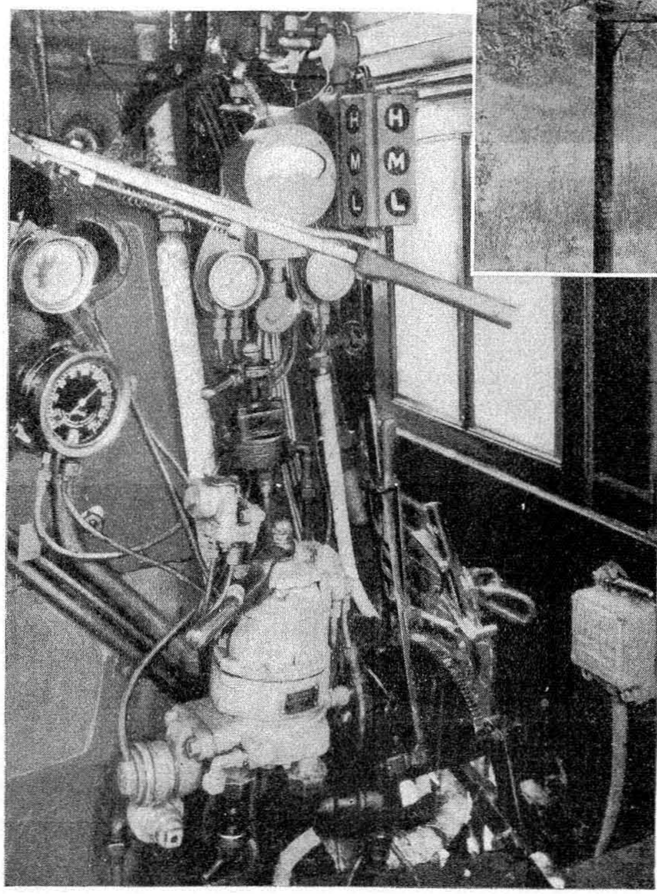
Santa Fe Is Operating Trains by Cab Signaling With Train Control

Capacity of double-track line increased substantially by either-direction operation without wayside signals

By G. K. Thomas
Assitant Signal Engineer, System, A. T. & S. F.

and R. E. Liston
Air Brake Inspector, A. T. & S. F.

Relay case and pole framing at block location



Cab signal, speed indicator, and engineman's brake valve

PURSUANT to the orders of the Interstate Commerce Commission in 1922 and 1923, the Atchison, Topeka & Santa Fe installed a complete system of automatic train control and cab signals on the Illinois division between Fort Madison, Ia., and Pequot, Ill., a total distance of 175 miles of double track. The system used is the Union Switch & Signal Company's continuous three-speed control and circuits are so arranged that trains may be run in either direction on either track by signal indication and with complete automatic train control protection. All equipment was installed by railway company's forces. Previous to the installation of automatic train control this territory was handled under manual block except three short stretches totaling 37 miles which was equipped with automatic block signals.

The first order of the commission covered the territory between Fort Madison and Chillicothe, Ill., 102 miles, and this installation was placed in service on January 1, 1925. On March 28, 1927, the manual block system and automatic block system on this territory was abolished, all trains being governed thereafter by the automatic train control system. The second order covers the territory between Chillicothe and Pequot, 73 miles, which installation was completed March 31, 1927.

No wayside signals are used except at interlocking plants. Engine cab signals only are used to indicate the maximum speeds at which trains may operate. The cab signal consists of a three-light unit mounted in front of the engineman, in which illuminated letters indicate the permissible speeds. Letters show to the front and left so that both the engineman and fireman can observe the indication. The engine equipment on passenger and freight engines is adjusted so as to impose the speed limits.

The track is divided into sections or blocks of 3,800 ft. to 4,200 ft. in length averaging 4,000 ft. and circuits are so arranged that a train occupying any block imposes "low-speed control" on the portion of that block to the rear of the train and also throughout the entire length of the first block in the rear, as well as "medium-speed control" throughout the entire length of the second block in the rear. Thus a train traveling over the road carries behind it continuously, a zone of low-speed control of 4,000 to 8,000 ft. and behind that a zone of medium-speed control of 4,000 ft.

This spacing of blocks was determined on the basis of a heavily loaded oil train, which has the lowest braking power of any class of train operated on the division. It provides ample margin to insure safety under all ordinary conditions of operation. A chart of the controls set up in the rear of a train through an interlocking plant and between stations is shown in Fig. 1.

On the Illinois division, 19 regular passenger trains are operated on week days and 17 on Sundays, as well as numerous freight trains and extra sections of passenger trains, the average movements each day being approximately 40 trains. Approaching Chicago, the eastern terminal of the Santa Fe, both passenger and freight business is especially heavy eastbound during the early morning hours, and the same is true westbound during the late evening hours. This condition results in the fleeting of trains, both passenger and freight, eastbound in the morning and westbound at night, and in order to facilitate traffic, the system was so arranged that both tracks can be used for the same direction of traffic whenever this is deemed necessary. This system of reversing traffic permits freight trains to operate on the scheduled time of passenger trains and eliminates delays on sidings and in the terminal before starting.

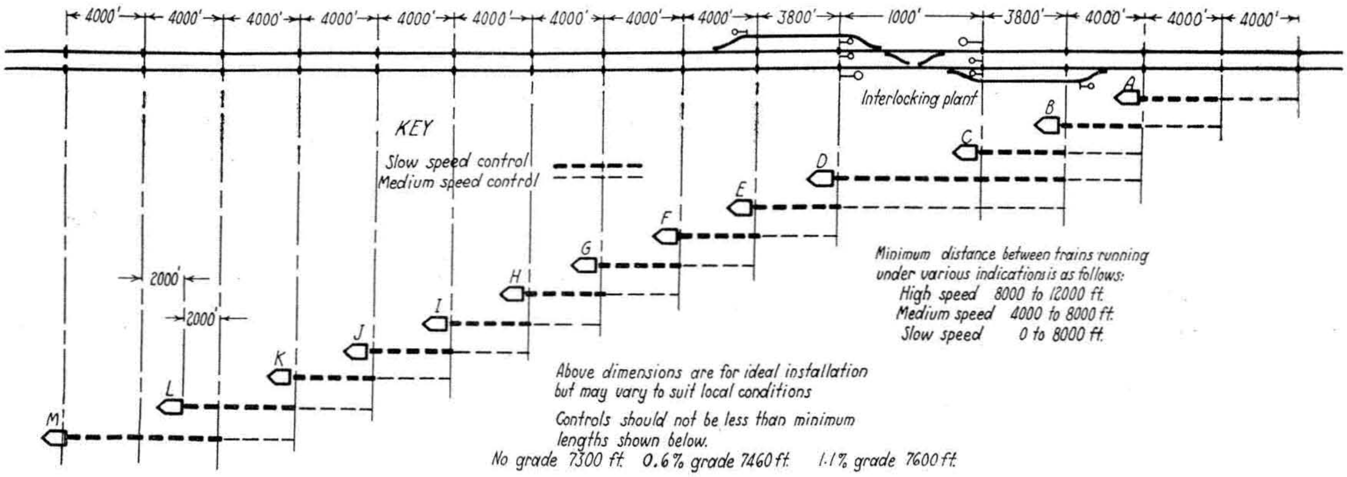


Fig. 1—Control chart rear of train

Either-Direction Operation Facilitates Movements

Freight trains running on the scheduled time of passenger trains between Fort Madison and Chillicothe have reduced their running time from 30 min. to 1 hr. 30 min. below the time which would have been consumed under conditions existing previous to placing the system in operation. In addition, the tonnage has been increased by about 500 tons, the average loaded train now consisting of about 84 cars as compared with a previous average of 74 cars. This latter change was made possible because, under the new conditions, a freight train very seldom has to go on a siding but can be kept moving with very few stops between terminals. This also must result in longer life of equipment and less consumption of fuel.

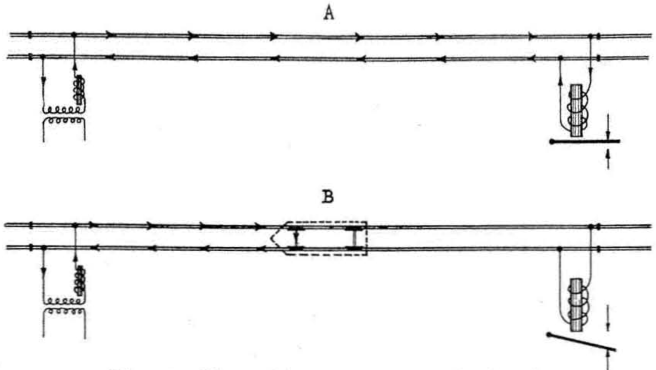


Fig. 2—Alternating current track circuit

The new system greatly facilitates the performance of heavy track work such as rail replacements, surfacing, ballasting, etc., and also facilitates traffic when such work is being performed, because trains may be detoured over the other track. This has proved already of practical advantage. All of the above have a definite money value, although it would be difficult to determine the total value of this saving in time.

Examination of train sheets shows that under present conditions 5 to 10 reversals are made per day. Traffic is not heavy at the present time and it is likely that the number of reversals will be increased considerably with increased traffic.

When a train is to be detoured against the normal current of traffic the operators at all stations concerned are authorized by train order to carry out the reversal. Such movements of trains are authorized by signal indication only, except where interlocking plants are not provided. At such stations trains must not cross over to run against the normal current of traffic except when authorized by train orders.

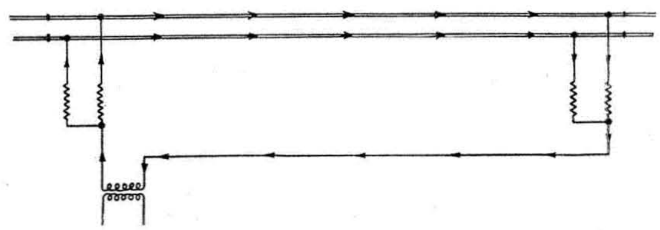


Fig. 3—Alternating current loop circuit

The line traverses a rolling country with ruling grades of 0.6 per cent except a short section of 1.1 per cent pusher grade westward. There are long stretches of tangent track throughout most of the territory, but curves and cuts occur in many places which would make it difficult to locate wayside signals in such a manner as to provide a good view. Fogs occur inthe vicinity of the Mississippi river extending at times over the entire territory equipped with automatic train control. These conditions make cab signaling especially desirable and enginemen are enthusiastic in its praise. During heavy storms or other periods when the view is obscured and time is lost on the portion of the division not operated under automatic train control, it is not unusual to find that this time is made up on the territory where train control is in operation.

The following is a copy of the special rules for operation under automatic train control:

Rules for Operation of Trains for Automatic Train Control and Cab Signal Indication Double Track Territory

"(1) Effective noon, Monday, March 28, 1927, between East Ft. Madison and Chillicothe depot, trains will be governed by the automatic train control system. All operating rules and special instructions will remain in effect except as hereinafter modified.

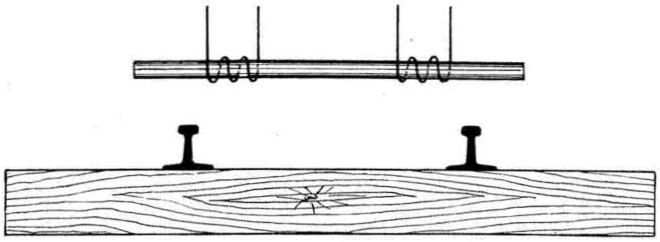


Fig. 4—Inductive relationship of engine receivers and running rails

"(2) Manual block system and automatic block signal system on this territory will be abolished. Interlocking distant signals will be removed. Engines backing up must be operated under control and not in any case to exceed a speed of 20 miles per hour.

"(3) Engine cab signals will indicate the maximum speed at which a train may operate, that is:

	Passenger	Freight
"H" High	65	45
"M" Medium	40	30
"L" Low	20	20

except that while operating with a low indication, trains must run under control. Rule 789 is hereby modified to permit speeds in excess of 10 miles per hour for main line movements against the current of traffic when passing dwarf signals which give a proceed indication. The absence of a light in the engine cab signal must be regarded as a low indication.

"(4) Trains will run against the current of traffic when authorized by signal indication, from stations having interlocking plants to such stations where returned to the 'current-of-traffic' track. Before trains cross over to use the other main from stations that do not have interlocking plants, such crossover movements must be authorized by train order reading per following example:

'No. 56, Engine 1054 use westward track from Laura. They will then proceed on signal indication. This will supersede time table authority.'

"(5) When train control seriously interferes with maintaining schedule time of train, it will stop at first open office and ask for instructions. The train control equipment on engines must not be cut out. Engines not equipped with train control, or with same inoperative, must not be used in road service outside yard limits without train order defining specifically the movements authorized, except second engine double-heading.

"(6) When night signals are displayed, trainmen on a train that is being passed by train on opposite main track will turn the marker, on the side next to the opposite main track, green as an indication to the passing train that a train with marker so displayed is being regularly handled on the opposite main track and in the clear of the main track that the other train is using.

"(7) Rule 99 must be observed in automatic train control territory, as elsewhere (flagging rule)."

Description of Control

The three-speed continuous control system necessarily requires the establishment of three different electrical conditions in order to provide the three controls. These three conditions are brought about by the proper control of alternating current circuits in the rails which establish magnetic fields around the rails and affect receiving apparatus mounted on the front and rear of the locomotive. The energy picked up by these receivers is amplified in two stages and used to operate the engine relay on the locomotive. Each track section is equipped with an individual set of controlled circuits, two separate circuits being used as follows:

Diagram *A* (Fig. 2) is the "track circuit," in which a small transformer feeds current into the rails and this is received at a track relay at the other end of the section. The current in the track circuit flows through a limiting impedance coil to the track, down one rail, through the track relay or the axles of any train which may be in that particular section, and back through the other rail. Incidentally quite a large part of the total current may leak from rail to rail through ground as in any d-c. track circuit. Diagram *B* shows the same track circuit occupied by a train moving from right to left and it will be noted that the current is shunted away from the relay by the axles of the train so that the armature of the relay drops by gravity on the back contacts. These contacts are used to control circuits in such a way as to indicate the presence or non-presence of a train on the particular track section concerned.

In the "loop circuit" (Fig. 3), current travels down both rails in the same direction. It leaves the loop transformer at one end of the circuit, divides through

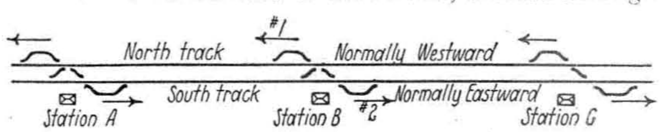


Fig. 5—Traffic direction control scheme between interlockers

two resistance coils and flows down both rails in the same direction under the train. At the end of the track section it is again brought together through two resistance coils and returns over a wire installed on the pole line.

Figure 4 shows in a diagrammatic way the engine receiver, one of which is mounted in front of the first pair of wheels on the locomotive and another at the rear of the tender with a vertical clearance of about six inches above the rail. This is a structure of laminated iron with coils mounted thereon in such a manner as to pick up energy, inductively, from the magnetic field around the rails. The "track receiver" being at the front of the locomotive, picks up track energy before it is shunted by the wheels. The coils on the track receiver are connected in such a manner that the voltages induced in them are additive when the current is passing through the two rails in opposite directions, as indicated for the track circuit in Fig. 2. The "loop receiver," being mounted on the rear end of the tender, is out of the zone of track circuit current because this has been shunted through the wheels of the locomotive. The coils of the loop receiver are connected in such a manner that the voltages induced in them are additive for currents passing through both rails in the same direction. Thus they pick up energy from the loop circuit which is shown in Fig. 3.

The "high-speed" indication is established when the track is unoccupied for a specified distance ahead. It is brought about by energization of both the "track circuit" and the "loop circuit" with the normal direction of current flowing in each circuit. The "medium-speed" indication is established when the track is occupied at a specified distance ahead. This is brought about by energization of both the "track" and the "loop" circuits with the current in the latter circuit reversed. The "low-speed" indication is established when the track is occupied at a specified shorter distance ahead. This is brought about by de-energization of either the track circuit or the loop circuit.

Interlocking Plants Retain Wayside Signals

A total of 26 interlocking plants are located in the distance of 175 miles, making the average distance between interlocking plants 6.7 miles. With the exception of two electric interlocking plants protecting the draw spans of bridges across the Mississippi river at Fort Madison and the Illinois river at Chillicothe, all of these plants are mechanical with single-unit, three-color light signals on main lines and single-unit, two-color light signals on side tracks. Complete approach and route locking is provided at all plants in both directions on each main track. The arrangement shown in Fig. 1 is typical of the track and signal layout at the majority of the interlocking plants, consisting of two main line crossovers and two passing sidings. Although this is a simple track arrangement there is considerable circuit complication due to special loop circuit controls in the four approaches to the plant and throughout interlocking limits. These complications are greatly increased by necessary arrangements for reversing automatic train control circuits to take care of reverse traffic movements.

Each interlocking plant is provided with an illuminated track diagram. In addition to the usual spot lights indicating track occupancy of the various sections, the diagram is provided with spot lights which indicate the traffic "set-up" on the normally approaching tracks, established by the adjacent plants in each direction as well as track occupancy throughout the entire distance between plants in the normally leaving direction on each track. Thus the leverman has all necessary information as to traffic "set-up" and movements of trains. The diagram also contains four green spot lights which repeat the four main-line color-light signals. The lamps in these four spot lights are bridged by low resistance units and connected in series with the green or yellow signal light, thus providing positive indication of the clearing of signals.

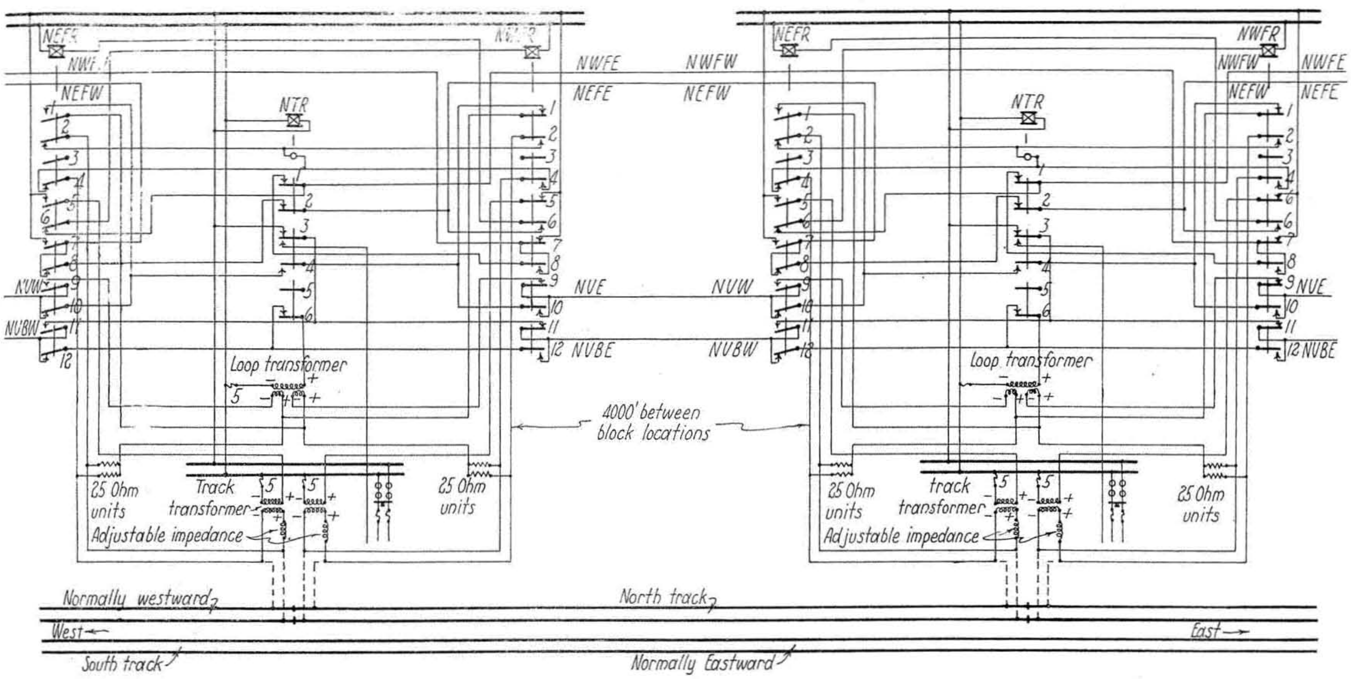


Fig. 6—Circuits employed in traffic direction cab signaling for north track of double-track line

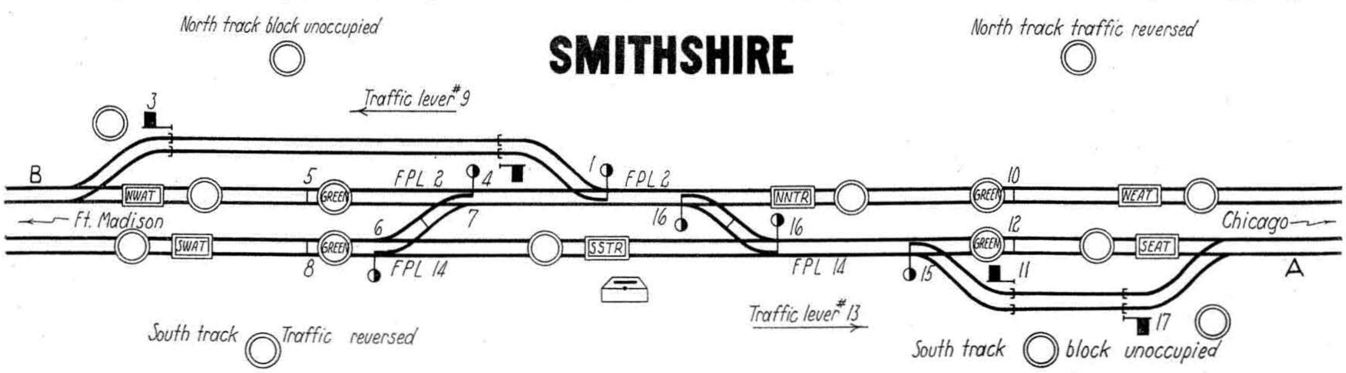


Fig. 7—Track diagram as mounted in interlocking tower for conveying train operating information to levermen

Traffic Reversal

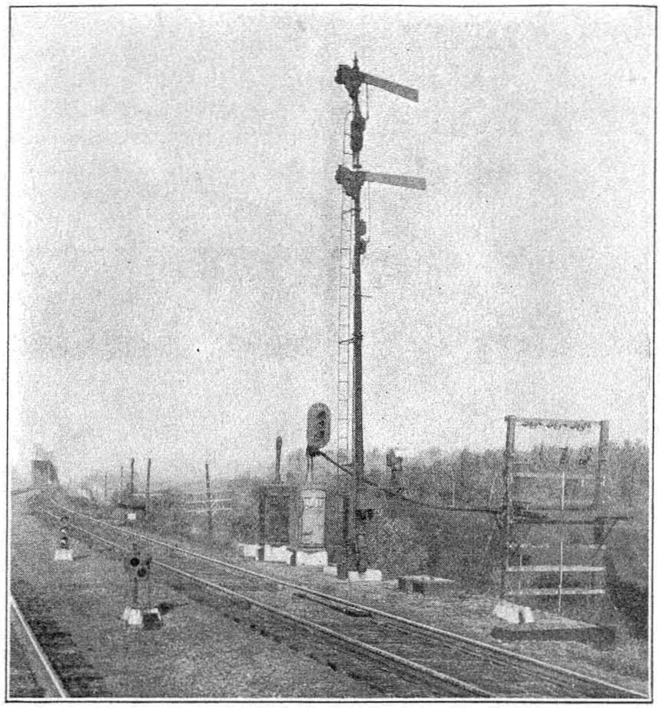
Traffic reversal is manually controlled from each interlocking plant. The normal current of traffic is to the right, westward trains normally occupying the north track and eastward trains occupying the south track. Each interlocking machine contains two traffic levers, one of which governs the traffic direction "set-up" to the next interlocking plant on the north track, while the other governs the "set-up" to the next interlocking plant on the south track. Referring to Fig. 5, the interlocking plant at *B* contains two traffic levers designated *No. 1* and *No. 2*. Lever *1* when normal establishes a westward traffic "set-up" between *B* and *A* on the north track for trains to proceed at high speed from *B* to *A*. If it is desired to reverse traffic in this section it is necessary to reverse lever *1*, which will establish traffic "set-up" eastward on the north track from *A to B*, releasing eastward signals at *A* so that they may be cleared to move trains from *A* to *B* at high speed. Where necessary to permit switching moves against the traffic "set-up," a push button is provided so that signals may be caused to indicate "proceed under control." Any movement against the traffic "set-up" is necessarily at low speed because both track and loop circuits are then set for the opposite direction of traffic. Traffic lever *No. 2* at *B* controls the traffic "set-up" on the south track between *B* and *C* in the same manner as described for lever *1*. Some of the interlocking plants, as indicated at *C* are not provided with reversing crossovers but with a few exceptions all are provided with complete traffic reversing equipment controling the normally leaving track in each direction as far as the next interlocking plant. Thus when it is desired to move a train from *A* to *B* against the current of traffic at normal speed, the traffic "set-up" for such move must be established by the leverman at *B* before the leverman at *A* can clear the signal to authorize such a move.

La Rose interlocking machine with covers of special circuit controller cabinet, in rear, removed

Design and Construction

Figure 6 shows the actual circuits used at two adjacent block locations controlling the north track. A similar set of circuits are used at each block location for the south track, all of the equipment for the north track being in one side of the double instrument case, and all of that for the south track in the other side. Typical block location cases fully wired and in operation, are shown in the photographs. The circuit in Fig. 6 is set up for normal westward traffic on the north track. Traffic relay *NWFR* is energized and *NEFR* is de-energized. These relays are controlled by the traffic lever at the interlocking plant to the right of the circuit and the traffic "set-up" established at the first block location is relayed to the next block location to the left. This action takes place from block to block throughout the entire distance between interlocking plants and since track and loop circuits are selected through contacts on the two traffic relays at each block location, the entire system of circuits is set up for westward or eastward train movements by placing the traffic lever respectively normal or reversed. Similar circuits used for the south track have their "set-up" controlled by a traffic lever at the interlocking plant to the left and the condition is relayed block to block from left to right.

Two track transformers are used for each track at each block location with their secondaries permanently connected to the rails and primary windings so controlled that only one transformer is energized for each traffic direction "set-up." Only one track relay is used and this has its track winding connected to one side or the other of insulated joints, depending upon traffic direction "set-up." The relative polarity of track circuits always remains the same.



Semaphore signals at Illinois river drawbridge interlocking prior to replacement with color-light signals

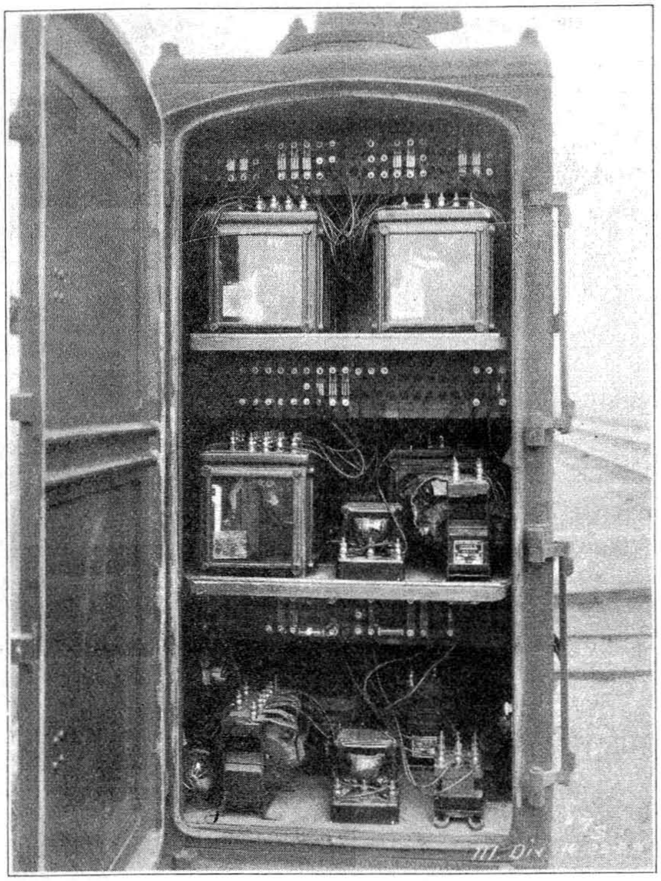
Only one loop transformer is used for each track at each block location. It is provided with two secondary windings, only one of which is on closed circuit for each traffic direction "set-up." The primary winding of a loop transformer receives energy from the next block location ahead in the direction of traffic set up, and is controlled from one or the other of the outside wires of the three-wire, 110/220-volt source, depending upon occupancy or unoccupancy of the second block ahead. This results in reversing the relative polarity of the loop circuit in a given block when the second block ahead is occupied. The primary of the loop transformer is also controlled through a front contact on the track relay in the first block ahead. Thus "low-speed" and "medium-speed" control for track occupancy in the first and second blocks ahead is established by properly controlling the loop circuit.

The design is such that line circuits serve a dual purpose, each wire being used for a different purpose, depending upon the direction of traffic which is set up. Traffic levers are electrically locked in the normal or reverse position by track occupancy throughout the entire block between stations or by clearing a signal to authorize such occupancy.

The design, installation and maintenance of circuits is greatly facilitated by the system of wire nomenclature used. Standard diagrams similar to those shown in Fig. 6 are used throughout the entire system. Circuit nomenclature is standardized at interlocking plants based on A. R. A. nomenclature and geographical directions and the entire system of nomenclature is such that maintainers quickly become familiar with the circuits so that they need refer to plans only in case of some unusual condition.

Control Features at Interlockers

Santa Fe standard signaling is used at all interlocking plants; each main line signal being provided with only one three-color unit and each side track signal with one two-color unit. When the plant is lined for a through route the signal may indicate green or yellow, depending upon track occupancy in advance. When the track is lined for a crossover or turn-out move the signal will indicate yellow and the two "ATC" blocks immediately approaching the signal will respectively impose "medium-speed" and "low-speed" control. The detector circuit in the plant will also impose "low-speed" control, thus assuring low speeds for such movements. When the signal indicates "stop" the two "ATC" blocks immediately approaching it are set to impose "medium-speed" and "low-speed" control, respectively. The yellow control of signals is non-automatic except for track occupancy of the detector section. The green control is established automatically by the line-up and unoccupancy of track circuits in advance. The automatic blocking of trains is accomplished entirely by the cab signal and automatic train control system, while fixed signals interlocking plants are used only to properly control moves through the plant and to authorize through moves. There are no fixed distant signals. Leave-siding signals are provided at the far ends of passing sidings and these are interlocked with traffic levers to prevent movements out of sidings against the direction of traffic "set-up."



Block location instrument case for north track

All controlling circuits operate on 60 cycle, single-phase power. The track circuits are energized by 400 v.a., air-cooled track transformers, 110-volt primary with various taps on the secondary winding which provide voltages from 1.5 to 18 volts in 1.5-volt steps. The loop transformers are 30 v.a., air-cooled, 110-volt primary with two secondary windings having taps to provide various voltages from 11 to 30 volts. A reactive device is used to limit the current flow from the track transformer and resistance units are used in the loop circuit so that the track and loop currents in the rails are approximately in quadrature providing the proper phase displacement for operation of the Type TV-20, two-element, engine relay.

Cartridge fuses protect secondary transformers and the main secondary power feeders at each location. They are used in as few circuits as possible consistent with the protection desired, because every fuse which is installed adds one more possibility of failure due to lightning.

The track relays are two-element, two-position Model-15. Traffic direction relays are Type SLV-12 and the majority of other line relays are Type SLV-13. All of the signal and track control apparatus, with the exception of some of the equipment used for highway crossing protection, was supplied by the Union Switch & Signal Company. Local repeating relays and electric locks at interlocking plants are handled on 6 volts direct current energized by small storage batteries on a.-c. floating charge.

Rail Contractors Employed to Operate Highway Crossing Signals

There are many crossing bells and automatic flagmen used to protect highway crossings throughout the installation and because of the high cost of cutting track sections and providing complete reversing facilities at each cut section, it was decided to use track instruments for controlling highway crossing devices. Fusticlo directional track instruments are used and the circuits are operated on 6 volts direct current fed by small storage batteries on a-c. floating charge. These circuits are arranged to operate the highway protective devices when trains approach the crossing in either direction on either track. Two-conductor Parkway cable is used for underground connections to track contactors and also for connections to switch indicators and electric lights on switch stands. For all other track connections creosoted trunking is installed underground and wires sealed in pitch.

The relays, air cooled transformers and other apparatus at block locations are housed in large double instrument cases with three shelves on each side. These were specially designed by the Union Switch & Signal Company for the purpose and are mounted on cross-shaped concrete foundations made by the Massey Concrete Products Corporation. The concrete piers for supporting cable posts were also supplied by Massey, eliminating all necessity for concrete work in the field. The instrument cases were wired at a central point and shipped out to their locations in the field complete with all fixed equipment located in them, relays and other movable parts being added later.

Ohio Brass Company welded signal bonds are used throughout except that boot-leg connections and jumpers at switch points and frogs are heavy stranded galvanized iron wires with 3/8-in. welded pin. Insulated track joints at block locations are installed opposite. Gravel ballast is used throughout the limits of the installation because this can be economically obtained from a large gravel pit located at Chillicothe. Track circuit conditions are fairly good on the westward track, but there is considerable leakage on the eastward track due to brine dripping from refrigerator cars carrying meat and other products to the Chicago markets. The majority of the track circuits on the westward track operate successfully on the 4½ volt tap on the track transformer, while on the eastward track it is necessary to use 7½ or 9 volts. Loop circuits carry about 1½ amp. divided equally in the two rails and controlled through back contacts on the track relay at the receiving end of the circuit so that the loop is normally de-energized and becomes energized only when the front wheels of a locomotive or car pass into the track section. This has the effect of decreasing the consumption of power on the system and improving the operation of the circuit.

Switch circuit controllers are provided at all non-interlocked switches, with two No. 9 shunt wires connected to each main line rail to shunt the track circuit when the switch point is more than 1/8 in. open. Loop circuits are cut through normally closed contacts on these controllers and Hayes derails on the side tracks are pipe-connected to switch stands. Fouling jumpers consist of four No. 6 copper wires installed in conduit cleated to the tie, just back of the frog and bonded direct to the rail with duplex channel pins. The turn-out is bonded to a point back of clearance. Light type switch indicators are used at non-interlocked switches.

Pole Line Features

A separate pole line is used for the automatic train control and signal system between Fort Madison and Ancona consisting of 25-ft. poles except where longer poles are necessary through interlocking plants, over crossings and for other special conditions. Butt-treated Western yellow pine poles are used between Fort Madison and Chillicothe and full creosoted Southern pine poles between Chillicothe and Pequot. Forty-four poles are used per mile, making the spans 120 ft., except that crossing spans are not in excess of 100 ft. Between Ancona and Pequot 30-ft. and longer poles are used to accommodate the Postal Telegraph Cable Company's 30 line wires which are carried on three cross-arms beneath the secondary A. T. C. and signal wires.

The three No. 6 B & S bare copper high-tension power wires are carried on a cross-arm at the top of the pole. Secondary wires are carried on 10-pin cross-arms spaced 4 ft. below the high-tension cross-arms. These are No. 8 BWG bare galvanized iron wire except where copper wire is necessary to provide higher conductivity and to increase its life through yards and other places where iron wire would deteriorate rapidly. No wire smaller than No. 9 B & S is used. The main common is No. 6 B & S bare copper wire and bronze connectors are provided at block locations for opening the common for test purposes. Separate commons are used for each section of the system extending between interlocking plants. All circuits are ungrounded except between Stronghurst and Monica, a distance of 61 miles, where the common is grounded as a special test for lightning protection.

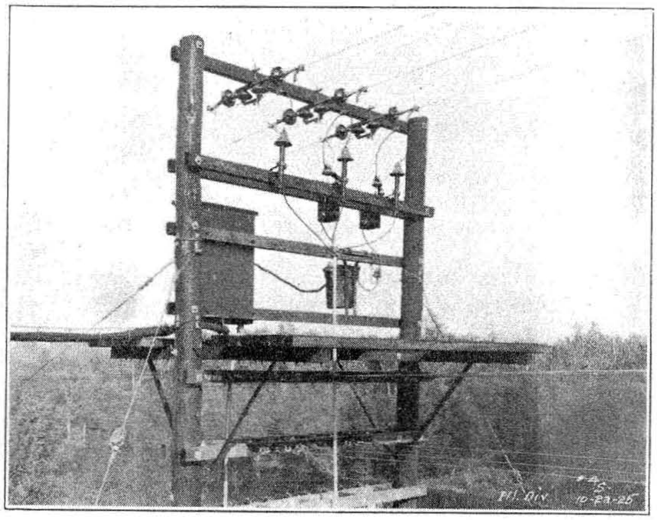
Power System

Power is transmitted at 60 cycles, 3-phase, ungrounded with power transformers connected in closed "delta." The line voltage between Chillicothe and Fort Madison is 6,600 volts, while that between Chillicothe and Pequot is 4,400 volts. The higher voltage was used between Fort Madison and Chillicothe to provide sufficient power for the addition of wayside signals in case they were considered necessary. Prior to the installation between Chillicothe and Pequot it was decided definitely that wayside signals would not be used and the consequent reduction in power requirements made it possible to use 4,400 volts in the latter territory. The power consumption averages about 350 v.a. per mile for the entire system, including interlocking plants and some station lighting. An increase of about 20 per cent may occur during very wet weather.

The high tension power system is divided in four separate main sections as listed below:

Ft. Madison to Galesburg	54 miles
Galesburg to Chillicothe	48 miles
Chillicothe to Streator	40 miles
Streator to Pequot	33 miles

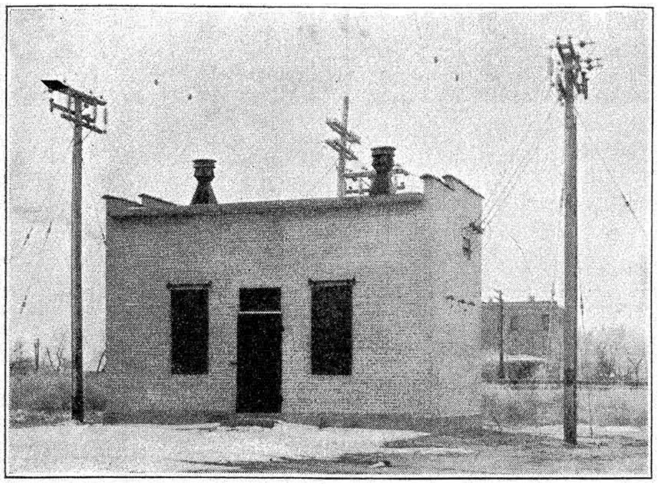
Continuity of power is provided by automatic substations feeding the system at Fort Madison, Galesburg, Chillicothe, Streator and Coal City, the latter point being two miles west of Pequot. The substation equipment supplied by the General Electric Company is arranged so that power is normally fed from one end of each main section and in case this source is interrupted due to any cause the automatic equipment functions, cutting off the source which has been interrupted and immediately connecting the power source at the other end of the line. This action takes place so rapidly that only a slight blink in the lights is noticeable. No main line fuses are used but oil circuit breakers at all substations are adjusted to trip on heavy overloads and a time delay feature is provided so that they will not trip unless the overload is sustained for an appreciable period. During an electrical storm it is not unusual for the power connection to change back and forth from one end of the line to the other at frequent intervals without a complete interruption of power at any time.



Transformer and terminal pole, H-structure with sectionalizing switches—Rear view showing high tension arresters

Commercial power at 60 cycles is purchased at all of the points listed except at Fort Madison, where 25-cycle power from Keokuk, Ia., is used. At this point duplicate frequency-changer sets of 45 kva. capacity are used to change from 25 to 60-cycle frequency. The power feeders, as well as all secondary circuits, are carried across the Mississippi river and the Illinois river in submarine cables.

All pipe framework and cases of transformers, oil switches and contactors in substations are grounded. The equipment at Fort Madison and Galesburg is housed in the power company's stations. Special brick substation buildings are provided at Chillicothe and Streator and a steel switch house is used at Coal City with the transformers and other weatherproof equipment mounted on a platform supported on four poles. Air-brake switches are provided on the line poles outside substations so that the stations may be cut-out or cut-around in emergency. The Chillicothe station cannot be cut-around owing to the difference in voltage at each side but power can be fed through it if this should become necessary. Air-break sectionalizing switches are installed near all railways stations, averaging about 3.5 miles apart, so that short sections of the line may be de-energized when necessary to perform work on the line or when testing for trouble.



Automatic substation at Chillicothe, Ill.

At each block location, averaging 4,000 ft. apart, a 1½ kva. Type-H oil-cooled transformer supplies power for all local circuits at 110 volts, single phase. The load is approximately equally distributed to the three phases on a mileage basis by assigning each phase to a certain section of line between interlocking plants and providing six sections of this kind to each main section of the power system. This makes it possible to rotate the connections to the phases so as to strike a balance near the middle of each main section. High-tension fused cut-outs are used at all transformer locations and provision is made at interlocking plants so that the transformers feeding the plant may be energized from either side of the air-break sectionalizing switches. Thus the plant can be kept in operation while an adjacent section of the transmission line is de-energized to permit the performance of work without danger.

Lightning Protection

Three high-tension lightning arresters are installed on the "H" pole frame at each block location, and, as a test, at about 30 per cent of the locations an additional set of three arresters are installed at the adjacent poles at each side of transformer locations. Choke coils are used in the connections from the high-tension line to the fused cut-out boxes leading to line transformers, and also at the entrances to substations and pot-heads leading to submarine cables. At interlocking plants a set of three high-tension arresters are mounted on the adjacent pole at each side of the transformer "H" pole construction as there was no space available on the latter structure to accommodate them. Between Fort Madison and Chillicothe compression chamber lightning arresters are used, while pellet type arresters are used between Chillicothe and Pequot. The secondary circuits are protected by Premier arresters mounted in arrester boxes at all terminal poles, and pin-point arresters mounted on the terminal boards in all relay housings.

An artificial ground is provided for the high-tension arresters on the pole line and a separate ground for the secondary arresters on the same pole. Each ground consists of three 1-in. galvanized iron pipes driven 10 ft. in the ground about 5 ft. apart. The two outside pipes are bent inward and welded to the center pipe at a point about 4 ft. above the level of the ground. The center pipe extends all the way up to the lightning arresters near the top of the pole. No artificial grounds are used in connection with pin-point arresters, as these tie into the track wires and the rails serve as ground connections. Between Streator and Coal City a ground wire is installed on the high tension cross-arm for test. This is grounded at every fourth pole, using one driven pipe for each ground.

Very severe electrical storms occur throughout the equipped territory, and while numerous cases of blown fuses have resulted from these storms, there has been practically no lightning damage to signal apparatus up to the present time.

Engine Equipment

Approximately 90 locomotives are used in road service on the Illinois division, all of these being equipped for automatic train control. The various parts of automatic train control making up the engine equipment have been grouped and located on the engine where convenient and space was available. The pneumatic parts were so grouped, primarily for reducing to a minimum the number of pipes necessary to connect these groups or portions. However, the space available for mounting on a modern locomotive determined the maximum size of each group. The electrical equipment was grouped so that it could be housed to exclude moisture and to simplify wiring. The location of several parts of the electrical equipment was fixed by the function each performed. The principal parts or groups of the equipment are located on a Mikado type locomotive as follows:

The control governor, including timing, valves, relay valves and electro-magnets, is mounted on a wrought iron bracket above the front deck, ahead of and slightly below the smoke arch. The governor is driven through a vertical, telescopic shaft which, in turn, is driven by a set of gears mounted on an extension of the front truck axle. The application portion, which contains a pilot valve, the main application valve, the equalizing piston, reduction limiting and insuring valves, suppression valves, split-eliminating valve and four small reservoirs, is located on top of the boiler near the main steam dome. The engineman's brake valve is placed in the usual location in the cab, the handle being in easy reach of the engineman when seated. The acknowledging valve is mounted slightly above and between the brake valve and the boiler back head.

The equipment box containing the amplifier, the a-c. vane type train control relay and an electro-pneumatic cut-out relay is located on top of the boiler, just back of the main sand dome and is mounted at right angles to and on the center line of the boiler. The dynamotor, which produces energy for the plate circuits of the amplifier, is mounted on the end of the equipment box. The track receiver is fastened to the heel of the pilot with the lowest point about six inches above the top of the rail. The loop receiver is mounted on a cast bracket under the bumper beam on the rear of the tender, with the lowest point approximately five inches above the top of the rail.

The cab signal with air gages and speed indicator are grouped on the boiler back-head slightly above the line of vision and in front of the engineman when seated in his usual position. The high speed cut-out switch is mounted on the wall of the cab below the windows and in easy reach of the engineman. The electric speed indicator provided in the engine cab has a dial clearly marked to indicate the speeds at which automatic brake applications will occur when the various speed limits are imposed by the automatic train control system.

The functioning of individual parts of the Union continuous automatic train control system has been described in detail in previous issues of *Railway Signaling,* however, the operation of the control equipment as a whole as installed on the Santa Fe will, no doubt, be of interest.

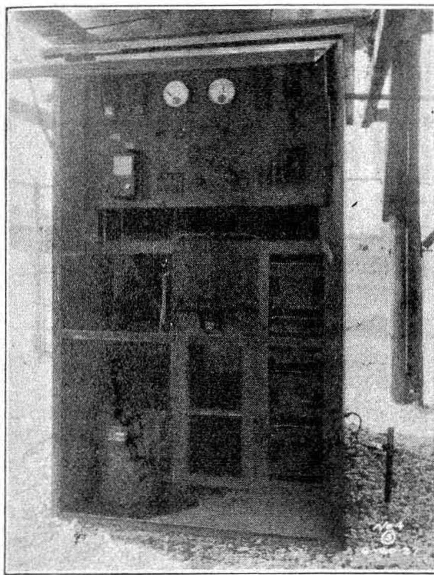
How Speed Control Is Used in Train Operation

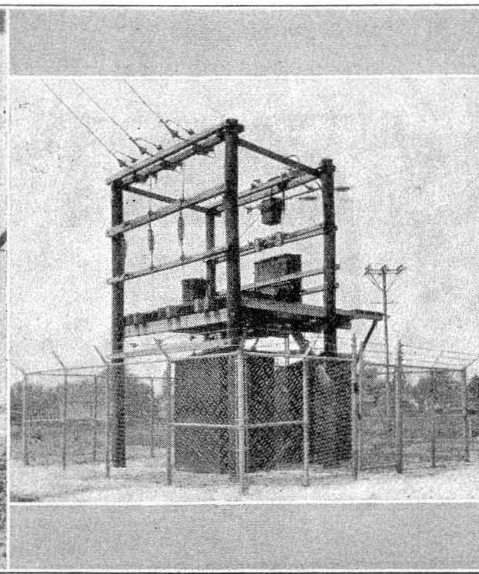
If a train is running under "high-speed" indication and exceeds "high speed," an automatic application will be made in five seconds, which will be visually indicated on the air gage by the main reservoir pointer or red hand dropping to brake pipe pressure; however, if the engineman laps his brake valve promptly after the application begins, it will persist only until the train speed is reduced slightly below the "high-speed" limit, when the application piston will move to normal position restoring main reservoir pressure to the feed valve and the engineman's brake valve, which will be indicated by the "flip" or return of the main reservoir needle, or red hand on the air gage to normal position, at which time the engineman may manipulate his brake valve and release the brakes in the usual manner.

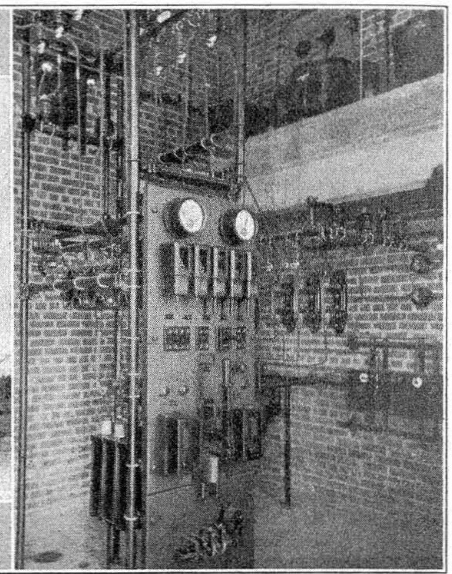
If a train is running under "high-speed" indication and a change of indication from "high" to "medium" is received, an automatic brake application will result, if the train is running above the "medium-speed" limit, after a "blow-out" delay period depending on the speed of the train—30 sec. if train speed is just above "medium" and 5 to 8 sec. if the train is at or near the "high-speed" limit. This application can be avoided if the engineman reduces the speed below "medium" before the end of the delay period. If the train speed is not reduced and an automatic application takes place, it will persist until the train speed is reduced below the "medium-speed" limit when a release can be made by the engineman, provided the brake valve has been in lap position long enough to restore main reservoir pressure to the feed valve and brake valve which will be indicated by the return of the main reservoir hand on the air gage to normal position. No automatic brake application will occur with a change of indication from "H" to "M" if the train is running at less than medium-speed limit.

An automatic brake application will occur when a train is running at any speed, or standing, when a change of indication from "H" to "L," or "M" to "L" occurs, unless the change of indication is *"acknowledged,"* and train speed reduced (if necessary) below the low-speed limit before the end of the "blow-down" delay period. If the engineman fails to acknowledge a change of indication to "low speed," an automatic brake application will result in 5 to 40 sec., depending on the train speed. If an automatic brake application starts, the engineman *must* lap his brake valve and train speed must be below the "low-speed" limit before the brakes can be released.

In all cases where an automatic application is made, the engineman must lap his brake valve and leave it in lap position until the red hand of the air gage re-


Outdoor installation of automatic switching equipment


Power substation for train control—Automatic equipment housed below transformer platform


Interior of Chillicothe substation—Control panel in foreground

turns to normal, as in no case will an automatic application of the brakes be released automatically. The engineman must acknowledge all changes of indication to low speed, otherwise an automatic brake application results. An acknowledgement is made by moving the valve handle forward to the acknowledging position immediately after a change to "L" indication and leaving same in that position until the blow-down gage pressures are below 30 lb., or until the indication changes from "L" to "M" or to "H," and then returning the handle to normal position.

An automatic application suppression feature is provided whereby the engineman can forestall an automatic brake application by making a manual reduction of sufficient amount and in time to reduce the train speed below the imposed limit at approximately the same point where it would be accomplished by the functioning of the automatic application valve. Should the engineman fail to make sufficient application to reduce the speed below the imposed limit in the time allowed, the automatic apparatus will make a further brake pipe reduction to complete a full service application. The suppression feature is provided, primarily, to avoid an automatic reduction on top of a manual reduction where the manual reduction is sufficient to reduce the speed at proper time and rate, and thus permit the engineman to handle his train without undue interference by the automatic apparatus.

An electric "cut-out" is provided for "setting up" the train control equipment when running off train control territory. This control consists of a switch, conveniently located in the cab, controlling a circuit which energizes the "high-speed" magnet through a stick relay. This switch must be operated while the engine is passing over a special highly energized circuit which is provided at each end of the train control territory. The stick relay cannot be picked up unless the switch lever is moved to the "cut-out" position immediately upon entering the high-speed cut-out section, left in that position until the cab signal lights go out and then returned to the normal position at once (within three seconds), after the lights go out. When a high-speed electrical "cut-out" is obtained a train may proceed at speeds up to maximum on non-equipped territory.

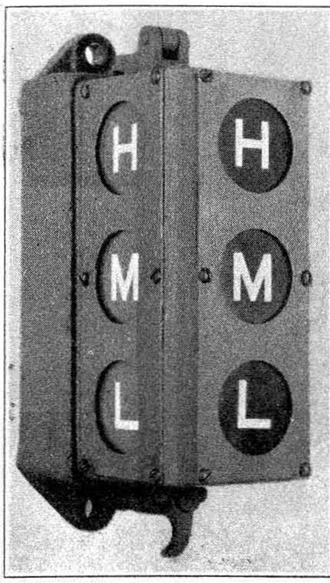
A permanently-energized "cut-in" circuit is provided at the entrance to train control territory so that the train control will be automatically "cut-in" regardless of the occupancy or unoccupancy of the first block.

Maintenance of Engine Equipment

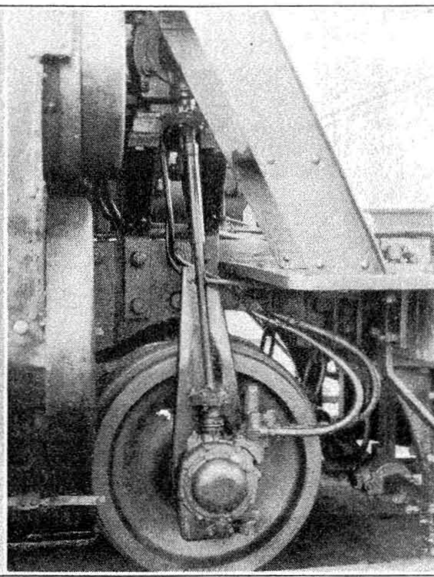
An organization has been developed and plans carefully worked out for adequately maintaining the train control engine equipment. Inspectors are employed at each engine terminal who test thoroughly and inspect each engine arriving at the terminal. To do this the engine is "spotted" on a special test circuit so arranged that all operating conditions are duplicated. Air pressure is maintained in every pipe and a check is made for leakage; each air valve is moved in a normal manner to check its operation and each timing feature is checked within fixed limits. Each electrical circuit is energized, checked for continuity and each electrical function is operated normally and checked within fixed limits of voltage and current for operation. This is followed by a test for grounds and of headlight generator voltage. A complete record is made of these tests on a proper form, and this record, together with the engineman's report of road operation, accompanies the engine into the roundhouse where it is checked by attendants who repair all defects noted and make sufficient tests to assure that repairs have been made properly. This report is later filed as a record of condition of equipment.

When an engine is ready for a trip and before it leaves the terminal, the equipment is again checked by an inspector for operating characteristics and finally the engineman runs the engine over a special test track and checks the operation. An engine is never allowed to leave a terminal unless the equipment functions properly under all tests.

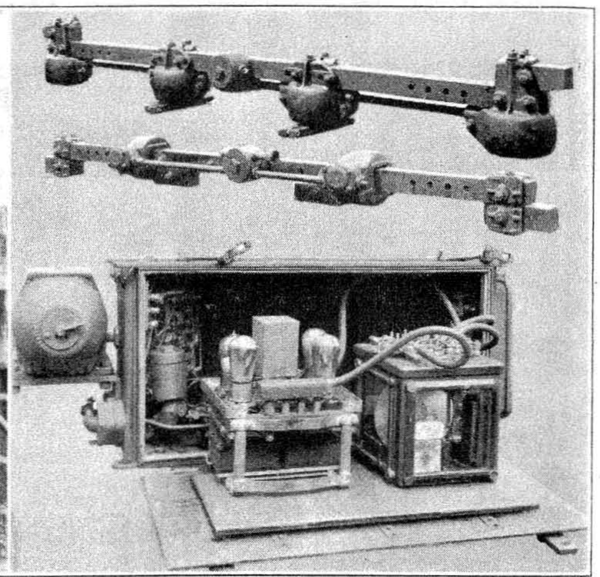
The same careful inspection and high degree of workmanship is demanded in the maintenance of train control engine equipment as is required for the proper operation of wayside signals and with such maintenance, the automatic train control is operating satisfactorily.



Speed limit indicator which is mounted in cab



Telescopic drive shaft connection to governor



Top—Loop receiver with four coils; Middle—Track receiver; Bottom—Engine equipment box