

March 3, 1931.

C. S. BUSHNELL

1,794,582

TRAIN CONTROL

Filed May 10, 1924

9 Sheets-Sheet 1

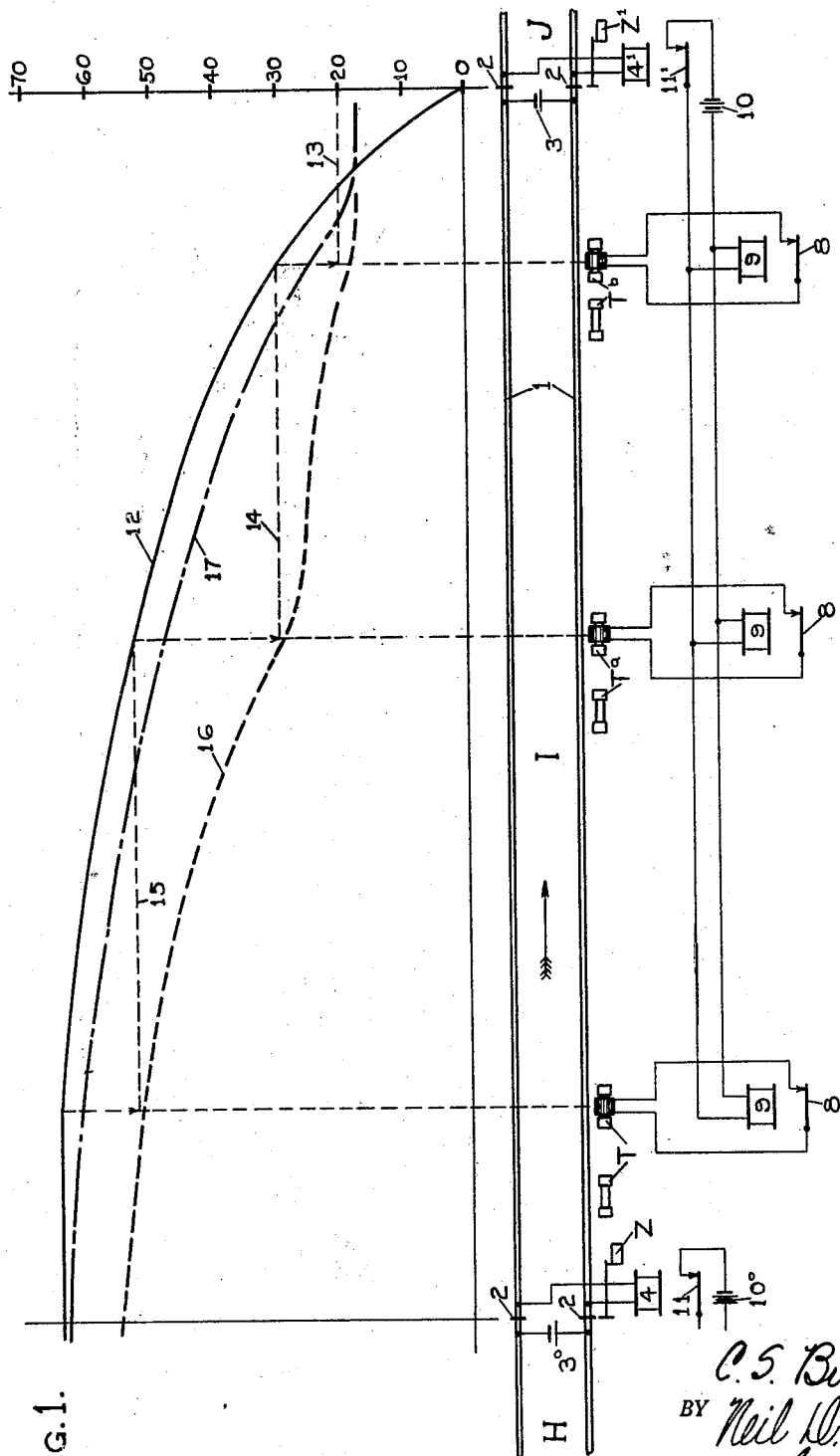


FIG. 1.

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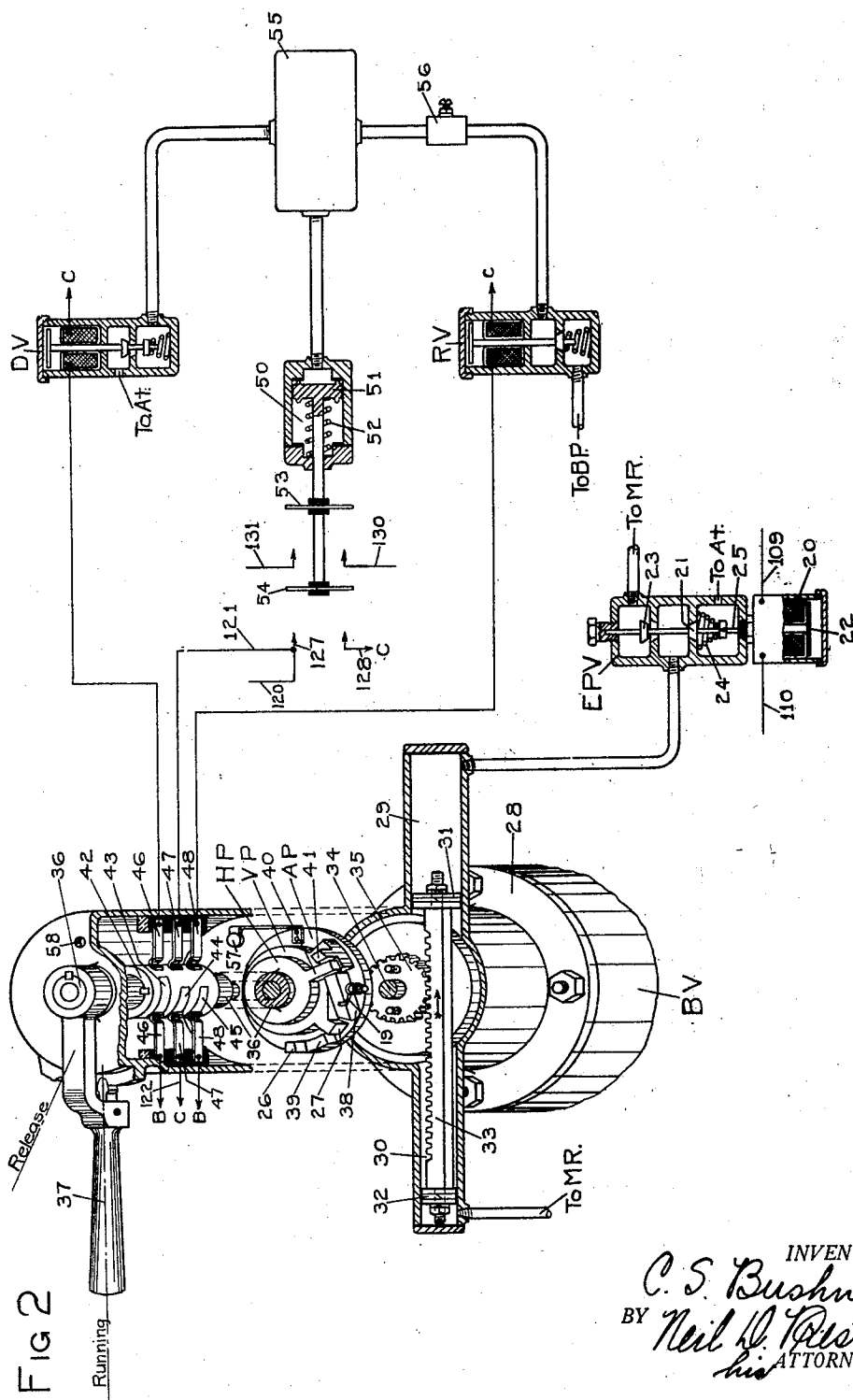
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TRAIN CONTROL

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9 Sheets-Sheet 2



March 3, 1931.

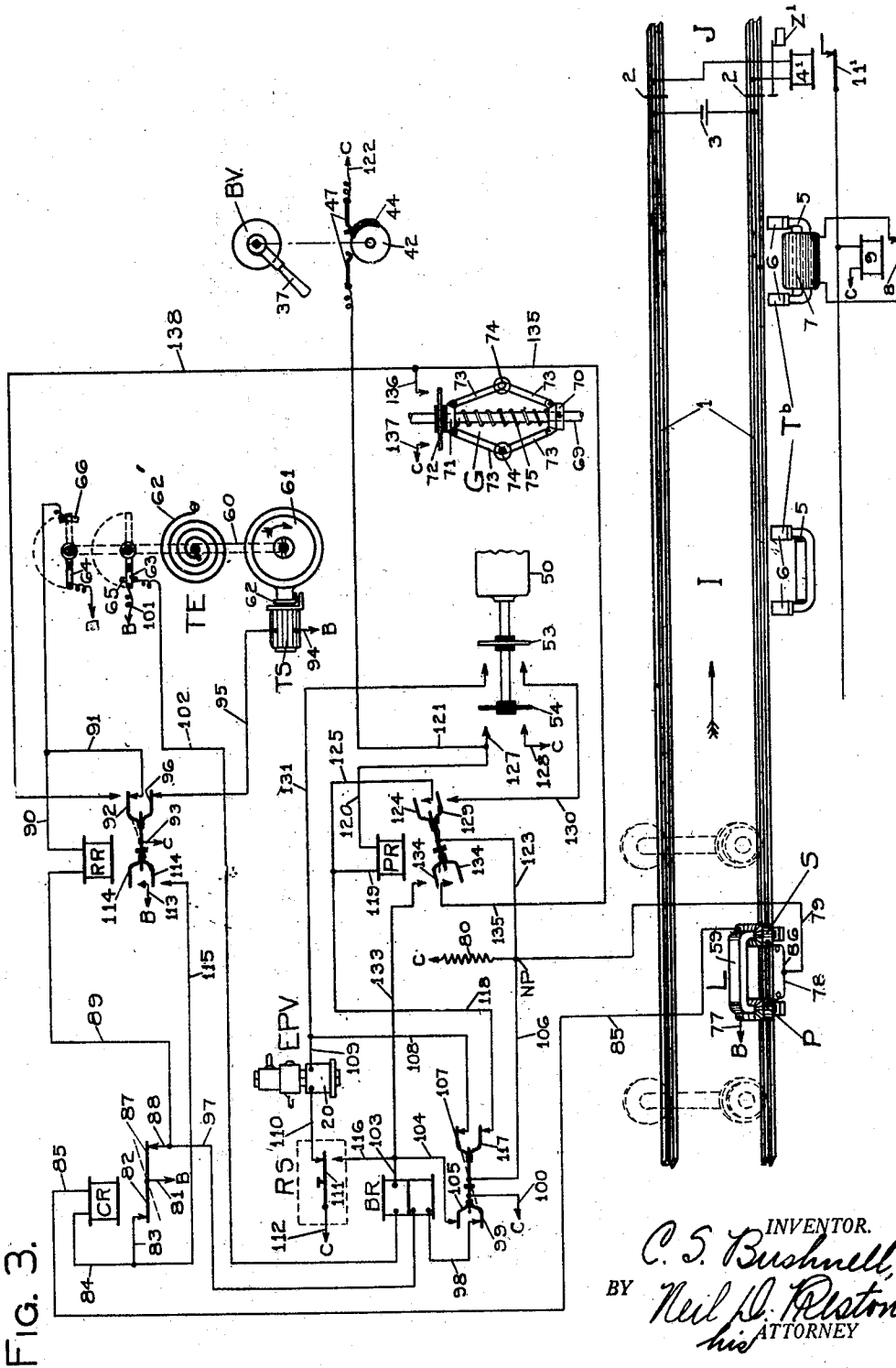
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TRAIN CONTROL

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9 Sheets-Sheet 3



March 3, 1931.

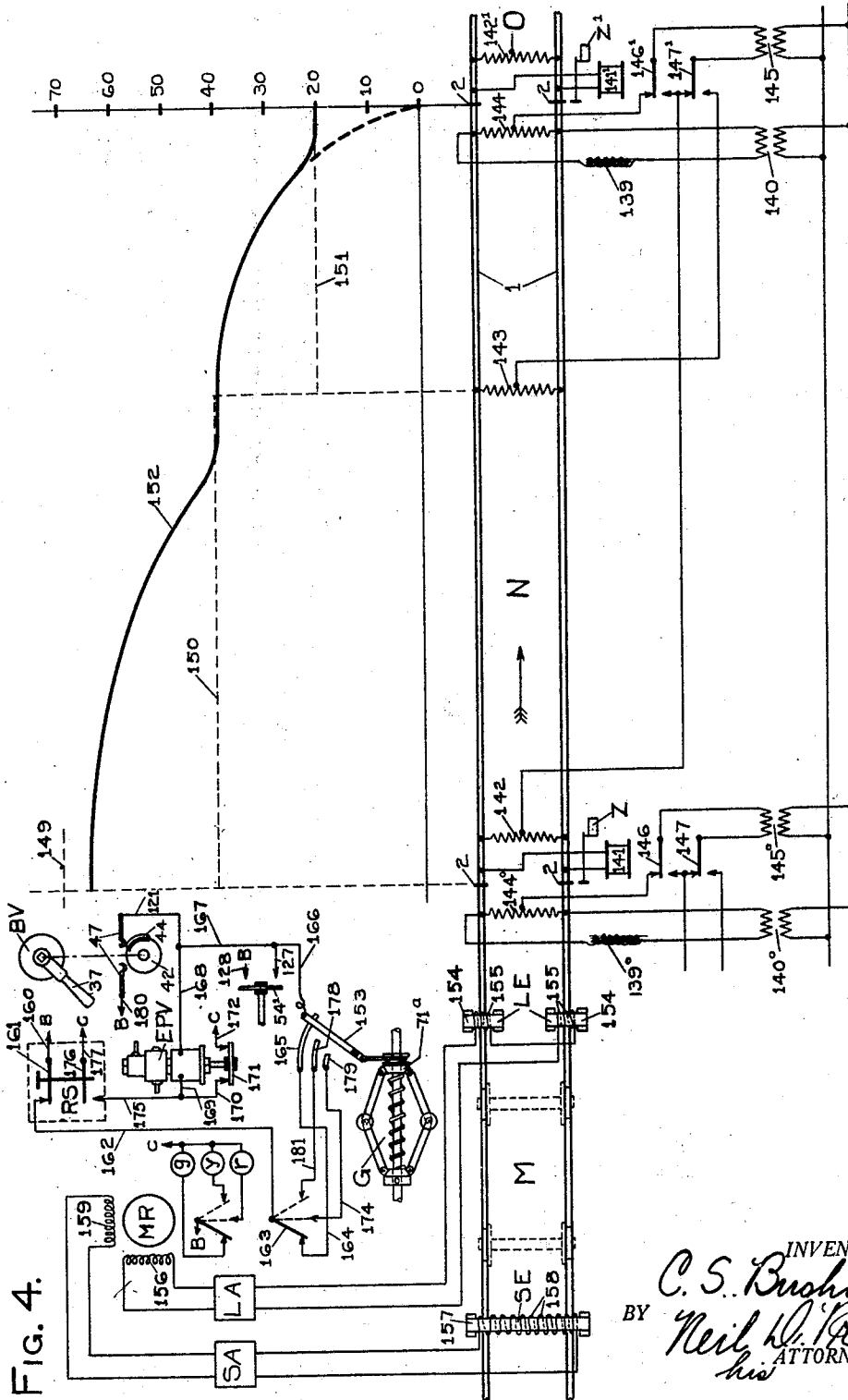
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FIG. 5.

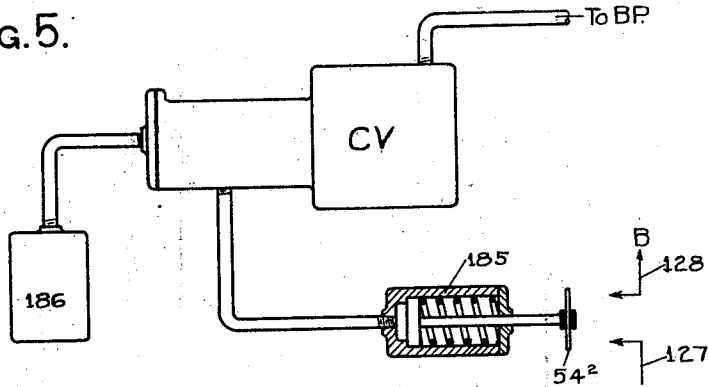
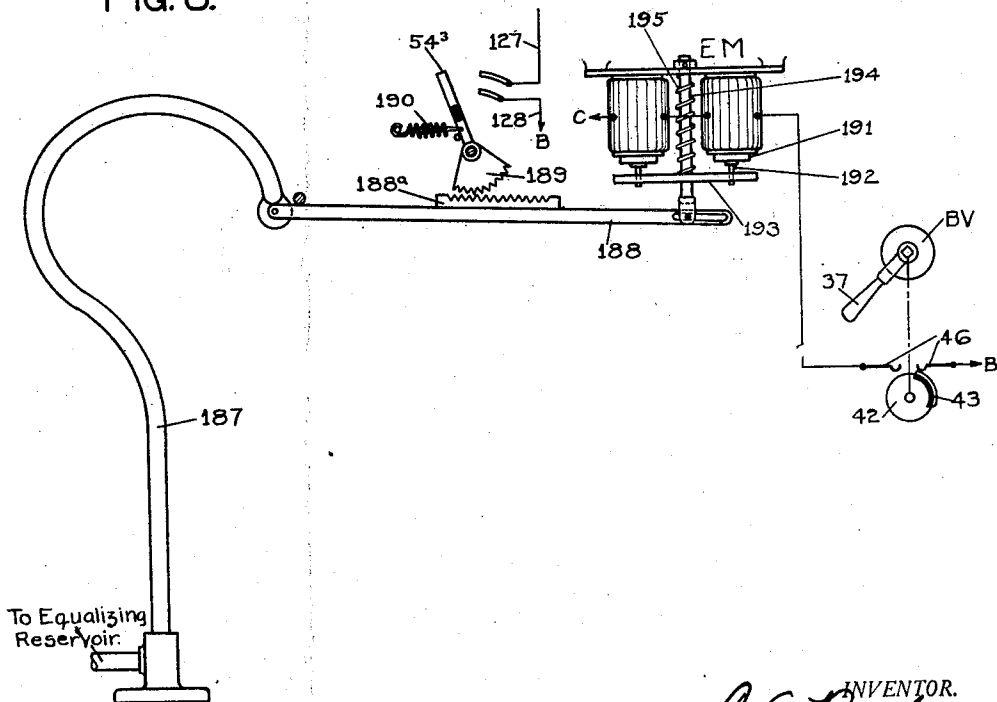


FIG. 6.



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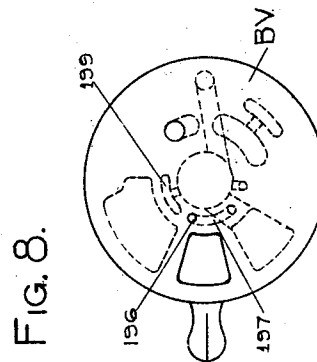
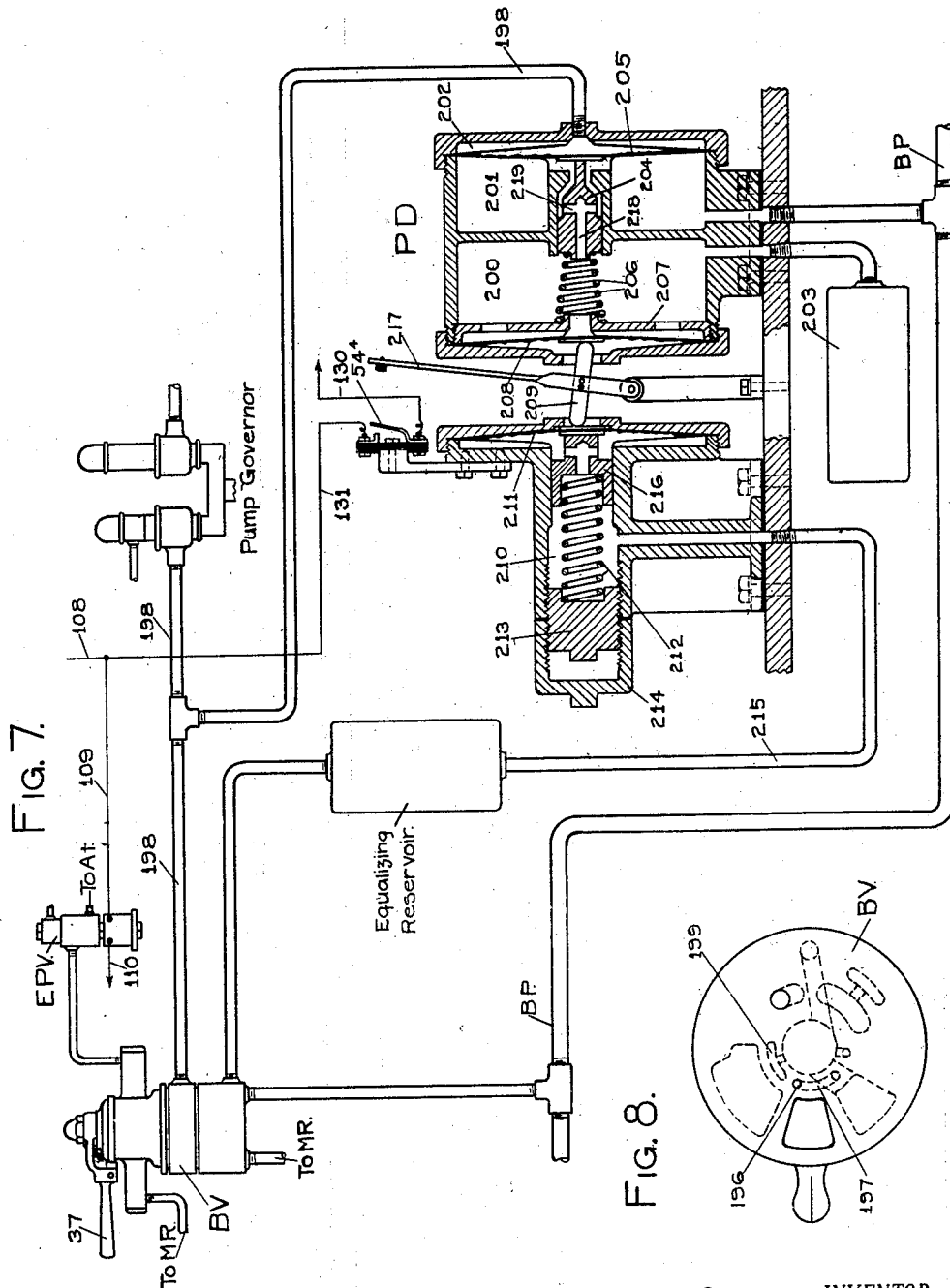
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TRAIN CONTROL

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9 Sheets-Sheet 6



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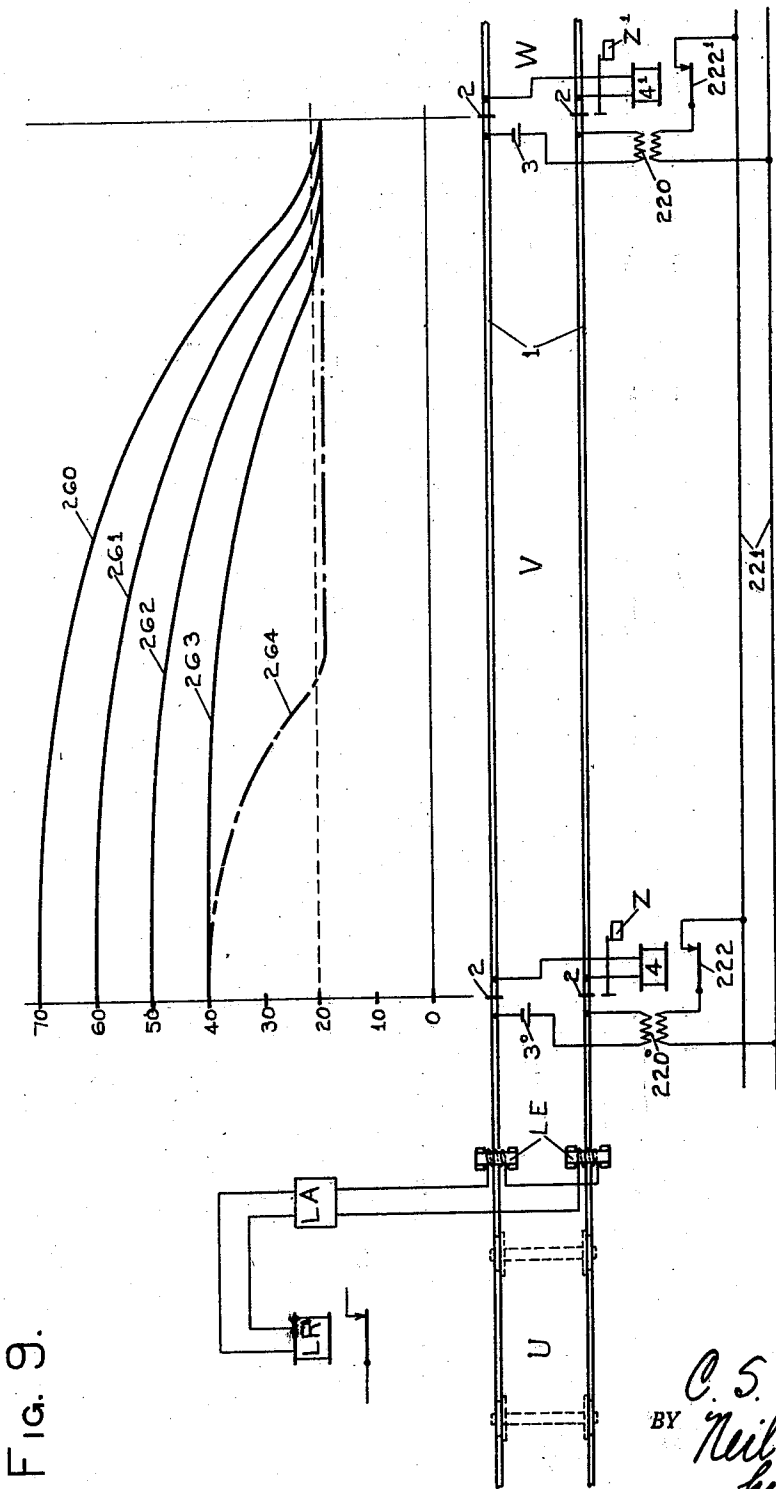
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TRAIN CONTROL

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9 Sheets-Sheet 7



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TRAIN CONTROL

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FIG. 10.

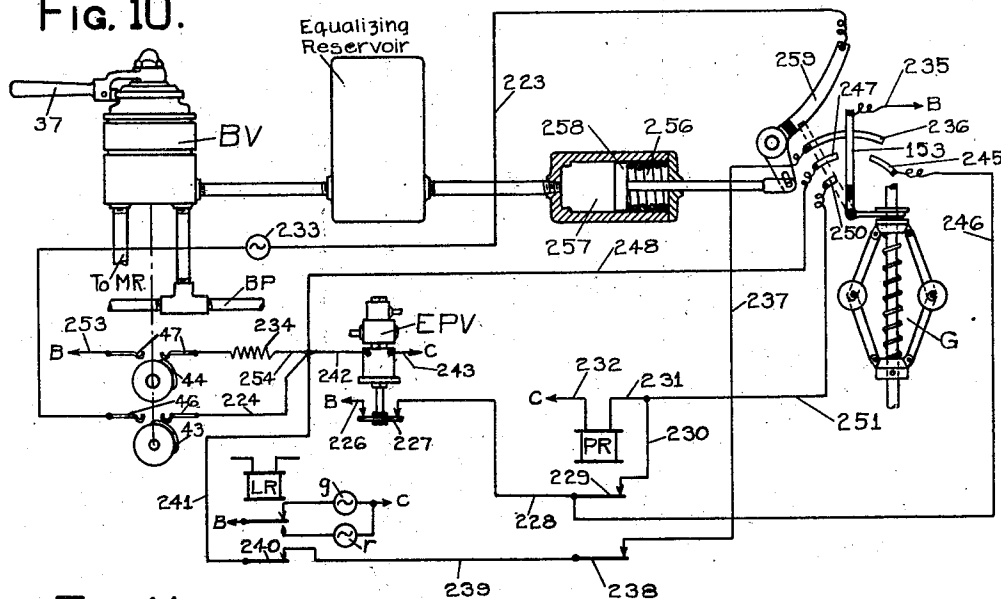


FIG. 11.

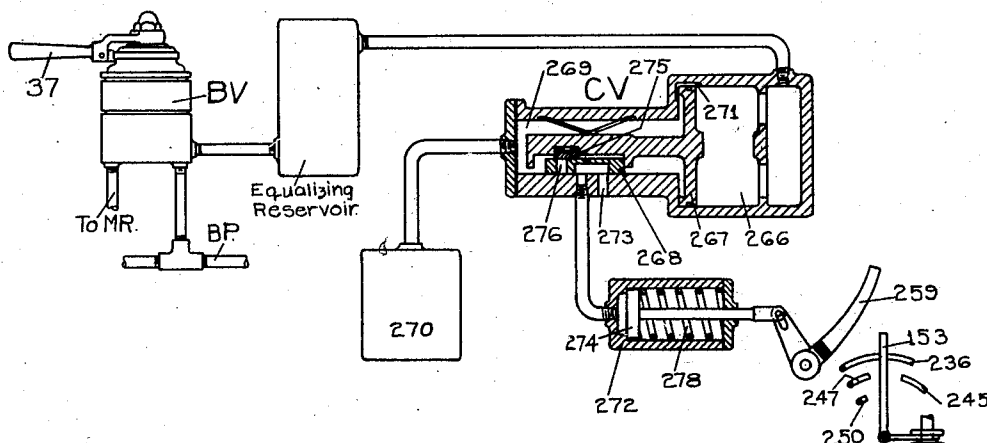
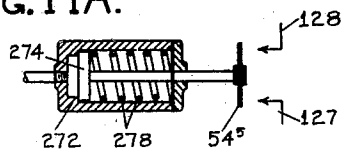


FIG. 11A.



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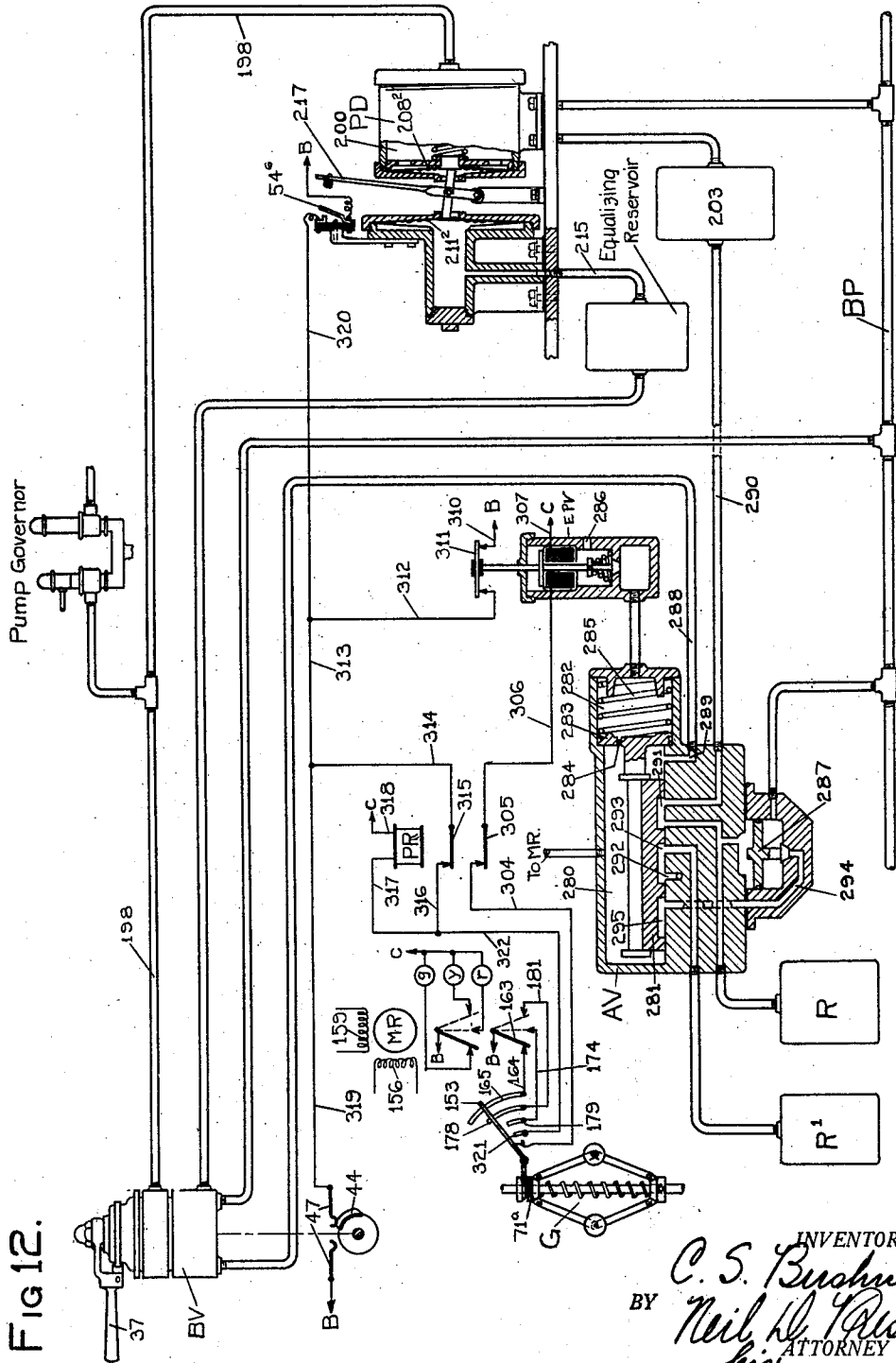
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TRAIN CONTROL

Filed May 10, 1924

9 Sheets-Sheet 9



UNITED STATES PATENT OFFICE

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TRAIN CONTROL

Application filed May 10, 1924. Serial No. 712,269.

This invention relates to automatic train control system for railroads and deals more particularly with the problem of maintaining or enforcing vigilance on the part of the engineer in obeying the unfavorable indications of the trackway block signals, or cab signals if used.

According to the theory on which the present invention may be said to be predicated, it is desirable, in designing an automatic train control system, to maintain to the highest degree the vigilance and care of the engineer in the handling of his train which exists at present and affords a very high degree of safety. In other words, it is considered expedient to avoid substitution of the safety afforded by automatic devices for that now given by the engineer, making the automatic train control system of such a character as to supplement the present vigilance and care of the engineer. It is thought that a train control system of this type would surely add to the safety of train movement, retaining all of the safety at present obtained and providing the automatic protection in addition.

Roughly speaking, the object of an automatic train control system is to stop the train or reduce its speed, if safety requires, in the event that the engineer fails to do so. This means that it becomes necessary to determine automatically what the safe speed for a train is at different points in its travel under different conditions of traffic and impose automatic control of the brakes if these safe speed limits are exceeded. As a practical proposition, on account of the variation in grades, braking power of trains, block lengths, and other practical limitations, it becomes very difficult to accurately determine automatically the safe speed limits at all points, with the result that the speed limits which are enforced by the system of train control are more or less inaccurate in practice and frequently represent a compromise between conflicting factors.

One simple way of enforcing vigilance of the engineer is to inflict some sort of penalty whenever the engineer fails to control his train properly and the automatic train control system has to apply the brakes. In

short, every automatic brake application is accompanied by a penalty. In carrying out this scheme of maintaining vigilance, it becomes necessary for the engineer to have the speed of his train at all times below the arbitrary speed limits automatically set up, that is, the engineer must keep below the "dead-line" of automatic control in order to avoid the penalty. On account of the inaccuracies in this dead-line of automatic control, not only does it become difficult under some circumstances for the engineer, without special manipulation, to keep below this line, but also there is likely to be an unnecessary delay and impairment of train movement.

For these reasons, it is proposed, according to the present invention, to enforce vigilance of the engineer in another way which, briefly stated, consists in inflicting a penalty whenever an automatic brake application occurs, unless the engineer has manifested his vigilance by taking the appropriate action prior to such automatic brake application. In other words, the engineer may suppress the penalty associated with the automatic brake application by taking suitable action prior thereto. According to this invention, the engineer may suppress the penalty by manually controlling the brakes in such a fashion as to bring about a stop or reduction in speed of the train just as effectively as would be brought about by the automatic control. The idea is that, if the engineer goes about slowing down or stopping the train himself before the automatic control takes effect, he has manifested his vigilance in the best fashion and is entitled to avoid the penalty even though an automatic brake application should occur on account of the inaccuracies of the arbitrary speed limits.

This invention is specially concerned with the problem of providing automatic devices operating only if the engineer has brought about the proper brake control in time to justify suppression of the penalty. In this connection, it is reasoned that, inasmuch as the manual brake application required is assumed to be the equivalent or a substitute for the automatic brake application, such manual application should be of

the same character and intensity as the automatic brake application on which the arbitrary speed limits automatically set up are based. Similarly, the critical speed limits automatically enforced are selected on the assumption that the initiation of a brake application at that particular speed and point along the track will suffice to stop the train or reduce its speed safely; and, consequently, it is sufficient to justify suppression of the penalty if the engineer just prior to exceeding the critical speed limits himself initiates a manual brake application. Explaining more specifically, the theory is that the engineer may properly suppress the penalty if he places the engineer's brake valve in the service position before exceeding the critical speed limits, since such movement initiates a manual brake application as promptly as necessary for safety.

With the ordinary type of air-brake equipment, if the engineer were required to keep this engineer's brake valve in the service position for a considerable time in order to suppress the penalty, there would be an unnecessary over-reduction in the brake pipe pressure and waste of air. Hence, it is desirable to provide additional means permitting the engineer to lap his brake valve, provided he has kept this valve in the service position long enough to assure an adequate brake application. One type of such means, herein disclosed, consists of a time measuring device which permits lapping of the engineer's brake valve if it has been held in the service position for a time (about six or seven seconds) sufficient to reduce the equalizing reservoir pressure and assure an adequate application of the brakes. Another type of such means operates upon the drop in pressure in the equalizing reservoir and permits lapping of the engineer's brake valve after the equalizing reservoir pressure has been reduced the desired amount.

Since the penalty under consideration is associated with the automatic brake application, this penalty may be suppressed by preventing operation of the devices causing such brake application, inasmuch as the penalty exists only if there is an automatic brake application, and a suppression of operation of such automatic brake applying mechanism carries with it the suppression of the penalty. On the other hand, since it is the penalty which it is desired primarily to suppress, the system may be organized on the basis of suppression of penalty only, allowing the automatic brake applying mechanism to operate each time the critical speed limits are exceeded, irrespective of what action may have been taken by the engineer. The latter arrangement has the advantage that the automatic brake applying mechanism is kept in good operating condition by frequent use; whereas in the former arrangement, this mechanism, except for occasional tests, never operates except in those rare cases where the engineer has not been vigilant. If the penalty only is suppressed, it will be recognized that the automatic brake applying mechanism may often be operating to reduce brake pipe pressure at the same time as the engineer's brake valve, so that this mechanism should be constructed in such a way that no objectionable results will occur because the automatic venting of the brake pipe is going on concurrently with the manual venting.

Another important aspect of the problem of automatically controlling the air-brakes of trains for train control purposes has reference to limiting the amount of brake pipe reduction occurring upon an automatic brake application. Those familiar with the air-brake art will readily appreciate that the brakes are applied to the fullest extent after a certain limited reduction in brake pipe pressure has been made, and further reduction in brake pipe pressure is merely a waste of air which must be replaced before the system has been re-charged to normal. Now, where there is a suppression of penalty by a timely manual brake application, it is especially important that the brake pipe reduction occasioned by the respective manual and automatic control should be correlated so as to avoid an over-reduction; and more particularly it is desirable that the automatic mechanism should cut off as soon as the desired reduction has been made, whether due in whole or in part to manual control, or to automatic control.

Another aspect of the problem of automatic braking refers to what is generally known as "split application". In handling the brakes on a tonnage train, it is frequently expedient to make the application of the brakes by two or more separated reductions in brake pipe pressure so as to govern the slack and avoid shocks between cars. Consequently, the penalty suppressing means should preferably permit the engineer to make split applications; and this requirement modifies in some particulars the character of the devices determining that an adequate reduction in brake pipe pressure has been made. While the automatic brake applying mechanism of this invention may be organized to give automatic split applications, it is considered that the suppression of penalty characterizing the invention makes such automatic split applications of less importance, for the reason that the engineer may split his manual applications and get the slack under control before exceeding the critical speed limits.

The principal and primary objects of this invention are to provide various forms of devices, and organizations and combinations of devices to meet these various requirements

and problems briefly outlined above. The fundamental principles of the invention have been worked out in several forms, and have also been applied to different types of speed control systems. The particular disclosure, however, is more illustrative of the character of means constituting the present invention than a comprehensive showing of all ways in which the invention may be practiced; and it should be understood that the invention is not limited to any particular structure or organization herein disclosed, but is susceptible of adaptation and modification to meet the needs of any particular situation.

Various specific objects, purposes, advantages, and characteristic features of the invention will appear as the description progresses.

In describing the invention in detail reference will be had to the accompanying drawings in which:

Fig. 1 shows the trackway equipment of a train control system of the intermittent time-distance interval type having the present invention applied thereto, and also illustrates the permissive speed and braking characteristics for one particular block;

Fig. 2 illustrates the usual engineer's brake valve having a valve actuator applied thereto, whereby an unpreventable brake application may be made automatically, and further shows means for suppressing a penalty if an automatic brake application is anticipated by a manual brake application;

Fig. 3 shows the car-carried circuit arrangement of a train control system of the time-distance interval type of Fig. 1, the apparatus shown in Fig. 2 having been shown conventionally;

Fig. 4 illustrates the car-carried and trackway apparatus of a train control system of the continuous inductive type having the present invention applied thereto;

Fig. 5 illustrates a penalty suppressing means in which a miniature brake cylinder having a pressure therein corresponding to that existing in the main brake cylinders is employed so as to determine when an adequate brake application has been made.

Fig. 6 illustrates a modified arrangement for determining when an adequate brake application has been made.

Figs. 7 and 8 illustrate a still different modified arrangement for suppressing the penalty, in which a predetermined reduction from normal in the equalizing reservoir pressure suppresses the penalty; and also serves to permit the engineer to return the rotary valve to the lap position after an automatic brake application has been effected, to prevent excessive venting by such automatic application;

Fig. 9 shows the trackway equipment and a portion of the car-carried equipment of a two-position continuous inductive train con-

trol system, and graphically illustrates how the speed of the train may be reduced in a caution block for different entrance speeds without the infliction of a penalty;

Fig. 10 shows the remainder of the car-carried equipment shown in Fig. 9;

Fig. 11 illustrates a modified form of penalty suppressing means similar to that shown in Fig. 10;

Fig. 11^a shows a penalty suppressing means like that shown in Fig. 11 but having a modified form of contact associated therewith which closes a circuit when a predetermined degree of brake application has been initiated; and

Fig. 12 illustrates a train control system similar to that shown in Fig. 4 in which the penalty alone is suppressed without suppressing automatic operation of the brake control device, and in which a separate brake applying device is used which limits the degree of brake application regardless of a concurring or preceding manual brake application.

In order to fully disclose the manner in which the invention may be applied to various types of train control systems, the invention has been illustrated in connection with two entirely different systems, namely (1) the intermittent inductive time-distance interval speed control type; and (2) the continuous inductive speed control type. The first portion of the specification is directed to the intermittent type and the latter part to the continuous inductive type.

Intermittent system

Trackway apparatus.—Referring particularly to Fig. 1, there has been shown trackway apparatus for an intermittent time-distance interval type train control system applied to a portion of automatic signal territory. The track rails 1 are divided by insulated joints 2 into blocks, the block I and the adjacent ends of two other blocks H and J being shown. Since the various blocks are the same, like parts of each block are designated by like reference characters with distinctive exponents. Although the train control system in question may be used in connection with trackway signals of any type, either color light, position light or semaphore signals, semaphore signals Z have been shown conventionally without illustrating their well-known control devices and circuits.

The exit end of each block is provided with a suitable source of trackway energy, illustrated as a battery 3; and the entrance end is provided with a track relay 4. On the right hand side of the track, the direction of traffic being from left to right as indicated by the arrow, are pairs of trackway elements T for inductively transmitting control influences to suitable car-carried apparatus under cau-

tion traffic conditions of the block. Since the car-carried apparatus, as will appear hereinafter, responds only to two successive control influences in less than a predetermined time, only one element T of each pair need be made inactive under clear traffic conditions, the other element always being active. Each of these track elements T (see Fig. 3) comprises a U-shaped core 5 preferably constructed of a high grade of laminated magnetic material terminating in enlarged pole pieces 6. The controllable track element is also provided with a coil 7 on its core 5 which is normally closed in a circuit of low resistance through the front contact 8 of a line relay 9. Referring to the block I, these various line relays 9 of each block are connected in multiple across line wires which, under clear traffic conditions, are energized by the battery 10 through the front contact 11 of the track relay 4¹.

In Fig. 1 there has been graphically illustrated by vertical and horizontal dotted lines the speed limits set up at the three control points at which the pairs of track elements T are located. In this diagram the solid line 12 represents the speed-distance brake application curve of a certain train, the vertical distances representing miles per hour, and the horizontal distances representing points in the block in question. The horizontal dotted line 13 represents the speed limit enforced by the pair of elements T^b, the dotted line 14 the speed enforced by elements T^a, and the dotted line 15 represents the speed set up by the elements T. It is thus noted that the train may run at speeds at various points in the blocks as indicated by the dotted line 16 without exceeding the permissive speed limits. As more clearly pointed out hereinafter, the train may travel at speeds as indicated by the dot-and-dash line 17 under caution traffic conditions if the engineer has anticipated the automatic brake application by effecting an adequate brake application or initiating such a brake application.

Car-carried apparatus

Electro-pneumatic valve EPV.—As an automatic brake applying device, an electro-pneumatic valve EPV has been shown in Fig. 2 which may be used to vent the brake pipe directly, if its winding 20 is deenergized, may actuate a suitable brake valve actuator, such as shown in Fig. 2 and described hereinafter, or may control a suitable pneumatic device for applying the brakes in any desired manner, such, for instance, as shown in Fig. 12. This device EPV comprises a three compartment casing having valve ports in the two separating partitions. The lower port is closed by a valve 21 when the winding 20 is energized, and the armature 22 is in its elevated position; and the upper port is closed by a valve 23 when the winding 20 is deener-

gized, the valve 23 being maintained closed by a compression spring 24, the weight of the valves 21 and 23, the armature 22 and the valve stem 25.

Brake valve actuator.—In Fig. 2 there has been illustrated the usual engineer's brake valve BV, including the usual rotary valve provided with standard ports, from which the valve cap has been removed and for which a special cap 28 has been substituted. This cap 28 is provided with opposed cylinders 29 and 30 in which move pistons 31 and 32 connected together by a rack 33.

Extending up from the usual rotary valve (not shown) is a valve stem 34 on which is pivotally mounted a pinion 35 having two upwardly extending pins which are adapted to engage the actuator plate AP. Movement of the rack 33 in one direction or the other rotates the pinion 35 and actuator plate AP in the corresponding direction. Directly above the actuator plate AP is a valve plate VP, which is directly connected to the valve stem 34 in any suitable manner, so that rotation of this plate VP rotates the rotary valve. Directly above the valve plate VP is a handle plate HP, which is directly connected to the sleeve 36 to which is keyed the usual engineer's brake valve handle 37.

Under normal operating conditions, when the winding 20 of the valve EPV is energized, main reservoir pressure is present in both of the cylinders 29 and 30, and the rack 33 is moved to the left hand extreme position, because the cylinder 29 is larger than the cylinder 30. The handle 37 is directly coupled to the valve plate VP by the latch 38 held in position by a coil spring 19. Under such normal conditions, the handle 37, which is shown in the normal running position, may be moved to the release position, carrying with it the valve plate VP and handle plate HP held together by the latch 38, so that the engineer may apply the brakes or release them without interference by the actuator mechanism, the lap, service and emergency positions of the handle not having been specifically indicated.

When an automatic brake application is initiated as a result of deenergization of the valve EPV, causing the rack 33 to move toward the right because the cylinder 29 is vented to atmosphere, the actuator plate AP moves in a counter-clockwise direction; and during the first portion of its movement (this being an idle movement), the cam 39 raises the latch 38 and thereby unlatches the handle plate HP from the valve plate VP. Further movement of the rack from the left to the right moves the valve to the service brake applying position by reason of engagement of the upstanding lug 26 on the actuator plate AP with the extending arm 27 of the valve plate AP. The engineer cannot hold off, so to speak, or prevent an automatic brake

application by moving his handle 37 to the release position, because the engineer's valve is unlatched from the valve plate and rotary valve, as far as movement in the clockwise direction of the handle is concerned; but the engineer may move the valve to the emergency position, because the arm 40 extending from the handle plate HP engages the upstanding lug 41 on the actuator plate AP upon counter-clockwise movement of his handle. It should be understood that the automatic apparatus may move the brake valve to the service position, by the engagement of lug 26 with the extending arm 27, but will not again move the valve to the running position when the device EPV is again energized, because there is no mechanical connection between the actuator plate AP and the valve plate VP for movement of the actuator plate in the clockwise direction. This is desirable because it requires a positive act by the engineer each time the brakes are released.

Penalty and suppressing means.—In the particular form of the invention shown, the penalty imposed upon the engineer for negligence or neglect to take the appropriate action consists in requiring the train to be brought to a stop before the brakes can be released and the train proceed at speed. This is accomplished by providing a suitable reset switch RS, which is so located on the locomotive that it is accessible only by one standing on the ground, and which is so protected that it cannot be held closed. Consequently, when the engineer fails to take the appropriate action in manifestation of his vigilance, and the automatic apparatus on the locomotive assumes a certain condition, the brakes cannot be released and the train proceed, until it has been brought to a stop and someone has operated the reset switch from the ground.

The embodiment of the invention shown utilizes electrical control of devices primarily, and hence, the penalty inflicting means, together with the means for suppressing such penalty, involve the opening and closing of contacts. As a part of the penalty suppressing means, the engineer's brake valve is provided with contacts which are opened and closed in certain positions of the brake valve. In the form shown in Fig. 2, on the sleeve 36, to which the engineer's brake valve handle 37 is fixed, is a collar 42 of insulating material to which are fastened contact strips or segments 43, 44 and 45; and adjacent to these segments are pairs of contact fingers 46, 47 and 48, which are bridged by said segments in different positions of the valve handle. The contact finger 43 is of such length that it bridges and electrically connects its cooperating pair of fingers 46 if the engineer's valve handle is in the lap, the service, or the emergency position. Similarly, the contacts 44 and 45 bridge their

respective pairs of contact fingers with the engineer's valve handle in either the service or the emergency position.

For reasons outlined hereinbefore, it is desirable, in connection with the suppression of the penalty, to have automatic means responding if, and only if, the engineer has made the desired manual control of air-brake system sufficient to assure a brake application of the required intensity. In this particular arrangement under consideration, it is assumed that the engineer has exercised the required manual control when he has made a certain predetermined reduction in the pressure in the equalizing reservoir of the air-brake system. The operation of the usual type of air-brake system is well known, and the function of the equalizing reservoir pressure is familiar to those skilled in the art, so it will be sufficient to point out that a reduction in equalizing reservoir pressure is automatically followed by a reduction in brake pipe pressure to correspond, and that so far as the manual control of the air-brake system is concerned, this has been fully accomplished as soon as the equalizing reservoir pressure has been reduced the desired amount.

For the purposes of this disclosure it has been assumed that the speed restrictions automatically imposed by the train control system will be based upon a full service brake application, corresponding to full equalization of pressure between the auxiliary reservoir and brake cylinder of each car. Roughly speaking, such a full service application represents about 20 pounds reduction in the brake pipe pressure, and correspondingly in the equalizing reservoir pressure. With the typical equipment it takes about 6 or 7 seconds to make a 20 pound reduction in equalizing reservoir pressure. Putting it another way, if the engineer's brake valve is held in the service position for 6 or 7 seconds, the pressure in the equalizing reservoir will drop in this time sufficient to produce substantially a full service application. In short, if we measure the time that the engineer's brake valve is kept in the service position, we have a measure also for the amount of reduction in equalizing reservoir pressure. It is desirable to permit the engineer, if expedient to do so, to make the manual full service application in two or more stages, that is, split the reductions; and accordingly, the time measuring device should be able to respond to the summation of time intervals and become active after the total time the engineer's valve has been in the service position, without any intervening release or recharge, is equal to 6 or 7 seconds.

Referring now to the specific means shown in Fig. 2, a cylinder 50 has a movable piston 51 therein, which is urged in one direction (to the right, as shown) by a compression coil spring 52. This piston 51 is provided with

a packing or rings, in accordance with approved practice, so as to prevent leakage by it; and to insure a quick or snap movement, this piston has ridges on its faces cooperating with gaskets in the extreme position of the piston. Insulated contact disks or members 53 and 54 are fixed to the rod or plunger of the piston 51, and engage pairs of fixed contacts, shown conventionally as arrows, when the piston has shifted to its extreme left hand position.

The right hand side of the piston 51 is in communication with a small capacity reservoir 55. The pressure in this reservoir 55 is controlled by two electro-pneumatic valves DV and RV of suitable construction, which in turn, are controlled electrically in accordance with the position of the engineer's brake valve handle. The valve DV, if deenergized, connects the reservoir 55 to atmosphere, but if energized closes its exhaust. The winding of this valve DV has its energizing circuit through the contacts 43—46 of the engineer's valve, so that said valve DV is energized if the engineer's valve is in the lap, service, or emergency positions, but is deenergized for the running or release positions. The other valve RV, if energized, connects a suitable source of pressure, in this instance the brake pipe, to the reservoir 55 through an adjustable restricted orifice 56, so that the flow of pressure into said reservoir varies in accordance with time. If the valve RV is deenergized, such supply of pressure is cut off. This valve RV is energized by a circuit through the contacts 45—48 closed with the engineer's brake valve in the service or the emergency positions.

With the engineer's brake valve in the normal running position, the parts are in the position shown in Fig. 2, both of the valves DV and RV being deenergized, the reservoir 55 at atmospheric pressure, and the piston 51 held in the right hand position by its spring. When the engineer moves his brake valve to the service position, both of the valves DV and RV are energized, the valve DV closing and cutting off the exhaust from the cylinder 55, and the valve RV opening to admit pressure at a slow rate to this reservoir. The size of the reservoir 55 and the area of the restricted orifice 56 are selected so that after the expiration of the desired time (assumed to be 6 or 7 seconds), the pressure in this reservoir builds up to the point where, acting on the exposed right hand face of the piston 51, it overcomes the tension of the spring 52 and moves the piston toward the left. As soon as the piston 51 starts to move to the left, it breaks the gasket seal and exposes a larger area to the pressure in the reservoir, whereupon the piston shifts quickly to its extreme left hand position, since the increased area exposed to pressure more than compensates for the increased tension of the spring due to

contraction. When the piston 51 reaches its extreme left hand position, the contact members 53 and 54 engage their cooperating pairs of contacts. During the time that the engineer's brake valve was in the service position to bring about this result, the equalizing reservoir of the regular air-brake equipment was, of course, being vented; and before the expiration of the 6 or 7 seconds, it is certain that the pressure in this equalizing reservoir has been exhausted through the preliminary exhaust port in the engineer's brake valve to bring about the desired reduction. After this time, the engineer is supposed to lap his valve, thereby arresting further venting of the equalizing reservoir pressure and avoiding over-reduction in brake pipe pressure and useless waste of air. When the engineer moves his valve to the lap position, the valve RV is deenergized on account of the opening of the contacts 45—48, while the valve DV is kept energized and maintains the pressure in the reservoir 55 to hold piston 51 in its left hand position and keep contact disks 53—54 in their circuit closing position.

If the engineer should attempt to release the brakes by moving his valve to the running or release position, the valve DV is deenergized and opens to exhaust the pressure in the reservoir 55 immediately, whereupon contact disks 53—54 at once assume the open position, to cause the actuator to again operate the brake valve to the service position, and enforces speed restrictions as more particularly pointed out hereinafter. While the engineer cannot release the brakes, he may split the reduction into two or more stages, moving the valve back and forth between the service and lap positions. In the service position, the valve RV is energized and pressure builds up in reservoir 55 in accordance with the lapse of time; and so long as the engineer does not go beyond the lap position to the running or release position, the valve DV is maintained energized to hold what pressure may have been built up in the reservoir 55. It will be evident that the piston 51 does not shift until the accumulated or total time that the engineer's valve has been in the service position equals 6 or 7 seconds. By virtue of this arrangement, the engineer may make a partial application of the brakes to adjust the slack before exceeding the critical speed limits, and is not necessarily required to make his manual application all in one stage. After the critical speed limits are exceeded, however, the engineer must maintain his brake valve in the service position until the necessary reduction in equalizing reservoir pressure has been made. In other words, the engineer may split his applications as much as he pleases before crossing the "dead-line" of permissible speed limits, but after crossing this line, he must keep his brake valve in the service position until the proper manual brake applica-

tion has been set up, it being obvious that this is necessary to be sure of safety, inasmuch as the speed limits are based upon a continuous one-stage reduction, and to assure under most unfavorable circumstances the equivalent manual application, all reductions after crossing the dead-line should be made in one stage.

Influence receiving car element.—The reference character L designates a car-carried element comprising an inverted U-shaped core 59 of laminated magnetic material terminating in enlarged pole pieces. The legs of this core 59 are provided with a primary coil P and a secondary coil S respectively. This car element L is preferably supported from the truck of the railway vehicle in a manner so as to cooperate with the track elements T (see Fig. 1) through a small intervening air gap of from $1\frac{1}{2}$ to $2\frac{1}{2}$ inches, the middle of this air gap being, say, $3\frac{1}{4}$ to $3\frac{3}{4}$ inches above the top of the track rails.

Relays.—The car-carried apparatus of the intermittent time-distance interval system shown in Fig. 3 includes relays CR, RR, BR and PR. The first three of these relays are preferably sensitive and immune to jars and vibrations, this being accomplished by making their armatures very light and well-balanced and by supporting them about a vertical axis so that swinging and jarring of the railway vehicle will not tend to operate such armatures. The penalty relay PR need not be quick acting necessarily, but is preferably constructed substantially the same as the first three relays mentioned. These relays are provided with suitable contacts which are more conveniently described in connection with the operation.

Time element device.—In order to determine if two control influences are received from the trackway apparatus in less than a certain interval of time, it is necessary to have a reliable time element device on the vehicle which measures the time between successively received control influences. In the system shown in Fig. 3 this time element device is one that functions on the principle of acceleration or deceleration of a mass similar to timing mechanism in watches.

This device TE has been shown conventionally and comprises a shaft 60 to which is fastened a balance wheel 61. This balance wheel 61 is held in its normal position by a time starting magnet TS acting on an armature 62 fastened to the non-magnetic balance wheel 61. This shaft 60 and the balance wheel 61 are biased so as to assume an intermediate position substantially 90° toward the right of its normal position, in which it is shown, by a spiral spring 62', and is provided with contacts 63 and 64 adapted to contact with stationary contacts 65 and 66 respectively during different parts of the full oscillation of the wheel. If the time starting

magnet TS is momentarily deenergized, the balance wheel 61 will be swung in the clockwise direction, and passes its biased position at substantially 90° making a swing of almost 180° , after which it will swing back almost to its initial position, and if the time starting magnet TS is again energized will again be attracted to its normal position.

Speed responsive device.—One element of the car-carried apparatus is a speed responsive device which reflects the speed at which the vehicle is traveling at any point along the trackway; and in the particular arrangement shown this device G is of the centrifugal type, including a shaft 69 driven from the wheels of the vehicle in any desired manner. On this shaft 69 is pinned a sleeve 70 and is slideably supported a collar 71 having a contact disk 72 connected thereto but insulated therefrom. To the sleeve 70 and the collar 71 are pivotally secured links 73 which are pivotally connected at their free ends to fly balls 74, a compression coil spring 75 surrounding the shaft 69 tending to separate this sleeve and collar as far as possible. Rotation of the shaft 69 causes the fly balls 74 to separate and pull the collar 71 down against the tension of the spring 75, so that the contact disk 72 assumes a position depending on the speed of the shaft 69 and closes a circuit when the speed of the train is less than a certain value, assumed to be about 20 miles per hour.

Operation of intermittent system Figs. 1 to 3

In order to simplify the circuit diagram of the car-carried apparatus, certain circuits start from a terminal marked B of a suitable source of energy, such as a battery, and terminate at a common return wire marked C connected to the other terminal of said source; and other circuits start or stop at a neutral point of the system designated NP. In the arrangement shown, the primary coil P of the car element L is energized by the following circuit:—beginning at the terminal B, wire 77, primary coil P, wires 78 and 79, neutral point NP, through discharge resistance 80, back to common return wire C. The flow of current through this circuit causes the neutral point NP to assume a certain intermediate potential between that of the terminals B and C.

Under normal conditions of the apparatus shown, the control relay CR and secondary coil S are connected in series between the terminal B and the neutral point NP by a circuit which may be traced as follows:—terminal B, wire 81, front contact 82 of the control relay CR, wires 83 and 84, winding of the control relay CR, wire 85, secondary coil S, wires 86 and 79 to the neutral point NP.

With this control relay CR energized, the following circuit for the repeater relay RR may be traced:—beginning at the terminal B of the battery, wire 81, front contact 87,

wires 88 and 89, winding of the repeater relay RR, wires 90 and 91, front contact 92 of the repeater relay RR, wire 93 back to common return wire C.

5 With the repeater relay RR energized, the following circuit for the time starting magnet TS may be traced:—beginning at the terminal B, wire 94, winding of the time starting magnet TS, wire 95, front contact 96 of the repeater relay RR, wire 93, back to common return wire C.

10 Another circuit is energized by the control relay CR when energized which includes the same front contact 87 and which may be traced as follows:—beginning at the terminal B, wire 81, front contact 87, wires 88 and 97, lower winding of the brake control relay BR, wire 98, front contact 99 of the brake control relay BR, and wire 100 back to common return wire C.

15 The circuit just traced is a stick circuit for the lower winding of the brake control relay BR. A stick circuit for the upper winding of this brake control relay BR is closed when the time element device TE is in its normal position and may be traced as follows:—beginning at the terminal B, wire 101, contacts 63—65 of the time element device, wire 102, upper winding of the brake control relay BR, wires 103 and 104, front contact 105 of the brake control relay BR, and wire 100, back to common return wire C.

20 With the brake control relay BR energized, the electro-pneumatic brake control device EPV is energized by a partial circuit starting from the neutral point NP as follows:—wire 106, front contact 107, wires 108 and 109, winding 20 of the EPV, wire 110, reset push button switch 111 only accessible from the ground, wire 112, back to common return wire C. It is of course noted that the current flowing in this partial circuit also flows through the primary coil P, the complete circuit beginning at the terminal B of coil P and ending at C of the reset switch RS.

25 With these various circuits closed as described, sufficient current will flow in the primary winding P to the neutral point NP to set up a large magneto-motive-force in the car-element L establishing a certain amount of flux, a large part of which, it is believed, passes through leakage paths and a certain part of which passes through the secondary coil S.

30 It should be noted at this time that the control relay CR is connected in series with the secondary coil and has a potential impressed upon it depending on the voltage impressed across the primary coil P. This is desirable because shunting of the primary coil or a reduction in primary current on account of depreciation of the source of energy, and the like, causes a similar change in the potential across the secondary coil S. In other words, weakening of the primary field causes

lowering of the potential across the relay CR, so that a smaller impulse will cause dropping of this relay. The discharge resistance 80 serves two purposes, namely:—permits the flow of current in the primary coil P when the device EPV is deenergized, and also acts as a discharge resistance to prevent arcing at the relay contact when the circuit for the device EPV is opened.

70 *Caution conditions—speed not excessive.*—Let us assume that the block J is occupied by a train, thereby depriving the track relay 4¹ of energy and in turn deenergizing the line relays 9 so that the coils 7 on the track elements T, T^a and T^b are open circuited, making these track elements active.

75 Let us further assume that a train, equipped with the car apparatus shown in Figs. 2 and 3, is moving in the block I and passes the first pair of track elements T at a speed less than that shown by the dotted line 15. When the car element L passes over the first track element T, bridging of this element L by the core 5 causes a sudden increase of flux in the secondary coil S. This increase of flux, it is believed, is largely due to a diversion of flux from the leakage paths, and to a certain extent is due to the increase in the total flux passing through the primary coil P. As the car element L recedes from the track element T, the flux passing through the secondary coil S again reduces to normal. This sudden increase and decrease of the flux passing through or linking the secondary coil induces a voltage in this coil corresponding to a single cycle of alternating current electromotive-force. The coil S is preferably so connected in the circuit with the control relay CR that the first wave of this single cycle of voltage is in a direction to oppose the voltage of the battery, thus decreasing the current through the control relay CR enough to cause its armature to be retracted by its biasing spring (not shown) to the dotted line position. With the control relay CR once deenergized, it remains in its deenergized position until restored by some other means, because its stick circuit has been broken.

110 With the control relay deenergized, the stick circuit for the repeater relay RR is broken, thereby deenergizing this relay RR and in turn the time starting magnet TS of the time element device TE, thus starting the time element device on its cycle of operation in a clockwise direction. Deenergization of the control relay CR at this time also interrupts one of the stick circuits (including the lower winding) of the brake control relay BR; but this relay, however, remains in its energized position by reason of its other stick circuit including contact 63—65 of the time element device. As soon as the repeater relay RR assumes its deenergized position, a pick-up circuit for the control relay CR is com-

pleted as follows:—beginning at the terminal B, wire 113, back contacts 114 of the repeater relay RR, wires 115 and 84, winding of the control relay CR, wire 85, secondary coil S, wires 86 and 79, back to the neutral point NP. The completion of this pick-up circuit again picks up the control relay CR which is then maintained up by its stick circuit heretofore traced. The restoration of the relay CR in turn again picks up the repeater relay RR. During the time that the relays CR and RR are being restored, the brake control relay BR is held up by the stick circuit through its lower winding which is closed at the contacts 63—65 during a small part of the cycle of the time element device TE. It will be evident at this time, if the control relay CR were deenergized while the time element device TE is performing its cycle of operation, and the contacts 63 and 65 are broken, the stick circuit for the lower winding of the brake control relay BR would also be broken at this time, and the brake control relay BR would assume its deenergized position. Since, however, it has been assumed that the speed of the train is less than that indicated by the dotted line 15, the time element device TE will have completed its cycle of operation and will again be in the normal position before the car element L traverses the second track element of the first pair, so that passage of the car element L by the second element of the pair causes the same cycle of operation to take place without deenergizing the brake control relay BR.

The same operation occurs at the second pair of track elements T^a, provided the speed of the train is below the limiting speed indicated by the dotted line 14, this speed limit being lower because the track elements of this pair are spaced closer together. At the pair of track elements T^b the speed of the train must be still lower to avoid automatic control. A speed distance curve representing possible or typical performance which the train may follow and avoid automatic braking is indicated by the dash-curve 16.

Caution condition—speed excessive—engineer not vigilant.—For the next operating condition to be discussed, assume that the block J is occupied as before, making the block I a caution block and rendering the second track element of each pair active; and suppose that the engineer fails to observe the caution signal at the entrance to the block I or fails for some reason or another to reduce speed below the critical speed limits, and, furthermore, neglects to initiate or complete a manual brake application before exceeding these speed limits. Under this assumption, the train passes the first pair of track elements T at a speed higher than the speed limit for this pair, represented by the dotted line 15, and the engineer's brake valve

is in the running position. As the train passes the first track element of the pair T, the relays CR and RR drop their armatures and are then restored by pick-up circuits including contacts 114 and 66 the same as above described, and the balance wheel of the time element device is set into motion. Since the speed is assumed to be too high, the train reaches the second track element of the pair T before the balance wheel of the time element device has returned to its initial position to close contacts 63—65. Consequently, when the relays CR and RR drop their armatures the second time at the second track element of the pair, both of the stick circuits for the relay BR are broken, one at the front contact 87 of the relay CR, and the other at the contacts 63—65 of the balance wheel. The armature of the relay BR, therefore, moves at once to its retracted position (shown dotted); and subsequent closure of the front contact 87 of this relay CR or the contacts 63—65 of the time element device will not serve to restore this armature. In short, the armature of the relay BR is moved in its retracted position and remains there until the relay BR can be reset.

The retraction of the armature of the relay BR interrupts the energizing circuit for the valve EPV, closing valve 23 (see Fig. 2) and opening valve 21. Pressure is then exhausted from behind the large piston 31, and the main reservoir pressure constantly acting on the small piston 32 shifts the rack 33 toward the right. As previously explained, this movement of the rack 33, driving the actuator plate AP, first releases the latch 38 from engagement with the arm 40, and then by reason of contact of the lug 26 with the arm 27 of the valve plate VP, drives the engineer's rotary valve, free from the handle 37, to the service position. The engineer cannot prevent this movement, since his handle is unlatched from the rotary valve for movement towards the release position; but the engineer can at any time move the rotary valve still further to the emergency position.

Under the conditions assumed the engineer has not been vigilant and hence the penalty should be enforced. This is accomplished by requiring the train to be stopped and the reset switch RS operated, in order to permit reenergization of the relay BR. It may be explained here that other forms of penalty are, of course, applicable to the arrangement shown in Fig. 3. For instance, instead of establishing the pick-up circuit for reenergizing the relay BR by manual manipulation of the reset switch RS, this may be done by closure of contacts of the speed responsive device G, which are closed only after the speed of the train has been reduced to a very low speed, such as two miles per hour, meaning that the train has been brought substantially to a stop. Such a modification is in-

licated in other forms of the invention hereinafter explained and its applicability to this particular embodiment is too obvious to require specific illustration.

5 When the engineer pushes this push button 111, the time element device TE in the meantime having returned to its normal position, a pick-up circuit for the brake control relay BR is established which may be traced as follows:—wire 101, contacts 63—65 of the time
10 element device TE, wire 102, upper winding of the brake control relay BR, wires 103 and 116, push button 111, wire 112, back to common return wire C. With the brake control
15 relay BR in its energized position, the stick circuit for this relay as heretofore traced is again closed. With the brake control relay BR again picked up the device EPV is energized after the engineer restores RS to its
20 normal position, the rack 33 and the actuator plate AP are returned to the normal position; and the engineer may release the brakes by moving his handle to the service position, latching the handle plate HP to the valve
25 plate VP and then returning the handle to the running or release position.

The engineer has been penalized by being required to come to a full stop and get out to
30 operate the reset switch RS, which is only accessible from the ground; and this is proper because he was not vigilant and did not either reduce speed or apply the brakes manually. Further, it should be noted that the reset
35 switch RS cannot be maliciously tied down, so as to avoid the penalty, because the push button 111 has to be in its upper position before the device EPV may be energized and if
tied down, the train could not move.

Caution condition—speed excessive—penalty suppressed.—Let us assume that the train
40 in question is entering the block I under caution traffic conditions at a speed of about 65 miles per hour, as indicated by the dot-and-dash line 17 at the entrance to the block I. Let us further assume that the engineer is
45 alert, and upon entering the block I, observes the caution signal, and realizing that the speed of his train is higher than the safe or restricted speed limit provided by the train
50 control system, initiates a manual brake application to reduce speed, and accomplishes this initiation by putting his brake valve in the service position before the train reaches the pair of track elements T.

55 As soon as the engineer puts his brake valve in the service position, a pick-up circuit for the penalty relay PR is established and may be conveniently traced as follows:—beginning at the neutral point NP, wire 106,
60 front contact 117 of the relay BR, wires 118 and 119, relay PR, wires 120 and 121, contacts 47—44 on the engineer's brake valve, and wire 122 to the common return wire C.

65 It will be observed that the circuit just traced includes the front contact 117 of the

relay BR; and consequently the engineer must act before the relay BR is deenergized, as above explained, by the passage of the train over a pair of track elements at excessive speed. Once the penalty relay PR is energized, it is maintained energized by a stick
70 circuit that may be traced as follows:—beginning at the neutral point NP, wire 123, front contact 124 of relay BR, wires 125 and 119, relay PR, wires 120 and 121, contacts
75 47—44 and wire 122 to the common return wire C. By reason of this stick circuit, the relay BR may open its front contact 117 without causing the penalty relay PR to be deenergized. After the engineer has kept
80 his brake valve in the service position for a time long enough to make the required brake application (assumed to be about 6 or 7 seconds), the piston 51 (see Fig. 2) shifts and moves the contact disks 53 and 54 into engagement with their cooperating contacts, where-
85 upon the engineer may move his valve to the lap position, but no further, and the penalty relay be maintained energized, the electrical connection to the common return wire C
90 through wires 127 and 128 being substituted for that through wires 121 and 122.

With respect to the automatic operation just described, it is important to note that the engineer must act before exceeding the
95 speed limit in order to have the penalty relay energized before the relay BR is de-energized and thereby avoid the penalty which is inflicted with this relay PR de-energized, at the time the speed limit is exceeded. Consequently, the engineer must be alert and vigilant in watching out for the block signals and must act before any automatic operation
100 occurs on the train, if he is to avoid the penalty. This means that the engineer is obliged to keep a good watch along the track and will be more likely to observe obstructions on the track than if his attention is diverted to signaling devices in the cab. If the engineer
105 is vigilant and manually applies the brakes himself in obedience to the caution signal and excessive speed, then the train will be safely stopped, even if the train control equipment should be for any reason out of
110 order. Another point of interest is that it is not necessary, in order to forestall the penalty, that the engineer should have in effect a full service application before exceeding the critical speed limit, but is merely required
115 to have his brake valve in the service position. Safety is assured by this arrangement because it takes about as much time for the automatic device to bring about a brake application as it does by the engineer's brake
120 valve.

Assuming that the engineer has been vigilant and the penalty relay PR has been energized, when the train passes the pair of track
125 elements T at excessive speed, the brake control relay BR is deenergized. In short, the
130

vigilance and anticipatory manual brake application of the engineer does not avoid the automatic brake control, all of the automatic brake setting devices operating the same as if the engineer had not been vigilant.

The electro-pneumatic valve EPV is deenergized, and the valve actuator (Fig. 2) operates automatically; but since the engineer's valve has already been placed manually in the service position, the operation of the valve actuator is merely an idle movement, unlatching the engineer's brake valve handle 37 from the rotary valve itself. As soon as the engineer's brake valve has been in the service position for 6 or 7 seconds, the contacts 53 close; and since the penalty relay PR is energized, the electro-pneumatic valve EPV is reenergized by a circuit as follows:—commencing at the neutral point NP, wire 123, front contact 129 of relay PR, wire 130, contacts 53, wires 131 and 109, valve EPV, wire 110, push button 111 and wire 112 to the common return wire. The reenergization of the valve EPV restores the parts of the brake valve actuator to normal position, and the engineer may now lap his valve and avoid further reduction in the equalizing reservoir pressure and the resultant reduction in brake pipe pressure. If it should happen that the engineer has had his brake valve in the service position 6 or 7 seconds before passing the pair of track devices T at excessive speed, then the contacts 53 are closed, and the valve EPV would not be deenergized or the actuator operated when the brake control relay BR is deenergized. In other words, after a predetermined reduction in equalizing reservoir pressure has been made, further reduction by automatic operation is prevented.

The engineer cannot defeat the objects of the invention; and if he should attempt to release the brakes after avoiding the penalty and before automatic restoration of the train control equipment, then as soon as the engineer places his brake valve in the release or running position, the valve DV (Fig. 2) opens, the reservoir pressure 55 is quickly vented, and the contacts 53 and 54 open, and the electro-pneumatic valve EPV is immediately deenergized. The engineer's brake valve actuator is accordingly automatically operated at once, taking the control of the brake valve out of the hands of the engineer and automatically moving it to the service position. The opening of the contacts 54, with the brake valve in the running or release position, interrupts the stick circuit for the relay PR and causes its armature to assume the retracted position; and since the relay BR is assumed to be deenergized at this time, the relay PR can not be energized again by putting the engineer's brake valve in the service position. Consequently, the penalty is inflicted, and also the valve EPV remains deenergized irrespective of the

amount of reduction in the equalizing reservoir pressure. In short, the engineer may avoid the penalty, and in the particular arrangement shown, an over-reduction in brake pipe pressure, only if he acts in time and furthermore maintains the brake application.

In the particular arrangement shown, the pick up circuit for the valve EPV includes the front contact 129 of the penalty relay PR, so that this valve can be energized after a predetermined reduction has been made only in the event that the engineer is vigilant. This arrangement is adopted on the theory that such over-reduction as might occur would serve as an additional penalty, requiring in some instances extra time to pump up the brake pipe pressure. Some users, however, may consider that such over-reduction should be avoided at all times, and this can readily be done by omitting the front contact 129 of the relay PR and connecting the wire 130 directly to the neutral point NP, such a change being so obvious as not to require illustration. With such a modified arrangement, the electro-pneumatic valve EPV will be reenergized for each automatic operation after a predetermined reduction has been made in equalizing reservoir pressure, corresponding to a time of 6 or 7 seconds, whether the engineer has been vigilant or not. Such re-energization of the valve EPV permits the engineer to lap his valve and avoid over-reduction. He cannot, however, release the brakes, otherwise the valve DV of Fig. 2 is deenergized and the valve actuator operated in the same manner as previously described to take over the control of the brake valve automatically.

In the form of the invention just described, it will be noted that there can no objectionable action occur on account of the simultaneous occurrences of the automatic and the manual brake control, because the same device, namely the engineer's brake valve, is used for both the automatic and the manual brake application.

Release after automatic operation—engineer vigilant.—Assuming that the engineer has been vigilant, as above described, and also that speed of the train is above the arbitrary speed limits imposed by the system. The train leaves the first pair of track elements T with the relay BR deenergized and the penalty relay PR energized. The engineer's brake valve may be still in the service position, or may have been moved back to the lap position, in case there has been time enough to effect a predetermined reduction. With the car equipment in this condition, there are three different contingencies under which this equipment may be restored to the normal condition to permit release of the brakes, namely:—(a) the speed of the train is reduced below the permissive speed limits at the next

or a succeeding pair of track elements; (b) traffic conditions clear up and the signal ahead changes from stop to either caution or clear; and (c) the speed is brought down to a minimum.

(a) Assume that the manual brake application started by the engineer slows down the train sufficiently to make its speed at the next pair of track elements T^a less than the speed limit at this pair. As the train passes the first track element of the pair T^a the relays CR and RR are deenergized in the same way as occurs at each active track element. Remembering that the penalty relay PR is assumed to be energized, the relay BR is energized as soon as the relay RR is deenergized by a circuit which may be traced as follows:—commencing at B, wire 101, contacts 63—65 of the time element device, wire 102, upper winding of relay BR, wires 103 and 133, contacts 134 of relay PR closed, wires 135 and 138, back contact 92 of relay RR, to the common return wire C. As soon as the relay BR attracts its armature and closes its front contact 105, the stick circuit for its upper winding is established; and very quickly thereafter the stick circuit for the lower winding is established by the restoration of the armature of the relay CR. The time element device is set into operation in the regular way, but since the speed is assumed to be below the automatic speed limit, the time element device gets back to its initial or normal position before the relay CR is deenergized at the second track element of the pair T^a , with the result that the relay BR remains energized. It will be evident that if the speed of the train had been excessive, the relay BR, even though momentarily energized upon closure of the back contact 92 of the relay RR, would at once be again deenergized. Hence, a permanent release is possible only if the speed of the train has been brought below the permissible speed limits automatically imposed. Such re-energization of the relay BR is only for a second or so, depending on the time of operation of the time element device TE which determines the spacing of the track elements of each pair; and such temporary energization of said relay BR produces no objectionable results. Even though there is time for the valve EPV to become energized and the pistons 31 and 32 of the brake valve actuator to return to normal, there will not be time for the engineer to release the brakes. It should be noted that this momentary energization of the relay BR can occur only if the penalty relay PR is energized and its front contacts 134 are closed. Consequently, if the engineer had not been vigilant at the first pair of track elements, no subsequent action on the part of the engineer in reducing speed or otherwise will avail to avoid the penalty.

(b) If it should happen that, while the train is traveling in the block I between the pairs of inductors T and T^a , the block J next in advance should become unoccupied, it will be evident that it is proper to permit the following train to resume speed, providing the engineer has been vigilant and it is not necessary to enforce a penalty. As soon as the block J becomes unoccupied, its track relay 4¹ picks up and energizes the line relays 9 to put the second track element of each pair in its inactive or non-controlling condition. As the following train passes over the first track element of the pair T^a , inasmuch as this first track element has no coil thereon and is always active, the relays CR and RR on the train are deenergized in the same way as before described, and the brake control relay BR is re-energized, assuming that the engineer has been vigilant and the armature of the penalty relay PR is attracted. Since traffic conditions have cleared and the second track element of the pair T^a is inactive, there is no second operation of the relays CR and RR, and hence the relay BR remains energized irrespective of the speed. Thus, the brake control relay BR is maintained energized, and the engineer can release the brakes and proceed at any speed throughout the remaining portion of the block I.

(c) Assuming that the engineer has been vigilant, and that the manual brake application, followed up by automatic control, has brought the speed of the train down to some selected minimum speed, such as 20 miles per hour, the contacts 72 of the speed-responsive device G are closed, whereupon the upper winding of the relay BR is energized by a circuit through the front contacts 134 of the relay PR, the same as before traced, and through wires 136 and 137 and contacts 72 of the speed responsive device G to the common return wire C. The engineer may now release the brakes and proceed, subject, however, to subsequent control by the track elements. This automatic restoration at low speed assures that the brakes may be released and the train proceed without being required to stop, even though the braking power of the train, the grade on which it is running, and like factors may be such as to bring the train to a stop at some point between the pairs of track elements, it being obvious that in such event the automatic restoring operations above described under (a) and (b) which require passage over a track element, do not take place.

Clear traffic conditions—speed excessive—no automatic braking or penalty.—Let us assume now that the train in question enters the block I when this block I and the block J in advance are not occupied. Under this condition the track relay 4¹ assumes its energized position and thereby energizes the line relays 9 and places the coil 7 of the second element

of each pair in a closed circuit of low resistance. When the train passes over the first element of the pair T, the time element device TE is initiated upon its cycle of operation the same as in the cases heretofore discussed. Since it has been assumed that the train is moving at excessive speed, the train will pass by the second element of this pair before the time element device completes its cycle. The brake control relay BR will, however, when passing by this second element not be deenergized even though the time element device has not returned to its normal position, because no control influence is transmitted to the control relay CR when passing by a track element having its winding 7 closed in a circuit of low resistance. One theory by which this inaction may be accounted for, is that the passage of a few lines of flux through the track element T causes a current to flow in the short circuited coil 7 which is in a direction to oppose the flux producing it, so that very little flux change through the track element T takes place. Since very little flux passes through the track element, the flux distribution from the primary coil P is only slightly changed and very little change of flux through the secondary coil S takes place, so that very little, if any, voltage is induced in this secondary coil. In other words, the winding on the track element acts as a bucking coil and bucks back, so to speak, any magnetic flux trying to pass through its coil, so that the track element even though of low reluctance allows the passage of only a very small amount of flux.

General operating result.—From the foregoing explanation it will be appreciated that the form of the invention shown in Figs. 1, 2 and 3 meets the desirable requisites hereinbefore explained in a simple and efficient manner. The artificial or arbitrary speed limits are enforced by application of the time-distance interval principle, which enables any particular desired speed limit to be set up at any particular point along the trackway, making it possible to vary the speed limits as required to meet the varying braking conditions along the railroad. The engineer is required to be alert and vigilant under penalty of being required to stop. Putting it another way, if the engineer is vigilant and takes the appropriate action, he is entitled to run his train with less difficulty, whereas if not vigilant, he is required to stop. The engineer may avoid the penalty at all times by keeping speed of his train below the automatic speed limits. Also, even though exceeding the speed limits, the engineer may avoid the penalty if he takes anticipatory action toward stopping the train by a manual brake application. The safety of the train is assured, even though it may be running above the arbitrary speed limits, because it is certain that the train is being slowed down,

either by an automatic brake application or by a manual brake application. It will be obvious that the penalty only is suppressed, the automatic setting mechanism operating each time the speed is excessive. If the engineer has been vigilant, he may release the brakes and proceed as soon as:—(a) the speed of the train has been brought down below the safe speed limit at a pair of track elements; or (b) the train passes a pair of track elements after the block ahead has cleared up; or (c) the speed of the train has been brought down to a predetermined minimum. The whole arrangement materially facilitates the handling of the train by the engineer, inasmuch as he is not obliged to keep below an artificial "dead-line" of limiting speed, in order to avoid a penalty, but is able to run without penalty and advance as rapidly as safety will permit by merely initiating a manual brake application as soon as the speed of the train and its location is such as to require slowing down. Other advantageous features of the system organized as just described will be apparent without specific explanation.

Continuous inductive system

Trackway apparatus.—In Fig. 4 of the drawings there has been illustrated a section of railway equipped for three position distinctive traffic indication which includes means for continuously transmitting to suitable car-carried apparatus a control influence corresponding to the particular traffic condition existing. For convenience the block N and the adjacent ends of two other blocks M and O only have been shown. These blocks are provided with the usual track circuit including an alternating current source of energy as indicated by the track transformer 140 and the usual limiting impedance 139 at the exit end thereof, and with a suitable track relay 141 adapted to respond to alternating current. As well known by those skilled in the art of railway signaling, this track transformer 140 results in the flow of alternating current in one direction in one of the rails and back again in the opposite direction in the other rail; and for convenience this current may be called the "track circuit" or "loop circuit" current.

In addition to this track circuit current, it is desirable to transmit another current which is distinctive and which for convenience may be called the "simplex current". This simplex current flows through both rails along the trackway in multiple in the same direction. In order to transmit this simplex current, balancing resistances 142, 143 and 144 are bridged across the trackway at the entrance, at an intermediate point, and at the exit end of each block. The middle point of these balancing resistances are connected to the secondary winding of a transformer

145 in various ways depending on traffic conditions ahead.

Under clear traffic conditions, this simplex current for the block N is supplied to the track rails in one direction relative to the track circuit current by a line circuit through front contacts 146¹ and 147¹ of the track relay 141¹ of the next block O in advance, thereby permitting the flow of simplex current through the entire length of the block N which has a positive polarity or phase relation to the loop circuit current; and under caution traffic conditions, with the contacts 146¹ and 147¹ in their lower position, a circuit is completed for the flow of simplex current between the entrance of the block and the balancing resistance 143 which has a negative phase relation to the loop circuit current of the block. In other words, if these currents are detected on the railway vehicle they may be applied to a relay to produce torque in a normal direction when passing through a clear block, in a reverse direction when passing through a caution block between the entrance end of such block and the balancing resistance 143, and cause deenergization of this relay when the vehicle moves in a caution block beyond the balancing resistance 143, because no simplex circuit current is present beyond this point under caution traffic conditions, and also assume the deenergized position when moving in an occupied block because even though simplex circuit current is present, loop circuit current is shunted by the train ahead.

There is also shown in Fig. 4 above the block N horizontal dotted lines 149, 150 and 151 indicating suitable permissive speed limits automatically imposed on the train respectively, under clear traffic conditions, as it enters the block N under caution conditions, and as it approaches the exit end of this block under caution conditions. Fig. 4 also shows a speed-distance curve 152 which may be said to be representative or typical of contemplated train performance. This illustration is for explanatory purposes primarily, and it should be understood that the speed limits selected and the shapes and the curves are merely representative.

Car-carried apparatus

Speed responsive device.—The car-carried apparatus shown in Fig. 4 includes a speed-responsive device G of the centrifugal type substantially the same as that shown in Fig. 3, except that the collar 71^a is provided with an external groove instead of a contact disk. A contact arm 153 is pivotally supported adjacent this speed-responsive device G and has a bifurcated extension engaging the groove of the collar 71^a, so that the arm 153 assumes a position depending on the speed of the train. Arranged to be engaged by this arm 153 are curved contact strips of different length, so that circuit connections are

made for different ranges of speed of the train.

Influence communicating means.—Supported by the locomotive and in front of the first axle thereof is a pair of influence receiving car elements LE, each of which comprises a core 154 of magnetic material having thereon a coil 155. These coils 155 are connected in series so that voltages induced therein due to currents flowing in the opposite direction in the two rails are cumulative. The circuit including these coils is connected to the input side of a loop circuit amplifying device LA, having its output leads connected to a winding 156 of a main car relay MR. This amplifying device LA includes suitable thermionic or vacuum tube amplifiers and associated devices of a suitable type familiar to those skilled in the art, and serves to magnify the feeble current detected by the elements LE. At another point on the locomotive, and preferably in the rear of the tender, is a simplex receiving element SE, which comprises a core 157 extending across both of the track rails, and which has a coil 158 connected to the input side of a simplex amplifying device SA, this device SA being similar to the device LA and having its output circuit connected to the other winding 159 of the main car relay MR.

Since the track or loop circuit is a reactive circuit and the simplex circuit is a resistive circuit, the currents flowing in these two circuits will be considerably displaced in phase; and if these currents are detected, amplified and applied to the relay MR, they cause this relay to produce a torque in a direction to close the contacts as shown, when the train is moving in a clear block, and produce a torque in the reverse direction when the simplex current is reversed.

The main car relay MR is a suitably constructed two-element alternating current relay which has its rotor or vane, constituting the movable or operating element, biased to a neutral or deenergized position by counterweights or equivalent means. The contacts of this relay MR are shown conventionally as swinging fingers arranged to cooperate with stationary contacts (shown as arrows) in the three different positions of the operating element of this relay. When the track rails are supplied with simplex and loop circuit currents having one phase relation, corresponding to clear traffic conditions, the contact fingers of the relay MR assume the left hand inclined position shown in full lines; when this phase relation is reversed to correspond with caution traffic conditions, these fingers swing to the other inclined position shown by dotted lines; and when either the simplex or the loop circuit current is cut off, corresponding to danger traffic conditions, one or the other of the field windings of the relay MR is deenergized and its contact fingers drop to the

biased position shown by vertical dotted lines.

Other detail features of the circuit arrangements and operation of the system of continuous inductive control between the track and a train are familiar to those skilled in the art and need not be described in detail.

Cab indicators.—In order to inform the engineer as to traffic conditions ahead, at a convenient place in the cab suitable signals are preferably used to show the position of the main car relay MR. In the particular arrangement shown, these signals comprise a green, a yellow and a red lamp which are illuminated to indicate clear, caution or danger conditions respectively by circuits which may readily be traced in the drawings.

Brake control apparatus.—Suitable means is employed to act upon the regular air-brake equipment of the locomotive or train and produce an automatic application of the brakes. The circuit organization shown in Fig. 4 provides for the automatic control of an electro-pneumatic valve EPV; and it should be understood that this valve acts in a suitable manner, whenever deenergized, to set into operation a device, such as the brake valve actuator of Fig. 2, which causes an automatic application of the brakes. The particular form of means controlled by the valve EPV for producing a brake application is not material; and this valve EPV may control an automatic brake application valve, such as described hereinafter in connection with other forms of the invention, as well as the brake valve actuator of Fig. 2, or in fact any suitable type of means acting upon the regular air brake system to produce an automatic brake application.

The arrangement of Fig. 4 is assumed to include contacts on the engineer's brake valve, as shown in Fig. 2, which are closed in the service or emergency position of said valve or its handle, together with means for closing contacts after a predetermined reduction has been made in the equalizing reservoir pressure, such as the arrangement of valves DV and RV, reservoir 55, piston 51, and contacts 53 and 54 shown in Fig. 2. For simplicity in illustration, it is assumed that such means responsive to a predetermined reduction in equalizing reservoir pressure will be of the form shown in Fig. 2; and in Fig. 4 is shown a contact disk 54¹ which is operated the same as the contact disk 54 in Fig. 2.

In Fig. 4, the penalty is assumed to consist in requiring the train to be stopped so that a reset switch RS, accessible only from the ground, may be operated. This reset switch is provided with two push buttons mechanically connected together but insulated from each other so that they are simultaneously operated.

Operation of Fig. 4

Under clear traffic conditions, both simplex and loop circuit currents of the normal

or positive polarity or phase relation are picked up and amplified on the train, and the contact fingers of the relay MR assume the full-line positions shown in Fig. 4, lighting the proceed or green lamp *g* (the circuit for which is obvious), and energizing the electro-pneumatic valve EPV by a circuit which may be traced as follows:—beginning at B, wire 160, push button 161 and its normally closed contact, wire 162, contact 163 of relay MR normal, wire 164, contact strip 165, arm 153, wires 166, 167 and 168, valve EPV, wires 169 and 170, normally closed contacts 171 of valve EPV, and wire 172 to C.

The length of the contact strip 165 is such that the arm 153 will not leave engagement therewith until the actual running speed of the train is above the selected maximum speed limit, indicated by the line 149, and assumed to be 65 miles per hour. At all speeds below this maximum of 65 miles per hour, and so long as clear traffic conditions prevail, the electro-pneumatic valve EPV is maintained energized by the circuit just traced.

Assuming the block N to be a caution block due to the presence of another train in the block O, the track relay 141¹ of the block O is deenergized and the phase relation of the simplex and loop circuit currents is reversed for the first part of the block N between the resistances 142 and 143, while the simplex circuit current is cut off for the last portion of the block N between the resistances 143 and 144. As the following train enters the caution block N, the car relay MR moves its contact fingers to the reverse position, on account of the reversed phase relation of the loop and simplex circuit currents picked up, amplified and supplied to its field windings 156 and 159. This reversal of the relay MR extinguishes the clear lamp *g* and lights the caution lamp *y*, and also shifts the energizing circuit for the valve EPV just traced through contact strip 165 over to the contact strip 178. The contact strip 178 is shorter, and the arm 153 remains in engagement therewith only so long as the speed of the train is below the sub-maximum or medium speed represented by the line 150 and assumed to be 40 miles per hour. Consequently, in order to maintain the electro-pneumatic valve EPV energized by this circuit, the speed of the train must be below this 40 miles per hour. As the train advances beyond the resistance 143 and fails to pick up simple circuit current, the contact fingers of the relay MR assume the middle deenergized position, shifting the circuit for the valve EPV over to wire 174 and through the shortest contact strip 179, corresponding to a minimum speed, indicated by the line 151 and assumed to be 20 miles per hour. At the same time the caution or yellow lamp

is extinguished and the danger or red lamp is lighted.

As the train advances into the block O, assumed to be still occupied, the contact fingers of the relay MR remain in their deenergized position, since the loop circuit current is cut off from the following train due to the presence of the other train ahead.

The foregoing is a brief description of a three-speed continuous inductive control system, employing the usual cab signals, and providing for a quick or abrupt change in speed limits from a maximum to a medium or sub-maximum, and to a minimum or low speed. It should be understood that this showing and description of this particular type of continuous inductive system is merely illustrative and that other well-known adaptations or modifications may be employed, using cams or equivalent means, such as shown in the patent to Simmen #1,150,309, August 17, 1915, or other delayed action means, for making a gradual change from the maximum to the medium and from the medium to the low speed limits, instead of an abrupt change. It is recognized that other substitutions or adaptations of means may be made in the form of speed control system to be used in connection with the subject matter of this invention; but in order to simplify the disclosure, no attempt is made to show the various adaptations and modifications that would have the characteristic features of the invention and come within its scope.

In the continuous inductive control system, the vehicle-carried apparatus is in continuous communication, so to speak, with the trackway equipment, and may respond instantaneously to any change in the track circuits or to the presence or absence of trains in the same block. In other words, any change in traffic conditions, either favorable or unfavorable, is immediately manifested upon the train by a change in the position of the contact fingers of the relay MR. Consequently, if a train is traveling in a caution block and the next block in advance becomes unoccupied, the relay MR assumes its normal condition, and the maximum speed limit is at once automatically reinstated. Similarly, if a train is traveling in a danger block and is in the rear of the balancing resistance 143, the removal of danger conditions by the closure of a switch, advance of the train ahead, or the like, results in the relay MR assuming its reversed or caution condition, changing the speed limit from the minimum to the sub-maximum or medium; but if the train in the danger block is ahead of the resistance 143, the advance of the train ahead into the next block in advance does not cause change of the relay MR, which remains in its deenergized condition and continues to enforce the minimum speed limit. Likewise, any unfavorable change in traffic conditions,

from clear to caution, or from either to danger, results in the relay MR assuming a corresponding condition and immediately imposing the corresponding speed limit. These features are characteristics of the type of continuous inductive control system shown and need not be elaborated upon.

Penalty and suppressing means.—The train may travel at all times without penalty so long as its speed is below the particular speed limit then in force. For instance, if the train enters the caution block N at a speed below the medium speed of 40 miles per hour, no action upon the part of the engineer is necessary, nor is there any penalty. Likewise, if the train reduces its speed below the minimum speed of 20 miles per hour before reaching the resistance 143, then no action by the engineer is necessary and there is no penalty.

It will be readily appreciated, however, that strict adherence to these maximum, medium and minimum speed limits, which are arbitrarily selected and automatically established, at all points along the railroad, in all blocks, on all grades, and on all trains of the same class (freight or passenger), will not permit the train to travel as rapidly at all times as safety would permit. To take a specific example, referring to the block N of Fig. 4, at the entrance to the block the speed of the train may safely be somewhat less than 65 miles per hour, providing a brake application is immediately initiated; and it is not necessary for the train to be at such a low speed as 40 miles per hour. For these reasons, one purpose of the invention is to make it possible for the train to be running at speeds in excess of the arbitrary speed limits, and at the same time provide for enforcement of vigilance.

Engineer not vigilant—penalty.—Let us assume that the train, with the parts of the car equipment as shown in Fig. 4, enters the block N while in the caution condition, and further assume that the engineer is asleep or negligent, and for some reason fails to observe the caution indication of the block signal Z or take the appropriate action in recognition of the caution indication of this signal. Also, assume that the speed of the train is somewhat less than its maximum speed limit of 65 miles per hour and above 40 miles per hour. When the train enters the block N and the car relay MR changes to the caution condition, the speed limit of 40 miles per hour is immediately put into effect: and since the speed of the train is assumed to be above this limit, and also remembering that the engineer is supposed to take no action, the electro-pneumatic valve EPV is deenergized, producing an automatic application of the brakes. The speed controlled energizing circuits for the valve EPV all include its own contacts 171 closed only

so long as this valve is energized. Consequently, upon deenergization of the valve EPV, contacts 171 open, and the only way this valve can again be energized is by operation of the reset switch RS.

Upon deenergization of the valve EPV and the resultant automatic brake application, the contact disk 54¹ will shift to its circuit closing position, provided the automatic brake applying means is of such character (see Fig. 2, for example) as to act upon the regular equalizing reservoir. With other types of brake applying means, the engineer must move his brake valve to the service position to close the contacts 44—47, in order to be able to reset the valve EPV. Assuming either the contacts 54¹, or the contacts 44—47 to be closed, then upon operation of the reset switch RS, a circuit is established for energizing the valve EPV as follows:—from B, wire 128, disk 54¹, wire 127 and 167 to wire 168, or from B, wire 180, contacts 44—47 and wire 121 to wire 168, thence through valve EPV, wires 169 and 175, push button 176 closed, and wire 177 to C.

The reset switch RS cannot be fastened down, because upon operation thereof the opening of the normally closed contacts of push button 161 cuts off energy from the relay contact finger 163, so that the valve EPV cannot be energized by any one of its regular speed controlled circuits. With the reset switch RS operated, the valve EPV can be maintained energized only so long as either the engineer's brake valve is in the service position so as to close contacts 44—47, or else the equalizing reservoir pressure is reduced so as to shift the contact disk 54¹ to its circuit closing position. Obviously, the train cannot proceed under these conditions, and any attempt to release the brakes merely brings the automatic brake control into effect. Consequently, the reset switch RS after each operation thereof must be restored to the normal position before the train can proceed.

The same operation is true on a change in the speed limit from the medium to the minimum, if the speed is excessive and the engineer is not vigilant.

Engineer vigilant—penalty suppressed.—

To avoid the penalty just described, if the engineer does not keep the running speed of his train below the speed limits set up, he must have his brake valve in the service position before the speed controlled circuits for the electro-pneumatic valve (through the contact strips 165, 178 and 179) are broken, that is, before the valve EPV becomes deenergized and opens its contacts 171. Assume that the engineer, recognizing the existence of danger and his excessive speed, places his brake valve in the service position before the valve EPV is deenergized on account of the excessive speed. Under these conditions an auxiliary circuit for main-

taining the valve EPV energized is established as follows:—commencing at B, wire 180, contacts 44—47, wires 121 and 168, valve EPV, wires 169 and 170, contacts 171 of valve EPV and wire 172 to C.

After the engineer has held his valve in the service position long enough to produce the required reduction for an effective brake application, in this instance determined by measurement of time, the contact disk 54¹ assumes the circuit closing position, and establishes an alternative multiple circuit, including wires 127 and 128, to maintain the valve EPV energized, so that the engineer's brake valve may be returned to the lap position. This expedient avoids useless waste of air that otherwise might be occasioned by requiring the engineer to keep his brake valve in the service position for an extended period.

So long as the speed of the train is above the existing speed limit, so that there is no circuit through any one of the speed contact strips 165, 178 and 179 capable of energizing the valve EPV, then the engineer must either have his brake valve in the service position, or must be maintaining a certain reduction in equalizing pressure. In short, the brakes must either be applying or must be held applied, meaning that the train is being slowed down by an effective manual brake application.

If the engineer should attempt to release the brakes while above the speed limit in force, the valve EPV is at once deenergized and brings into effect the automatic brake control apparatus, since the contacts 44—47 are open, the engineer's valve being in the release or running position, and the contact disk 54¹ is quickly opened by the improper movement of the engineer's valve to a release position. If the valve EPV governs a brake valve actuator, such as shown in Fig. 2, the deenergization of the valve EPV, upon attempt of the engineer to release the brakes, throws the engineer's brake valve back to the service position automatically in spite of the engineer, together with all the attending actions heretofore described. Likewise, if the valve EPV controls an automatic brake application valve, such as to be later described; this application valve will automatically maintain the brake application, and may bring about a still further reduction in brake pipe pressure, depending on its construction. In any event, the engineer's attempt to release the brakes is futile, and the deenergization of the valve EPV occurs so quickly that there is not sufficient time to bring about any actual release of the brakes.

One important and valuable characteristic feature of this arrangement will be recognized by reference to the performance curve 152 in Fig. 4 which shows the speed-distance curve along which the train may run without penalty, if the engineer is vigilant, and by

comparing the facility of train movement established by such curve with that existing if the train were obliged to enter the block at a speed below the medium speed limit of 40 miles per hour, indicated by the line 150. Assuming that the entrance speed of a train into a caution block is just a little below the normal clear running or maximum speed limit, it will be evident that this invention permits the train to advance with just as much facility as safety will permit, in spite of the fact that there is an abrupt change in speed limits. If the train should be entering the caution block or passing the corresponding control point at an intermediate speed between the maximum and the medium speed limit, the enforced manual brake application will, of course, bring about a reduction in speed somewhat earlier than is actually necessary for safety; but on account of the capability of the system of giving instantaneous release upon clearing up of traffic conditions, such premature reduction in speed will not ordinarily reduce the facility of train movement. If the train should enter the caution block at a low speed, as for example, when passing a signal that has changed from stop to caution, this train may accelerate up to the medium speed and advance with as much facility as safety permits up to the point where the further reduction from the medium to the minimum speed should be made. Other advantageous features of organization of Fig. 4 will be readily apparent in view of the foregoing disclosures.

Modification of Fig. 5

In connection with the matter of suppressing penalty or automatic brake valve operation, it is desirable, for reasons already explained to make provision for the closure of a contact, or perform an equivalent function, after a predetermined brake application has been made. In the modified arrangement of Fig. 5, certain contacts, shown as a contact disk 54² cooperating with stationary contacts indicated by arrows, are automatically closed after the brake pipe pressure has been reduced a certain amount. It will be readily appreciated that the intensity of brake application is reflected by the brake cylinder pressure. In the typical air-brake system, the brake cylinder pressure depends, among other things, upon the initial brake pipe pressure and upon the amount of reduction in brake pipe pressure. In the arrangement of Fig. 5, parts are organized to correspond to the auxiliary reservoir, triple valve, and brake cylinder of the car equipment, and these parts act automatically to close a contact after a certain pressure has been developed in the part corresponding to the brake cylinder.

Referring to Fig. 5, the outline of a suitable control valve CV is shown, which is

similar in construction and has the operating functions of the ordinary triple valve. One specific arrangement of such a control valve is specifically shown in Fig. 11 and is hereinafter described. In Fig. 5 is shown a spring air-switch 185 corresponding in many respects to the usual air brake cylinder in the way it is connected to the valve CV, and which air switch comprises an air-tight piston connected to the contact disk 54² and having its movement governed by pressure supplied from the control valve CV opposed by a compression spring. The volume of the cylinder with the contact disk 54² in its circuit closing position together with the volume in the connecting pipe, corresponds to the volume in the automatic brake cylinder with the regular piston displacement. A small reservoir 186 corresponds to the regular auxiliary reservoir and is of a volume to work properly with that of the air-switch 185. Normally, the brake pipe is connected to the reservoir 186, and the miniature brake cylinder of air-switch 185 is connected to atmosphere. As the brakes are applied by a reduction in brake pipe pressure, the piston and slide valve (to be later described) of the control valve CV shift, the same as in the regular triple valve, and close the exhaust of the air-switch 185 and connect the reservoir 186 to this air-switch. The parts then function in the same way as the regular car equipment to produce a pressure in the cylinder of the air-switch 185 corresponding to the amount of reduction in brake pipe pressure, and after the pressure in this cylinder has attained some predetermined value, say corresponding to a twenty pound reduction, the contact disk 54² is shifted to its circuit closing position.

It will be observed that this modified arrangement of Fig. 5 requires that the brake pipe pressure itself shall actually be reduced before the contacts 54² are closed. In another form to be later described (Figs. 11 and 11^a) these contacts are closed after a predetermined reduction has been made in equalizing reservoir pressure, using similar principles and a similar method of operation.

If the engineer attempts to release the brakes, as soon as the brake pipe pressure has been raised sufficiently to cause the triple valves on the cars to shift, the control valve EV also operates, venting the air-switch 185 to atmosphere and instantly opening the contacts 54². The engineer may make his applications in one or more stages, and the contact disk 54² will assume its circuit controlling position if the total reduction equals that required.

Modification of Fig. 6

Another means for automatically determining that the engineer has effected such control of the airbrake system as will insure an effective brake application of the desired in-

tensity, is shown in Fig. 6. As already stated, the engineer has done all that is necessary to manually apply the brakes as soon as he has brought about the proper reduction in the equalizing reservoir pressure. While the reduction in equalizing reservoir pressure might be measured by a single spring air-switch operable at a certain pressure, this arrangement would be accurate only if the normal running brake pipe pressure, and likewise equalizing reservoir pressure that corresponds thereto, are always the same. For instance, if the air-switch were designed to close at 50 lbs., it would close after a 20 lb. reduction in equalizing reservoir pressure, providing the initial or running brake pipe pressure were 70 lbs.; but if the brake pipe pressure were 90 lbs., then the air-switch would not close until after a reduction in the normal brake pipe pressure of 40 lbs. In practice the normal brake pipe pressure varies somewhat on different roads, on different locomotives, and also on the same locomotive at different times. For instance, a locomotive may be used at times in freight service and at other times in passenger service and the feed valve is adjusted correspondingly to give the brake pipe pressure suitable for freight and passenger service. Also, the feed valve is adjusted on some railroads to give different brake pipe pressures for level and grade work. Hence, it is desirable to provide a means, responsive to a predetermined reduction in equalizing reservoir pressure, which operates after such predetermined reduction irrespective of the initial or running brake pipe pressure.

In the specific arrangement shown in Fig. 6, a Bourdon tube 187 is connected to the equalizing reservoir; and the free end of this tube will move from right to left when the pressure in this reservoir is reduced. A suitable electro-magnet EM supports the free end of a link 188 having its other end pivotally connected to the free end of the Bourdon tube 187. Integral with the link 188 is a rack 188^a which is adapted to engage with a gear sector 189 if, and only if, the electro-magnet EM is energized. This gear sector 189 is normally held in one extreme position against a stop by a coil spring 190 and has a movable contact 54³ adapted to engage suitable stationary contacts connected thereto, for suppressing a penalty in the same manner as accomplished by contact 54 as heretofore described.

The particular electro-magnet EM shown comprises a back yoke of magnetic material having two cores 191 provided with extending pins 192 of non-magnetic material. The pins 192 guide the armature 193 which is connected to or integral with a slidable rod 194 and is held in its lower position by a compression spring 195. This electro-magnet EM is energized only if the engineer's brake valve BV is in the lap, service or emergency posi-

tion, that is, when the contacts 43—46 are closed.

Each time the engineer's brake valve is placed in the running or release position, the magnet EM is deenergized, thereby allowing the spring 190 to open the contacts 54³ and make the penalty suppressing means ineffective, and at the same time allowing the rack 188^a to assume a new initial position corresponding to and depending on the pressure to which the brake pipe is being recharged with the brake valve in such position. Let us assume that the engineer's brake valve is in the normal running position and that the feed valve is adjusted to deliver a pressure of 90 pounds. Let us now assume that the engineer moves his brake valve to the service position and keeps it there until the equalizing reservoir pressure has been reduced enough to cause a service brake application corresponding to, say a 20 lb. reduction. As soon as the engineer's valve is placed in the service position, the electro-magnet EM is energized, thus causing engagement of the rack 188^a with the sector 189. The gradual reduction in the equalizing reservoir pressure by reason of the position of the brake valve causes the contact 54³ to move toward the right, and it will reach the stationary contacts when a 20 lb. reduction has been made. The Bourdon tube 187 is so constructed that it gives the same increments of movement to the rack 188^a at all pressures for the same difference in pressure, suitable gearing or the like being used if necessary to secure such uniform motion. If now the engineer moves his valve to the lap position the circuit for the magnet EM remains closed and the contact 54³ is kept closed.

The contacts 54³ close only if a predetermined reduction in equalizing reservoir pressure has been made from normal after the engineer's brake valve has been in the running position. This is true regardless of whether the feed valve is set for 70 pounds or 90 pounds, since there is no cooperation between the rack 188^a and the sector 189 until the brake valve handle 37 is moved to the right of the running position, so that the contact 54³ is closed only after a full service brake application has been initiated by a predetermined reduction in equalizing reservoir pressure and so long as the brakes are not released.

In this modification of Fig. 6, the engineer may make his reduction in the equalizing reservoir pressure in one or more stages, and the contacts 54³ are closed after the total reduction has reached the amount selected. If the engineer should attempt to release the brakes after making either a partial or the full application required, the contacts 43—46 open the instant the engineer moves his brake valve to the running or release position, whereupon the electro-magnet EM is deenergized, the

bar 188 and the rack 188^a drop and release the sector 187, and the sector 189 is thrown by the spring 190 to the normal position shown, opening the contacts 54³ and inflicting the penalty, with the brake application automatically continued or a greater reduction made, depending on the type of automatic brake control apparatus.

Modified penalty suppressing means (Figs. 7 and 8)

Another way of determining when a full service brake application has been initiated consists in the provision of a closed chamber, in which the brake pipe pressure existing just before the brake valve is moved to the right hand of the running position is trapped, which is then compared with the pressure existing in the equalizing reservoir. This may be accomplished in various ways, one of which is illustrated in Fig. 7. In the arrangement shown in Fig. 7, the normal running brake pipe pressure is trapped by apparatus operated entirely pneumatically.

In the well-known engine-tender or ET equipment, the pump governor which controls the air pressure automatically, includes an excess pressure head and a maximum pressure head. In the standard ET equipment this excess pressure head pipe 198 is connected to the hole 196 in the valve seat of the engineer's brake valve, and this hole is in communication with the cavity 197 when the brake valve is in either the release, the running or the holding position; this cavity 197 is in constant communication with main reservoir pressure and this pipe is blanked or not connected to anything, when the valve is in any other position. In order to be sure and release the pressure from the pipe 198 (excess pressure head pipe) for all positions, an additional cavity 199 has been provided in the standard engineer's brake valve to connect this pipe to atmosphere when the brake valve is in either the lap, the service or the emergency position. This cavity 199 is in constant communication with the center exhaust opening of the engineer's brake valve.

In the particular arrangement shown, a spring pressure device PD is used to compare trapped brake pipe pressure with equalizing reservoir pressure, so that a predetermined reduction in the equalizing reservoir pressure below that which existed in the brake pipe before such reduction was made can be determined. The right hand portion of this spring pressure device PD comprises a casing divided into three chambers or compartments 200, 201 and 202 which are connected to a capacity reservoir 203, the brake pipe BP, and the excess pressure head pipe 198 respectively. The compartments 200 and 201 are separated by a valve 204 which is open when there is pressure in the excess pressure head pipe (that is, with en-

gineer's brake valve in release, running or holding position) by reason of the diaphragm 205 acting against this valve 204 in opposition to the force of the compression spring 206 having its opposite end resting against the partition 207 in the compartment 200. The passage for the air through this valve includes the hole 218 extending axially through the valve 204 to the cross-ducts 219. Each time the pipe 198 is vented to atmosphere the valve 204 is closed, thereby trapping the existing brake pipe pressure in the capacity reservoir 203. The left hand side of the compartment 200 is provided with a similar diaphragm 208 which exerts a force against the cross piece 209 fastened to the contact operator 217 corresponding to the brake pipe pressure trapped in this chamber 200.

The left hand portion of this spring pressure device PD comprises a chamber 210 having a diaphragm 211 acting against the other end of the cross piece 209. In addition to this pressure acting on the cross piece 209, due to the pressure acting on the diaphragm 211, is the pressure of a compression spring 212 having its other end supported in an adjustable block 213. The effective pressure of this spring 212 may be changed at will by removing the cap 214 and applying a wrench to the block 213 which is threaded in the chamber 210. This chamber 210 is connected by a pipe 215 to the usual equalizing reservoir of the braking system.

It should be noted that the spring 212 is maintained in proper aligned relation and is slidably positioned by a piston or sliding block 216 acting directly against the diaphragm 211. Also the diaphragms 202 and 211 are provided with stops to limit their movement away from the chambers with which they are associated, this provision being made to protect them in case excessive pressure is applied thereto. In practice the spring 212 is preferably adjusted to a value to produce a force corresponding to 20 lbs. per square inch acting on the diaphragm 208, so that the pressure existing in the capacity reservoir 203 must be 20 lbs. above that existing in the equalizing reservoir in order to cause closure of the contacts 54⁴ by movement of the contact operator 217.

Let us assume that the handle of the engineer's brake valve BV is in the normal running position and that the engineer has moved it to the service position. As soon as it reaches the lap position and so long as it remains there, or in the service or emergency position, the excess pressure pipe 198 is discharged to atmosphere through the auxiliary cavity 199 provided in the rotary brake valve. This permits the diaphragm 205 to be moved to the right by action of the brake pipe pressure and the spring 206, so that the valve 204 seats against the valve seat and cuts off com-

munication between compartments 201 and 200, thereby trapping the then existing brake pipe pressure in the capacity reservoir 203 and the chamber 200 until the brake valve is moved to the left of the lap position. With the engineer's brake valve in the service position, the equalizing reservoir is vented to atmosphere in the usual manner; and if the pressure in this reservoir and that existing in the chamber 210 is reduced to a value about 20 pounds less than that trapped in the chamber 200 and capacity reservoir 203, the contact operator 217 is moved to the left far enough to close the contacts 54⁴. This closure of contacts 54⁴ may be used to prevent the infliction of a penalty in the same manner as contacts 54 and 54¹; and this arrangement is applicable to any of the systems heretofore described. For example, referring to Fig. 3, the contact disks 53 and 54 operated by the piston 51 of Fig. 2 may be replaced by the contacts 54⁴ operated by the device PD of Fig. 7, giving the same result, the only difference being that in one case the existence of the desired reduction in equalizing reservoir pressure is determined by the interval of time that the engineer's brake valve is in the service position, and in the other case by the difference in the normal running equalizing reservoir pressure and its reduced pressure. Similarly, the modified construction of Fig. 7 may be used in the arrangement of Fig. 4 to take the place of the contact disk 54¹.

The modified construction of Fig. 7 permits the engineer to make his reduction in one or more stages prior to exceeding the permissive speed limit. The amount of reduction required in equalizing reservoir pressure is the same, irrespective of the setting of the feed valve, or the normal running brake pipe pressure, being in fact a predetermined reduction in the equalizing reservoir and brake pipe pressure existing at the time the manual brake application is initiated.

If the engineer should attempt to release the brakes after making a partial or full reduction in the equalizing reservoir pressure, upon movement of the engineer's brake valve to the release or running position, the pipe 198 is charged and the valve 204 opens, connecting the capacity reservoir 203 to the then lower brake pipe pressure. The pressure in the reservoir 203 at once drops; and the contacts 54⁴ if closed at once open, and if not closed, the engineer is obliged to bring about a still greater reduction to bring about their closure, that is, 20 lbs. less than the just previous reduced brake pipe pressure. If the speed is excessive at the time the engineer attempts to release the brakes, the opening of the contacts 54⁴, together with the fact that the engineer's brake valve is in the service position, results in the enforcement of a penalty and continuation of the braking by

automatic control. In this way the engineer is deterred from attempting to release the brakes, and the safety of train movement is assured by taking over the control of the brakes automatically.

In the particular modification shown in Fig. 7, the contacts 54⁴ are used to establish an auxiliary energizing circuit for the valve EPV which controls a brake valve actuator, such as shown in Fig. 2. Presuming that this scheme is applied to the type of system shown in Fig. 3, when the train exceeds the speed limit at a pair of track elements, the valve EPV is deenergized and the engineer's brake valve is automatically shifted to the service position, unless prior to exceeding this speed limit, the engineer had brought about a full service application sufficient to close the contacts 54⁴. Assuming that the engineer had his brake valve in the service position prior to exceeding the speed limit, so as to suppress the penalty as already explained in connection with Fig. 3, but not soon enough to bring about sufficient reduction to close the contacts 54⁴, the valve EPV would be deenergized and the engineer's brake valve automatically operated. The engineer could follow the automatic movement of the rotary valve by the handle 37 (see Fig. 2); and as soon as the required reduction in equalizing reservoir pressure had been made and the contacts 54⁴ had closed to energize the valve EPV, then upon retraction of the actuator plate AP to its normal position, the engineer would be able to latch his handle to the rotary valve and return the rotary valve to the lap position. In short, while the device shown in Fig. 7 for actuating the contacts 54⁴ does not act automatically to limit the amount of reduction occurring upon automatic brake control, it permits the engineer to do so in much the same way as in the arrangement shown in Fig. 3. In order to give the engineer adequate information as to when he may lap his valve after an automatic brake application, the actuator plate AP has an indicator disc 57 riveted thereto which preferably is distinctively colored, and is visible through the hole 58 only when the rack 33 and plate AP are in their normal inactive position. If the engineer should attempt to release the brakes after getting the rotary valve back to the lap position, the contacts 54⁴ would at once open, as previously explained, deenergizing the valve EPV (assuming the speed to be excessive) and forcibly putting the rotary valve back to the service position in spite of the engineer's efforts. Also, the penalty will then be imposed and an over-reduction required, for reasons previously explained, thereby constituting an additional deterrent to discourage the engineer from attempting to defeat the purposes of the invention.

The spring pressure device PD of Fig. 7 may be used simply as a predetermined reduc-

tion cut-off device, if desired, irrespective of the suppressing of penalty, that is, providing for the re-energization of the valve EPV after automatic control thereof to permit the engineer to lap his valve.

Modified continuous inductive system

A modified form of a continuous inductive control system is shown in Fig. 9, and is conveniently referred to as a two-position system, giving two indications aboard the train, corresponding to signalling or train control current on and current off. Such two indications or controls permit setting up automatically two different speed limits, a maximum and a minimum.

One way in which such a two-position system may be organized is shown in Fig. 9. In series with the track battery 3 at the exit end of each block is the secondary of a transformer 220, the primary of which is connected across an alternating current transmission line 221, if the track relay 4 of the block next in advance is picked up. Consequently, there is impressed across the track rails of each block at the exit end thereof under clear traffic conditions both the direct current track circuit voltage and the alternating current signalling voltage; and when a train enters a block under such clear traffic conditions, there is alternating signalling current flowing in track rails ahead of its first pair of wheels and axles, and this current may be picked up and amplified. Under caution traffic conditions, that is, with the block next in advance occupied, the alternating signalling current is cut off; and similarly if the block is occupied by another train ahead in this same block, the signalling current is cut off from the following train due to the shunting action of the wheels and axles of the train ahead. The inherent impedance of the track relay 4 prevents objectionable flow of alternating current through its windings. For alternating current track circuits the signalling or train control current has a special frequency different from the track circuit current frequency different from the track circuit current frequency. This is necessary because it is impossible to use the regular alternating track circuit current for train control purposes in such two-position system, inasmuch as such track circuit current cannot be cut off of the first block in the rear of an occupied block without also effecting de-energization of the track relay of the next, or second block, in the rear of such occupied block, and so on, ad infinitum, or at least to the beginning of equipped territory.

The locomotive or motor car at the head of the train carries two loop circuit receiving elements LE above the track rails in front of its first pair of wheels and axles, and the windings of these elements are connected in series. The induced voltage is amplified by

a suitable amplifier LA, and also preferably rectified, and is applied to a two-position direct current car relay LR. Under clear traffic conditions, this relay LR is energized, but under either caution or danger traffic conditions, it is deenergized.

Such a two-position system of inductive continuous control may obviously be employed in connection with the car equipment shown in Fig. 4, in lieu of the three-position system shown, the difference being that instead of three speed limits there will be only two speed limits.

Modification of Fig. 10

In Fig. 10 is shown a modified form of brake control apparatus and penalty suppressing means in which the intensity of the brake application needed to suppress the penalty depends on how much the speed is excessive. In the modifications heretofore described, a manual brake application of the same intensity as the automatic brake application, for instance a full service application, is necessary to suppress the penalty; and this is true whether the speed of the train is only a little above the safe permissive speed limit or a great deal above this speed limit. For example, referring to Fig. 4, the same application to suppress the penalty is necessary whether the train enters the caution block at 60 miles per hour and follows the curve 152, or enters at 45 miles per hour. In some cases, particularly for freight or tonnage trains. It is desirable to arrange the penalty suppressing means such that the brake application required is no more than what is necessary for safety, so that if the speed of the train is relatively low, it may proceed without penalty under a partial brake application made manually.

Also, in the forms of the invention heretofore disclosed, the same penalty is imposed for exceeding the maximum speed limit under clear traffic conditions as for exceeding the caution speed limit. On account of this penalty for exceeding the maximum speed limit, the engineer in practice is likely to keep his normal running speed well below the speed limit; yet it is evident that the train can advance over the road under clear signals with safety at speeds just below the maximum speed limit. While the maximum speed limit may be eliminated, it is considered desirable to maintain such a maximum speed limit for most operating conditions; but to facilitate train movement under clear signal, it is thought best to omit the penalty for exceeding the maximum speed limit and retain it only for the caution speed limits.

These features have, for sake of simplicity, been shown in Figs. 9 and 10 in conjunction with a two-position continuous inductive control system; but it will be observed that

this particular form of control is not essential.

Referring to Fig. 10, the car relay LR is controlled in the manner indicated in Fig. 9. The engineer's brake valve is provided with contacts 43—46 and 44—47, the same as before described. The valve EPV controls a brake valve actuator or equivalent automatic brake applying means. A speed-responsive device G, driven from the car wheels, moves an arm 153 to different positions in accordance with the actual running speed of the vehicle; and contact strips 236, 247 and 250 engage the arm 153 to open and close circuits for different running speeds. Assuming a maximum speed limit of 70 miles per hour, and a minimum speed limit of 20 miles per hour, the arm 153 engages the strip 236 from zero speed to 70 miles per hour, the strip 245 from 60 to 65 up to 75 or 80 miles per hour, the strip 247 from zero to 20 miles per hour, and the strip 250 for 2 miles an hour or under, i. e., substantially zero speed.

Arranged to electrically contact in a suitable manner with the end of the arm 153 is a curved arm or cam member 259 insulated and pivotally supported as shown. This cam member 259 is connected to a piston 258, and is worked back and forth to correspond with the position of this piston. The piston 258 has an air-tight fit in a cylinder 257, one end of which is connected to the equalizing reservoir, and the other end to atmosphere through clearance around the piston rod. Acting on the right-hand side of the piston 258 is a compression coil spring 256.

Referring to the modification shown in Fig. 10, the parts are shown in the normal position. The penalty relay PR is normally maintained energized through a stick circuit which may be traced as follows:—beginning at the terminal B of a battery, wire 226, front contact 227 of the EPV, wire 228, front contact 229 of the penalty relay PR, wires 230 and 231, winding of the penalty relay PR, wire 232 back to common return wire C.

Under the clear traffic conditions assumed, with the car relay LR energized and the penalty relay PR in its energized position, the valve EPV is maintained energized through the following circuit:—beginning at the terminal B, wire 235, contact 153, of the governor G, contact segment 236, wire 237, front contact 238 of the penalty relay PR, wire 239, front contact 240 of the relay LR, wires 241 and 242, winding of the EPV, wire 243, back to common return wire C. With the device EPV in its energized position, the brakes are entirely under the control of the engineer. The clear or green cab signal *g* is lighted by a circuit that will be obvious.

Assume that the engineer exceeds the maximum speed limit of, say, 70 miles per hour, that is, moves at a speed so that the contact

arm 153 moves entirely off of the segment 236 and thereby deenergizes the device EPV. The contact arm 153 of the governor G engages the stationary contact strip 245 before it disengages the contact strip 236, so that the penalty relay PR is held up by another circuit as follows:—beginning at terminal B, wire 235, contact arm 153, contact segment 245, wire 246, front contact 229 of the penalty relay PR, wires 230 and 231, winding of the relay PR, wire 232, back to common return wire C. By reason of this auxiliary circuit for the penalty relay PR, this relay is maintained energized even though the EPV is deenergized, so that the engineer is not penalized when he exceeds the maximum speed limit under clear traffic conditions assumed to be about 70 miles per hour. As soon as the speed is reduced below 70 miles per hour, the device EPV is again picked up and the brakes may be thereafter released by the engineer, and a slight further reduction in the speed again opens the auxiliary circuit just mentioned.

Let us assume that the train in question is just about to enter the block V, when the block W is occupied by another train, and that the train in question enters the block V when its speed is above the minimum speed of 20 miles per hour. As the train enters the block V, the loop circuit relay LR is deenergized, because no alternating current is present in the block V. As soon as the loop circuit relay LR assumes its deenergized position, the green or clear lamp *g* is extinguished and the red or danger lamp *r* is energized and the permissive speed is abruptly reduced to 20 miles per hour, and the circuit for the EPV heretofore traced is interrupted. Consequently an automatic brake application takes place because the 20 mile per hour circuit, which may be traced as follows, is not yet completed:—beginning at the terminal B, wire 235, contact arm 153, contact segment 247, wires 248 and 242, winding of the EPV, wire 243, back to common return wire C. As the device EPV assumes its deenergized position, the stick circuit for the penalty relay PR heretofore traced is broken, and this relay assumes its deenergized position, so that, even if traffic conditions ahead should immediately clear up, the device EPV would not pick up, because its clear or maximum speed circuit is broken at the front contact 238 of the relay PR. In other words, the engineer must be penalized before he can again travel at a speed in excess of 20 miles per hour, this penalty consisting in requiring the engineer to reduce the speed substantially to zero, whereupon a pick up circuit for the penalty relay which may be traced as follows is completed:—beginning at the terminal B, wire 235, contact arm 153, 2 M. P. H. contact segment 250, wires 251 and 231, winding of the penalty relay PR, wire 232, back to common

return wire C. As soon as this penalty relay PR picks up, the contact 238 is closed, and if traffic conditions ahead have cleared up in the meantime, the loop relay LR assumes its energized position, thereby changing the cab indication from red to green and completing the high speed circuit for the device EPV. With the device EPV in its energized position, the stick circuit for the penalty relay PR is again completed, so that, the train may again proceed in accordance with traffic conditions ahead.

It should specially be noted that, after the EPV is de-energized because the train has exceeded the caution speed limit, a penalty is inflicted upon the engineer consisting in requiring the train to be brought substantially to a stop before he can again allow the train to proceed in excess of 20 miles per hour, but that he may travel at any speed less than 20 miles per hour thereafter as long as he wishes. After he brings the train to a stop he may thereafter again travel at 70 miles per hour provided traffic conditions are clear. This manner of inflicting a penalty permits the engineer to take the penalty at a time when it least interferes with the movement of other trains, for instance, if the train is just about to pass a clear interlocking point the taking of the penalty by the engineer may be postponed until he has passed such point.

Let us assume that the train in question is entering the block V when the block W is occupied. The speed at which the train may enter this caution block V may be different under different conditions. The train may be traveling at the maximum speed limit of about 70 miles per hour, or for some reason the train may not have attained its maximum speed and may enter this caution block at some lower speed, such as 60 miles per hour, or 50 miles per hour, or even 40 miles per hour. It will be clear that the interests of safety are satisfied if the train is brought to a certain low or minimum speed by the time it reaches the end of this caution block. If the train enters the caution block at the maximum speed, a full service application is necessary to make a timely reduction in its speed, as indicated by the performance curve 260. However, if the entrance speed is lower, say 60 miles per hour, a lighter brake application will serve to reduce the speed to the required minimum in the available distance, as shown by the curve 261; and the same is true for still lower speeds, as shown by the curves 262 and 263 for 50 and 40 miles per hour. In short, the intensity of the brake application necessary to control the train safely is variable dependent upon the entrance speed; and since the manual brake application needed to justify suppression of the penalty does not have to be any greater than that required for safety, it becomes expedient to make the intensity of such suppressing

manual brake application dependent upon the entrance speed.

Referring to Fig. 10, in order to explain how this desirable result is obtained by the particular apparatus illustrated, let us first assume that the train enters the caution block V at its maximum speed of 70 miles per hour. Let us further assume that the engineer in obedience to the caution indication of signal Z initiates a service brake application just before entering the block V. To make such a brake application the engineer moves his brake valve to the service position, whereby the following circuit for the EPV is completed:—beginning at the terminal B, wire 253, contacts 44—47 of the engineer's brake valve BV, resistance 234, wires 254 and 242, winding of the EPV, wire 243, back to common return wire C, so that the device EPV is held up at least while the brake valve is in the brake applying position. If the engineer keeps his brake valve in such a position until a full service brake application has been initiated, the pressure in the equalizing reservoir is reduced to an extent that the spring 256 in the cylinder 257 moves the piston 258 to the left a distance where the contact arm 259 is engaged by the contact arm 153 for all speed positions below 70 miles per hour. Consequently the device EPV will remain energized, even though the engineer laps his valve, through the following circuit:—wire 235, contact arm 153, curved contact 259, wire 223, signal lamp 233, contacts 43—46 (closed in lap, service and emergency) wires 224 and 242, winding of the EPV back to common return wire C. The speed of the train is reduced safely as indicated by the speed-distance curve 260 in Fig. 9 of the drawings.

Since the device EPV, and consequently the penalty relay PR, have not been de-energized no penalty is inflicted upon the engineer, although he has exceeded the permissive speed limit of 20 miles per hour when passing through the block V under caution traffic conditions. As soon as the speed has been reduced below this value of 20 miles per hour, the contact arm 153 engages the contact segment 247, and the EPV is independently held up by a circuit including this contact segment 247; and the engineer may release the brakes and proceed at this speed limit.

It should be noted that the engineer is advised that he has made an adequate reduction in equalizing reservoir pressure as soon as contacts 153 and 259 get into contacting relationship by the illumination of signal lamp 233, this lamp being lighted by reason of the potential drop across resistance 234 so long as the engineers brake valve remains in a brake applying position and by reason of the energizing current flowing through the device EPV when the brake valve is re-

turned to the lap position. This signal lamp 233 also advises the engineer when he may release the brakes as a result of having reduced the speed to less than 20 miles per hour, since this lamp is then extinguished by being shunted by the wire 248 and contact 247. This lamp 233 is also extinguished as soon as traffic conditions change to clear by being shunted by contact 236, wire 237, contact 238, wire 239, contact 240 and wire 241 (assuming the train is moving in a caution block with the device EPV held up by an anticipatory brake application); and the engineer may determine whether the extinguishing of lamp 233 is due to a reduction in the speed of the train below 20 miles per hour or the clearing up of traffic conditions ahead by noting the indicating condition of cab signals *g* and *r*.

Let us now assume that the train is entering the block V under the same (caution) traffic conditions while traveling at a lower speed of 60 miles per hour. In this case the engineer need not make a full service brake application, for all that is necessary is the initiating of a brake application of a degree sufficient to cause the curved contact arm 259 to be engaged by the contact arm 153 at a speed of 60 miles per hour, instead of causing engagement of these contacts 153 and 259 at 70 miles per hour as was true in the previous case. With a brake application of this value effective the train will slow down as indicated by the speed-distance curve 261. The brakes may be released as soon as the speed is less than 20 miles per hour, without the infliction of an automatic brake application and associated penalty.

When the train enters the block V under speeds of 50 and 40 miles per hour respectively, and the engineer makes a brake application just sufficient to avoid the penalty, the train will assume speeds at various points in the block as indicated by the curves 262 and 263, respectively.

As will appear from the curves 260 to 263 inclusive the degree of brake application insisted upon in order to prevent the penalty from being inflicted is such, that the train is not brought to the danger control speed of 20 miles per hour unnecessarily quickly and that this low speed limit is reached near the end of the block in each case. This is done in order to facilitate the movement of traffic as much as possible and is accomplished by making the engaging edge of the contact arm 259 of the proper shape, so that engagement of this arm with the end of the contact arm 153 occurs at an equalizing reservoir pressure reduction which causes a brake application of sufficient intensity to bring about the required speed reduction. It is of course assumed, in the particular arrangement shown, that the brake pipe is recharged to a certain value, that is to the same feed valve pressure, each time the brakes are released,

so that equalizing reservoir pressure below this value indicates the degree of brake application initiated. If desired, the devices shown in Figs. 5, 6 and 7 may be used (see Fig. 11) for determining the position of the curved contact 259, and in this event this contact will always precisely indicate the degree of brake application initiated or effective irrespective of variations in initial brake pipe pressure.

It should be noted that the penalty preventing circuit just traced and including the contacts 153 and 259 also includes the contacts 43—46 on the engineer's valve closed when this valve is in either the lap, service or emergency position. These brake valve contacts 43—46 are included in this circuit so that the engineer is unable to release the brakes while the EPV is held up by this circuit. A full release of the brakes would not be possible, even though this contact were omitted, because the EPV would be deenergized by breaking of the penalty preventing circuit at the contacts 153—259 as soon as the equalizing reservoir became recharged. The system is, however, preferably constructed as shown, so that the brake application initiated at the entrance of the block must be maintained; but if desired, the valve contacts 43—46 may be omitted, in which event a stronger brake application must be insisted upon at the entrance of a block for the same entrance speed and other conditions, otherwise safety might be violated on account of the engineer's power to make a partial release of the brakes while following the performance curves 260 to 263 of Fig. 9, and the possibility that the train might dangerously over-run such performance curve before the automatic brake application could come into effect.

It is thus noted that the employment of a penalty suppressing means as in Fig. 10, which takes into consideration the speed of the train at the time the brake application is made, facilitates train movement in that it allows the train to move at a higher rate of speed in the latter part of the block, when entering the block under certain speeds as indicated by curves 260—263; than would be true if a full service brake application were required to avoid the penalty. The dot-and-dash curve 264 roughly illustrates the speed of the train at various points in a block when it enters at a speed of 40 miles per hour with a full service brake application effective. In other words, the relation between the curves 263 and 264 shows the advantage of a penalty suppressing means such as shown in Fig. 10 over that shown in Figs. 2, 3, 4, 5, 6 and 7.

Intermediate release of speed restrictions is of course afforded in a caution block as soon as traffic conditions ahead clear up; and the engineer will be informed by a change in the cab signals *g* and *r*, so that he may again

proceed unrestricted as discussed more in detail in connection with Fig. 4.

Modified penalty suppressing means of Fig. 11

In Fig. 11 has been shown a penalty suppressing means for suppressing penalty to an extent depending on the speed of the train similar to that shown in Fig. 10 which employs means for determining the extent of a brake application similar to that shown in Fig. 5, that is, employs a miniature brake cylinder in which pressure exists corresponding to that existing in the brake cylinders on the train, which is controlled by a control valve similar to a triple valve. In the arrangement shown in Fig. 11, however, this control valve CV is connected directly to the equalizing reservoir instead of the brake pipe as shown in Fig. 5. This is done so that the pressure in the miniature brake cylinder reflects equalizing reservoir pressure rather than brake pipe pressure. It takes a period of time for the brake pipe pressure to be reduced to correspond to equalizing reservoir pressure, depending on the length of the train; and since the engineer has done all that is necessary by reducing equalizing reservoir pressure to the required amount, it is not necessary to wait for the brake pipe pressure to drop before allowing the engineer to lap his valve.

This control valve CV comprises a piston chamber 266, in which an air-tight piston 267 for operating a slide valve 268 is adapted to move. The slide valve 268 end of this piston extends into the chamber 269 which is connected to a miniature auxiliary reservoir 270. In the normal position of this control valve CV, as shown, the chambers 266 and 269 are connected together through a feed groove 271 extending around the piston 269; and the various chambers are normally at equalizing reservoir pressure. The miniature brake cylinder 272 is connected to atmosphere through the exhaust port 273 under normal conditions, as shown.

Let us assume that the pressure in the equalizing reservoir, chambers 276 and 269, and in the miniature auxiliary reservoir is about 90 pounds per square inch, and that the engineer moves his brake valve to the service position for 6 or 7 seconds, thereby venting the equalizing reservoir to about 70 pounds. As soon as the equalizing reservoir pressure drops, the piston 267 moves toward the right, blanking the feed groove 271, so that chambers 276 and 269 are no longer in communication. Movement of the piston 267 further toward the right causes the small slide valve 275 to move off of port 276; and when this piston 267 assumes its extreme right hand position, the miniature brake cylinder 272 is connected to the miniature auxiliary reservoir through the port 276. This causes air to flow from the

miniature auxiliary reservoir to the brake cylinder, thereby reducing the pressure on the left side of piston 267. As soon as the pressure on the left side of piston 267 is reduced to a little less than that of the equalizing reservoir, the piston 267 moves toward the left far enough to cause the small slide valve 275 to block the port 276, so that no further flow of air is permitted. This position of the control valve CV is called the lap position, since in this position all of the ports are blocked. By reason of the pressure existing in the miniature brake cylinder 273, as a result of a service brake application, the curved contact 259 assumes a position to engage the contact arm 153 at a speed of 70 miles per hour or less, the spring 278 being of the proper strength to accomplish this end.

If the engineer releases the brakes by moving his brake valve to the running or release position, the pressure in the equalizing reservoir is increased and causes the piston 267 to move to the left, again connecting the miniature brake cylinder 272 to atmosphere through the exhaust port 273, and again recharging the miniature auxiliary reservoir 270 to the pressure of the equalizing reservoir through the feed groove 271.

It is thus noted that the control valve CV functions very much like the triple valve of the usual air brake system, and that the miniature brake cylinder pressure corresponds to that of the usual car brake cylinder, but that this pressure exists before that in the usual brake cylinder, because it is controlled directly by the equalizing reservoir instead of being controlled by the brake pipe. The pressure in the miniature brake cylinder 272 corresponds very closely to what actually exists eventually in the brake cylinders on the train due to the reduction in equalizing reservoir pressure that has been made; and this is true irrespective of the initial brake pipe pressure.

With respect to the accuracy of this construction, it is of course, evident that the spring 278 is compressed under the varying pressures, so that there is a change in the volume of the cylinder 272 at the left hand side of the piston 274 in this cylinder 272; whereas in the regular car brake cylinder, the volume behind the piston is theoretically the same, with a fixed adjustment of piston travel, regardless of the pressure in the cylinder. The movement of the piston 267, required to move the arm 259 throughout its operating range, may, however, be made small and so that the position assumed by the arm 259 corresponds very closely to the amount of braking effort actually existent. Arrangements may be made in practice, if desired, to give the piston 274 a free travel before engaging the spring 278 to correspond with the free piston travel in the regular car brake cylinder.

The air-switch arrangement of Fig. 5 may be used with the control valve CV connected to the equalizing reservoir instead of to the brake pipe, by merely making the piston of the brake cylinder operate an air-switch instead of the arm 259, as shown in Fig. 11^a. In this modification of Fig. 11^a, the strength of the spring 278, together with the change in volume on the left hand side of the piston, is so selected that the piston will not move out far enough to put the contact disk 54⁵ in its circuit closing position until some predetermined reduction in equalizing reservoir pressure has been made. It will be evident that such a modified arrangement has advantages over what is disclosed in Fig. 5, in that the penalty or operation is suppressed as soon as the engineer has made the required reduction in equalizing reservoir pressure, and the engineer may lap his valve at that time instead of being obliged to keep his brake valve in the service position until the brake pipe pressure itself has fallen to a certain value. In one case the resultant brake pipe pressure is something definite and corresponds to the reduced equalizing reservoir pressure; whereas in the other case (Fig. 5), the resultant in brake pipe pressure will be somewhat lower than the required amount, depending upon the length of the train, inasmuch as the engineer is obliged to keep his brake valve in the service position until the brake pipe pressure has fallen to the selected value, and in doing so will naturally over-reduce the equalizing reservoir, depending upon how slowly the brake pipe reduction follows that of the equalizing reservoir.

Modification of Fig. 12

For various reasons, some of which already have been given, it is desirable to have the automatic brake control apparatus operate each time the speed of the train is excessive regardless of whether or not the brakes have been applied manually. For one thing, if the automatic brake control apparatus operates each time the speed is excessive, the engineer is able to note and report failure of operation of this apparatus, and may also take special precaution in running his train when he has noted failure of response of the automatic brake control apparatus. Also, apparatus of the pneumatic type is more apt to stick or fail to operate if it is kept inactive for a long time, than if it is kept in good working order by occasional operation; and such apparatus is more often found out of order by reason of insufficient usage rather than by excessive usage. The failure of operation of pneumatic apparatus is largely due to the drying up and hardening of oil, plunger gaskets and other parts, or to the accumulation of dirt, rust, moisture, and the like, all of which may be avoided if the parts are operated frequently.

For reasons previously explained, it is desirable to have a limited amount of reduction in brake pipe pressure for automatic braking. Also, if the system is so organized that the automatic brake applying means operates each time the speed is excessive, automatic venting of the brake pipe will occur simultaneously with manual venting, unless the engineer has made manually the required full reduction previously; and it is important to construct the apparatus such that there are no objectionable results occurring from such simultaneous venting. Also, in those instances where the engineer has been vigilant, there will be more or less manual reduction in the normal brake pipe pressure existent at the time the automatic brake applying means starts to function; and to avoid useless waste of air, the automatic brake applying means should cut off and stop venting at the same point as it would have done had there been no previous manual reduction. Finally, the manual reduction in brake pipe pressure required to suppress the penalty, as well as the automatic reduction, should be uniform and approximately the same in amount, regardless of the variations in the normal running brake pipe pressure which will occur in practice due to changing of the feed valve adjustment for any reason. For the purposes of explanation, a full service application is presumed, corresponding to full equalization of auxiliary reservoir and brake cylinder pressure; and the existence of such reduction, independent of initial brake pipe pressure, is best determined by ratios or percentages, inasmuch as this more truly represents the existence of a reduction to full equalization than a spring device or other means responding to a fixed difference in pressure.

In the arrangement shown in Fig. 12, the automatic operation of the brake applying apparatus is not suppressed, but this apparatus is operated each time the speed of the train is excessive, regardless of whether a manual brake application has been started or is fully effective. In the arrangement shown, the automatic brake applying means is a separate device independent of the engineer's brake valve, which includes a predetermined reduction device including two reservoirs, one of which is normally charged to brake pipe pressure, and the other of which is normally connected to atmosphere. When this apparatus is initiated, these two reservoirs are placed into communication, so that the pressures in these reservoirs equalize and determine the pressure to which the brake pipe shall eventually be vented. In the particular arrangement shown, the normally charged reservoir is connected to the brake pipe only when the brake pipe is or is being recharged and is cut off from the brake pipe as soon as either a manual or an automatic

brake application is initiated, so that the reduction in brake pipe pressure is the same whether a manual or an automatic brake application is initiated, so that the reduction in brake pipe pressure is the same whether a manual brake application has preceded the automatic operation of this apparatus, whether both were initiated simultaneously, or whether the automatic apparatus alone has been initiated.

Referring to Fig. 12 of the drawings, the car-carried apparatus shown includes the main relay MR, cab signals and speed control apparatus the same as that shown in Fig. 4 of the drawings and is controlled by influences communicated from the trackway in the same manner. The penalty relay PR shown in Fig. 12 is the same as that shown in Fig. 10 and is controlled in substantially the same way. The differential pressure device PD shown in Fig. 12 is the same in many respects as that shown in detail in Fig. 7 of the drawings. This differential pressure device PD shown in Fig. 12 functions the same as the one shown in Fig. 7, except that the amount of venting necessary to close contact 54^o has a definite ratio to the initial brake pipe pressure; whereas the amount of venting necessary to close contact 54⁺ in Fig. 7 is a constant and is determined by the spring 212. In Fig. 12 the spring 212 is omitted and the diaphragm 211² is of such size, as compared with the size of diaphragm 208², that contact 54^o is closed when the equalizing reservoir pressure drops to a predetermined percent or ratio of the initial brake pipe pressure trapped in chamber 200 and the capacity reservoir 203.

In Fig. 12 has been shown an automatic brake applying device which is entirely separate from the usual engineer's brake valve, which for convenience will be referred to as an "application valve" and is designated AV. The application valve AV is made up of a valve chamber 280 containing a slide valve 281 and seat of the usual construction, and a cylinder portion 282 containing a piston 283 connected to the slide valve in the usual way. The valve chamber 280 is connected to the main reservoir, and this pressure keeps the valve 281 on its seat. The main reservoir pressure is also supplied to the right hand side of the piston 283 through a restricted leakage hole 284. Bearing against the right hand side of the piston 283 and tending to move it to the left, is a compression spring 285, which is strong enough to overcome the friction of the slide valve 281 on its seat, and which acts to move the piston 283 and slide valve 281 to the left hand position shown, whenever the pressures on opposite sides of said piston are equal. The chamber on the right hand side of the piston 283 may be connected to atmosphere through a port 286 much larger than the hole 284 through the

piston, upon deenergization of an electro-pneumatic valve EPV of the usual and well known construction. This valve EPV is also provided with contacts 311 closed only while the valve winding is energized.

In the lower part of the application valve casing is a piston and valve 287 corresponding to the equalizing piston and discharge valve contained in the lower part of the usual engineer's brake valve. The lower side of this piston 287 is connected to the brake pipe, and the upper side is connected to a capacity reservoir R.

The parts of the application valve AV are shown in Fig. 12 in the normal or release position. The valve EPV is energized, closing the exhaust to atmosphere from the right hand side of the piston 283 and permitting the pressures on opposite sides of said piston to equalize, so that the spring 285 moves the piston and the slide valve 281 to the left hand position shown. A pipe 288 for supplying main reservoir pressure to the feed valve and engineer's brake valve, is connected to a port 289 in the seat of the slide valve; and with the slide valve 281 in the normal position shown, this port is uncovered, permitting free communication between the main reservoir and the engineer's brake valve for release and recharging purposes. Under the normal conditions under discussion, the engineer's brake valve is in the running position, charging the excess pressure governor head pipe 198 and opening the valve 204 (see Fig. 7) to connect the reservoir 203 to the brake pipe BP. This reservoir 203 is, in turn, connected by pipe 290 and cavity 291 to the capacity reservoir R of the application valve AV. The reduction reservoir R¹ of the application valve AV is connected to an exhaust port 292 through the cavity 293. The passage 294 from the equalizing discharge piston valve 287 is blanked at the cavity 295.

Upon deenergization of the valve EPV, the pressure on the right-hand side of the piston 283 is quickly exhausted; and the pressure on the left-hand side forces the piston and slide valve 281 to the right in opposition to the spring 285. This movement of the slide valve 281 blanks the port 289 and cuts off main reservoir pressure from the pipe 288 leading to the engineer's brake valve, so that the engineer cannot interfere with the brake application or release the brakes, so long as the application valve AV is in this brake applying position. The cavity 291 disconnects the capacity reservoir R from the brake pipe. The cavity 293 disconnects the reduction reservoir R¹ from atmosphere and connects the capacity reservoir R and reduction reservoir R¹ together. The pressure in the capacity reservoir R, corresponding to the normal brake pipe pressure, blows down into the reduction reservoir R¹, lowering the

pressure on the upper side of the discharge piston 287. This reduction preferably takes place slowly, and, if necessary, a restricted port may be interposed in the communication between the two reservoirs. As the pressure drops above the discharge piston 287, the higher brake pipe pressure on the under side raises it and opens the discharge valve, allowing the brake pipe pressure to vent to atmosphere.

The piston and discharge valve 287 are designed to act the same as the equivalent parts in the engineer's brake valve, and serve to regulate the discharge from the brake pipe to conform to a limited rate. As soon as the pressure in the brake pipe drops to that in the capacity reservoir R, the discharge valve closes. Hence, the brake pipe pressure will not drop at a higher rate than that at which the pressure in the capacity reservoir R drops; and the parts are proportioned such that this drop in pressure occurs at the same rate as the regular equalizing reservoir pressure drops through the preliminary exhaust port in the engineer's brake valve. Consequently, the application valve AV may be venting the brake pipe in the manner just described simultaneously with the venting of the brake pipe at the engineer's valve, without increasing the rate in brake pipe reduction and possibly throwing the triple valves into the quick action or emergency position.

As soon as the pressure equalizes in the reduction reservoir R¹ and the capacity reservoir R, and the brake pipe has dropped to this resultant pressure, the exhaust valve 287 closes and remains closed. It will be observed that the resultant reduction in brake pipe pressure is determined by the ratio of the volumes of the capacity reservoir R and the reduction reservoir R. The capacity reservoir R is always at the normal or initial brake pipe pressure existing at the time the engineer's brake valve was last in the running or release position, since this capacity reservoir is connected with the brake pipe through the valve 204 of the device PD only so long as the engineer's valve is in the running or release position. Consequently, the reduction in brake pipe pressure occurring upon automatic braking will be the proper amount irrespective of the initial brake pipe pressure, being a proportion or percentage of this initial brake pipe pressure and corresponding to that required to produce a full service or full equalization brake application.

Upon re-energization of the valve EPV, the exhaust port 286 closes, and pressure at once equalizes on opposite sides of the piston 283, so that the spring 285 is able to move the slide valve 281 to the normal release position shown. After the slide valve 281 returns to its release position, the port 289 is uncovered, supplying main reservoir pressure to the engineer's brake valve, so that the

engineer may release the brakes. If the engineer's brake valve should happen to be in the running position at this time of automatic restoration of the application valve AV, as for instance in case the engineer has become incapacitated, the release of the brakes takes place automatically, though more slowly than with the engineer's valve in the release position and to avoid this contingency, which is contrary to what is now considered to be the best practice, other expedients (not shown) may be applied to prevent automatic release of the brakes after an automatic application with an incapacitated engineer, requiring for example the movement of the brake valve to the lap position in order to restore the application valve AV. Such expedients have been proposed and are known; and since they form no essential part of the organization constituting the present invention, such expedients, together with others that may be desirable to provide a thoroughly complete and practical system, have not been shown.

After the slide valve 281 has been restored to its release position, the pressures eventually come to the normal condition after release of the brakes and recharging of the brake pipe. The reduction reservoir R¹ is vented to atmosphere through the cavity 293 and the exhaust port 292. The reservoir R¹ is connected by the cavity 291 and pipe 290 to the capacity reservoir 203; and as soon as the valve 204 (see Fig. 7) of the device PD opens, if not already open, these reservoirs R and 203 assume a pressure corresponding to that existing in the brake pipe, which is the normal running pressure after the air-brake system has been fully recharged.

Operation of Fig. 12

The car relay MR is assumed to be controlled to any one of its three different positions by track equipment such as shown, for example, in Fig. 4. The cab signals or indicators *g*, *y* and *r* are automatically lighted and extinguished as traffic conditions change, the same as in the system shown in Fig. 4. The parts are shown in Fig. 12 in the normal position corresponding to clear traffic conditions and a speed below the maximum normal running speed. As the train travels through caution and danger blocks, and as traffic conditions clear up, the movement of the contact 163 of the relay MR connects the terminal of the battery or other source of current (indicated at B) to one of the contact strips 165, 178 or 179, as in Fig. 4, thereby providing for automatically applying the brakes in case a predetermined maximum, a medium, or a minimum speed limit, respectively, is exceeded.

So long as the actual running speed of the train is below the particular speed limit in force at the time, whether that speed limit be the maximum, the medium, or the mini-

mum, the valve EPV is maintained energized by a circuit including three branches in multiple, which may be traced as follows:—commencing at B, contact finger 163 of the relay R, wire 164, 174 or 181, depending on the position of this contact finger, contact arm 153, wire 304, front contact 305 of the penalty relay PR, wire 306, winding of the valve EPV, and wire 307 to C.

So long as the valve EPV is energized, the penalty relay PR is maintained energized by a normal stick circuit as follows:—beginning at B, wire 310, front contact 311 of the valve EPV, wires 312, 313 and 314, front contact 315 of relay PR, wires 316 and 317, relay PR and wire 318 to C.

If the existing speed limit is at any time exceeded, the energizing circuit for the valve EPV is opened at the arm 153, and the application valve AV operates in the same way as just described to give a measured automatic brake application. This operation of the application valve AV, and the resultant automatic brake application, occurs irrespective of whether or not the engineer has been vigilant. The engineer, by being alert, may suppress a penalty but can not suppress the automatic braking.

Let us assume first that the engineer is alert, and before exceeding the speed limit, that is, prior to the deenergization of the valve EPV, places his brake valve in the service position. The contacts 44—47 are thereby closed, and the penalty relay PR is maintained energized by an auxiliary stick circuit as follows:—commencing at B, contacts 44—47, wires 319 and 314, front contact 315 of relay PR, wires 316 and 317, relay PR, wire 318 to C. The engineer must have his brake valve in the service position before exceeding the speed limit, otherwise the penalty relay PR is deenergized upon opening of the contacts 311 of the valve EPV; and the opening of the front contact 315 of said relay PR makes it impossible for the engineer to energize this relay by closure of the contacts 44—47. In short, the engineer must take anticipatory action, and cannot wait until the automatic control takes effect.

As soon as the engineer places his brake valve in the service position, the pipe 198 is exhausted to atmosphere for the same reasons hereinbefore explained in connection with Fig. 7, and the valve 204 (see Fig. 7) automatically closes to trap the normal running brake pipe pressure in the reservoir 203. If the engineer keeps his brake valve in the service position, the equalizing reservoir pressure gradually drops; and when it has dropped to the point where it has substantially the same ratio to the normal brake pipe pressure in the reservoir 203 as the area of the diaphragm 208² has to the area of the diaphragm 211², the arm 217 shifts and closes the contacts 54⁶, thereby establishing a second

auxiliary energizing circuit for the penalty relay PR as follows:—commencing at B, contacts 54⁶, wires 320, 313 and 314, front contact 315 of relay PR, wires 316 and 317, relay PR and wire 318 to C. On account of the establishing of this second auxiliary stick circuit for the relay PR, the engineer may now lap his brake valve without penalty, since the relay PR will be maintained energized by the closure of the contacts 54⁶, in spite of the opening of the contacts 44—47.

If the engineer should attempt to release the brakes while the speed is excessive, the penalty relay is deenergized, because its normal stick circuit is open at the contacts 311, its first auxiliary stick circuit is open at the contacts 44—47 (the engineer's brake valve being in a releasing position), and the second auxiliary stick circuit is open at the contacts 54⁶, which, if not open at the time, will immediately open due to the charging of the pipe 198, opening of the valve 204, and the drop in pressure in the reservoir 203 upon its connection to the brake pipe now at reduced pressure.

From this explanation it can be seen that, in order to maintain the penalty relay PR energized and avoid the penalty of being required to come to a stop, as more fully explained hereinafter, the engineer must initiate a manual brake application before exceeding the speed limit existing at any time, and must keep his brake valve in the service position until a predetermined reduction in equalizing reservoir pressure has been made, and cannot move the brake valve beyond the lap position, so long as the speed of his train is excessive. In short, the engineer must initiate, complete and maintain an effective brake application in order to forestall the penalty. The engineer may, however, split applications before exceeding the speed limit, that is, may make a partial application and hold it for a time to adjust the slack before exceeding the speed limit. The partial applications, if made, are automatically added together, so to speak, in determining the intensity of the manual brake application, since the contacts 54⁶ respond to the reduction in pressure in the equalizing reservoir whether made in one or a plurality of stages.

Assuming that the engineer has been vigilant and has maintained the penalty relay PR energized, as soon as the running speed of the train drops below the existing speed limit, or the speed limit is changed to a higher limit, the energizing circuit for the valve EPV is re-established at the contact arm 153 and one of the contact strips 165, 178 and 179, as the case may be. Upon re-energization of the valve EPV, the application valve AV automatically assumes the release position, as previously explained, permitting the engineer to release the brakes. If the engineer moves his brake valve handle to the release posi-

tion, and then to the running position, in accordance with the regular manipulations to release the brakes, the pipe 198 is charged; the valve 204 opens, and the capacity reservoirs 203 and R are connected to the brake pipe and assume the pressure to which the brake pipe is recharged.

In case the engineer is not vigilant, and the relay PR is deenergized, its front contact 305 opens, so that the valve EPV will not be energized even though the speed of the train falls below the existing speed limit, and the brakes cannot be released. The automatic brake application, which occurs each time the existing speed limit is exceeded, remains in force until the train has been brought substantially to a stop, whereupon the contact arm 153 engages the short two miles per hour contact strip 321, thereby establishing a pick up circuit for the relay PR as follows:—commencing at B, contact finger 163 of the relay MR, through the wire 164, 174 or 181, depending on the position of said finger, contact strip 165, 178 or 179, arm 153, strip 321, wires 322 and 317, relay PR and wire 318 to C. As soon as the relay PR is energized and its front contact 305 closes, the valve EPV is energized, since the speed is substantially zero and some one of the branch circuits through the contact strip 165, 178 or 179 must be closed; and upon re-energization of the valve EPV, and the closure of its contacts 311 establishes the normal stick circuit for the relay PR. The engineer may now release the brakes and proceed, subject to the speed limit that may be existing at that time. It may be explained here that automatic re-energization of the penalty relay PR by very low speed contacts 321 on the speed responsive device G serves the same purposes and function as the reset switch RS shown in Figs. 3 and 4, and such automatic re-energization of the penalty relay is considered preferable by some railroads on the ground that there are some places, such as trestles, tunnels and the like, where it is difficult and dangerous for the engineer to dismount and operate the reset switch.

Among the characteristic features and advantages of this modification shown in Fig. 12, will be noted that the penalty only is suppressed, and automatic operation of the brake applying mechanism occurs each time the speed is excessive. The action of the engineer in suppressing the penalty must be anticipatory, the same as in the other forms of the invention herein disclosed; but the engineer is permitted to make partial applications prior to exceeding the speed limit, and is not obliged to keep the brake valve in the service position any longer than is necessary to make two or more applications which all together constitute an effective application. The automatic application valve AV

in conjunction with the device PD gives a predetermined reduction in brake pipe pressure irrespective of the normal running brake pipe pressure or previous partial manual reductions in the brake pipe pressure, such predetermined reduction being determined as a ratio or a percentage rather than as a definite difference. Similarly, the device PD permits the engineer to lap his brake valve after making a predetermined reduction in equalizing reservoir pressure; and such reduction is the same regardless of the initial brake pipe pressure and is a ratio or a percentage rather than a difference.

In order to clearly illustrate how the present invention may be applied to various types of train control systems found in practice, it has been shown applied to three distinct and different types of systems. These systems are shown in Figs. 3, 4 and 10 and comprise a time-distance interval type system, a three-position continuous inductive type system, and a two-position continuous inductive system, respectively. It is, however, desired to have it understood that the present invention relates to the suppression of a penalty, either separate from or together with an automatic application of the brakes of the train together with means to prevent excessive venting of the brake pipe, and that it may be applied to any system wherein vigilance and an automatic brake application are factors. In the systems shown in Figs. 3 and 4, the inflicting of a penalty is suppressed if the engineer's brake valve has been placed in a brake applying position before the train has exceeded certain permissive speed limits; and the engineer is permitted to discontinue venting of the brake pipe manually, that is, is permitted to return the engineer's brake valve to the lap position, when a predetermined degree of brake application has been obtained by manual control. In the system shown in Fig. 10, the engineer is permitted to restore the engineer's brake valve to the lap position after making a predetermined brake application which depends upon the speed the train was running when it entered territory, such as a caution block, requiring speed reduction. It should be understood that the specific means restricting the return of the engineer's brake valve to the lap position disclosed in connection with any one of these systems may be also applied to any one of the other systems.

Two distinctive types of automatic brake applying arrangements have been shown in these three systems. In one type the engineer's brake valve is actuated to the service position in a manner so that he cannot prevent its actuation; but in the other the brake pipe is vented by a separate pneumatically operated brake application valve, which when actuated cuts off main reservoir pressure from the usual engineer's brake valve so

that he cannot recharge the brake pipe and prevent an automatic application. For convenience one or the other of these brake applying means only has been shown in each one of these systems, but it should be understood that either method of effecting an automatic brake application may be used in all of these systems, providing certain slight changes are made which will be obvious to a person skilled in this art after studying the foregoing specification in connection with the drawings.

In Figs. 2, 3, 4, 5, 6, 7, 11^a and 12 are shown contacts which are closed only when a predetermined degree of brake application is effective, or has been manually initiated and eventually becomes effective. Each of these contacts are closed in a manner so that they will function properly, regardless of whether such brake application is made in a single step, or is made in successive steps by repeated movements of the engineer's brake valve to the service position and back to lap. In the arrangement shown in Fig. 2, this is accomplished by a time measuring means which adds together the several periods during which the engineer's brake valve is in the service position, providing it is not returned to a brake releasing position. Since these various contact closing mechanisms eventually accomplish the same purpose of permitting the discontinuance of venting of the brake pipe without the inflicting of a penalty, each one of these devices may be used in the system shown in Figs. 3 and 4, or any other system analogous in character, within the scope of the present invention. Also, since each of these contact operating devices moves in response to the degree of brake application initiated, these devices may be used to operate contacts associated with speed responsive devices driven from the wheels of the vehicle similarly to the device shown in Figs. 10 and 11, so that contacts closed in response to both speed and the degree of brake application initiated may be operated by the methods of determining the degree of brake application shown in Figs. 2, 5, 6, 7 and 12 as well as the arrangements shown in Figs. 10 and 11.

Similarly, a contact, closed when a predetermined degree of brake application has been initiated, may be actuated by the piston 258 shown in Fig. 10, instead of operating a contact as shown, the closure of which depends on the speed of the train.

In the arrangement shown in Fig. 7 of the drawings, the pressure device PD has been shown in a system for the purposes of permitting the engineer to move the engineer's brake valve to the lap position after it has been automatically moved to the service brake applying position; but this pressure device may be used in a system in which a penalty is inflicted if the engineer does not

anticipate an automatic brake application by a manual brake application, such as shown in Figs. 3, 4 and 10. Similarly it is desired to make clear that any one of the arrangements shown for closing a contact after a predetermined degree of brake application has been initiated, as shown in Figs. 2, 5, 6, 10, 11, 11^a and 12, may be used for the purpose illustrated in Fig. 7 of the drawings.

The various arrangements embodying this invention have been illustrated and described with the view of disclosing the nature of the invention and the idea of means underlying it; and a complete system of train control for practical use may require additional features, such as provisions for freight and passenger service, operation pilot or tender first, with or against traffic, single track operation, equipped and unequipped territory, and the like.

I desire to have it understood, therefore, that the invention is not limited to the particular means, construction, organizations and arrangements of parts and circuits shown and described.

What I claim is:—

1. In an automatic train control system including the usual air brake system comprising, a brake control device acting on said air brake system to cause a brake application if actuated, means for automatically actuating said device, means for inflicting a penalty each time said device is operated automatically, and means including a time element device superimposed on the air brake system for suppressing automatic operation of said device if the engineer's brake valve has been in the brake applying position for a predetermined time either in one or a number of periods and has thereby caused a predetermined reduction in the equalizing reservoir and has not thereafter been placed in a brake releasing position.

2. In an automatic train control system including the usual air brake system comprising, a brake control device acting to cause a brake application by said air brake system if said device is actuated, means for automatically actuating said brake control device, means for inflicting a penalty each time said device is automatically operated, and means for preventing operation of said penalty inflicting device including a time element device superimposed on said air brake system and effective to prevent such penalty if the equalizing reservoir has been vented for a predetermined period of time regardless of whether or not such venting took place during a single period and providing the equalizing reservoir has not been recharged in the meantime.

3. In an automatic train control system including the usual air brake apparatus, the combination with a brake control device which applies the brakes of the train by vent-

ing the brake pipe when operated, a speed responsive device driven from the wheels of the vehicle, means for penalizing the engineer if said brake control device is operated, said
 5 penalty consisting in requiring the train to be brought to a stop, means for automatically actuating said brake control device if the train exceeds a predetermined speed limit determined by said speed responsive device,
 10 and means for suppressing the actuation of said penalty inflicted means without suppressing automatic operation of said brake control device if the engineer anticipates the automatic initiation of a brake application
 15 by initiating a manual brake application.

4. In an automatic train control system the combination with a brake control device acting on the usual air brake system and automatically actuated to cause a brake application by said system if the speed of the
 20 train is excessive, a penalty inflicting device for inflicting a penalty if the engineer allows the speed of the train to exceed a predetermined value, and means for suppressing actuation of said penalty inflicting device effective if an adequate brake applica-
 25 tion has been made or initiated comprising, means connected to the equalizing reservoir of the usual air brake system which assumes a position dependent on the pressure in said
 30 reservoir, means for closing a penalty preventing circuit effective after a predetermined distance of movement of said last mentioned means has taken place and means for
 35 coupling said last two mentioned means together when the usual engineer's brake valve is moved from a brake releasing to a brake applying position.

5. In an automatic brake control apparatus, the combination of a brake control device acting on the usual air brake system and automatically actuated to effect an automatic brake application by said system if the
 40 speed of the train is excessive, a penalty inflicting device for inflicting a penalty if the engineer allows the speed of the train to exceed a predetermined value, and means for suppressing actuation of said penalty inflicting
 45 device effective if an adequate brake application has been initiated comprising, means connected to the equalizing reservoir of the air brake system which assumes a position corresponding to the pressure in said
 50 reservoir, and means for closing a penalty preventing circuit effective if a predetermined distance of movement of said last mentioned means from normal has taken place, regardless of the initial pressure exist-
 55 ing in said equalizing reservoir.

6. In an automatic brake control apparatus for railway trains, the combination of a brake control device acting on the usual air brake system and automatically actuated to
 60 cause a brake application if the speed of the train is excessive, a penalty inflicting device

for inflicting a penalty if the engineer allows the speed of the train to exceed a predetermined value, and means for suppressing actuation of said penalty inflicting device effective if an adequate brake application has
 70 been initiated or consummated comprising, a capacity reservoir, means pneumatically operated for connecting said capacity reservoir to the brake pipe when the engineer's brake valve is in a brake releasing position
 75 and for trapping the existing air pressure in said capacity reservoir when said brake valve is in the lap or the brake applying position, and means for closing a circuit when the pressure in the equalizing reservoir is a
 80 predetermined amount lower than that in the capacity reservoir.

7. In an automatic train control system, the combination with the usual air brake system in which the rotary valve of the usual
 85 engineer's brake valve is provided with an additional cavity whereby the excess pressure head pipe is connected to atmosphere when said valve is in the lap or in a brake applying position, and means for determining
 90 when a predetermined brake application has been initiated comprising, a capacity reservoir, means governed by pressure in the excess pressure head pipe for connecting said reservoir to brake pipe pressure or trapping
 95 existing pressure in said reservoir, depending on the presence and absence respectively of pressure in said excess pressure head pipe, and means for comparing the pressure in said capacity reservoir with that existing in
 100 the equalizing reservoir for determining the degree of brake application initiated or consummated.

8. In an automatic train control system, the combination with the usual air brake system modified by having the usual engineer's
 105 brake valve provided with an additional cavity whereby the excess pressure head pipe is connected to atmosphere when said valve is in the lap or in a brake applying position, and means for determining when a predetermined
 110 brake application has been initiated comprising, a capacity reservoir, means governed by pressure in the excess pressure head pipe for connecting said reservoir to brake pipe pressure and for trapping existing pressure in said reservoir respectively depend-
 115 ing on the presence or absence of pressure in said excess pressure head pipe, and means for closing a circuit when the pressure in the equalizing reservoir of said air brake system is a predetermined amount less than that
 120 existing in the capacity reservoir, whereby a circuit is closed when a predetermined brake application has been initiated.

9. In an automatic train control system, the combination with the usual air brake system modified by having the usual engineer's
 125 brake valve provided with an additional cavity whereby the excess pressure head pipe
 130

is connected to atmosphere when said valve is in the lap or in a brake applying position, and means for determining when a predetermined brake application has been initiated comprising, a capacity reservoir, means governed by pressure in the excess pressure head pipe for connecting said reservoir to brake pipe pressure or trapping existing pressure in said reservoir, and means responsive to the difference in pressure existing in said capacity reservoir and the usual equalizing reservoir.

10. Means for closing a circuit when a brake application of a predetermined degree has been initiated upon the usual automatic air brake system and so long as such brake application continues to be effective comprising, the elements of the usual air brake system including an engineer's brake valve modified by having an additional cavity cut in the rotary valve thereof whereby the excess pressure head pipe is connected to atmosphere when the brake valve is in the lap, service or emergency position, a capacity reservoir normally in communication with the brake pipe, means for blocking the communication between said reservoir and the brake pipe when no pressure exists in said excess pressure head pipe, and circuit closing means actuating when the pressure in the equalizing reservoir of said air brake system is a predetermined amount below that of the pressure in the capacity reservoir.

11. An automatic train control system comprising, automatic means for applying the brakes of the usual air brake system in the event that the speed of the train is excessive, and means for penalizing the engineer effective when the speed of the train exceeds any of the predetermined speed limits set up under adverse traffic conditions but ineffective if the speed limit set up under favorable or clear traffic conditions is exceeded, and means for suppressing operation of said penalty inflicting means effective if and only if a brake application of a predetermined extent has been initiated or is effective.

12. An automatic train control system comprising, a brake control device normally maintained energized and inactive, a normally energized penalty inflicting relay, means for deenergizing said relay and inflicting a penalty when the train exceeds certain predetermined speed limits determined by a speed responsive device, and means for independently energizing said relay when the speed of the train is above a certain value under clear traffic conditions.

13. An automatic train control system comprising, a brake control device normally maintained energized and inactive, a normally energized penalty inflicting relay, means for deenergizing said relay each time the brake control device is deenergized as a

result of excessive speed, and means for independently maintaining said relay energized effective if the speed of the train as indicated by a speed responsive device driven from the wheels of the vehicle is above a certain value under clear traffic conditions.

14. An automatic train control system of the speed control type comprising, a normally inactive brake control device acting on the usual air brake system, means for deenergizing said device if the speed of the train is excessive, a penalty inflicting means requiring the engineer to bring the train to a stop made effective when said brake control device is automatically deenergized, said penalty inflicting means including means permitting the train to travel indefinitely at only a limited speed if said brake control device has been deenergized and continuing to restrict the train to this limited speed until the train has been brought to a stop and certain devices have been restored.

15. An automatic train control system comprising, a normally energized brake control device acting on the usual air brake system which applies the brakes when deenergized, means for deenergizing said device if the speed of the train as indicated by a speed responsive device driven from the wheels of the train is excessive, means for inflicting a penalty if said device is deenergized, and means for preventing deenergization of said device of an adequate brake application has been initiated or is effective, said last mentioned means including a contact closed if less than a predetermined pressure exists in the equalizing reservoir as compared with the speed at which the train is traveling.

16. Means for determining when a brake application of a predetermined value has been initiated on the usual air brake system comprising, a miniature auxiliary reservoir; a miniature brake cylinder; and means for connecting the equalizing reservoir of the usual air brake system to the miniature auxiliary reservoir and connecting the miniature brake cylinder to atmosphere when the pressure in the equalizing reservoir is higher than the pressure in the miniature auxiliary reservoir, for connecting the miniature auxiliary reservoir to the miniature brake cylinder when the pressure in the equalizing reservoir is less than that in the miniature auxiliary reservoir, and for isolating said equalizing reservoir said miniature brake cylinder and said miniature auxiliary reservoir from each other when the pressure in the miniature auxiliary reservoir has fallen in response to flow of air to said miniature brake cylinder and is again equal to that existing in the equalizing reservoir.

17. Means for determining when an adequate reduction in brake pipe pressure from normal has been made comprising, a circuit

closer and means for actuating said circuit closer when the pressure in the equalizing reservoir has been reduced a predetermined percentage below the previously existing brake pipe pressure.

18. Initial brake pipe pressure trapping means for air brake systems of the usual type including an engineer's brake valve and having an automatic brake applying device associated therewith comprising, a chamber, normally connected to the brake pipe, and two independent means pneumatically operated for trapping pressure in said chamber effective if a manual or an automatic brake application is initiated respectively.

19. An air brake system comprising, the combination with the usual air brake apparatus including the usual brake pipe, equalizing reservoir and engineer's brake valve, of an automatic brake applying device, and pneumatically operated means effective when either a brake application has been made manually by the engineer's brake valve or has been made by actuating said automatic brake applying device for trapping the brake pipe pressure existing before either of these devices were actuated to a brake applying position, said means continuing to confine the air so trapped until the engineer's brake valve or the brake applying device have been returned to normal.

20. Train control apparatus superimposed upon the usual air brake system including the usual brake pipe, engineer's brake valve and equalizing reservoir comprising, an automatic brake control device, means for penalizing the engineer if he allows said brake control device to be initiated when no manual brake application has been initiated by said brake valve, and means for determining when an adequate manual or an adequate automatic brake application has been initiated functioning by determining the ratio between the existing brake pipe pressure previous to such manual or automatic initiation of a brake application and that existing in the equalizing reservoir at the time of such determination.

21. In an automatic train control system, the combination with the usual air brake apparatus including the usual brake pipe and engineer's brake valve, of automatic brake applying apparatus comprising, a reservoir normally connected to the brake pipe, an automatically operable brake applying device adapted to vent the brake pipe to an extent dependent on the pressure in said reservoir, pneumatically operated means for trapping existing brake pipe pressure in said reservoir when the engineer's brake valve is moved to a brake applying position, means for trapping existing brake pipe pressure in said reservoir when said automatically operable brake applying device is moved to its active position,

and means for penalizing the engineer if he allows an automatic brake application to occur without making an anticipatory manual brake application.

22. An automatic train control system superimposed on the usual air brake system including the usual brake pipe, engineer's brake valve and equalizing reservoir comprising, a speed responsive device driven from the wheels of the vehicle, automatic brake applying apparatus adapted to vent the brake pipe of the braking system if the speed of the vehicle is excessive, penalizing means adapted to inflict a penalty when said automatic brake applying apparatus is actuated, means for suppressing operation of said penalizing means without suppressing operation of said brake applying apparatus, and means for limiting the venting of the brake pipe by said automatic brake applying means to a predetermined extent including a capacity reservoir normally connected to the brake pipe but isolated from the brake pipe when either a manual or an automatic brake application is initiated.

23. In an automatic train control system, the combination with the usual air brake system including the usual charged brake pipe, equalizing reservoir and an engineer's brake valve, and of means for causing an automatic application of the brakes if predetermined permissive speed limits are exceeded and for penalizing the engineer if he does not himself initiate a brake application before such speed limits are exceeded comprising, pneumatically operated means for trapping initial brake pipe pressure when either a manual or an automatic brake application is initiated, an electrically operated, normally energized penalty inflicting device, other means for energizing said penalty inflicting device when a manual brake application is being initiated including a pressure device operated when a predetermined relation between the pressure trapped and that of the equalizing reservoir pressure exists.

24. In an automatic train speed control system of the type in which a speed responsive device driven from the wheels of the vehicle is employed for indicating the speed of the train, the combination with a normally inactive brake control device, means for rendering said brake control device active to apply the brakes if the train exceeds a prescribed speed limit regardless of whether or not the engineer has himself applied the brakes, and means for penalizing the engineer if and only if he has not initiated a brake application manually before said brake applying device was rendered active.

25. In an automatic train speed control system of the type in which a speed responsive device driven from the wheels of the vehicle is employed for indicating the speed of the train, the combination with a normally inac-

tive brake control device, means for rendering said brake control device active to apply the brakes if the train exceeds a prescribed speed limit, an engineer's brake valve, and means for penalizing the engineer only if the initiation of the brake application is due to operation of said brake control device rather than to manual operation of said engineer's brake valve when both said brake valves and brake control device are operated in overlapped relation.

26. In an automatic train control system, the combination with a speed responsive device on the railway vehicle driven from the wheels thereof, a brake control device which is normally energized by a circuit including a contact on said speed responsive device and which if de-energized effects a brake application through the medium of an air brake system of the usual type, an engineer's brake valve, a contact associated with said brake control device which is closed when said brake control device is normal, a normally energized penalty inflicting device which inflicts a penalty upon the engineer each time it is operated, an energizing circuit for such penalty inflicting device including a contact operated by such penalty inflicting device and the contact of said brake control device, an auxiliary circuit for said penalty inflicting device including the contact of said penalty inflicting device and two contacts in multiple one of which is closed if the engineer's brake valve is in a brake applying condition and the other of which is closed if an adequate brake application has been initiated, whereby said penalty inflicting device is de-energized if said brake control device is actuated before the engineer's brake valve has been moved to a brake applying position or an adequate brake application has been initiated.

27. In an automatic train control system, the combination with an air brake system of the type wherein the brake pipe is normally charged and wherein venting thereof effects a brake application, the combination of an engineer's brake valve, a normally energized brake applying device separate from said engineer's brake valve which device if de-energized effects a brake application, a speed responsive device driven from the wheels of the vehicle having contacts included in the energizing circuit of said brake applying device which contacts are open if the speed of the vehicle is excessive, and penalizing means rendered active to inflict a penalty upon the engineer if the brake applying device is de-energized before the engineer's brake valve is moved to a brake applying position or an adequate brake application has been initiated manually and the engineer's brake valve has not thereafter been moved to a brake releasing position.

28. Mechanism for determining when sufficient reduction in brake pipe pressure has

been made manually to cause an adequate brake application to take effect in an air brake system of the type in which the brake pipe is normally charged and in which venting of the brake pipe effects a brake application including the usual equalizing reservoir comprising; a pressure head pipe; an engineer's brake valve having a running, a lap and a service position; which engineer's brake valve applies fluid pressure to said pressure head pipe when in the running position but vents said pipe when in the lap or service position; a capacity reservoir; means for trapping brake pipe pressure in said capacity reservoir; and means responsive to a predetermined fluid pressure difference in said capacity reservoir and said equalized reservoir.

29. Mechanism for determining when sufficient reduction in brake pipe pressure has been made manually to cause an adequate brake application to take effect in an air brake system of the type in which the brake pipe is normally charged and in which venting of the brake pipe effects a brake application including the usual equalizing reservoir comprising; a pressure head pipe; an engineer's brake valve having a running, a lap and a service position; which engineer's brake valve applies fluid pressure to said pressure head pipe when in the running position but which vents said pipe when in the lap or service position; a capacity reservoir; means for trapping brake pipe pressure in said capacity reservoir; and means responsive if a predetermined ratio of fluid pressure in said capacity reservoir and said equalizing reservoir exists.

30. Brake control apparatus for air brake systems of the type in which the brake pipe is normally charged and in which venting of the brake pipe effects a brake application, a pressure head pipe, an engineer's brake valve for venting and charging said brake pipe, and for applying fluid pressure to said pressure head pipe when said valve is in the running or release position and for releasing pressure from said pressure head pipe when said valve is in the lap or service position; a capacity reservoir; automatic brake applying means; trapping means for trapping brake pipe pressure in said capacity reservoir upon the release of pressure from said pressure head pipe; penalty inflicting means; means for preventing said penalty inflicting means from becoming active if the equalizing reservoir pressure has been reduced to a certain extent below the pressure trapped in said capacity reservoir; and means for preventing the automatic brake applying means from venting the brake pipe to more than a predetermined extent below the pressure existing in the capacity reservoir.

31. Brake control apparatus for air brake systems of the type in which the brake pipe is normally charged and in which venting

of the brake pipe effects a brake application, an engineer's brake valve for controlling the brakes by venting and charging said brake pipe, automatically operated brake applying mechanism controlled by suitable train control mechanism for venting said brake pipe, penalizing means which if actuated inflicts a penalty upon the engineer, means for preventing said penalizing means from becoming active if either the engineer's brake valve is in a brake applying position or a brake application has been made manually and the engineer's brake valve assumes the lap position before said brake applying mechanism is operated, means for preventing excessive venting of the brake pipe if the brake pipe is caused to be simultaneously vented by the engineer's brake valve and said brake applying mechanism, and means for preventing excessive venting of the brake pipe if only said automatic brake applying mechanism is operated.

32. Brake control apparatus for air brake systems of the type in which the brake pipe is normally charged and in which venting of the brake pipe effects a brake application, an engineer's brake valve for controlling the brakes by venting and charging said brake pipe, automatically operated brake applying mechanism controlled by suitable train control mechanism for venting said brake pipe, said brake applying mechanism including means whereby the brake pipe is vented to a predetermined extent below that of the brake pipe pressure existing before a brake application was started even though the brakes were partially manually applied, and means for penalizing the engineer if said brake applying mechanism is automatically operated.

33. Brake control apparatus for air brake systems of the type in which the brake pipe is normally charged and in which venting of the brake pipe effects a brake application, an engineer's brake valve for controlling the brakes by venting and charging said brake pipe, automatically operated brake applying mechanism controlled by suitable train control mechanism for venting said brake pipe, said brake applying mechanism including means whereby the brake pipe is vented to a predetermined extent below that of the brake pipe pressure existing before a brake application was started even though the brakes were either partially or wholly manually applied, and means for penalizing the engineer if the brakes are applied wholly by said brake applying mechanism.

34. Brake control apparatus for air brake systems of the type in which the brake pipe is normally charged and in which venting of the brake pipe effects a brake application, an engineer's brake valve for controlling the brakes by venting and charging said brake pipe, automatically operated brake applying

mechanism controlled by suitable train control mechanism for venting said brake pipe, said brake applying mechanism including means whereby the brake pipe is vented to a predetermined extent below that of the brake pipe pressure existing before a brake application was started even though the brakes were either partially or wholly manually applied, and means for penalizing the engineer if said automatic brake applying mechanism is operated while the engineer's brake valve is in the running or release position.

35. Brake control apparatus for air brake systems of the type in which the brake pipe is normally charged and in which venting of the brake pipe effects a brake application, an engineer's brake valve for venting and charging the brake pipe to effect an application and a release of the brakes respectively, an automatic brake applying mechanism for effecting a brake application, a reservoir normally connected to the brake pipe, and means for isolating said reservoir from the brake pipe and from atmospheric pressure if either the engineer's brake valve is operated to a brake applying position or said brake applying means is rendered active.

36. Brake control apparatus for air brake systems of the type in which the brake pipe is normally charged and in which venting of the brake pipe effects a brake application, an engineer's brake valve for venting and charging the brake pipe to effect application and release of the brakes respectively, automatic brake applying mechanism for effecting a brake application, a reservoir normally connected to the brake pipe, and means for isolating said reservoir from the brake pipe and from atmospheric pressure if either the engineer's brake valve is operated to a brake applying position or said brake applying means is rendered active, and means for penalizing the engineer if the engineer's brake valve is not moved to a brake applying position nor an adequate brake application has been made when said automatic brake applying means is initiated.

37. Differential pressure mechanism for indicating when equalizing reservoir pressure has dropped below initial brake pipe pressure to a certain extent comprising, the usual engineer's brake valve having a pressure head pipe associated therewith which pressure head pipe is connected to pressure fluid when the brake valve is in the running position and is vented to atmosphere when the brake valve is in the lap or service position, a differential pressure device having two chambers, one chamber of which is normally connected to the brake pipe and the other of which is normally connected with the equalizing reservoir, means for isolating said one chamber from the brake pipe when said pressure head pipe is vented to atmos-

phere, and means associated with said differential pressure device which responds when a predetermined relation exists between the pressure in said two chambers.

38. Differential pressure mechanism for indicating when equalizing reservoir pressure has dropped below initial brake pipe pressure to a certain extent comprising, the usual engineer's brake valve having a pressure head pipe associated therewith which pressure head pipe is connected to pressure fluid when the brake valve is in the running position and is vented to atmosphere when the engineer's brake valve is in the lap or service position, a differential pressure device having two chambers, one chamber of which is normally connected to the brake pipe and the other of which is connected with the equalizing reservoir, means for isolating said one chamber from the brake pipe when said pressure head pipe is vented to atmosphere, and means associated with said differential pressure device which responds when the pressure in one chamber is a predetermined amount lower than the pressure in the other chamber.

39. Differential pressure mechanism for indicating when equalizing reservoir pressure has dropped below initial brake pipe pressure to a certain extent comprising, the usual engineer's brake valve having a pressure head pipe associated therewith which pressure head pipe is connected to pressure fluid when the engineer's brake valve is in the running position and is vented to atmosphere when the engineer's brake valve is in the lap or service position, a differential pressure device having two chambers, one chamber of which is normally connected to the brake pipe and the other of which is connected with the equalizing reservoir, means for isolating said one chamber from the brake pipe when said pressure head pipe is vented to atmosphere, and means associated with said differential pressure device which responds when the ratio of pressures in said two chambers is a predetermined value.

40. Pressure reduction indicating means for indicating when a predetermined reduction in brake pipe pressure has been made in air brake systems of the type in which the brake pipe is normally charged and in which venting of the brake pipe effects a brake application, and which systems include the usual engineer's brake valve and an equalizing reservoir comprising; pressure responsive means responsive to the pressure existing in the equalizing reservoir, and means responsive to changes in said pressure responsive means rendered active when the engineer's brake valve is moved to a brake applying position, whereby the reduction taking place after the engineer's brake valve is moved to the brake applying position only is indicated.

41. Pressure reduction indicating means for indicating when a predetermined reduction in brake pipe pressure has been made in air brake systems of the type in which the brake pipe is normally charged and in which venting of the brake pipe effects a brake application, and which systems include the usual engineer's brake valve and an equalizing reservoir comprising: pressure responsive means responsive to the pressure existing in the equalizing reservoir, and means normally assuming a non-indicating condition placed into clutched engagement with said pressure responsive means when said engineer's brake valve is moved to a brake applying position.

42. Pressure reduction indicating means for indicating when a predetermined reduction in brake pipe pressure has been made in air brake systems of the type in which the brake pipe is normally charged and in which venting of the brake pipe effects a brake application and which systems include the usual engineer's brake valve and an equalizing reservoir comprising; pressure responsive means responsive to the pressure existing in the equalizing reservoir, an indicating member, and means for causing engagement of said member with said pressure responsive means when the engineer's brake valve is moved to a brake applying position.

43. Pressure reduction indicating means for indicating when a predetermined reduction in brake pipe pressure has been made in air brake systems of the type in which the brake pipe is normally charged and in which venting of the brake pipe effects a brake application and which systems include the usual engineer's brake valve and an equalizing reservoir comprising; pressure responsive means responsive to the pressure existing in the equalizing reservoir, an indicating member, a normally de-energized electro-magnet which if energized effects a clutching engagement of said member with said pressure responsive means, and an energizing circuit for said electro-magnet including a contact closed when said engineer's brake valve is in a brake applying position.

44. In an automatic train control system usable in connection with an air-brake system of the engine-and-tender type in which the engine and tender brakes are controlled separately from the train brakes and including the usual engineer's brake valve and an equalizing reservoir; the combination of an auxiliary brake cylinder, auxiliary reservoir, and triple valve mounted on the tender and connected to the brake pipe in the same way as are the corresponding units of the braking apparatus on the cars of the train; means for penalizing the engineer if the brakes are automatically applied; and means for preventing an automatic brake application and the resulting penalty taking effect if the

brakes are manually applied to a predetermined extent as determined by the condition of said auxiliary brake cylinder.

45. In an automatic train control system usable in connection with an air-brake system of the engine-and-tender type in which the engine and tender brakes are controlled separately from the train brakes and including the usual engineer's brake valve and an equalizing reservoir; the combination of an auxiliary brake cylinder, auxiliary reservoir, and triple valve mounted on the tender and connected to the brake pipe in the same way as are the corresponding units of the braking apparatus on the cars of the train; means for penalizing the engineer if the brakes are automatically applied; and means for preventing an automatic brake application taking effect if the brakes have been manually applied to an extent to cause substantial equalization between the pressures in said auxiliary brake cylinder and said auxiliary reservoir.

46. In an automatic train control system usable in connection with an air-brake system of the engine-and-tender type in which the engine and tender brakes are controlled separately from the train brakes and including the usual engineer's brake valve and an equalizing reservoir; the combination of an auxiliary brake cylinder, auxiliary reservoir, and triple valve mounted on the tender and connected to the brake pipe in the same way as are the corresponding units of the braking apparatus on the cars of the train; means for penalizing the engineer if the brakes are automatically applied; speed indicating means driven from the wheels of the vehicle for indicating the speed of the vehicle; and means for preventing the infliction of a penalty by an automatic brake application if a predetermined relation between the speed of the vehicle and the condition of said auxiliary brake cylinder exists.

47. In an automatic train control system usable in connection with an air-brake system of the engine-and-tender type in which the engine and tender brakes are controlled separately from the train brakes and including the usual engineer's brake valve and an equalizing reservoir; the combination of an auxiliary brake cylinder, auxiliary reservoir, and triple valve mounted on the tender and connected to the brake pipe in the same way as are the corresponding units of the braking apparatus on the cars of the train; means for penalizing the engineer if the brakes are automatically applied; speed indicating means driven from the wheels of the vehicle for indicating the speed of the vehicle; and means for preventing the infliction of a penalty by an automatic brake application if any one of a plurality of relations between the condition of the auxiliary brake cylinder and the speed of the vehicle exists.

48. In an automatic train speed control system of the type in which a speed responsive device driven from the wheels of the vehicle is employed for indicating the speed of the train, the combination with a normally inactive brake control device, means for rendering said brake control device active to apply the brakes if the train exceeds a prescribed speed limit, and means for penalizing the engineer if he has not initiated a brake application of a value depending upon the speed at which the train is running at the time.

49. In an automatic train control system; the combination with a normally electrically energized brake control device on the vehicle; penalizing means for penalizing the engineer; and a speed responsive device driven from the wheels of the vehicle coordinated with said brake control device and penalizing means, and effective to de-energize said brake control device without actuating said penalizing means if the speed of the vehicle is excessive while a manual brake application is in effect, and effective to deenergize said brake control device and actuate said penalizing means if the speed of the vehicle is excessive and the brakes have not been manually applied.

50. In an automatic train control system, the combination with a normally electrically energized brake control device on the vehicle, a penalizing device for penalizing the engineer, and speed responsive means driven from the wheels of the vehicle co-ordinated with said brake control device and said penalizing device to actuate both of these devices if the vehicle speed is excessive when no manual brake application is in effect and to actuate the brake control device only if the brakes have been manually applied.

In testimony whereof I affix my signature.
CHARLES S. BUSHNELL.

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