged by a wind-driven generator



. 8—Diagram of the track circuit operation in a station-to-station block

to be operated to the yellow position, but the lamp is not yet lighted. Then 180 code is fed from this signal 325 eastward through the track circuits to signal 54L. Receipt of this 180 code, in combination with a C.T.C. control from the dispatcher's office to this location, causes westward signal 54L to display the green aspect. Thus, in order to clear signals for a westward train, the track circuits are fed from west to east.



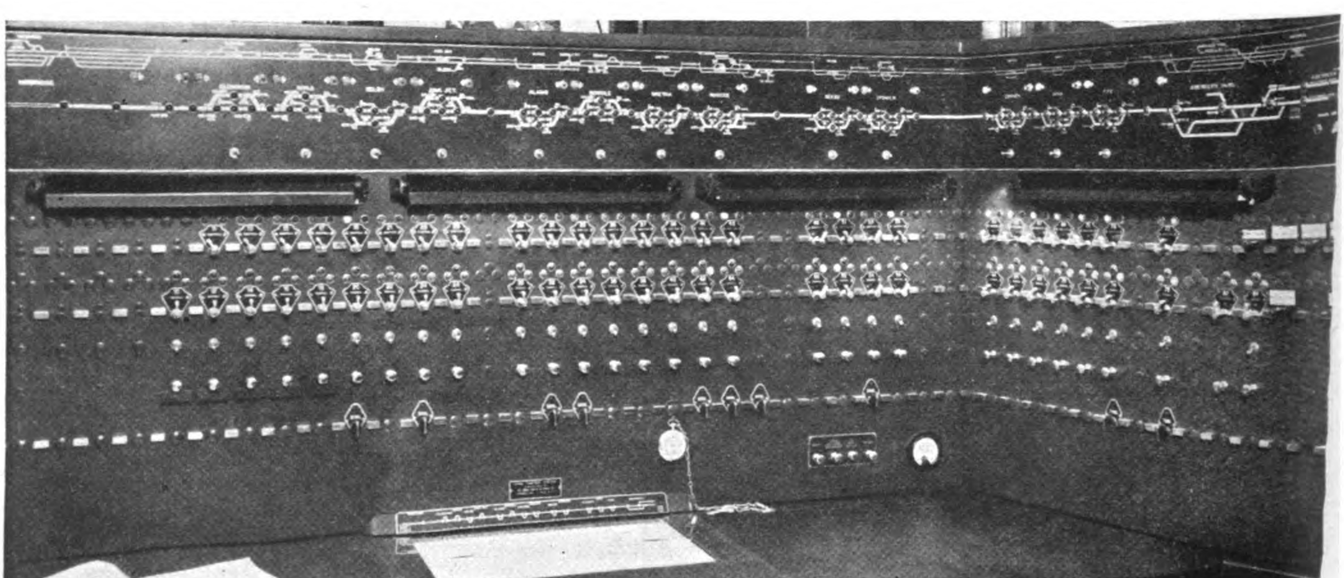
At each of the switch locations the batteries are located in the instrument house

The lamps in the intermediate signals are normally extinguished, being lighted by approach control circuits when a train is traveling in the direction which the signal controls, enters the track circuit in approach to the signal to be lighted. The basic circuits, shown in Figs. 6 and 7, are now applied, with certain additional features, as shown in Fig. 9. An item not shown in previous diagrams is a 1.2-ohm adjustable resistor in series with the track battery, and connected across this resistor is a 0.3-ohm relay known as the approach relay. This LAR, which is the left approach relay to light the lamp in the westward signal L, is connected with the feed of the track circuit RT.

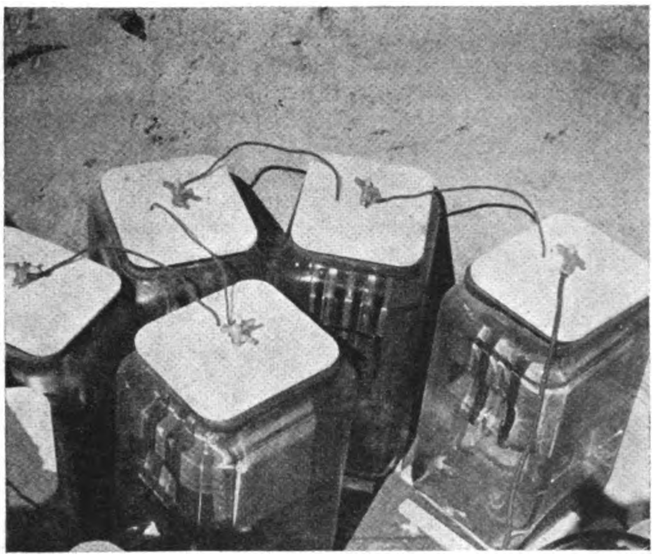
When a line up is for a westbound train, code is being sent eastward that is to the right, on track circuit RT. When the westbound train enters the far end of track circuit RT and proceeds toward signal L, shown in Fig. 9, the shunting of the track circuit increases the current fed from the battery to the track, and when the current increases to a certain amount determined by adjustments of resistors, the relay LAR starts to follow code, i.e., pick up and release with each outgoing pulse of code. A front contact of relay LAR closes a circuit to pick up relay LAPR, and due to the slow release characteristics of this relay, it stays up as long as relay LAR follows code. A circuit, through a front contact of relay LAPR, lights the lamp in the westward signal L, and the lamp stays lighted until the rear of the train passes the signal.

Control of Directional Stick Relay

The control of the directional stick relay is shown in Fig. 9. The HPR is a slow release relay which is picked up by a circuit which is closed through a front contact of the HR relay. With a westward line up established, the HR and HPR relays are up, and the LTFPR, left front track repeater, and LTBP, left back track repeater, are up. Therefore, as shown in Fig. 9, battery B10 feeds through front contacts of LTFPR.



The control machine has a lever for each of the hand-throw switches



Primary batteries are used at all the signals that are located between the sidings

LTBPR and HPR. When the front trucks of the locomotive pass the signal and shunts track relay LTR, the relay HR is released and the circuit being discussed feeds through a back contact of HR to pick up relay LSR which sticks up through its own front and a back contact of HR.

When the rear of the westbound train passes signal 325, which is signal L, then the code transmitter repeater relay RCTPR, controlled through a front of the LSR to send 75 track code eastward through the various track circuits to signal 54L at Ipswich so that if also the dispatcher has sent out the proper control, the signal 54L will clear to the Approach aspect for a following train or, if the dispatcher has sent out the proper control, the leave-siding signal 54LB can be controlled for a westbound train to depart from the siding.

To Turn Off the Track Circuits

Referring to Fig. 8, and assuming that there is no second train, when the westbound train passes out of the station-to-station block between Ipswich and Beebe, then 75 code which had been in effect, again feeds eastward from the east end of Beebe to westward intermediate signal 325. This energizes the HR relay at that location, which releases the left stick relay LSR. A result is that 180 code, rather than 75 code, is then fed eastward through the remaining track circuits to the field station at the west end of Ipswich, and this causes an indication to be sent to the control machine to extinguish the lamp which indicated that the station-to-station block between Beebe and Ipswich was occupied. If the signal lever is normal, the receipt of this indication at the office causes a C.T.C. line control to go to the field station at Beebe to stop the 75 track code which was feeding eastward. This results in stopping the code in the track circuits all the way through the station-to-station block, so that the signal operating coils as well as the signal repeater relays and code transmitters are returned to the de-energized condition until another line up is to be established.

The circuits are so arranged at the head-block locations that a long pulse of battery is applied to the track when the station is coded off. This holds the TR relay up at the intermediate signals in the direction in which traffic was last set up and permits first the LTBPR relay to de-energize and in turn the HR and HPR relays which prevent the directional stick relays from picking

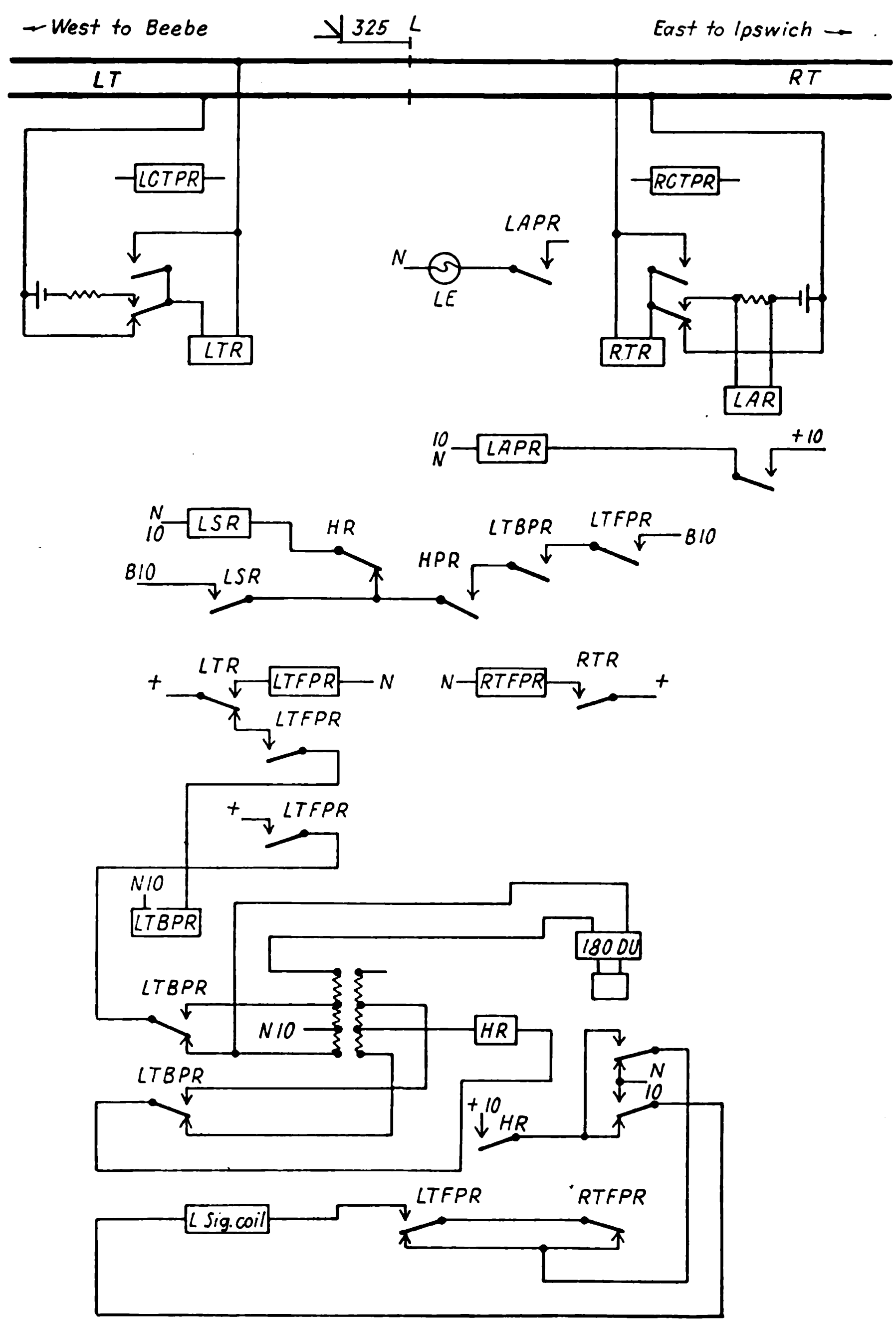


Fig. 9—Diagram of circuits at a distant signal location

up at the intermediate signal locations.

At towns where 220-volt a.c. commercial power is available, this circuit is extended out to the signal equipment housing at each of the siding switches. This power feeds through transformers to supply the signal lamps, and, through rectifiers, to charge eight cells of 160-a.h. Exide EMG9 storage battery. The eight cells as a whole feed the line code equipment, and five of these cells act as stand-by for the signal lamps in case of a power outage.

At the sidings where no commercial a.c. power is available, a wind-driven d.c. generator was installed to charge storage batteries. At these locations, the signal lamps are fed from the storage battery, and are on approach lighting control, this requiring track circuits about 500 ft. long on the siding in approach to the leave-siding signals. At these siding switch locations where wind generators are in service, there are two sets of 160-a.h. storage battery, one set of 8 cells to feed the line coding equipment and one set of 5 cells to feed the signal lamps and local circuits.

The wind generators are rated at 32 volts d.c., with a maximum output of 60 amp.; automatic controls being provided to control the charging rate and the duration of charge as may be required at each location. For example, if the battery voltage is low, the charging rate is 15 amp., but if the voltage is nearly normal, the rate is 1 amp. Each of these generators is mounted on top of a 50-ft. tower, the shaft of the armature is extended and carries three propeller blades each 7 ft. long. A wind of 6 m.p.h velocity is sufficient to operate the generator. As the wind velocity increases, the blades are automatically feathered so that the revolutions per minute will not exceed a certain maximum. The machine is normally in operation whenever the wind blows. Preparatory to inspecting the generator, a wire pull arrangement is operated to turn the generator on a vertical axis so that the blades are in line with the vane, thus taking wind force off of the blades and causing them to stand still.

These wind generators were manufactured and installed complete in place, by the Jacobs Wind Electric Company, Minneapolis, Minn. The machines are guaranteed for five years, and during this period, the manufacturer handles all maintenance and repairs.

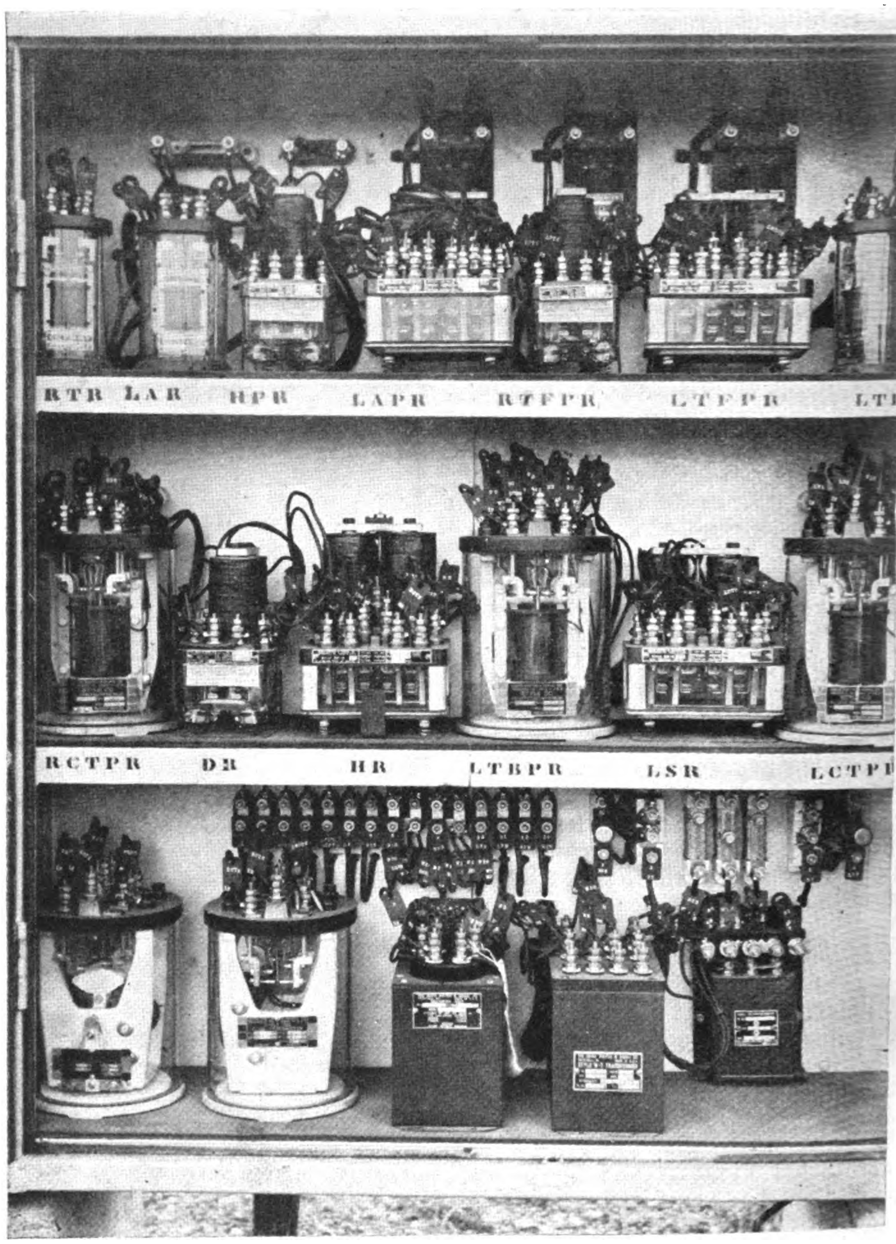
As explained elsewhere, in a station-to-station block between sidings, the track circuits and signals are normally deenergized being "turned-on," under control of the dispatcher when he is ready to line up for a train. Under these circumstances, and in consideration of the relatively medium number of trains, it is practicable to operate the track circuits and intermediate signals from primary batteries.

Each of the coded track circuits is fed from a set of two cells of 500-a.h. Edison primary battery. At each intermediate signal there is a set of 16 cells of 1,000-a.h. Edison primary battery which is normally on open circuit, but when a line up is being established, this battery operates a code transmitter. If the line up is westward for example, the battery at a westward intermediate signal also feeds the 250-ohm coil in the searchlight signal and the 5+3.5-watt signal lamp and the 1,000-ohm GYP signal repeater relay.

At each back contact coded track cut section there is a set of 16 cells of 1,000-a.h. primary battery to operate the track code transmitter.

A telephone is located at each switch and at other locations near stations. On each telephone there is a double-pole, double-throw switch by means of which the phone can be connected to either the dispatcher's circuit or to a separate block circuit. This block line can be used to patch the dispatcher's circuit, patching connections being provided at each station.

This installation of signaling was planned and constructed by railroad forces under the jurisdiction of L. B. Porter, superintendent of telegraph and signals. The major items of equipment were furnished by the Union Switch & Signal Company.



Relays, code transmitters and other apparatus at a distant signal