The Union Continuous Train Control

The Principles and Methods of Operation of the Two-Speed and Three-Speed Systems as Applied to Traffic Requirements

THE fundamentals of the continuous train control as developed by the Union Switch & Signal Company includes a source of power, the track elements, and the train elements. Alternating current is supplied at convenient locations to feed the transmission line that traverses the territory. Electric currents in the running rails, specifically known as the "axle current" and the "loop current" are furnished from the a. c. line, through small transformers. These currents are controlled by track and signal condition in advance. The train elements consist of the electric control, the governor control and air brake operation. Electrical control receives current from the track elements depending on track conditions, while the governor control is determined by the speed of the train. These functions acting in conjunction, control the operation of the air brakes under certain conditions and through the medium of visible indications inform the engineer of such conditions in advance.

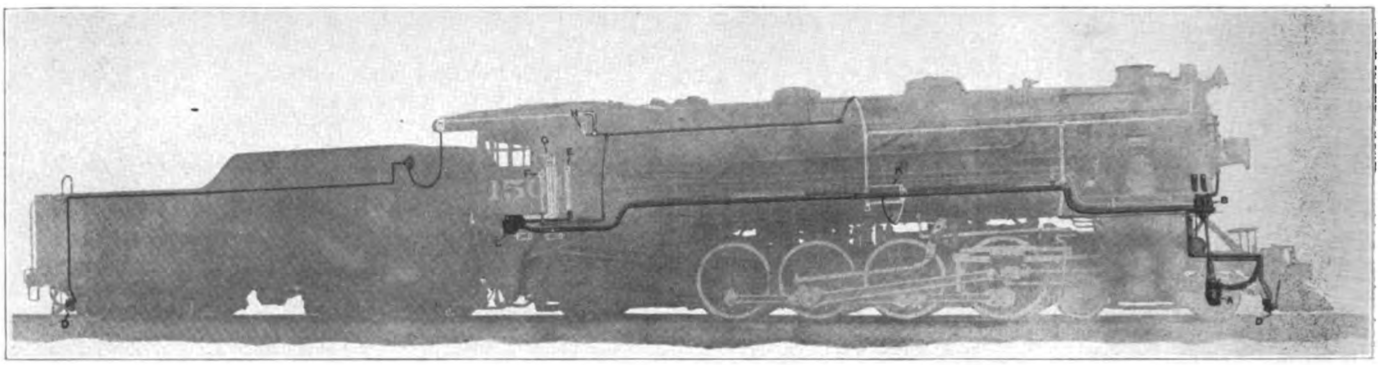

Fig. 1—Typical Installation of Continuous Inductive Train Control on Locomotive

Fundamental Features and Functions of Continuous Control

The continuous automatic train control enforces the operation of trains in accordance with signal indication and track conditions without relieving the engineman of any of his responsibility. So long as he complies with the signal indications, the control of the train is left in his own hands, but should he fail to comply with them the system takes control and either stops the train or reduces its speed. In such cases it applies the brakes but it never releases them—brake applications are made automatically but the release of such applications must always be made by the engineman himself. If, for any cause he cannot release his brakes his train is brought to a stop.

The system provides the engineman with a continuously-visible indicator on his engine from which he can at all times determine at what speed it is permissible to run. Any change in conditions immediately ahead of him are instantly registered on this indicator in sufficient time to enable him to increase or decrease speed as the case may be. In unforeseen occurrences such as a switch being opened, or a rail breaking immediately ahead of him this indicator gives him warning and the brakes are applied automatically. It is required that the engineer take some definite action (to be described later), at certain points to prove that he is alert, failing which his train will be stopped.

Under restriction the continuous system permits one train to follow another into an occupied block without stopping, provided the second train does not exceed the predetermined minimum speed. Should the first train clear the block by accelerating or taking a siding the fact is instantly recorded by the indicator of the second train, which can then in turn accelerate.

The system operates on the "closed circuit" principle which requires a continuous flow of current between the track and the train to permit the train to run at any speed above the predetermined minimum. The failure of that current to flow will stop the train, or bring its speed below the minimum permitted.

No trackway elements other than the running rails themselves are required. The wayside control consists of wire connections and other materials commonly used in signaling practice, such as relays and transformers. Hence, no questions of clearances are involved. The continuous train control can be installed with either direct or alternating current signaling on steam or electric railroads and is equally applicable to single or multiple track operation.

The emergency brake application is not made by the train control, the greatest automatic application being the regular service reduction. On the other hand, the train control does not prevent the engineman from making an emergency application nor does it ever interfere with the operation of his independent engine brake.

An important feature of this system is the fact that no change has been made in the manual operation of the engineer's valve G, Fig. 1. The brakes are applied automatically through the medium of the brake application valve C usually placed immediately below the cab as shown. The engineman can manipulate the engineer's valve as heretofore without interference from the automatic control except that he cannot effect a release under certain conditions.

Whenever an automatic application is made the air is cut off the engineman's valve. The automatic valve will not restore and give the engineman air until two conditions are fulfilled, i. e., the engineman's valve must be put to lap—and—the speed brought below the new speed limit. The acknowledging valve E is operated by a small lever located conveniently to the engineman's hand, which must be operated under certain conditions hereafter explained, to prove that he is alert. This action is called "acknowledging."

Cut-Out Switch, Double Heading and Special Operation

In leaving train-controlled territory the engineman must operate the lever of the cut-out switch F at the point of exit. This action in conjunction with the passage of the train over a specially energized section cuts out the train control apparatus entirely until the engine once more enters such territory when the apparatus automatically cuts in again without any action on the engineman's part. Should the engineer neglect to operate the cut-out switch F at the point of exit the brakes will be applied. As the train leaves controlled territory the indicator light goes out and is relighted when it re-enters such territory.

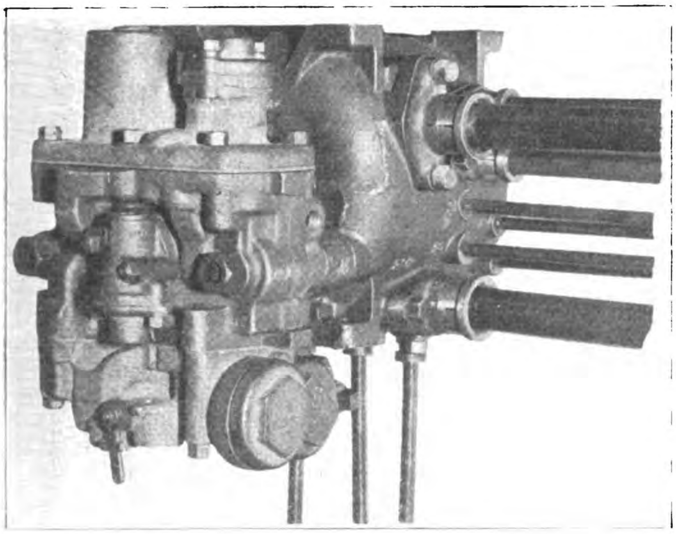

Fig. 2—Valve Group C, With Cut-Out Lever to Lower Left Corner

Except in case of suburban engines and others engaged in similar service, most railroads do not permit locomotives to exceed a speed of 15 or 20 miles per hour when running tender first. The continuous system enforces this rule in that an engine equipped with train control apparatus for forward running only cannot exceed the minimum speed in the normal direction of traffic when running tender first because the tender wheels shunt the axle circuit ahead of the pickup coils. Suburban engines may be equipped with an extra pair of pickup coils at the back of the tender and the engine circuit shifted from the front to the rear coils and vice versa through a circuit controller operated by the reversing lever, thus permitting running at speed with the tender ahead.

The pneumatic cut-out, shown in Fig. 2, is a part of the brake application group *C* (see Fig 1), and consists of a stop cock operated by a handle which is normally secured in the "cut-in" position by a car seal. If for any cause, it becomes necessary to cut out the train control apparatus on the road the engineman breaks the seal, thereby releasing the handle which can be turned so as to cut out the pneumatic portion of the train control apparatus, leaving the engineman free to operate his air brake manually. This pneumatic cut out does not affect the electrical apparatus, consequently, if the control is cut out due to a pneumatic or mechanical failure alone, the engineman still has the benefit of his indicator. When engines are double headed, or used as pushers, the train control equipment, except on the leading engine, is automatically cut out of service by the customary train pipe connections.

In the manual operation of air brakes it is usually the practice when making an application, especially in long freight trains, to make a full service reduction in train pipe pressure in two stages. The first a comparatively light one of about 7 lbs., "to bunch the slack," followed by a further reduction of about 13 lbs. after a short interval. This is known as the "split reduction." Split reduction is accomplished in both the two-speed and three-speed union train control systems.

In bucking snow it is often necessary to exceed the minimum speed limit of 20 miles per hour. In such cases snow plows can be equipped with two receiving coils as a permanent part of their equipment. These coils can be connected to the electrical train control equipment of the first engine behind the plow, and by so doing the plow can be pushed at any speed which the track conditions will permit, under full train control protection.

Principles of the Axle and Loop Circuits

When either the two or three-speed system is installed in connection with signaling controlled by alternating current track circuits the same current that operates the track relays for controlling the signals is also used to energize the engine pickup coils. While this fact makes a separate "axle circuit" unnecessary it requires the addition of a separate line and rail circuit for each track known as the "loop circuit." This is needed because the track circuit must be energized between "stop" and "caution" signals in order to display the caution indication of the wayside signal, whereas, without the use of the loop circuit, this same track circuit acting in its capacity of axle circuit, would have to be de-energized to give a brake application at the caution signal as already explained.

In a two-element train control system the track or axle circuit picked up by the front coils of the engine is one source of energy and the "loop circuit" the other. The loop circuit is carried on a wire on the pole line the entire length of the block and connected through resistance coils to both rails of the track at both ends of each block. A second pair of pickup coils on the engine connects the loop circuit to the "local element" of the engine relay. Since both axle and loop circuit have to be closed to energize the relay, the axle circuit between the stop and caution signals can remain closed and the relay de-energized by merely opening the loop circuit.

The two-element train control relay and the loop circuit are sometimes used with the two-speed system in train control territory where direct current track circuits are installed but usually because the engines operating in this territory also run over alternating current track circuits in other territory, or as an extra precaution against foreign current.

Characteristics of the Two-Speed System

There are two types of continuous train control known respectively as the "two-speed" and "three-speed" systems. The same fundamental principles of operation are common to both and up to this point of this article the principles of operation are the same for the two systems. The three-speed system provides greater flexibility than the two-speed and is consequently, better adapted to meet heavy traffic conditions than the latter, but since the two-speed is the simpler system it will be described first.

The two-speed system, as it name implies, permits the trains to run in occupied blocks at a predetermined minimum speed and at unlimited speed in unoccupied blocks. This consequently requires that the breaking point in the rear of every potential stopping point such as a signal, must be sufficiently far from that signal to insure that any train running at its highest possible speed will be stopped before reaching the signal if the brakes are applied automatically on reaching the braking point.

An engine equipped with the necessary apparatus for operating under the two-speed system in connection with direct current signaling, is shown in Fig. 1. This equipment consists of: The drive *A*, the governor and drive connections *B*, the brake application valve *C*, the receiver coils *D*, at the front of the locomotive the ac-

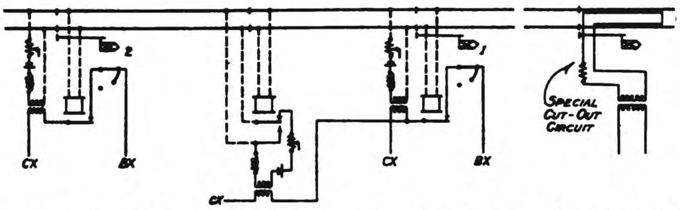

Fig. 3—Typical Two-Speed Circuits for Double Track A. C. Superimposed on D. C. Track Circuits

knowledgment valve *E*, the cut-out switch *F* used when leaving train control territory, the engineer's valve *G*, the speed limit indicator *H* and the equipment case *K* for housing the train control relay and other electrical apparatus. The second set of receiver coils shown at rear of tender are used for the three-speed system only as will be explained later. In addition to this the headlight generator is used to furnish current for the operation and control of the electrical apparatus on the engine while the compressed air is, of course, supplied from the regular compressor.

The typical alternating current connections for the single-element two-speed system, which are superimposed on direct current track circuits of automatic signaling on double track are shown in Fig. 3, similar connections on single track are shown in Fig. 4. The signals and track relays shown in the illustrations are a part of the signal system, and the train control current does not interfere with the operation of the d. c. track circuits.

The "track element" of the two-speed system is the combination of a transformer secondary, the running rails themselves, the front wheels and axle of the engine, the contacts of a relay or circuit controller and the wire connections, all constituting an electrical circuit. The alternating current mains furnish energy to the primaries of transformers placed at the exit end of each block, thus inducing a flow in the secondary above referred to. The secondary current flows down one rail towards an approaching or standing train, travels across the first wheels and axle of the engine to the opposite rail and returns to the transformer secondary. This is known as the "axle circuit."

Engine Circuits and Indicator Operation

The alternating current flowing along the rails induces a second current in the receiver coils *D* carried on the front end of the locomotive about six inches above the rail and protected from injury by the pilot. The current so induced in the engine coils is amplified by special power vacuum tubes energized from the headlight generator which in turn energizes the train control relay on the engine.

The train control relay through its front and back contacts causes one or the other of two lights to burn in the indicator *H*. One of these lights indicates that no speed restriction exists and burns when the axle circuit is closed and the engine relay energized.

The other electric light which indicates the minimum speed restriction, burns when the axle circuit is shunted or opened from any cause and the engine relay de-energized. The unrestricted speed is designated by the letter *H* and the restricted by *L*, meaning "high" and "low" speeds respectively. The train control relay also controls a local circuit which energizes an electro-pneumatic valve in the air brake connections. This remains energized as long as the axle circuit is closed but if opened from any cause it is de-energized and a brake application results.

Under normal operation the axle current is controlled by contacts on the signal and the track relay of the signal system as shown in the circuit plans but its continuity may also be interrupted by a broken or disconnected wire or a broken rail in which case the indicator will change to show low speed and the brakes will be applied. The "closed circuit" principle employed in railway signaling is therefore incorporated. If the con-

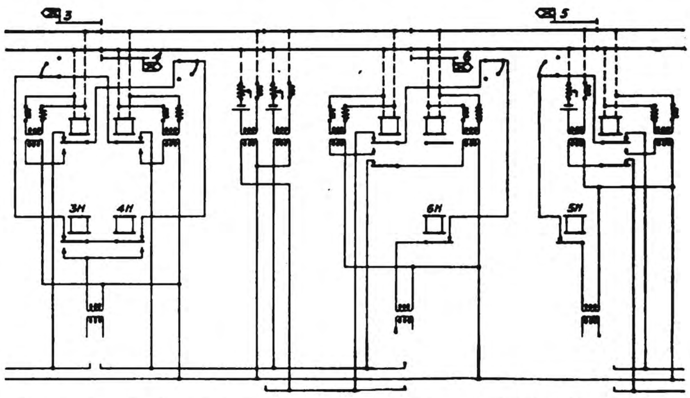

Fig. 4—Two-Speed Continuous Train Control Circuits, Single Track A. C. Superimposed on D. C. Circuits

trol of the brakes depended on the axle circuit alone it is evident from the foregoing that whenever this circuit was opened the brakes would be applied and remain so until released by some other act.

The Function of the Governor

The engine is, however, equipped with a centrifugal governor, shown at *B*, Fig. 1, operated from one of the engine wheels other than a drive wheel. The function of the governor is to shift a pneumatic valve when the speed of the train falls below the minimum and by so doing permits the release of the brakes by the engineman without stopping the train. The assembly of the governor and pneumatic valve is shown in Fig. 5. The train can proceed through an occupied block as long as it does not exceed the minimum speed. Should it exceed this speed, however, the governor reverses the valve and the brakes are applied. An auxiliary centrifugal governor is located directly on the axle, the purpose of which is to check the operation of the main governor. Should either governor fail to function properly the brakes will be applied and the train brought to a stop. The auxiliary governor is purely a safety device installed as an additional measure of precaution.

In order to avoid an automatic application at the braking point in the rear of a "stop" signal the engineman must always, irrespective of speed, operate the acknowledging lever, and if running above the minimum speed take proper action to bring the train below that minimum. If these two acts are performed he will be able to release after decelerating below the minimum and can continue to run at or below that speed. If he fails to "acknowledge," his brakes are applied and held for about 40 seconds before they can be released even though the train has decelerated below the new speed limit. The point at which an automatic application will be received after passing the braking point in the rear of a "stop" signal will depend on the speed at which that point was passed. The rule is that "the slower the speed the greater the distance the train can run before the brakes are applied"—the function which provides for this is called the "delayed application." This is effected by valves actuated by the governor working in conjunction with the automatic application valve.

Operation of Trains Under the Two-Speed System

Assuming that a train is starting from a railroad terminal on its regular run over a double track engine division on which three position automatic signals are in service and where the braking points, for the two-speed train control are placed at the caution signals. The train control installation starts outside the terminal area and extends the entire length of the division. As the train reaches the point where the two-speed control begins, as indicated by a marker, it passes over a permanently energized section which automatically cuts in the engine equipment and causes one of the two indicator lights to burn depending on track conditions ahead. In the case described the track is clear, hence, the *H* light is displayed, indicating unrestricted speed, thereby permitting the train to continue at any speed desired.

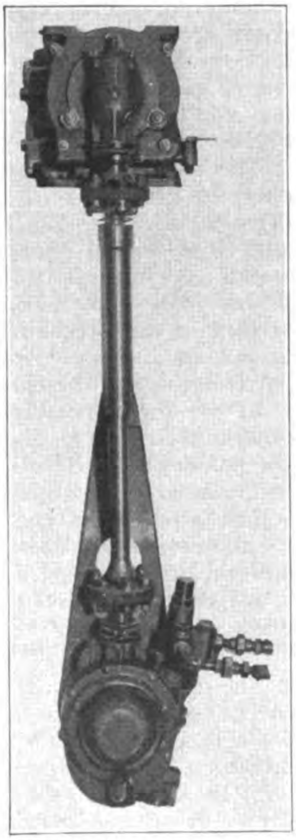

Fig. 5—Centrifugal Governor and Pneumatic Valve Unit

After running some distance it closes in on a preceding train and as a result finds the next block signal displaying "Caution." When it passes this signal the engineman operates his "acknowledgment lever" as prescribed and makes a brake application. The indicator light changed from *H* to *L* as the caution signal was passed indicating restricted or low speed. Due to the engineman's action in acknowledging the caution signal and his futher action in promptly reducing his speed below the prescribed minimum, which is assumed to be 20 miles an hour, an automatic application has been anticipated and the train enters the occupied block ahead without stopping at the home signal.

After running for some distance at less than 20 miles an hour he reaches a slight descending grade and inadvertently exceeds that speed. The engine governor acts and an automatic application is received, which again brings the speed below 20 miles an hour. He releases the brakes manually without having to stop and continues at 15 miles an hour to allow a safe margin for possible variations.

The preceding train has meanwhile increased its lead and cleared the block, consequently, the next signal ahead of the second train changes from "stop" to "caution." This signal was not visible to the engineman of the second train when the change occurred, being around a curve, but the indicator changed simultaneously from *L* to *H*, thereby permitting him to accelerate.

If he increases the speed accordingly but forgets to acknowledge the caution signal as he passes it, consequently an automatic application is received, and in this case, as a penalty for neglecting to acknowledge the caution signal, the brakes are applied and held for about 40 seconds before they can be released, even though the train has decelerated below the new speed limit. After this interval he is able to release his brakes in the usual manner and again proceeds at low speed.

The first train is now so far ahead that he runs under clear signals for a considerable distance at unrestricted speeds with the indicator displaying *H*. Suddenly without any warning, it changes to *L*, and the brakes are applied automatically. There is a sharp curve immediately ahead, beyond which an industrial spur track leaves the main line. If necessary the engineman may augment the automatic service application by moving his brake lever to the emergency position. The stop thus made prevents the train from striking some cars that a few seconds before had been pushed beyond the fouling point of the siding.

Three-Speed System

The three-speed continuous train control system possesses all the advantages of the two-speed type already enumerated and a number of others mentioned in the following description. This system imposes three speeds: High, medium and low—on a train in accordance with track conditions as indicated by the three signal indications, "clear," "caution" and "stop." High, or a predetermined maximum speed, is imposed in clear blocks, medium speed between caution signals and the braking point of a stop signal, and low, or a predetermined minimum speed, between this braking point and the stop signal and also in occupied blocks.

In the two-speed system a train can approach the braking point of a "stop" signal at unrestricted speed, hence the braking point must be sufficiently in advance of the signal to insure that any train running at its highest possible speed will be stopped before reaching the signal if the brakes are automatically applied at, or before reaching, the braking point. However, in the three-speed system the highest speeds at which any train can approach the braking point of a stop signal are the medium speeds (usually not over 45 miles per hour for passenger and 30 miles per hour for freight trains). Hence, the braking points in the three-speed system can be located much closer to potential stopping points than in the two-speed system.

In laying out a signaling system in accordance with the principles of three-speed train control, the caution signals should be located so that a train running at the predetermined maximum speeds (usually not over 70 miles an hour for passenger and 50 for freight trains), will be brought below their medium speeds respectively, if the brakes are automatically applied at, or before reaching, a signal displaying "caution." In the three-speed system there are in effect two braking points in each block, one at the caution signal and the second in advance of the home signal as described in the preceding paragraph. The first is usually called the *A* point and the latter the *B* point.

The point at which an automatic application will be received after passing the *A* or *B* points in the rear of a "stop" signal will depend on the speed at which those points were passed. The rule is that "the slower the speed the greater the distance the train can run before the brakes are applied"—the function which provides for this is called the "delayed application." This is effected by valves actuated by the governor working in conjunction with the automatic application.

In addition to the engine equipment mentioned in describing the two-speed system, the three-speed system has an additional set of receiver coils at the rear of the locomotive. The operation of the speed control and the speed indicator are somewhat different as will be mentioned later.

The typical alternating current connections as used with alternating current track circuits for automatic signaling are shown in Fig. 6. The signals and track relays shown are a part of the signal system. One "track element" of the three-speed system is the combination of a transformer secondary, the running rails, themselves, the front wheels and the axle of the engine, the contacts of a relay or circuit controller and the wire connections, all constituting an electric circuit. Alternating current mains furnish energy to the primaries of transformers placed at the exit end of each block, thus inducing a flow in the secondaries above referred to.

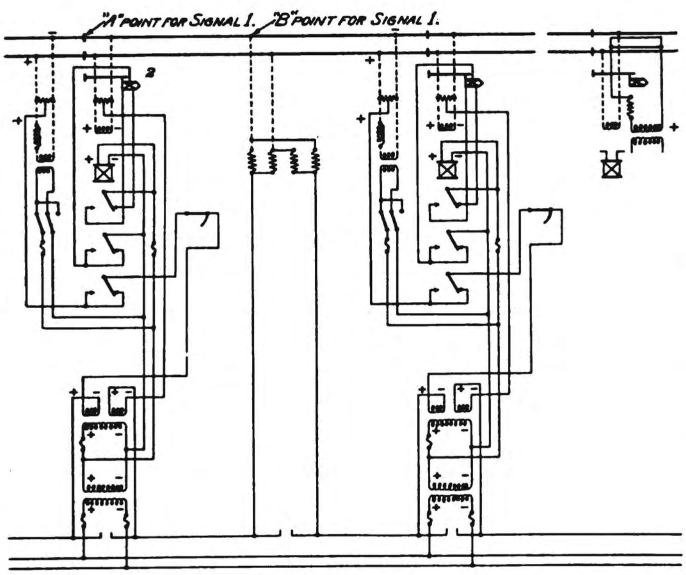

Fig. 6—Typical A. C. Connections As Used With A. C. Track Circuits for Automatic Signals

The secondary current flows down one rail towards an approaching or standing train, travels across the first wheels and axle of the engine to the opposite rail and returns to the transformer secondary. This is known as the "axle circuit."

The alternating current flowing along the rails induces a second current in the receiver coils *D* carried on the front end of the locomotive about six inches above the rail and protected from injury by the pilot. The current so induced in the engine coils is amplified by special power vacuum tubes energized from the headlight generator, which in turn energizes one coil of a three-position relay on the engine.

Extra Loop Circuit and Receiver

The other coil of the train control relay is energized by a second track element known as the "loop circuit." The loop circuit is the combination of a transformer secondary, track relay contacts or other controllers, a line wire for each track running the entire length of the block on the pole line and connected through resistance coils to both rails of the track at both ends of the block (also at such other points as special conditions require). The current from the transformer secondary traverses both rails of the track in parallel and returns over the line wire. This current is picked up by the rear collector coils *D* of the engine and through amplifiers energizes the local coils of the engine relay referred to above.

The contacts of this train control relay are capable of assuming three different positions. Vertical when either or both of the track and local coils are de-energized, to the right when current in the two coils has a certain phase relation, and to the left when the current in one of the relay windings is reversed.

The speed limit indicator of the three speed system has three lights, *H* indicating maximum speed, *M* medium speed and *L* minimum speed. These three lights are controlled by the contacts of the relay described above, the *H* light burning when the contacts are swung to the right, the *M* light when swung to the left and the *L* light when the contacts are vertical.

Electro-Pneumatic and Governor Control

The train control relay also controls local circuits which energize electro-pneumatic valves in the airbrake connections. These valves working in conjunction with the engine governor determine the speeds at which the train may run to comply with the track conditions immediately ahead.

The engine is equipped with a centrifugal governor operated from one of the engine wheels other than a drive wheel. The function of this governor is to open and close certain pneumatic valves in accordance with speeds at which the train runs. The operation of these valves in conjunction with the electrical control described in the preceding paragraph determines whether or not an automatic application will be imposed at the particular speed the train may be running at any time.

In the three-speed system provision is made in the governor to change the maximum and medium speeds for passenger and freight service respectively from one to the other by a properly authorized person. If, for instance, a passenger engine is assigned to freight service its maximum speed can be reduced from 70 to 50 miles and the medium speed from 45 to 30. The minimum speed for both classes of service is not usually varied.

Operation of Trains Under Three-Speed System

The operation of a train over a division equipped with the two-speed system has previously been described and we will now follow the course of another train on a road on which the three-speed system is installed in connection with three-position automatic block signaling on double track. As in the previous description the train control system begins outside the terminal area and extends the entire length of the division. After the train reaches the point where the system begins, indicated by a marker, it passes over a permanently energized section which automatically cuts in the engine equipment and causes one of the three indicator lights to burn, depending on the track conditions ahead of the train. In this particular case the track ahead is clear, hence the *H* light is displayed, indicating maximum speed which we will assume in this case to be 70 miles per hour for passenger and 50 miles per hour for freight trains.

The train proceeds for some distance at speeds varying with local conditions but below the maximum permitted, until it begins to run down a slight descending grade where it exceeds the maximum speed and receives an automatic application in consequence. The engineman laps his brake valve, the speed falls below the maximum, and he is then able to release the brakes and continue as heretofore.

After running for some distance the train closes in on a preceding train and as a result finds the next block signal displaying "caution." On passing the caution signal the engineman takes action according to the speed to avoid an automatic application, i. e., he handles the train by brake application, shutting off steam or otherwise, to get below the new speed limit before the automatic application would otherwise take effect. After passing the caution signal the speed limit indicator changes from *H* to *M*, indicating that he can continue to run at the medium speed.

The speed of the train falls below the medium and he continues on through the block without exceeding this limit until he reaches the breaking point indicated by the marker, at which point he operates the acknowledgment lever as prescribed and in addition handles the train, as at the caution signal, to bring from the medium to the minimum speed of 20 miles per hour and thereby avoid an automatic application. As it passes the braking point the indicator changes from *M* to *L*, indicating that he must not run about the minimum speed of 20 miles per hour.

It will be noted that by taking proper action the engineman has anticipated automatic application at both the caution signal and the braking point and has consequently retained full control of the train throughout the entire block. Due to the foregoing procedure the engineman is permitted to pass the stop signal at the minimum speed, which he does, and continues through the occupied block at or below that speed, keeping a lookout for the train ahead. If while running in this block he momentarily exceeds the minimum speed the governor acts and automatically brings the train down below that speed where he releases the brakes and continues as before.

While still traveling at this speed the train ahead takes siding and clears the main track, thus causing the block signal to change from "stop" to "clear." When this change occurred the block signal was not in sight of the engineman of the second train but the indicator changed simultaneously from "slow" to "high" speed, thereby permitting the engineman to accelerate.

A few miles further on he finds a block signal displaying caution and neglects to take the necessary action to bring the train down to medium speed soon enough. As a result an automatic application is received between the caution signal and the *B* point, bringing the train below the medium speed. He releases the brakes and later makes a manual application before reaching the braking point but neglects to acknowledge this point as he passes it and as a result the brakes are applied and held for about 40 seconds before they can be released, even though the train has decelerated below the new speed limit. This unnecessary stop has placed him slightly behind the regular running schedule and for the next few miles he has to make up time. Since the track ahead is clear, as indicated by the wayside signals and the speed limit indicator, he continues at speeds approximating the maximum.

While out of sight of the next wayside signal the indicator suddenly changes from *H* to *L* and he receives an automatic service application. A curve prevents him from seeing the track for any great distance, consequently he may augment the automatic application by a further reduction manually and brings the train to stop within the limits of vision. After being stopped he proceeds cautiously around the curve and finds a broken rail between his train and the next stop signal. The condition of the break is such, however, that it is safe for the train to pass over at low speed and as soon as the engine passes the break the indication changes back from "slow" to "high," indicating that the broken rail was the sole cause of the restrictive indication previously imposed on the train.

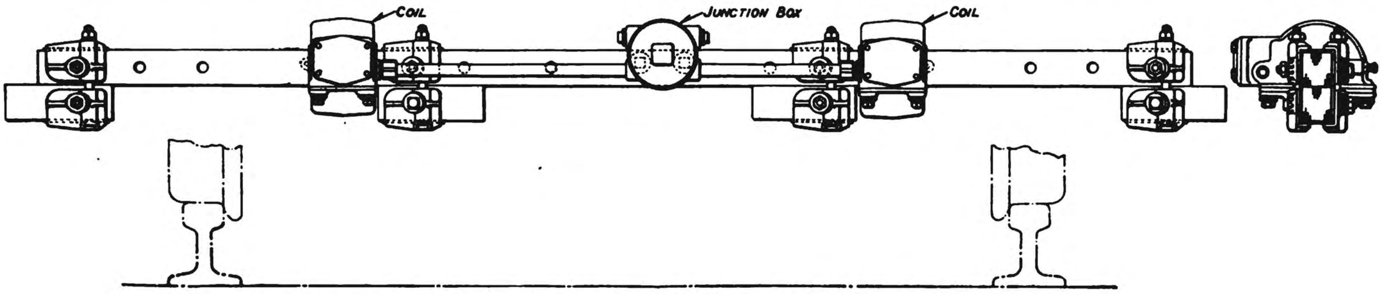

Fig. 7—Position of Receiver Coils With Respect to Rail Clearance

Track reversal on any track between points is accomplished by the co-operation of the two adjacent operators in manipulating "traffic direction" levers in their respective machines, which can only be done when the track to be reversed is unoccupied between the two stations.

The train whose movements have been described continues to the end of the division, where the engine is detached and proceeds to the round house. As it leaves the main track the engineman operates the cut out switch and the control apparatus is cut out until the engine enters the main line on its next run, when it is automatically cut in as previously described.

A Crossing Watchman in Austria