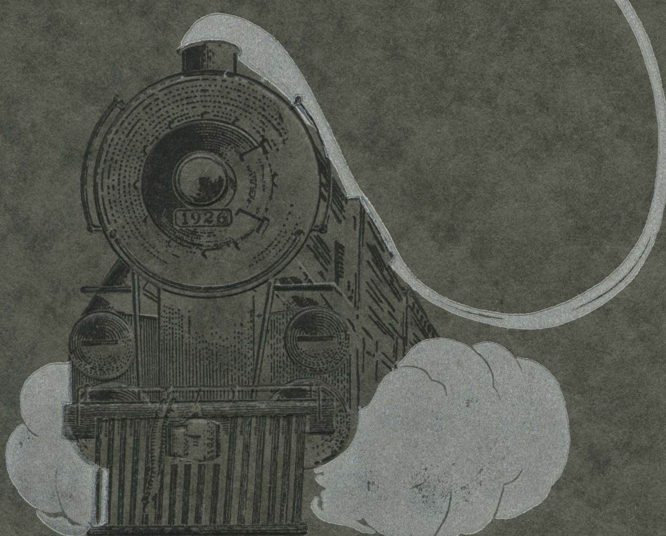
"Union" Automatic Continuous TRAIN CONTROL



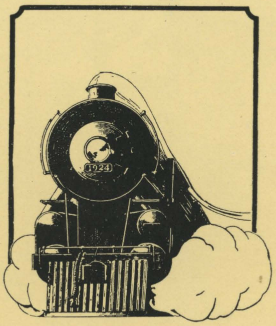
Union Switch & Signal Co.

SWISSVALE, PA.

BULLETIN 105

Automatic Train Control

"Union" Automatic *Continuous* TRAIN CONTROL



BULLETIN 105

OCTOBER, 1929

Union Switch & Signal Co.

Union Switch & Signal Company

PREFACE

The object of this bulletin is to describe the **Union** continuous inductive system of automatic train control in terms which will be readily grasped by railroad men and others interested, who may not be necessarily familiar with all the technical details of railway signaling and air brake practice.

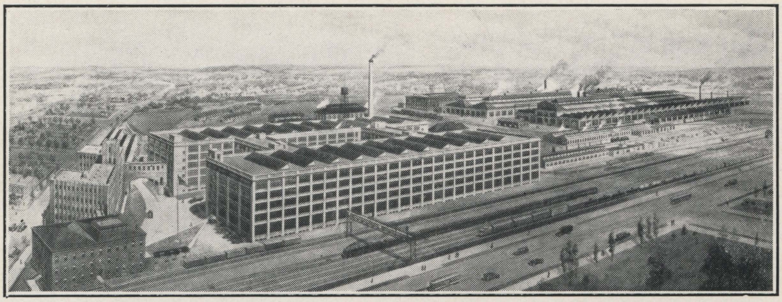
A brief history showing the development of train control is first presented and followed by a general description of the continuous system covering both the two and three-speed types each of which is later described separately.

The subject is presented as briefly as practicable, illustrations being used to simplify the descriptions wherever possible.

The reading matter is divided under titles and subtitles and a table of contents is provided for ready reference.

We are prepared to furnish further data, on application, to those more directly engaged in the installation and operation of train control.

The Union Switch & Signal Company



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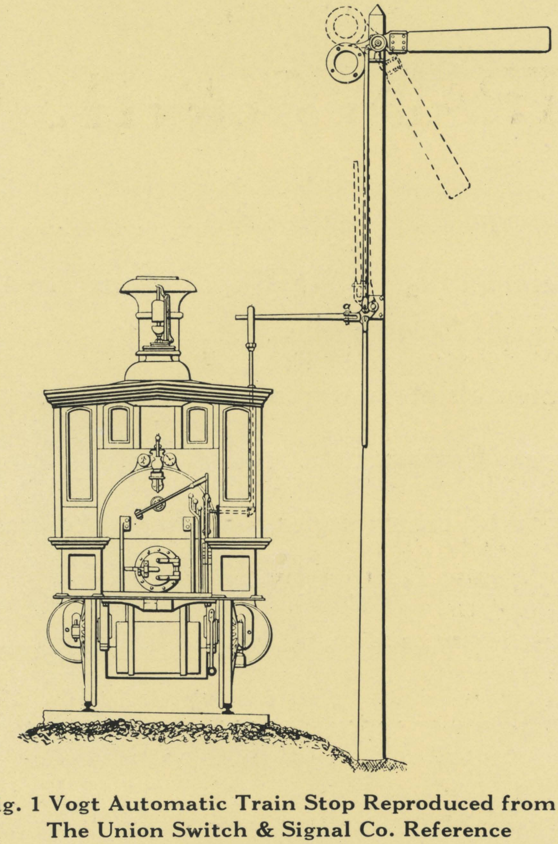


Fig. 1 Vogt Automatic Train Stop Reproduced from
The Union Switch & Signal Co. Reference
Book of 1889

"Union" Automatic *Continuous* TRAIN CONTROL

DEVELOPMENT

Automatic train control in a narrow sense is the combination of the principles of automatic signaling with what are generally termed "automatic train stops," defined in the Signal Dictionary as "Apparatus, mechanical and electro-magnetic for stopping trains by means **actuated from outside the train** (as at a signal post). In the simplest form a trip fixed on the roadway and moving in unison with the usual visual signal is made to open the air valve on the locomotive or car, thereby applying the air brakes or shutting off the propelling power, or both, independently of the engineman or motorman."

Automatic Stop

Very soon after the invention of the air brake the somewhat obvious idea was conceived of stopping trains through venting the train pipe by some device on the roadway. The first known method was an extension of the train pipe to the roof of the locomotive cab, terminating in a glass tube or stop cock, as shown in Fig. 1. The wayside semaphores were provided with arms which projected at right angles to the post when indicating stop. Should an engineman pass a signal in that position this arm would break the glass tube or open the cock and set the brakes. A trial installation of this device was made on the Pennsylvania Railroad and is illustrated and

Early Devices

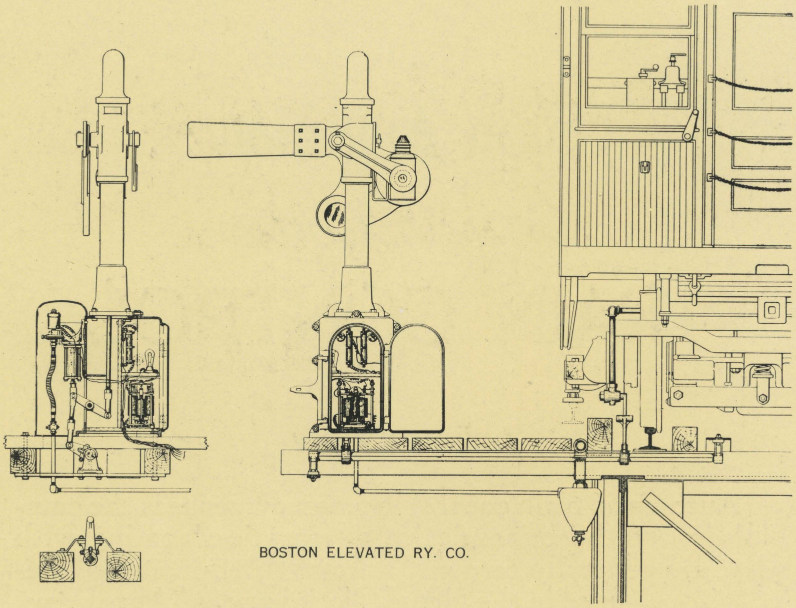


Fig. 2 Automatic Electro-Pneumatic Block Signal with Automatic Train Stop Attachment

described in our 1889 catalogue. Eventually, the same idea was applied to automatic semaphores on the Key Route in Oakland, California.

Boston Elevated

Automatic stops were installed on the Intramural Railroad at the World's Fair in 1893 and some years later on part of the Chicago Elevated Railroad; but the first permanently successful installation was made by The Union Switch and Signal Company on the Boston Elevated Railroad in 1900, as an adjunct to the electro-pneumatic interlocking and automatic signaling with which the road was equipped. This design (shown in Fig. 2) consisted of an angle cock in the train pipe located a short distance above the rails. The arm of this cock strikes what is known as a trip arm when the latter is in the vertical position thereby applying the brakes in the same manner as the original idea previously described. The trip arm is either connected directly to the semaphore as shown or actuated by a separate mechanism. When moved from the path of the angle cock by either means it permits free passage for a train.

This type has operated with entire success on the Boston Elevated since originally installed and many later extensions of the system have been made with only minor changes in design. Similar automatic stops have been very extensively applied by us on the Interborough Rapid Transit, and the Hudson and Manhattan of New York; the Philadelphia Rapid Transit Co., the Elevated Railroads of Chicago and other railroads of this nature.

Other Installations

Automatic stops of this same design were applied to the New York terminal of the Pennsylvania in 1910, but as this was a surface railroad it was necessary to provide means to prevent undesirable brake applications due to the arm of the angle cock striking obstructions other than the trip. A special stop valve and trip arm were, therefore devised as illustrated in Figures 3 and 4. In this design the brake valve and trip are practically toothed gears which engage with each other as the locomotive passes over the trip. When so engaged the middle tooth of the trip arm presses the vertical valve stem upward and sets the brake—any foreign obstruction such as a stone or timber would obviously be pushed to one side by the protecting teeth without engaging the valve stem in the center.

Pennsylvania Terminal

Our experience thus far in the development of train stops convinced us that while the foregoing devices met all the traffic requirements of the roads on which installed, involving the operating of regular passenger equipment on tracks protected against trespassers and weather, such devices were not suited to

Automatic Stops Only One Feature of Train Control

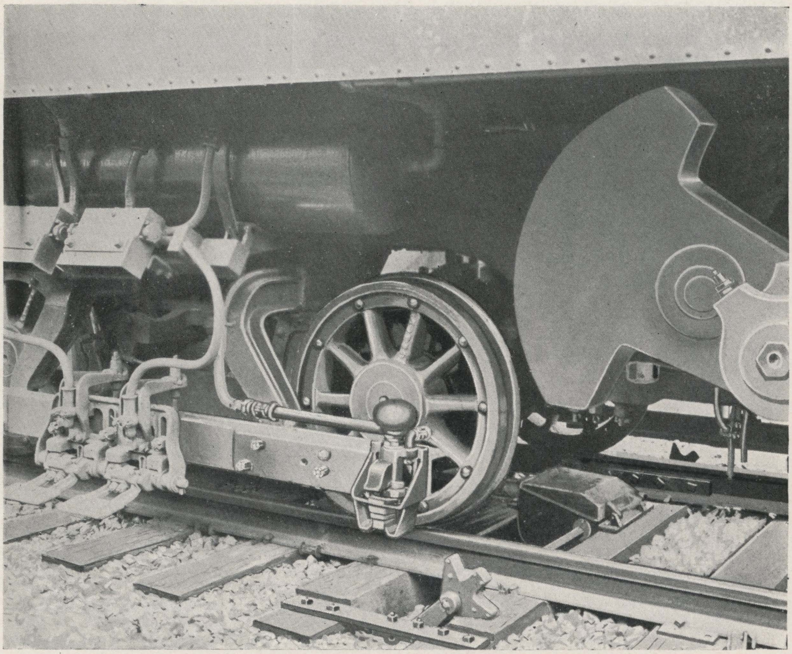


Fig. 3. Hill Automatic Train Stop; Valve on Locomotive and "Tripper" on Track at "Proceed"

meet the many conditions obtaining on surface railroads. As signal engineers we also realized that automatically **stopping a train was only one feature of train control.** It is true that the popular conception of train control is some device that will prevent collisions by stopping trains automatically if the engineman fails to do so, but as a prominent railroad officer once said about signals "We don't install them just to stop trains, their real function is to keep trains moving safely and expeditiously." This truth applies equally well to automatic train control and hence a well-designed system must be flexible enough to permit normal train operation with the maximum degree of safety and whenever possible increase the capacity of the tracks to which applied.

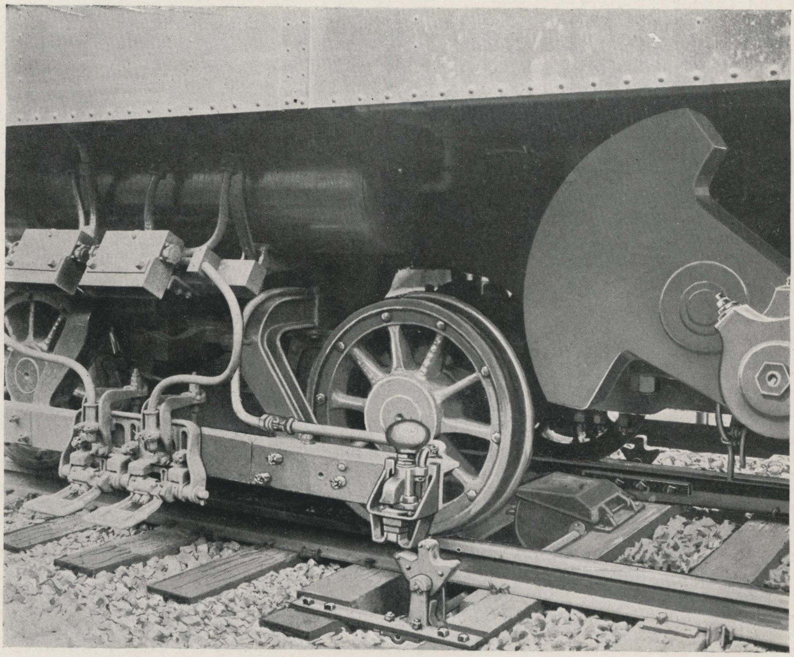


Fig. 4. Hill Automatic Train Stop; "Tripper" at "Stop"

With these facts in mind we conducted a series of service tests with a ramp system on the Lackawanna, New Haven and Pennsylvania Railroads. A distinctive feature of these tests was the use of the so-called "time and distance" idea in which the speed of a train was reduced when approaching a stop signal by the use of two ramps or other intermittent devices located such a distance from each other that if a train consumed less than a given time in running from the first to the second ramp when the next signal was at stop, it would receive a brake application at the latter; otherwise it could continue at a comparatively low speed.

Test with Ramps

The ramps were attached to the ties parallel to the rails, movable shoes to engage with them being carried on the engines. Electrical connections were made from the ramps to the signals in such a way that when a signal was clear the current that was picked up from the ramp by the locomotive shoes nullified the mechanical action of the latter when lifted by the ramp, in setting the brakes. When the signal was at stop, however, the ramp circuit was open, hence, there was no current to nullify this mechanical action, consequently a brake application resulted.

Troubles with Clearances

The service tests proved that the system would work as designed, but, in spite of endeavoring to take clearance problems into account, we found that they were practically insurmountable, more especially so if consideration were given to a universal system. As the contacting member on the locomotive must be high enough to clear lead rails and crossings, it follows that the ramp must be high enough above the top of the rail to engage the contacting member on the locomotive with some overlap to provide for pressure, wear and roll of the locomotive. There is also the question of horizontal clearance.

During our experiments these considerations were brought forcibly to our attention. On one installation, where we had carefully considered our clearances, the ramp would be mysteriously crushed down every once in a while, and we finally traced the cause to a wrecking car having some unusual dimensions. In another case, we found some low wheel switch engines whose main rod keys, with the main rod in its lowest position, were low enough to put a location close to the rail absolutely outside of the pale of consideration. In a third case, a highway on the slope of a hill, crossed the track at right angles. There was a good deal of snow on the ground which thawed by day, and as it ran down the highway was frozen by the lower night temperatures, and one night built up a chunk of ice alongside the rails so high that it tore the locomotive contacting piece off the locomotive first passing over it the next morning.

All of these troubles led to the preparation of composite clearance diagrams from data furnished us by a number of railroads. A study of these diagrams led us to the conclusion that there was no possible universal location for a trackway device.

Continuous Electrical Communication

In view of these disadvantages and the further fact that we had always realized the objections to any wayside elements on surface railroads tending to obstruct the right of way, we abandoned further experiments with intermittent devices and confined ourselves to the problem of continuous electrical communication between the track and moving or standing trains.

Continuous, Versus Intermittent Control of Signals

The first automatic signals were operated by track instruments in 1867 and the track circuit was invented in 1872. For over 20 years thereafter railroad opinion was about equally divided between the comparative merits of track instruments and track circuits for the operation of automatic signals. A few railroads had signal organizations but as a rule signaling was considered as somewhat of a minor accessory, and but little deference was paid the principles underlying sound Signal Engineering.

Track Instruments Replaced by Continuous Track Circuits

From about 1893, however, the installation of track instruments for the operation of automatic signals ceased and existing track instruments were gradually replaced by continuous track circuits. The intermittent control of automatic signals, may, therefore, be said to have come to an end in the nineties as far as steam roads were concerned. It was resurrected for a brief period when electrically operated railroads first considered automatic signaling, but the invention of the alternating current track circuit and the selective relay successfully solved that problem and the use of intermittent devices (mostly in the shape of trolley instruments) was confined to the lighter classes of electric railroads and only to a limited extent on them.

With our knowledge of the history of automatic signaling we always realized the shortcomings of intermittent train control and never abandoned the hope of eventually applying the continuous closed circuit principle to it throughout, which was finally accomplished.

Power Brake Development

Simultaneously with the evolution of railway signaling, that other great factor in train control, the power brake, had been consistently developed by the Westinghouse Air Brake Company. The direct control of the brake by signals was foreseen in the eighties as previously mentioned —it was actually consummated under service conditions on the Boston Elevated and since then the Air Brake Company and ourselves have worked along parallel lines towards the perfection of a joint system of automatic train control, they with the mechanical and pneumatic apparatus on the locomotive and we with the electric control thereof. The system, therefore, which we are about to describe is the result of experience gained under actual service conditions in the operation of railway signals and power brakes extending over half a century on the part of two companies each provided with ample facilities to carry out its part of the work.

A GENERAL OUTLINE OF WHAT CONTINUOUS TRAIN CONTROL ACCOMPLISHES

Relation to Signaling

Continuous automatic train control serves as a connecting link between signaling and brake operation; it is the interpretation of track conditions in terms of train speed.

Engineman's Responsibility

It enforces the operation of trains in accordance with signal indication and track conditions without relieving the engineman of any of his responsibilities. So long as he complies with signal indications, the control of the train is left in his own hands. Should he fail to comply with them, the system takes control and either stops the train or reduces its speed.

Non-Automatic Release

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.

Speed Limit Indicator

It provides the engineman with a continuously visible indicator on the locomotive 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 his speed as the case may be.

Unforeseen Occurrences

In unforeseen occurrences such as a switch being opened, or a rail breaking immediately ahead of him this indicator gives him instant warning and the brakes are automatically applied.

Acknowledging

It requires the engineman to take some definite action (to be described later) at certain points to prove that he is alert, failing which, his train will be stopped.

Change in Indications

Under proper restriction it permits one train to follow another into an occupied block without stopping providing 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.

Closed Circuit Principle

It operates on the "closed circuit" principle which requires the apparatus on the locomotive being energized due to the presence of current in the rails, in order to permit the engineman to run above the low speed limit. The failure of that current to flow will stop the train, or bring its speed below the minimum permitted.

Clearances

It requires no trackway elements other than the running rails themselves. The wayside apparatus consisting of relays, transformers, wire connections, etc., as ordinarily used with automatic signals, are located well outside clearance limits.

Service and Emergency Brake Applications

It never makes an emergency brake application, the automatic application never being of a greater value than that corresponding to a service reduction of the brake pipe pressure. On the other hand, it does not **prevent** the engineman from making an emergency application nor does it ever interfere with the operation of his independent locomotive brake.

Continuous Governor Control

It provides a governor on the locomotive to continuously control the speeds at which it may run depending on the track conditions under which it is operating.

Slow Orders It can be made to enforce slow orders either temporarily or permanently over sections of track at such places as curves, bridges, communities, or where work is in progress.

Installed Under Various Conditions It 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.

FUNDAMENTALS OF CONTINUOUS CONTROL

The Fundamentals of Continuous Control are:—

A. Sources of alternating current at convenient locations for supplying the transmission line which traverses the territory in which the train control system is installed.

B. Electric currents in the running rails specifically known as the axle currents and the loop currents. These currents are supplied to the rails from the A. C. mains through small step-down transformers, the currents being controlled by track and signal conditions in advance.

C. Currents induced (by the rail currents) in suitable receivers carried by the locomotive, which, through suitable apparatus, act conjointly with a speed governor to control the automatic application of the air brakes as conditions may require.

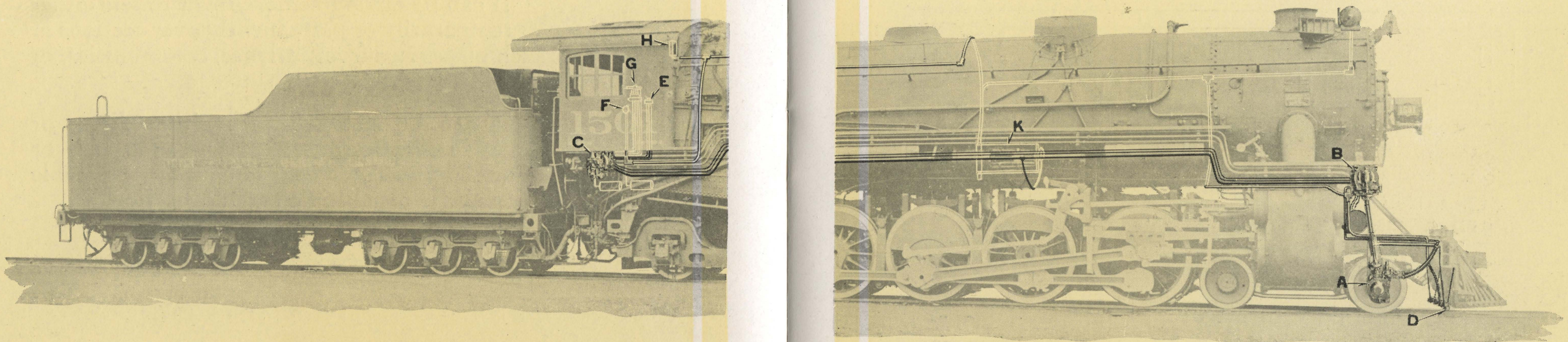


Fig. 5. Locomotive Equipment for Two-Speed Single Element Continuous Train Control System

TWO-SPEED SYSTEM

General

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 a certain point the apparatus employed is identical.

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.

Braking Point

This system, as its name implies, permits trains to run in occupied blocks at a predetermined minimum speed and at unlimited speed in unoccupied blocks. **This consequently requires that the braking 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 at the braking point.**

Apparatus

The apparatus used in continuous train control is divided into locomotive equipment and track or wayside connections.

Locomotive Equipment

Figure 5 shows a locomotive equipped with the necessary apparatus for operating under the two-speed system in connection with direct current signaling. This consists of:

The Drive "A".
The Governor and Drive Connections "B".
The Brake Application Valve "C".
The Receiver "D".
The Acknowledgment Valve "E".
The Cutout Switch "F" used when leaving train control territory.
The Engineer's Valve "G".
The Speed Limit Indicator "H".
The Equipment Case "K" for housing the train control relay and other electrical apparatus.

In addition to these, the headlight generator is used to furnish current for the operation and control of the electrical apparatus on the locomotive, while the compressed air is of course supplied from the regular compressor.

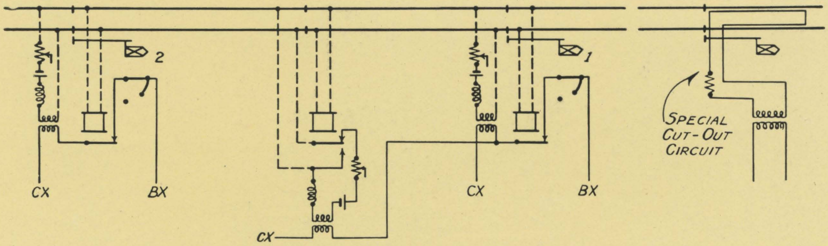


Fig. 6. Circuits for Single Element Two-Speed System Superimposed on Double Track with Direct Current Track Circuits

Track Connections

Figure 6 shows 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, while Fig. 7 illustrates similar connections on single track. The signals and track relays shown, are a part of the signal system. The train control current in no way interferes with the operation of the D. C. track circuits.

Track Element

The "track element" of the two-speed system is the combination of a transformer secondary suitably controlled by relay or circuit controller contacts, the running rails themselves, and the front wheels and axle of the locomotive.

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 referred to above.

Axle Circuit

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

Locomotive Circuits

The alternating current flowing along the rails induces a second current in the receiver "D", Fig. 5, carried on the front end of the

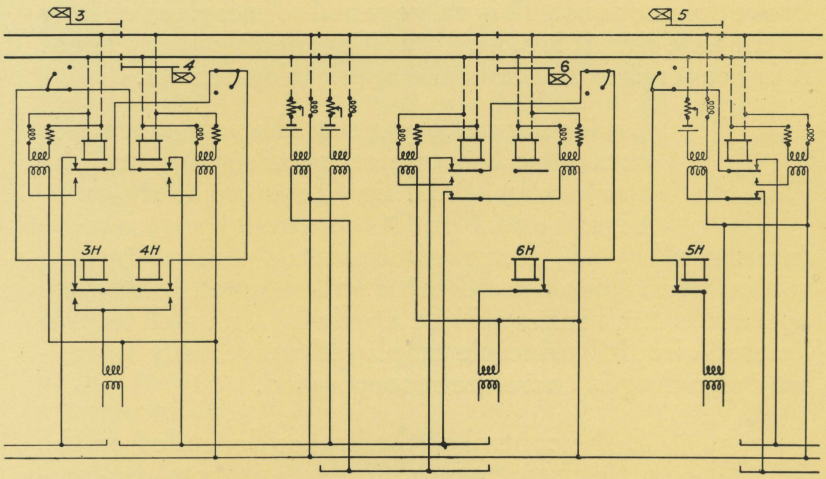


Fig. 7. Circuits for Single Element Two-Speed System Superimposed on Single Track with Direct Current Track Circuits

locomotive, about six inches above the rail and protected from injury by the pilot. The current so induced in the locomotive receiver is amplified by special power amplifier tubes for the purpose of energizing the train control relay on the locomotive. The plate circuits of the amplifier tubes are energized from the headlight generator.

Train Control Relay and Indicator

The train control relay through its front and back contacts causes one or the other of two lights to burn in indicator "H". One of these lights indicates that no speed restriction exists and burns when the axle circuit is closed and the train control relay is energized. The other light indicating the minimum speed restriction, burns when the axle circuit is shunted or opened from any cause and the train control relay is deenergized. 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 valve remains energized as long as the axle circuit is closed, but if opened from any cause it is deenergized and a brake application results.

Closed Circuit Principle

Under normal operation the axle current is controlled by contacts on the signal and the track relay of the signal system as shown in Figs. 6 and 7 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 well known "closed circuit" principle employed universally in railway signaling is therefore incorporated.

Governor Control

If the control 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 locomotive is, however, equipped with a centrifugal governor "B", Fig. 5, operated from one of the locomotive 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 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.

Brake Application Valve

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. 5. 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.

Releasing After Automatic Application

Whenever an automatic application is made the air is cut off the engineer's valve. The automatic valve will not restore and give the engineman air until two conditions are fulfilled, i. e., 1st—Engineer's valve must be put to lap—and—2nd—The speed brought below the new speed limit.

Acknowledging Valve

The acknowledging valve "E", Fig. 5 is operated by a small lever conveniently located 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."

Delayed Application

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.

Cutout Switch

In leaving "Train Controlled" territory the engineman must operate the lever of the Cutout Switch "F", Fig. 5 **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 locomotive once more enters such territory, when the apparatus automatically cuts in again without any action on the engineman's part. Should the engineman neglect to operate the cutout 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 reenters such territory.

Locomotives Running Tender First

Except in the case of suburban locomotives 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 a locomotive 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 receiver. Suburban locomotives may be equipped with an extra pair of receiver coils at the back of the tender and the locomotive 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 tender first.

Pneumatic Cutout

The Pneumatic Cutout, the operating lever for which is shown in the lower portion of Fig. 8, is a part of the brake application group "C", Figs. 5 and 10 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 of any automatic control.

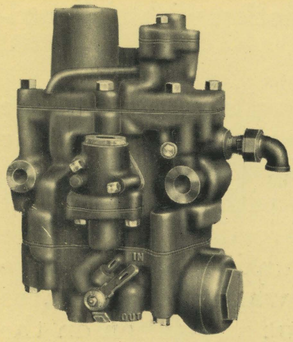


Fig. 8. Application Valve

This pneumatic cutout 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.

Double Heading

When locomotives are double headed, or used as pushers, the train control equipment, except on the leading locomotive, is automatically cut out of service by the customary train pipe connections.

Split Reduction

In the manual operation of air brakes it is usually the practice when making an application, especially for 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 pounds "to adjust the slack", followed by a further reduction of about 13 pounds after a short interval. This is known as the "split reduction" and adds materially to safe brake operation. It is incorporated in the automatic brake application of both the two and three-speed systems.

Anticipating Automatic Applications

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 re-

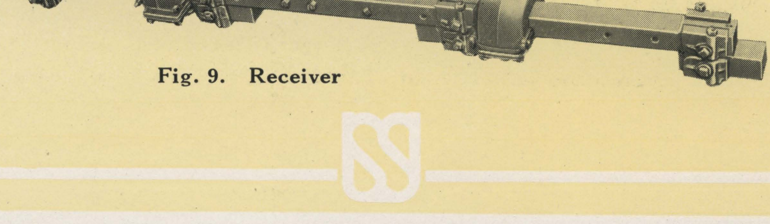
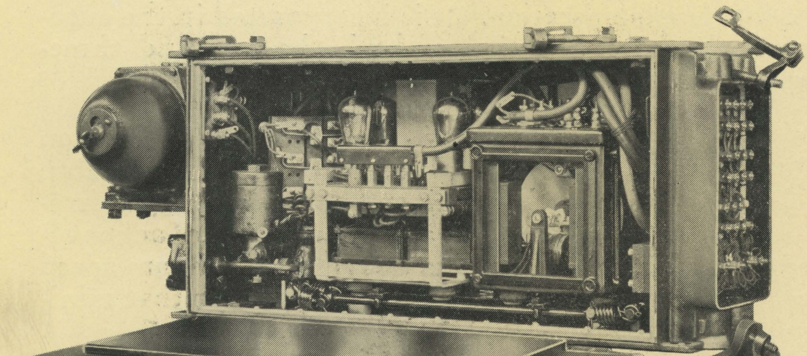


Fig. 9. Receiver

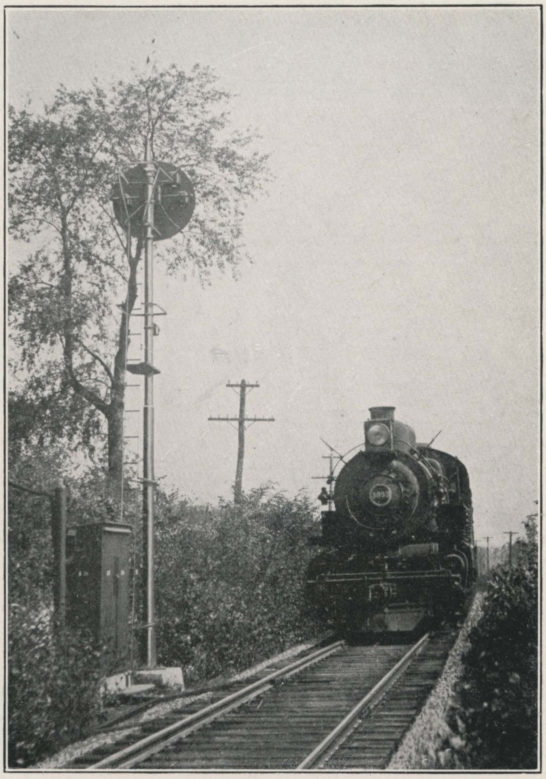
leased even though the train has decelerated below the new speed limit.

Snow Plows

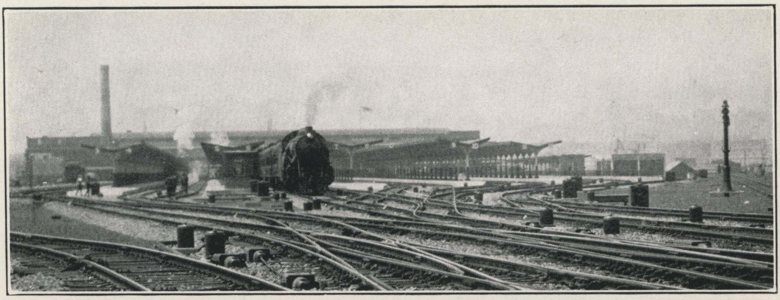
In bucking snow it is often necessary to exceed the minimum speed limit of 20 miles per hour. In such cases snow plows can be readily equipped with a receiver as a permanent part of their equipment. These coils can be connected to the electrical train control equipment of the first locomotive behind 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. This applies to both the two-speed and three-speed systems.



Locomotive Equipment Case



An Installation of Union Continuous Train Control
System on Lewistown Branch, P. R. R.



OPERATION OF TRAINS UNDER THE TWO-SPEED SYSTEM

In order to explain the control of a train under the two-speed system we will describe some operating conditions encountered in service.

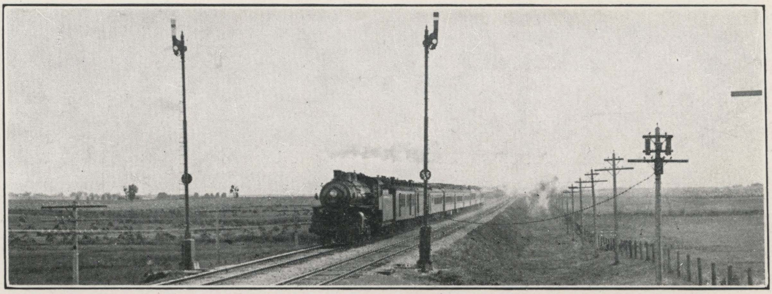
Entering Controlled Territory

Assume such a train starting from a railroad terminal on its regular run over a double track locomotive division on which three position automatic signals are installed and where the braking points are placed at the caution signals.

The train control system begins outside the terminal area and extends the entire length of the division.

As the train reaches the point where the two-speed control begins, indicated by a marker, it passes into a permanently energized section which automatically cuts in the locomotive 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.

After running some distance it closes in on a pre-



ceding train and as a result, finds the next block signal displaying "Caution."

Closing In On Preceding Train

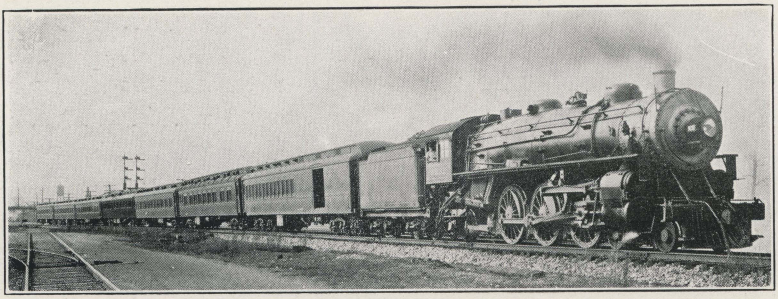
When it passes this signal the indicator light changes from H to L indicating that the restricted or low speed limit must be complied with. The engineman, therefore, operates his acknowledging valve as prescribed and makes a brake application.

Anticipating Automatic Application

Due to the engineman's action in acknowledging the caution signal and his further action in promptly reducing his speed below the prescribed minimum, which is assumed to be 20 miles an hour, an automatic application is anticipated and the train enters the occupied block ahead without stopping at the home signal.

Exceeding Minimum Speed in Occupied Block

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



Change to Less Restrictive Indication

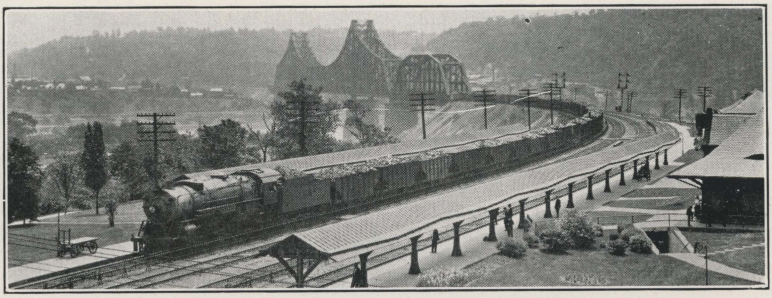
The preceding train has meanwhile increased its lead and cleared the block, consequently, the next signal ahead of the second train changes from "stop" to "caution." This signal was not visible to the engineman of the second train when the change occured, being around a curve, but the indicator changed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

Failure to Acknowledge Caution Signal

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 not only applied but are 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.

Sudden Change to More Restrictive Conditions

The first train is now so far ahead that it runs under clear signals for a considerable distance at unrestricted speed with the indicator displaying H. Suddenly without any warning, the indicator changes to L, and the brakes go on automatically. There is a sharp curve



immediately ahead, beyond which an industrial spur track leaves the main line. The engineman, therefore, augments the automatic service application by moving his brake lever to the emergency position and stops the train just in time to avoid striking some cars that a few seconds before had been pushed beyond the fouling point of the siding.

Permanent Speed Restriction

Further on the train runs through a town where local ordinances require that trains shall not exceed 20 miles an hour between certain points indicated by markers. The engineman acknowledges the marker in the same manner as a braking point and slows down to comply with these requirements, but had he neglected to do so the train control system would have enforced compliance as the track section between these markers was permanently connected with that end in view.

Reverse Running Under Despatcher's Orders

At the next telegraph office an order is received to run against traffic on the adjoining main track because a freight has broken down ahead of him. As he crosses over to the other track he operates a switch and this act in connection with the passage of the locomotive over a permanently energized section at the crossover cuts the train control out while running against traffic.

When the locomotive returns to its own track beyond the obstruction the control is automatically cut in again by another track section without any action on the part of the engineman.

Reverse Running Under Train Control

Some railroads equip their main lines so as to permit trains to run in either direction on one or more tracks, with full train control protection, the reversal of traffic being accomplished at interlocking plants. Traffic direction reversal on any track between such 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 affected is unoccupied between the two stations.

Operating Cutout Switch at End of Run

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

Two Element Track Control. Loop Circuit Necessary

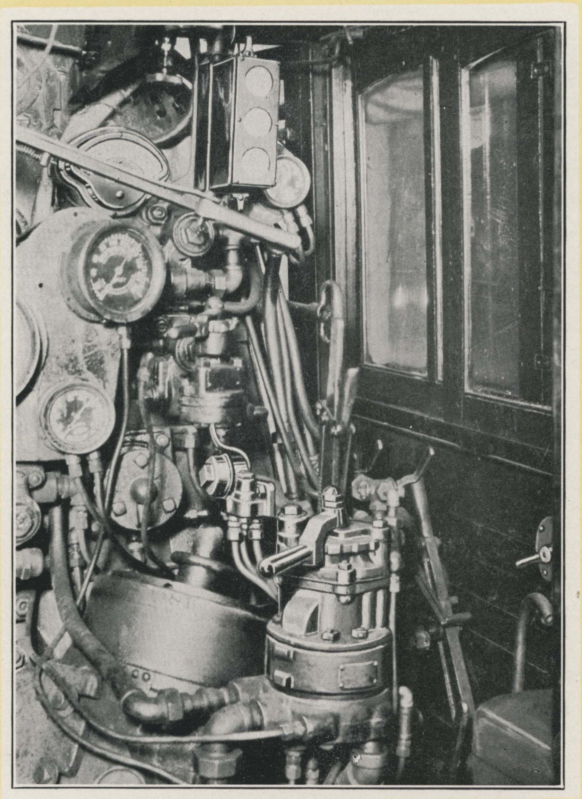
When either the two or three-speed system is installed in connection with signaling controlled by alternating current track circuits, the same current that operates the track relays for controlling the signals is also used to energize the locomotive receiver. While this fact makes a separate "axle circuit" 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 deenergized to give a brake application at the caution signal as already explained.

Description of Loop Circuit

In a two element train control system the track or axle circuit "picked up" by the front receiver on the locomotive 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 receiver on the locomotive is energized from the loop circuit and in turn energizes the "local element" of the train control relay. Since both axle and loop circuits have to be closed to energize the relay, the axle circuit between the stop and caution signals can remain closed and the relay deenergized by merely opening the loop circuit.

Other Uses

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 locomotives operating in this territory also run over alternating current track circuits in other territory, or as an extra precaution against foreign current. The arrangement of locomotive equipment required for the two-speed two element system is similar to that shown in Fig. 10.



Cab Equipment on Santa Fe Locomotive

THREE-SPEED SYSTEM

General

The three-speed continuous train control system is admittedly the highest development in automatic train control today. It possesses all the advantages of the two-speed type already enumerated and a number of others mentioned in the following description.

In describing the three-speed system it appears desirable to repeat a number of points previously covered in the two-speed system, in order to make the description complete in itself.

High, Medium and Low Speeds

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 a caution signal 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.

Braking Point

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 the rear of the signal to insure that any train running at its highest possible speed will be stopped before reaching the signal if the brakes

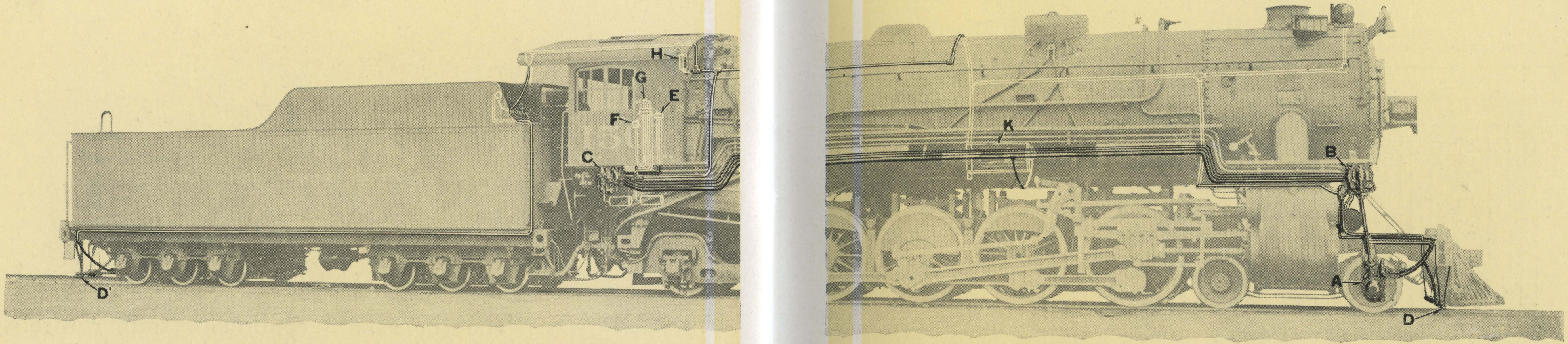


Fig. 10. Locomotive Equipment for Three-Speed Continuous Train Control System

are automatically applied at, or before reaching, the braking point (see page 18). 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 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.

Location of Caution Signals

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 perdetermined maximum speeds (usually not over 70 miles an hour for passenger and 50 for freight trains) will be brought below their medium speeds respectively, before reaching the braking point, if the brakes are automatically applied at, or before reaching, a signal displaying "Caution."

Two Braking Points in Three-Speed System

In the three-speed system there are in effect two braking points in each block, one at the caution signal and the second in the rear of the home signal as described in the preceding paragraph. The first is usually called the "A" point and the latter the "B" point (See Fig. 11).

Apparatus

The apparatus used in continuous train control is divided into locomotive equipment and track or way-side connections.

Locomotive Equipment

Fig. 10 shows a locomotive equipped with the necessary apparatus for operating under the three-speed system consisting of:

- The Drive "A".
- The Governor and Drive Connection "B".
- The Brake Application Valve "C".
- The Receivers "D" and "D'".
- The Acknowledgment Valve "E".
- The Cutout Switch "F" used when leaving train control territory.
- The Engineer's Valve "G".
- The Speed Limit Indicator "H".
- The Equipment Case "K" for housing the train control relay and other electrical apparatus.

In addition to these, the headlight generator is used to furnish current for the operation and control of the electrical apparatus on the locomotive, while the compressed air is of course supplied from the regular compressor.

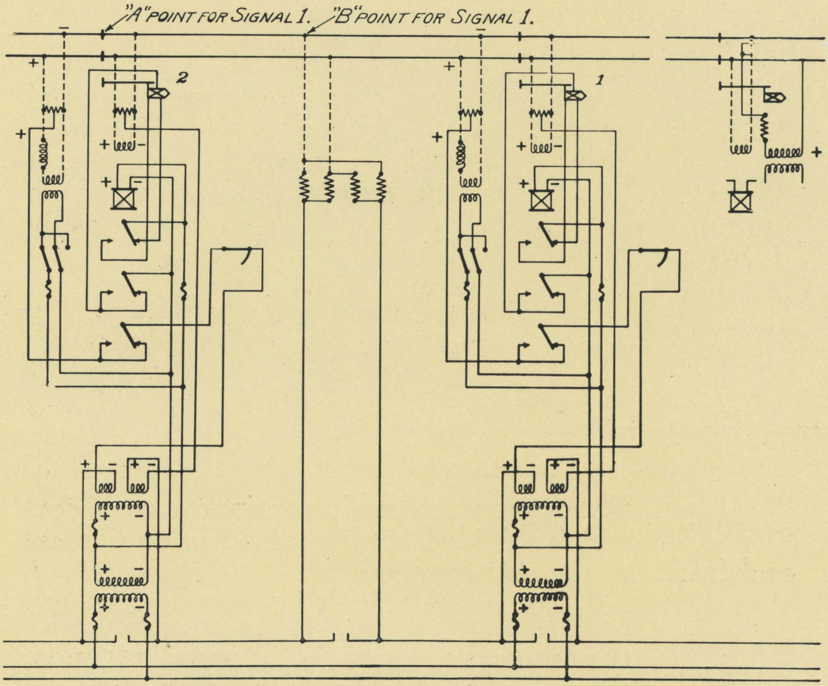


Fig. 11. Circuits for Three-Speed System Superimposed on Double Track with Alternating Current Track Circuits

Track Connections

Fig. 11 shows the typical alternating current connections as used with alternating current track circuits for automatic signaling. The signals and track relays shown are a part of the signal system.

Track Element

The "track element" of the three-speed system is the combination of a transformer secondary suitably controlled by relay or controller contacts, the running rails themselves, and the front wheels and axle of the locomotive.

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.

Axle Circuit

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

Locomotive Circuits

The alternating current flowing along the rails induces a second current in the receiver "D", Fig. 10, 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 locomotive receiver is amplified by special power amplifier tubes for the purpose of energizing one element of the train control relay on the locomotive. The plate circuits of the amplifier tubes are energized from the headlight generator.

Second Track Element Three-Speed System, Loop Circuit

The other element 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 receiver "D[1]", Fig. 10, of the locomotive and through amplifiers, energizes the local coils of the train control relay referred to above.

Three Position Train Control Relay

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 deenergized, to the right when currents in the two coils have a certain phase relation, and to the left when the current in one of the relay windings is reversed. Similar relays are extensively used under the same conditions in alternating current signaling.

Speed Limit Indicator

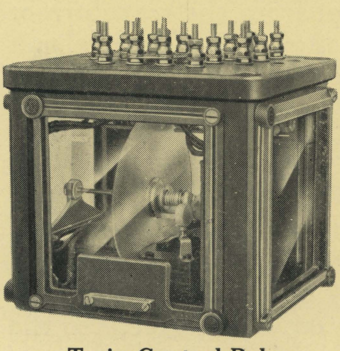
The Speed-Limit Indicator of the three-speed system has three lights, "H" indicating maximum speed, "M" medium speed and "L" minimum speed. These three lights are controlled by the contacts of the relay described above, the "H" light burning when the contacts are swung to the right, the "M" light when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

Electro-Pneumatic Control

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

Governor Control

The locomotive is equipped with a Centrifugal Governor "B", Fig. 10, operated from one of the locomotive 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 the medium speeds for passenger and freight service respectively from one to the other by a properly authorized person. If for instance, a passenger locomotive is assigned to



Train Control Relay

Change from Passenger to Freight Operation or Vice Versa

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.

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". 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.

Brake Application Valve

Releasing After Automatic Application

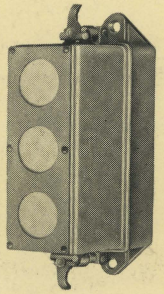
Whenever an automatic application is made the air is cut off the engineer's valve. The automatic valve will not restore and give the engineman air until two conditions are fulfilled, i. e., 1st—Engineer's Valve must be put to lap, and 2nd—The speed brought below the new speed limit.

Acknowledging Valve

The Acknowledging Valve "E" is operated by a small lever conveniently located 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."

Delayed Application

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



Speed Limit Indicator

application." This is effected by valves actuated by the governor working in conjunction with the automatic application valve.

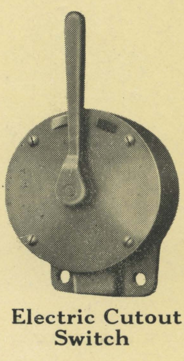
Cutout Switch

In leaving "Train Controlled" territory the engineman must operate the lever of the Cutout Switch "F" **at the point of exit.** This action in conjunction with the passage of the train over a specially energized track section cuts out the train control apparatus entirely until the locomotive once more enters such territory, when the apparatus automatically cuts in again without any action on the engineman's part. Should the engineman neglect to operate the cutout 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.

Engine Running Tender First

Except in the case of suburban locomotives and others engaged in similar service, most railroads do not permit locomotives to exceed a speed of 15 or 20 miles an hour when running tender first.

The continuous system enforces this rule in that a locomotive 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 receiver coils. Suburban locomotives may be equipped with an extra receiver at the back of the tender and the engine circuit shifted from the front to the rear receiver and vice versa through a circuit controller operated by the revers-ing lever, thus permitting running at speed, tender first. The pneumatic cutout, the operating lever for which is shown in the lower portion of Fig. 8, is a part of the brake application group "C" and consists of a stop cock oper-



Electric Cutout Switch

Pneumatic Cutout

ated 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. The handle can, however, be turned back to the "cut in" position at any time by the engineman and the automatic control restored.

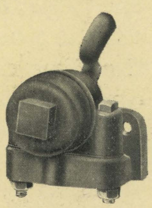
This pneumatic cutout does not affect the electrical apparatus, consequently, if the control is cut out due to a pneumatic or mechanical failure alone, the engineman still has the benefit of his indicator.

Double Heading

When locomotives are double headed, or used as pushers, the train control equipment except on the leading locomotive, is automatically cut out of service by the customary train pipe connections.

Split Reduction

In the manual operation of air brakes it is usually the practice when applying brakes 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 pounds "to adjust the slack"; followed by a further reduction of about 13 pounds after a short interval. This is known as the "split reduction" and adds materially to safe brake operation. It is incorporated in the automatic brake application of both the two and three-speed systems.



Acknowledging Valve

In order to avoid an automatic application at the caution signal the engineman must bring the train below the predetermined medium speed by taking proper action at or before passing the caution signal. If he passes the

Anticipating Automatic Application

caution signal at or below the medium speed no action on his part is necessary.

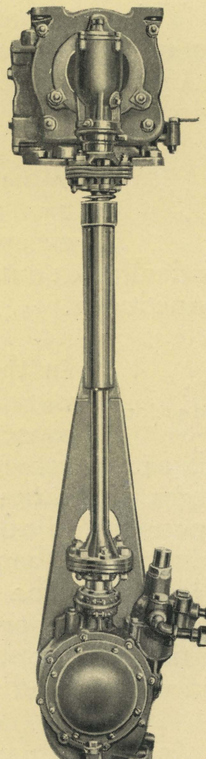
In order to avoid an automatic application at the braking point at medium speed in the rear of a stop signal the engineman must always, irrespective of speed, operate the acknowledging lever, and if running above the minimum speed, take proper action to bring the train below that minimum.

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", 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.

Snow Plows

In bucking snow it is very often necessary to exceed the minimum speed limit of 20 miles per hour. In such cases snow plows can be readily equipped with a receiver as a permanent part of their equipment. These can be connected to the electrical train control equipment of the first locomotive 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. This applies to both the two-speed and three-speed systems.



Governor and Axle Drive

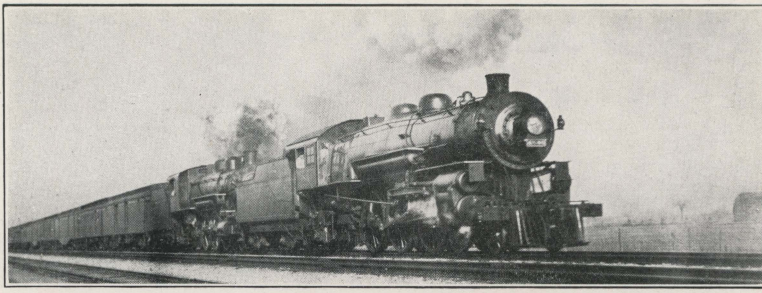
OPERATION OF TRAINS UNDER THREE-SPEED SYSTEM

Entering Controlled Territory

We have already described the operation of a train over a division equipped with the two-speed system and will now follow the course of another train over 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 locomotive 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 an hour for passenger and 50 miles an 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.



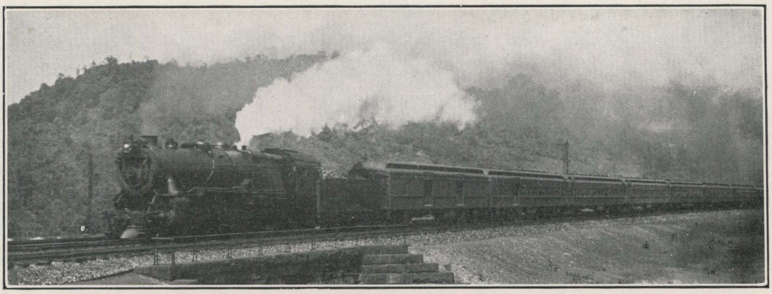
Closing in on Preceding Train

After running for some distance the train closes in on a preceding train and as a result finds the next block signal displaying "Caution." When it passes this signal the Speed Limit Indicator changes from "H" to "M" indicating that the medium speed limit must be complied with. The engineman therefore operates his acknowledging valve and takes action to avoid an automatic application, that is, he handles the train by brake application, shutting off steam or otherwise, to get below the new speed limit before the automatic application would take effect.

The speed of the train falls below the medium and he continues on through the block without exceeding this limit until he reaches the braking point indicated by the marker. At this point the Speed Limit Indicator changes from "M" to "L", indicating that he must not run above the minimum speed of 20 miles an hour. The engineman operates the acknowledgment lever as prescribed and in addition, handles the train as at a caution signal to bring it from the medium to the minimum speed of 20 miles an hour and therefore avoids an automatic application.

Anticipating Automatic Application

It will be noted from the foregoing that by taking proper action the engineman has anticipated automatic applications at both



the caution signal and the braking point and has consequently retained full control of the train throughout the entire block.

Passing Stop Signal

Due to the foregoing, 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.

Exceeding Minimum Speed in Occupied Blocks

While running in this block he momentarily exceeds the minimum speed. The governor acts and automatically brings the train down below that speed when 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 Speed Limit Indicator changed simultaneously from "slow" to "high" speed, thereby permitting the engineman to accelerate.

Change to less Restrictive Indication

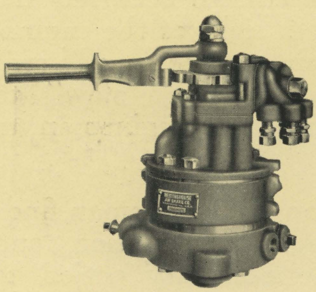
Failure to Reduce Speed at Caution Signal

A few miles further on the engineman 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.

Sudden Change to More Restrictive Indications

This unnecessary stop has caused the train to run slightly behind the regular running schedule and for the next few miles the engineman has to make up time. Since the track ahead is clear as indicated by the wayside signals and Speed Limit Indicator, he continues at speeds approximating the maximum.

While out of sight of the next wayside signal the Speed Limit 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 augments 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 rail had apparently just broken and if the train had run over it at a high rate of speed it would probably have been derailed. 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 locomotive 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.



Engineer's Valve

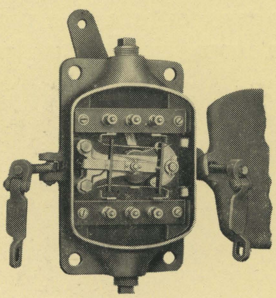
Permanent Speed Restriction

The train continues its normal schedule for a considerable distance and while doing so passes through a town where no scheduled stop is made but where on account of the local ordinances, a speed restriction of 20 miles an hour is required through a certain section. This fact is indicated by permanent markers and the engineman reduces speed as he passes the first marker and operates the acknowledgment valve in the same manner as when passing the braking point in the rear of a stop signal. These two acts permit him to run through the restricted territory at the minimum speed but had he neglected to come within the prescribed limit or failed to acknowledge the marker an automatic brake application would have been received.

Temporary Restrictions

A little further on a bridge on the main line is being strengthened and while the work is in progress orders have been issued to limit speed of passenger trains to 45 miles and the speed of freight trains to 30 miles an hour over the bridge.

Temporary markers have been placed alongside each track at the point where the temporary speed restriction takes place and the track connections of the train control system have been temporarily changed so that the medium speeds for both freight and passenger trains are enforced between these two points. The engineman, therefore, reduces speed to the prescribed medium as he passes the temporary marker and remains below that speed while passing over the bridge.



Reversing Switch

Had he failed to do so the system would have automatically applied the brakes and he could not have released them until he got below the medium speed.

At the next telegraph office he receives an order to run

Reverse Running Under Despatcher's Orders

against traffic on the adjoining main track because a freight has broken down ahead of him. As he crosses over to the other track he operates a switch and this act in connection with the passage of the locomotive over a permanently energized section at the crossover cuts the train control out while running against traffic. When the engine returns to its own track beyond the obstruction the control is automatically cut in again by another track section without any action on the part of the engineman.

Reverse Running Under Train Control

Some railroads equip their main lines so as to permit trains to run in either direction on one or more tracks with full train control protection, the reversal of traffic being accomplished at interlocking plants.

Traffic direction reversal on any track between such 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 affected is unoccupied between the two stations.

Operating Cutout Switch at End of Run

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

CONCLUSION

In the foregoing description we have attempted to outline some things which can be accomplished in the control of trains by establishing continuous electrical communications **between such trains and the tracks on which they run.** The real problem which has been successfully solved is the establishment of such **continuous communications.**

The possibilities in the way of future utilization are practically unlimited but the following may be mentioned:

(a) Increase in track capacity by providing for reverse running on any or all tracks of a multiple track system.

(b) The reduction or possibly the total elimination of flagging and

(c) The elimination of derails, smashboards and torpedoes.

Continuous control can be applied wherever the rails extend. As a result it possesses a flexibility far in advance of any other method so far devised. Just as the **continuous** track circuit has been adapted to many uses since its first conception so will **continuous** train control be developed in service to meet conditions as they arise in the future operation of railroads.

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