

Jan. 24, 1967

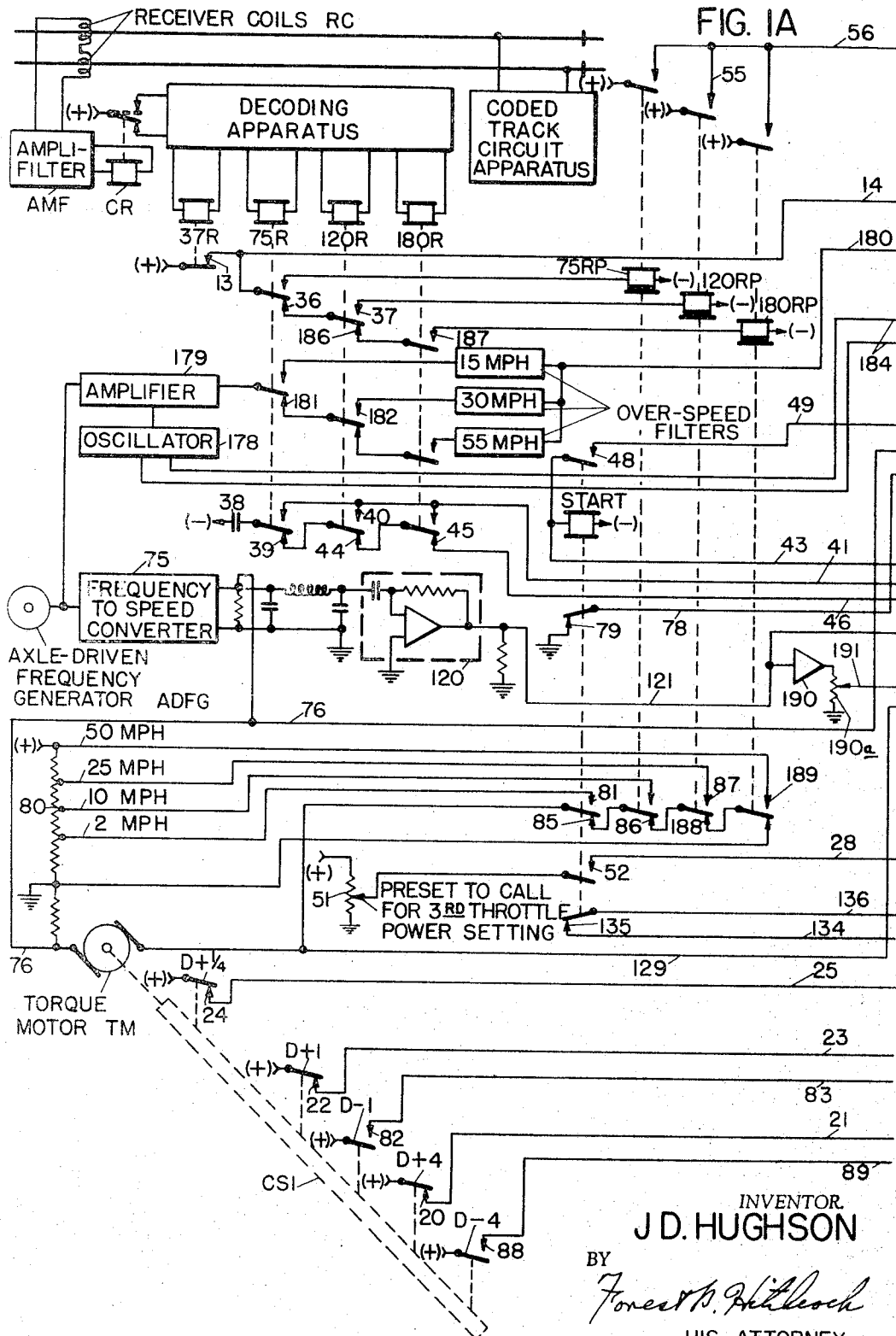
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3,299,834

CONTROL SYSTEM FOR RAILWAY TRAINS

Original Filed Sept. 14, 1962

5 Sheets-Sheet 1



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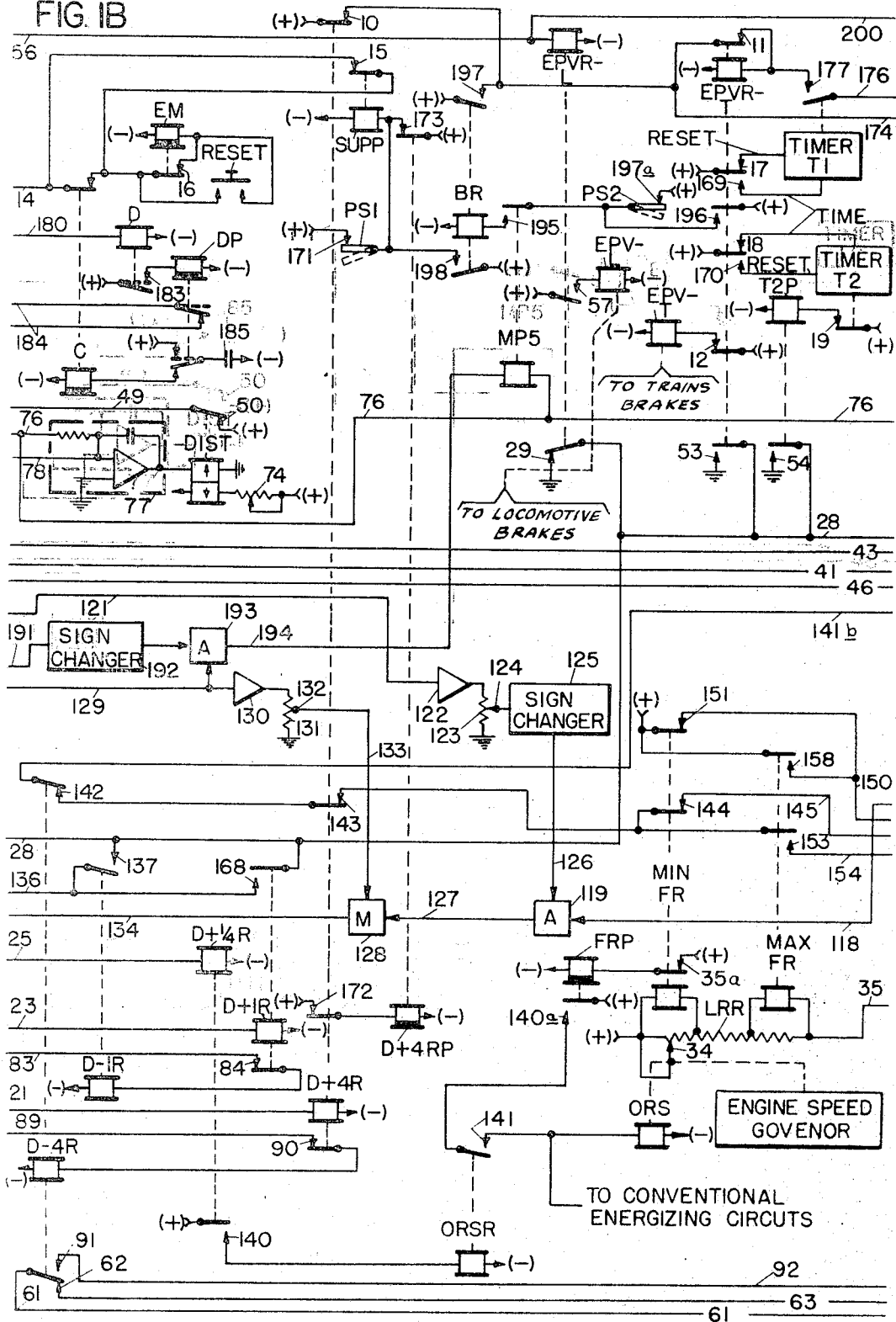
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CONTROL SYSTEM FOR RAILWAY TRAINS

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FIG. 1B



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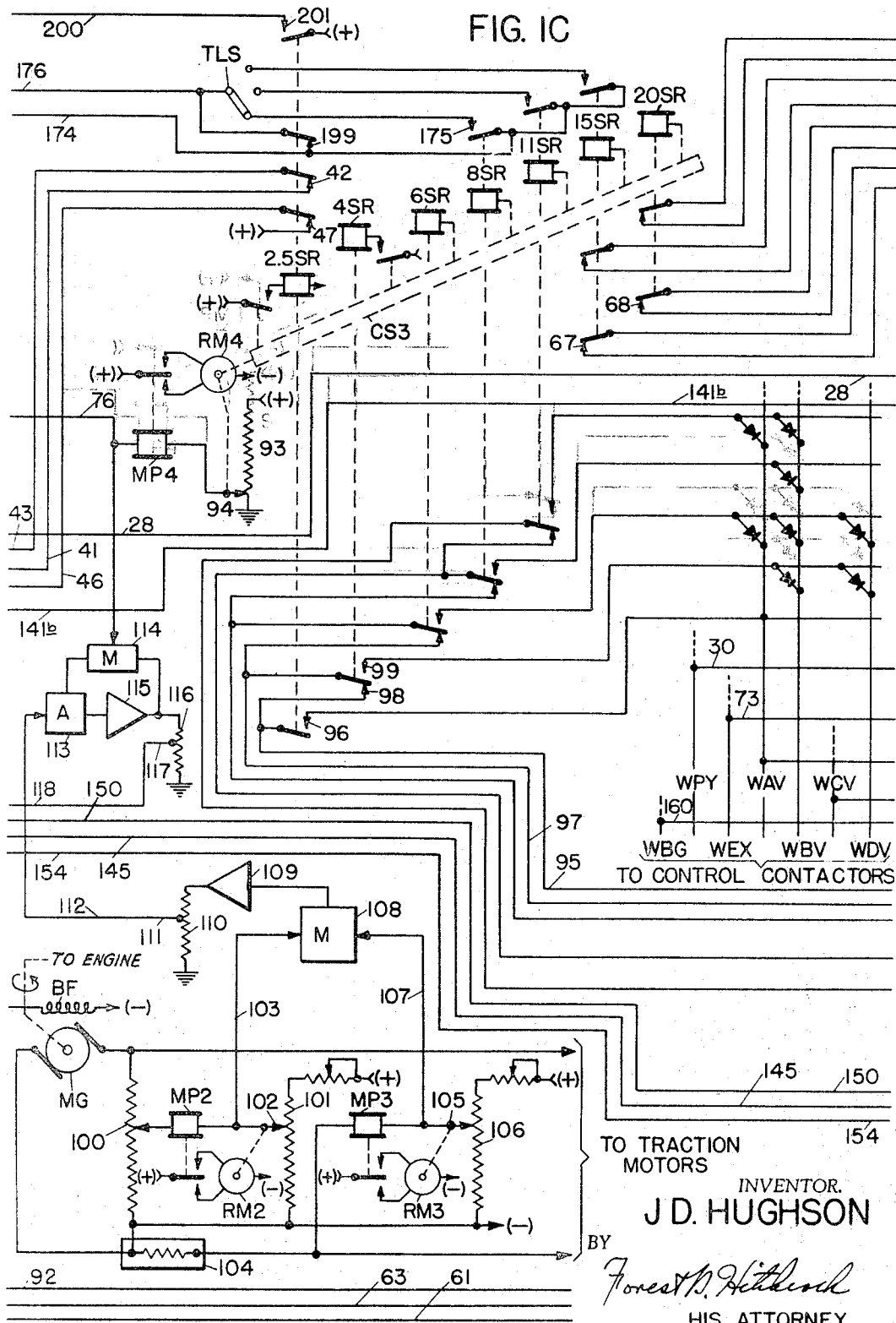
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CONTROL SYSTEM FOR RAILWAY TRAINS

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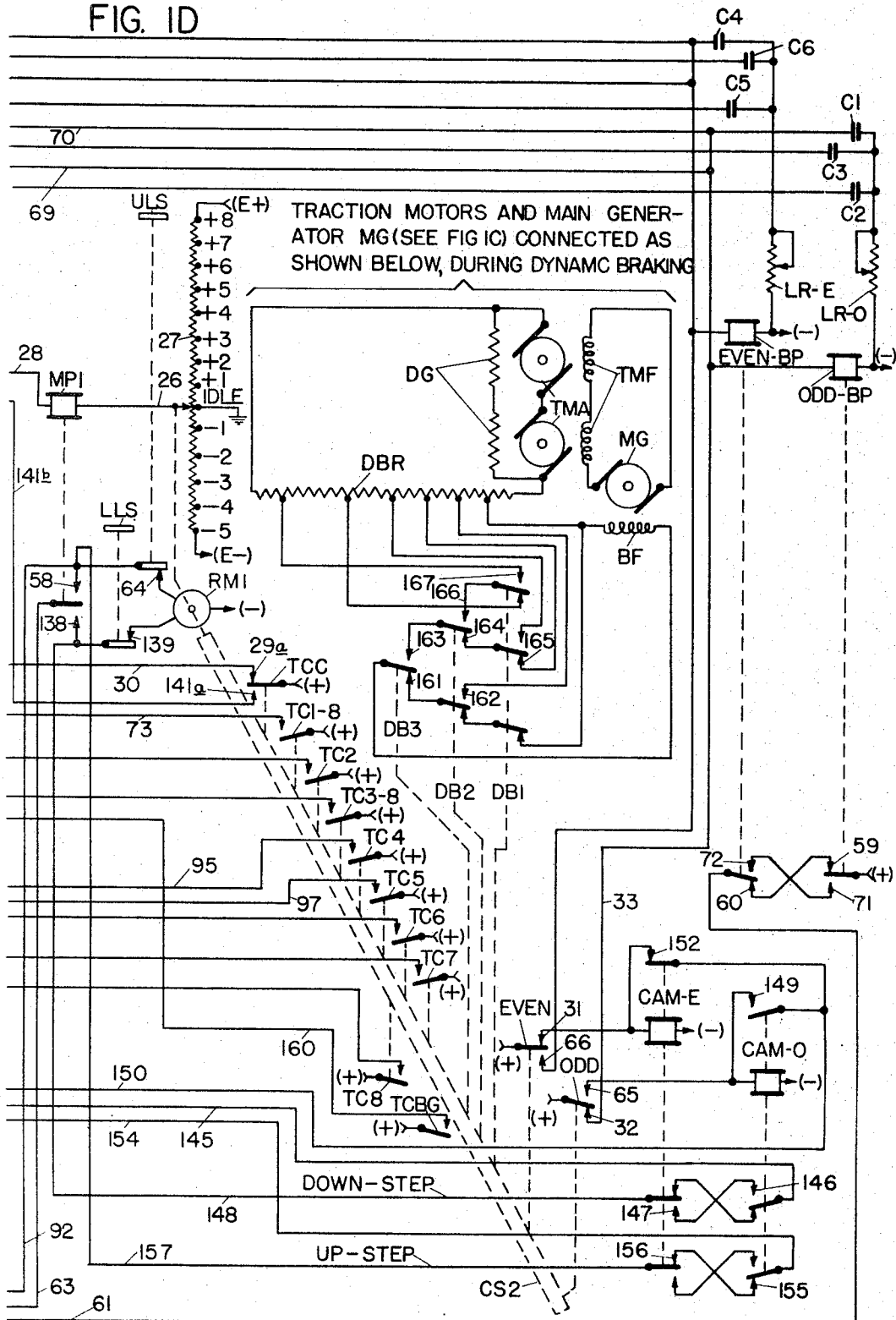
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CONTROL SYSTEM FOR RAILWAY TRAINS

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FIG. 1D



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CONTROL SYSTEM FOR RAILWAY TRAINS

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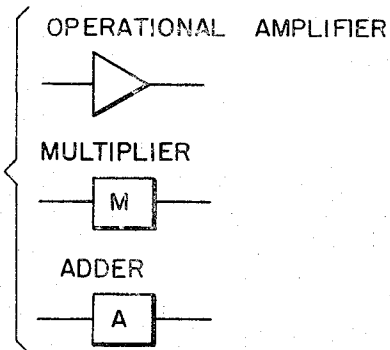
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FIG. 2

CONTROL CONTACTOR	DYNAMIC BRAKING					IDLE	DRIVING POWER							
	-5	-4	-3	-2	-1		+1	+2	+3	+4	+5	+6	+7	+8
PY						X								
EX							X	X	X	X	X	X	X	X
DV											X	X		
CV									X	X	X	X	X	X
BV											X	X	X	X
AV								X		X		X		X
BG 1	X	X	X	X	X									
DB 1	X		X											
DB 2	X	X			X									
DB 3	X	X	X	X										

X INDICATES CONTACTOR IS ENERGIZED

FIG. 3



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3,299,834

CONTROL SYSTEM FOR RAILWAY TRAINS

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Original application Sept. 14, 1962, Ser. No. 223,670, now Patent No. 3,240,929, dated Mar. 15, 1966. Divided and this application Jan. 13, 1966, Ser. No. 520,387
13 Claims. (Cl. 105-61)

This application is a division of my prior application Ser. No. 223,670, filed September 14, 1962 which has resulted in the issue of Patent No. 3,240,929, granted March 15, 1966.

This invention generally relates to vehicle control systems and more particularly pertains to a control system for controlling railway trains during automatic train operation.

During the automatic operation of railway trains, the throttle and brake mechanisms of the vehicle are selectively operated in accordance with coded speed control information communicated from the wayside to the train distinctive of the desired train running speed and selected, for example, in accordance with advance traffic conditions existing ahead of the train. In the control system previously proposed for automatically operating a train, the throttle mechanism of the locomotive is advanced according to a preselected pattern, for accelerating the train towards its desired or demand speed and the throttle is then adjusted in the vicinity of the desired running speed, again, in accordance with some predetermined throttling pattern preset into the control system.

Obviously, however, because of the variations existing in practice, for example, in the weights of the trains and the rolling resistances encountered by a particular train on different stretches of trackway, there may be times when control of the throttle mechanism of the locomotive solely in accordance with a preset pattern will not provide the desired smooth throttle operation necessary to properly maintain the desired speed; that is, the throttle may tend to "hunt" around the desired speed.

In view of the above, it is generally proposed in accordance with the present invention to consider various factors involved in the dynamics of a train at the desired or demand speed, such as, actual tractive effort being developed by the train locomotive, rolling resistance encountered, value of desired speed, mass and acceleration of the train, to determine the locomotive operation necessary to maintain the actual speed of the train at the desired speed.

More specifically, in the illustrated embodiment of the present invention, this determination of the proper locomotive operation is in the form of a computation of the horsepower required of the traction motors on a diesel-electric type locomotive to maintain the desired speed, during automatic train operation, and this computed required horsepower then adjusts the actual horsepower being developed, i.e. the driving power or dynamic braking developed by the locomotive traction motors.

In these previously proposed systems, when the train is required to slow down from a higher to a lower desired speed, an application of the train air brakes is called for and is maintained until the actual speed of the train decreases below a fixed value preselected for the automatic train operation.

Obviously, however, because of the practical variations in the time required for full release of the air brakes, for example, because of different length trains, there is a correct speed at which to initiate a release of the train braking mechanism when slowing down from a higher to a lower desired speed, so that the braking mechanism will be fully released at substantially the lower desired speed, to prevent the train speed from falling below the desired lower speed.

Therefore, it is further proposed in accordance with the present invention to provide means for computing the proper speed at which to initiate a release of a train braking mechanism, when going from a higher to a lower speed, in accordance with the various factors affecting such braking release, such as, for example, the acceleration of the train, the actual and desired train speeds, and the length of time required for the brake release. In the illustrated embodiment of the present invention, this computed brake release speed is utilized to automatically initiate the releasing of the air brakes on an automatic train when slowing down from a higher to a lower desired speed, as called for by coded speed control information communicated from the wayside to the train.

Although the foregoing discussion is mainly concerned with the automatic operation of railway trains, it should be understood at this time that, if desired, the computed required horsepower and proper brake release speed could also be used to give visual indications to the engineman, to aid him in properly operating the railway train under his control.

In view of the above, a general object of the present invention is to provide for determining the locomotive operation required to maintain a train at a predetermined desired speed.

A more specific object of this present invention is to compute the horsepower required of a train locomotive to maintain a desired train running speed and to adjust the actual horsepower being developed by the locomotive in accordance with this computed required horsepower.

A further object of the present invention is to automatically control the operation of the traction motor on a diesel-electric locomotive in accordance with the horsepower required to maintain a desired train speed called for by coded speed control information communicated from the wayside to the train during automatic train operation.

Another general object of the present invention is to determine the proper train speed at which to initiate a brake release when slowing down from a higher to a lower desired speed.

A further object of the present invention is to compute the proper speed at which to initiate a brake release when slowing down from a higher to a lower desired speed during train operation in accordance with coded speed control information communicated from the wayside to the train, and more specifically, to utilize this computed brake release speed for automatically initiating a release of the air brakes on an automatic train.

Other objects, purposes and characteristic features of the present invention will in part be pointed out as the description of the present invention progresses, and in part obvious from the accompanying drawings, to which reference will be made during this description, and in which:

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FIGS. 1A through 1D, when placed side by side, illustrate the train carried apparatus in accordance with one embodiment of the present invention, for operating an automatic railway locomotive of the diesel-electric type in accordance with coded speed control information communicated to the locomotive via the track rails;

FIG. 2 illustrates a chart showing the selective energization of the locomotive carried control contactors, provided on the diesel-electric type locomotives, in accordance with the driving power or dynamic braking to be supplied by the locomotive traction motors; and

FIG. 3 illustrates certain circuit symbols utilized in FIGS. 1A through 1D.

In order to simplify the illustrations in the drawings and facilitate in the explanation of the fundamental characteristics of the present invention, various parts and circuits have been shown diagrammatically in accordance with conventional symbols. Thus, arrows with associated symbols (+) and (−) are employed to indicate connection of the circuits to the opposite terminals of a suitable source of current and this source may be of any suitable characteristic for the purpose intended.

Referring now to FIG. 1A, a partial stretch of railway track T is shown, having certain Coded Track Circuit Apparatus connected to one end thereof for energizing the rails at various current pulse rate codes selected in accordance with predetermined desired speeds for the train. Although, this Coded Track Circuit Apparatus is shown in block form in FIG. 1A, it is intended here that the particular code rate, supplied by the apparatus to the track rails, be selected in accordance with traffic conditions existing in advance of the illustrated stretch of track.

Without attempting to limit the scope of the present invention, it is intended in this illustrated embodiment that when traffic conditions are such that the train is permitted to operate at its nominal high speed, a 180 code rate (180 pulses per minute) will be applied to the rails of the illustrated stretch of track, that when traffic conditions are such that the nominal medium train speed is desired, a 120 code rate will be applied to the track rails, and that when traffic conditions are such that the nominal low train speed is desired, a 75 code rate will be applied to the illustrated track rails.

This coded speed control information applied to the track rails of the illustrated stretch of track T, is then inductively received by receiver coils RC mounted on the leading end of the train. The received information is then amplified and filtered at amplifier AMF and is applied to certain Decoding Apparatus, of FIG. 1A, for selectively energizing a plurality of decoding relays R, dependent upon the desired train speed; i.e., a 180 code rate (relay 180R energized) will call for a high speed of fifty miles per hour, a 120 code rate (relay 120R energized) will call for a medium speed of twenty-five miles per hour, and a 75 code rate (relay 75R energized) will call for a low speed of ten miles per hour.

Referring to FIG. 1A, decoding relay 37R is assumed to be that type which will be picked up as long as a code rate of greater than 37 pulses per minute is being received and which will be dropped away, if the received code rate is less than 37 pulses per minute. In the illustrated embodiment, the reception of a 37½ code rate (relay 37R energized) will call for a service application of the air brakes, while a reception of a steady code rate or a "no code" condition (relay 37R deenergized) will call for an emergency application of the air brakes.

Generally speaking, this desired speed, as registered on the locomotive by the picking up of either relay 75R, 120R, or 180R, is then utilized by the apparatus illustrated in FIGS. 1A through 1D to compute the horsepower required of the locomotive traction motors (either driving power or dynamic braking power), to operate the train at the desired speed. However, before a clear understanding can be obtained, as to how this desired speed is utilized in computing the horsepower required of the

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locomotive traction motor, reference must be made to those equations involved in the train dynamics. Thus,

$$TEa - Fr = M \times Aa \quad (\text{Equation 1})$$

where

TEa is the actual tractive effort being developed by the tractive motors,

Fr is the rolling resistance of the train;

M is the mass of the train and is equal to the weight of the train W divided by the acceleration of gravity g, and

Aa is the actual acceleration of the train.

Rearranging Equation 1,

$$TEa - W/G \times Aa = Fr \quad (\text{Equation 2})$$

All of the left-hand quantities are either measurable on the locomotive during operation or else can be preset into the system when the train is made up.

From Equation 2, the tractive effort required TEr to just maintain a desired speed (acceleration equal to zero) is

$$TEa = Fr \quad (\text{Equation 3})$$

Therefore, the horsepower required HPr to maintain a desired speed is

$$HPr = C \times TEr \times Sd = C \times Fr \times Sd \quad (\text{Equation 4})$$

where

C is a known constant relating horsepower to tractive effort, and

Sd is the desired speed called for by the received code rate.

As will be discussed in detail hereinafter, the apparatus shown in the accompanying drawings includes the necessary computing circuits, arranged in accordance with the foregoing Equations 1 through 4, for determining the required horsepower HPr necessary to automatically operate the railway train at the desired speed Sd as called for by the track codes. This computed required horsepower HPr is then utilized, as will be described in detail hereinafter, to cause a plurality of cam operated switches TC of FIG. 1D to be selectively operated for selectively energizing a plurality of conventional control contactors (not shown) which are normally provided on the diesel-electric type locomotive.

More specifically, the operation of the cam operated switches TC of FIG. 1D, causes selective energization of a plurality of throttle control wires WBG, WPY, WEX, WAV, WBV, WCV, and WDV of FIG. 1C assumed to be connected to conventional control contactors (not shown) normally designated as the BG, PY, EX, AV, BV, CV, and DV contactors whose function is to control the operation of the locomotive traction motors, as is well known to those skilled in the art, in accordance with the desired driving power or dynamic braking required of these traction motors (see FIG. 2). For example, energization of control wire WBG of FIG. 1C and the associated control contactor BG (not shown) connects the locomotive traction motors for dynamic braking, as illustrated in FIG. 1D, wherein the desired degree of dynamic braking is controlled by selective energization of dynamic braking control contactors DB1, DB2 and DB3 in accordance with the chart of FIG. 2.

The +1 through +8 driving power designations shown in the chart of FIG. 2 correspond to the various increasing throttle positions or settings on diesel-electric type locomotives, wherein each of these settings is spaced from one another, as is well known by those skilled in the art, along a predetermined output power scale in accordance with the amount of driving power that can be developed under given operating conditions by the power unit in each throttle setting.

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Because of wheel slip considerations, it is desirable to prevent the higher throttle power settings when getting the train underway. Therefore, the energization of the aforementioned motor control wires and their associated control contactors is directed through various contacts on certain speed registering relays SR of FIG. 1C, to limit the operation of the locomotive throttle, as will be described, when getting the train underway.

Due to the slack action of the train, it is also desirable, in order to insure "smooth" starting of the train, to limit the locomotive throttle setting until the entire train is in motion, and furthermore, to prevent rapid changes in the throttle setting at the lower speeds. Therefore, as a feature, the system of the present invention provides means for limiting the throttle setting until the entire train is moving, and additional means whereby the rate of throttle setting can be maintained at relatively slow stepping rates until the actual speed of the train exceeds certain predetermined values.

Certain over-speed brake control apparatus is also provided, in the illustrated embodiment, to automatically cause application of the air brakes, if the train exceeds a certain preselected speed limit associated with the desired speed S_d . For example, if the actual speed of the train exceeds the desired speed by more than four miles per hour, a service application of the air braking system is automatically called for, and furthermore, if this service application is not properly initiated and the actual train speed exceeds the desired speed by more than five miles per hour, an emergency brake application is then enforced. As will be pointed out in detail hereinafter, during any air brake application, the locomotive traction motors are automatically connected in their "idling" condition.

As mentioned previously, the present invention also provides for determining the proper speed at which to initiate a brake release, when reverting from a higher to a lower demand speed. In order to understand this operation, it is necessary to consider the acceleration equations involved during this brake release operation.

Tests have shown that during a brake release, the acceleration of the train follows a straight line curve given by the equation,

$$Af = B \times t + Ao \quad (\text{Equation 5})$$

where

Ao is the acceleration at the beginning of the brake release,

B is the slope of the acceleration curve during the release,

t is the time involved, and

Af is the acceleration at time t .

With this type of acceleration curve, the speed of the train during the brake release is

$$Vf = \int Af \times dt = \int B \times t \times dt + \int Ao \times dt + Vo \quad (\text{Equation 6})$$

where

Vo is the train speed at the beginning of the brake release and

Vf is the train speed at time t .

Integrating Equation 6,

$$Vf = \frac{1}{2} B \times t^2 + Ao \times t + Vo \quad (\text{Equation 7})$$

Considering Equation 5, when the brake release is completed, the acceleration (actually a deceleration) due to braking effort is zero. Therefore, when the brakes are fully released,

$$Af = 0 \text{ and } B = Ao/t_1 \quad (\text{Equation 8})$$

where t_1 is the time at which the brakes are fully released.

When the brake release is completed, at time t_1 , it is desired that the train be travelling at its lower desired speed S_d . Therefore, by combining Equation 7 and Equa-

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tion 8 and substituting the desired speed S_d for the quantity Vf ,

$$S_d = Vo + Ao \times t_1 - \frac{1}{2} Ao \times t_1 = Vo + \frac{1}{2} Ao \times t_1 \quad (\text{Equation 9})$$

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$$Vo = S_d - \frac{1}{2} Ao \times t_1 \quad (\text{Equation 10})$$

where Ao is the measured acceleration of the train when the brake release is initiated.

As will be discussed in detail hereinafter, the apparatus shown in the accompanying drawings includes the necessary computing circuits, arranged in accordance with the foregoing Equations 5 through 10, for determining the proper speed Vo at which to initiate a brake release, when going from a higher to a lower desired speed, so that the brakes will be fully released substantially at this lower speed. Thus, while the train is decelerating, due to the brake application, the actual speed S_a is compared to the computed proper release speed Vo , and, when the actual speed decreases to this proper speed value, an automatic brake release is initiated, so that the lower demand speed will be realized, when the brakes are fully released.

Because of the length of time required for full brake release and the observed rapid increase in the coefficient of braking friction at low speeds, it is desirable to prevent a brake release, especially on long trains, if the actual speed of the train decreases below some predetermined value dependent upon the train length. Therefore, means are provided on the locomotive, in accordance with the present invention, whereby this predetermined speed value can be selected in accordance with the length of the train connected to the locomotive.

Illustrated conditions—train at standstill

Before beginning a detailed operational description, of the illustrated control system provided in accordance with the present invention, it is desirable to establish the normal conditions for the illustrated circuit apparatus, assuming that the receiver coils RC of FIG. 1A are receiving a $3\frac{1}{2}$ (service brake) code rate and that the automatic train is standing with its train brakes released and its independent locomotive brakes applied.

More specifically, locomotive brake control relay EPVR-L of FIG. 1B is deenergized at this time, to deenergize the locomotive electro-pneumatic valve EPV-L controlling the independent air brake system for the locomotive in such a way so that it causes a release of the locomotive brakes when energized and an application of the locomotive brakes when deenergized (as illustrated). Furthermore, train brake control relay EPVR-T of FIG. 1B is energized, at this time, by circuit extending from (+) in FIG. 1B, through front contact 10 of speed comparison relay D+4R, stick contact 11 of relay EPVR-T, and to (-). This energization of relay EPVR-T causes energization of the train electro-pneumatic valve, EPV-T through front contact 12 of relay EPVR-T, so that the train air brakes on the connected railway cars are released. Furthermore, emergency brake control relay EM, of FIG. 1B, which calls for an emergency application of the locomotive brakes when deenergized, is also picked up, during the normal stopping of the train, by circuit extending from (+) in FIG. 1A through front contact 13 of decoding relay 37R which indicates that a code rate about 37 pulses per minute is being received, wire 14 extending between FIGS. 1A and 1B, front contact 15 of suppression relay SUPP, stick contact 16 of relay EM, and to (-).

Referring to FIG. 1B, timer T1 is provided to insure a predetermined minimum time application of the train air brakes, after such brakes are once applied, while timer T2 delays application of the locomotive throttle until after the brakes are fully released, as will be pointed out in detail hereinafter. The picking up of relay EPVR-T of FIG. 1B thus causes timer T1 to be reset, over front contact 17 of relay EPVR-T, and timer T2 of FIG. 1B

to be energized, for its timing operation, over front contact 18 of relay EPVR-T. In the accompanying drawings, it is assumed that the train has been standing for quite some time, and therefore, timer T2 is shown as having completed its timing operation so that it closes its front contact 19, for energizing its repeater relay T2P.

When considering the normal stick circuit for train brake control relay EPVR-T, it was pointed out that the relay D+4R is normally energized while the automatic train is standing still. Referring now to FIGS. 1A and 1B, relay D+4R is normally energized by circuit extending from (+) in FIG. 1A, through back contact 20 of cam operated switch D+4, along wire 21 extending between FIGS. 1A and 1B, and to (-). Similarly speed comparison relay D+1R of FIG. 1B is normally energized over back contact 22 of cam operated switch D+1 and wire 23 extending between FIGS. 1A and 1B, while relay D+1/4R is normally energized over back contact 24 of cam operated switch D+1/4 and wire 25 extending between FIGS. 1A and 1B. As will be pointed out in detail, hereinafter, these cam operated switches D± are actuated depending upon a comparison of the actual train speed S_a to the desired or demand speed S_d , by the torque motor TM of FIG. 1A whose armature is operated to a position proportional to the difference between the actual and the desired speeds and which, in turn, operates a suitable plurality of cams (not shown) represented by the dotted rectangle CS.

As mentioned previously, the computed required horsepower HP_r determines the locomotive throttle power setting or dynamic braking necessary to maintain the desired speed S_d , called for by the received code rate. Referring to FIG. 1D, the locomotive power and dynamic brake setting is determined by the selective operation of a plurality of cam operated switches TC which, in turn, selectively energize the aforementioned throttle control wires WBG, WPY, WEX, WAV, WBV, WCV, and WDV of FIG. 1C connected to the conventional control contactors (not shown). More specifically, these cam operated switches TC are selectively operated by suitable plurality of cams, represented in FIG. 1D by the dotted rectangle CS2, in accordance with the operation of reversible motor RM1 which is controlled, in part, by a micropositioner MP1 in such a manner that they repeat the position of the movable contact arm 26 on the control resistor 27, as will be described.

The numerical designations appearing to the right of control resistor 27 in FIG. 1D are intended here to represent the various degrees of driving power and dynamic braking utilized in the illustrated embodiment of the present invention. Thus, the designation +1 through +8 represents increasing amounts of driving power; the designations -1 through -5 represent increasing amounts of dynamic braking, and the designation IDLE represents the "idling" setting of the locomotive throttle.

During the adjustment of the traction motors to the proper driving power or dynamic braking setting necessary to maintain the desired speed S_d , as called for by the computed required horsepower HP_r , the reversible motor RM1 is controlled by micropositioner MP1 of FIG. 1D, as noted above. This micropositioner MP1 is assumed here to be a sensitive polar type relay selectively operated to close its associated front and back contacts in accordance with the comparison of the required horsepower analog voltage appearing on wire 28, in the drawings, and the various voltage points designated on control resistor 27. Thus, the micropositioner MP1 is energized to close its illustrated front contact when the voltage applied to the left-hand side of its winding (along wire 28) is more positive than the voltage picked off by movable contact arm 26; it is energized to close its back contact when the voltage picked off by arm 26 is more positive than the analog voltage on wire 28, and it is centered (as shown) when the voltage difference across its winding is insufficient to cause its operation. In the selected embodiment,

the sensitivity of micropositioner MP1 is preset so that it requires a voltage difference across its winding of about 60% of the known voltage difference existing between adjacent points on control resistor before it will operate, in order to prevent jittery operation of the micropositioner.

Under the assumed standstill conditions, the left-hand side of micropositioner MP1 is connected to ground, along wire 28 between FIGS. 1D and 1B, and through back contact 29 of the locomotive brake control relay EPVR-L, while the reversible motor RM1 and the associated movable contact arm 26 will be in their respective "idle" conditions wherein contact arm 26 is positioned at the designated IDLE setting on resistor 27 and cam operated switch TCC is picked up and closes its front contact 29a to selectively energize wire 30 extending between FIGS. 1C and 1D and connected to the motor control wire WPY so that the associated control contactor PY (see FIG. 2) is energized to control the locomotive traction motors to their "idling" conditions.

Referring now to FIG. 1D, cam operated switches ODD and EVEN register whether the contact arm 26 is positioned at an "even" or "odd" designated setting on control resistor 27. Thus, under the assumed standstill conditions, with the movable contact arm 26 positioned at the IDLE setting of resistor 27, cam operated switch EVEN is picked up (as shown) to close its front contact 31 and thereby energize its front repeater relay CAM-E, while the cam operated switch ODD is presently closing its back contact 32 and thereby energizes its back repeater relay ODD-BP by a circuit extending from (+), through back contact 32 of the ODD cam switch, wire 33, and to (-). As will be pointed out in detail hereinafter, the back repeater relays ODD-BP and EVEN-BP are utilized to insure a relatively slow stepping of the locomotive throttle when getting the train underway.

Referring now to FIG. 1B, a conventional load regulator, including resistor LRR and adjustable tap 34, which is normally provided on the diesel-electric type locomotives, then provides the fine or vernier control of the locomotive speed around the throttle power or dynamic brake setting called for by the computed required horsepower HP_r , by varying the power output from the main generator MG (see FIG. 1C). This is accomplished, as is well-known to those skilled in the art, by automatically varying the current to the battery field winding BF (see FIG. 1C) of the main generator MG, in order that the desired speed be maintained.

Associated with this load regulator are relays MIN-FR and MAX-FR which detect when the load regulator has reached its left and right-hand limits respectively, as viewed in FIG. 1B, so that the locomotive throttle or dynamic brake setting can be automatically up-stepped or down-stepped, as will be described, from that called for by the computed required horsepower HP_r , to the next higher or lower setting in order to maintain at desired speed. Also associated with the load regulator of FIG. 1B is a conventional overriding solenoid ORS which, when deenergized, permits the tap 34 to move towards its so-called "balance point" on resistor LRR, and which when energized, moves tap 34 towards the minimum field position (as shown); i.e., to the left in the drawings.

With the locomotive traction motors in their "idling" condition, the overriding solenoid ORS is energized, as is well-known in the art, over the associated conventional energizing circuits (not shown) which are normally provided on the diesel-electric type locomotives, so that the adjustable tap 34 is in its illustrated minimum field position wherein the windings of relays MIN-FR and MAX-FR are both normally energized by current flowing from (+), through the center portion of resistor LRR, along wire 35 extending between FIGS. 1B and 1C, through the battery field winding BF of the main generator, and to (-). The minimum field repeater relay FRP of FIG. 1B is also normally energized, with the

train at standstill, over the obvious circuit including front contact 35a of minimum field relay MIN-FR.

In addition to its conventional energizing circuits normally provided on the diesel-electric type locomotive, the overriding solenoid ORS is also provided with an additional energizing circuit, to be described, in accordance with the selected embodiment of the present invention.

Getting underway

Assuming now that a 120 (medium speed) track code rate is received by receiver coils RC of FIG. 1A decoding relay 120R is picked up and energizes its repeater relay 120RP by a circuit extending from (+), through front contact 13 of relay 37R, back contact 36 of decoding relay 75R, front contact 37 of decoding relay 120R, and to (-). In the selected embodiment, these repeater relays RP are made slow dropaway to prevent an emergency brake application when changing from one desired speed to another.

This picking up of decoding relay 120R also completes the energizing circuit for starting relay START of FIG. 1A which includes capacitor 38, back contact 39 of relay 75R, front contact 40 of relay 120R, wire 41 extending between FIGS. 1A and 1C, back contact 42 of speed registering relay 2.5SR, and wire 43 extending between FIGS. 1C and 1A. It should be pointed out at this time, that capacitor 38 has been previously charged by a circuit extending through back contact 39 of relay 75R, back contact 44 of relay 120R, back contact 45 of relay 180R, along wire 46 between FIGS. 1A and 1C, through back contact 47 of speed registering relay 2.5SR, and to (+). Thus, when relay 120R picks up, in response to the 120 track code rate now being received by receiver coils RC, relay START can be picked up over the previously described pick-up circuit including capacitor 38. Once the relay START has been picked up, it is maintained in this picked up position by a stick circuit including its front contact 48, wire 49 extending between FIGS. 1A and 1B and back contact 50 of relay DIST, the relay DIST being operated generally in accordance with the distance travelled by the locomotive and being utilized to insure that the entire train is moving before the higher throttle settings are called for, and thereby insure "smooth" starting of the train.

This picking up of relay START then connects wire 28, leading to the left-hand side of micropositioner MP1 of FIG. 1D, to a preselected voltage value intended here to represent a required starting horsepower, equivalent with +3 setting of contact 26 of FIG. 1D on control resistor 27, until the entire train is moving as detected by the picking up of relay DIST. More specifically, this preset starting horsepower analog voltage is developed across resistor 51 of FIG. 1A and is applied, through front contact 52 of relay START, to wire 28 which extends between FIGS. 1A and 1D to the left-hand side of micropositioner MP1. However, it will be noted in FIG. 1B, that wire 28 is grounded until relay EPVR-L is picked up (locomotive brakes released) at back contact 29 of relay EPVR-L. Therefore, the preset voltage, calling for the +3 throttle setting of contact arm 26, is incapable of operating the micropositioner MP1, until these locomotive brakes are released. Obviously, this insures an IDLE throttle setting during application of the locomotive brakes, and referring to FIG. 1B, it will be noted that a similar arrangement, including back contact 53 and 54 of relays EPVR-T and T2P respectively, is provided which automatically calls for the IDLE throttle setting when the train brakes are applied.

Referring now to FIGS. 1A and 1B, the locomotive brake control relay EPVR-L is energized, in response to the picking up of repeater relay 120RP as previously described, by a circuit extending through front contact 55 of repeater relay 120RP and along wire 56 between FIGS. 1A and 1B. With the locomotive brake control relay EPVR-L picked up, the locomotive electro-pneu-

matic valve EPV-L of FIG. 1B is then energized, over front contact 57 of relay EPVR-L, to release the locomotive brakes, and furthermore, back contact 29 of relay EPVR-L is now open so that the preselected starting horsepower analog voltage, from resistor 51 of FIG. 1A and appearing on wire 28, is now applied to the left-hand side of micropositioner MP1 of FIG. 1D to cause reversible motor RM1 to operate contact arm 26 towards the +3 position on control resistor 27.

Since the right-hand side of micropositioner MP1 (movable contact arm 26) is connected to ground (the IDLE setting on resistor 27), the micropositioner MP1 is energized to close its front contact 58, by the current flowing from left to right in its winding. This closing of front contact 58 of micropositioner MP1 causes the reversible motor RM1 to be energized, for moving contact arm 26 in an upwardly direction along control resistor 27. More specifically, reversible motor RM1 is now energized by circuit extending from (+) in FIG. 1D, through front contact 59 of back repeater relay ODD-BP, back contact 60 of back repeater relay EVEN-BP, along wire 61 between FIGS. 1D and 1B, back contact 62 of relay D-4R, along wire 63 between FIGS. 1B and 1D, through front contact 58 of micropositioner MP1, contact 64 of the upper limit switch ULS, and to (-). Movable contact arm 26 is thus up-stepped to the +1 position on resistor 27 to call for the first throttle power setting.

With movable contact arm 26 now located at the +1 position on control resistor 27 (which is an "odd" designated position), cam operated switch ODD is now picked up to energize relay CAM-O, over front contact 65 of switch ODD, while the cam operated switch EVEN is now opened to energize its back repeater relay EVEN-BP, over back contact 66 of the EVEN cam switch.

Although back repeater relay ODD-BP is now deenergized, by the opening of back contact 32 of switch ODD, relay ODD-BP is temporarily retained in its picked-up position for a predetermined time, to interrupt the energizing circuit for reversible motor RM1, in order to insure a relatively slow stepping of the locomotive throttle when getting the train underway, because of the slack action of the train. Thus, back repeater relay ODD-BP is made slow releasing due to the resistance-capacitance network connected across its winding. More specifically, the dropaway time of back repeater relay ODD-BP is determined by capacitors C1, C2 and C3 and variable resistor LR-O which is set in accordance with the train length, connected in multiple with its winding. The capacitors C2 and C3 are respectively connected in multiple with the winding of relay ODD-BP through back contacts 67 and 68 of speed registering relays 15SR and 20SR respectively and wires 69 and 70 extending between FIGS. 1D and 1C, to cause a relatively slow dropaway time for back repeater relay ODD-BP, while the train speed is below fifteen miles per hour. However, above fifteen miles per hour, the dropaway time of relay ODD-BP is decreased somewhat from its low speed time rate, by the removal of capacitor C2 from the circuit, and, it is further reduced to its minimum (determined by capacitor C1) when the speed of the train exceeds twenty miles per hour, by the additional removal of capacitor C3 from the circuit.

Assuming now that back repeater relay ODD-BP has dropped away, reversible motor RM1 is once again energized, to up-step the movable contact arm 26 to the +2 position on resistor 27 to call for the next higher power setting by a circuit extending from (+) in FIG. 1D, through back contact 71 of back repeater relay ODD-BP, front contact 72 of back repeater relay EVEN-BP, and, through the previously described energizing circuit for motor RM1, including wires 61 and 63 extending between FIGS. 1D and 1B, and front contact 58 of micropositioner MP1.

Similarly, with the contact arm 26 now located on the +2 position of control resistor 27 (an "even" designated position), the back repeater relays EVEN-BP and

ODD-BP are reversed to their illustrated positions, with the capacitors C4, C5, and C6 determining the dropaway time for back repeater relay EVEN-BP, so that reversible motor RM1 may not operate the movable contact arm 26 to the +3 position on resistor 27, calling for the third power setting, until the relay EVEN-BP, has dropped away.

During the operation of movable contact arm 26, from the IDLE to the +3 position on control resistor 27, the locomotive throttle power setting is gradually increased due to the selective operation of the cam operated switches TC of FIG. 1D. More specifically, when the movable contact arm 26 is occupying the +1 position on control resistor 27, only cam operated switch TC1-8 is closed to energize the WEX control wire, over wire 73 extending between FIGS. 1D and 1C. Referring to FIG. 2, this calls for the first power setting of the locomotive throttle above "idle" and furthermore, since "idling" of the traction motors is no longer called for, the overriding solenoid ORS or FIG. 1B is now deenergized, as is well-known to those skilled in the art, to permit tap 34 to gradually move to the right along resistor LRR of the load regulator away from its minimum field position. It should be noted in FIG. 1B that when the tap 34 leaves its minimum field position, the winding of the minimum field relay MIN-FR is shunted, and therefore, relay MIN-FR, as well as its repeated relay FRP, is dropped away.

When the movable contact arm 26 is actuated to the +2 position on control resistor 27, as previously described, cam operated switches TC1-8 and TC2 are both closed to respectively energize motor control wires WEX and WAV of FIG. 1C, to call for the next higher (second) power setting of the locomotive throttle. Furthermore, when the movable contact arm 26 is operated to the +3 position on control resistor 27, cam switches TC1-8 and TC3-8 are closed and therefore, motor control wires WEX and WCV are selectively energized, to call for the third power setting of the locomotive throttle. In the above it should be noted that the numerical suffix associated with each of the cam operated switches TC represents the positions of contact arm 26 on which the particular cam operated switch is closed. For example, switch TC1-8 is closed on positions +1 through +8, while switch TC2 is closed only on position +2.

This increasing of the locomotive throttle setting obviously causes the locomotive to start in motion, and, as mentioned previously, relay DIST is provided to register when the entire train is moving so that the START relay can then be released, to increase the demand speed, as will be described, from two miles per hour to the twenty-five miles per hour requested by the received 120 code rate. Thus, because of train slack, the locomotive or leading end of the train will begin in motion before the trailing end, it is desirable to wait until the entire train is moving before the desired speed is changed to twenty-five miles per hour, in order to insure "smooth" starting. Therefore, relay DIST of FIG. 1B is provided with an upper pickup winding and a lower knockdown winding, the latter of which is normally energized by current value, selected by the setting of rheostat 74, which is adjusted in accordance with the known length of the train.

During normal running of the train, the actual train speed S_a is detected by an axle-driven frequency generator ADFG of FIG. 1A which is mounted on the locomotive and whose output is a frequency proportional to the actual train speed. This speed frequency analog is then converted by a Frequency To Speed Converter 75 to provide a voltage analog of the actual train speed S_a . However, until the entire train is in motion, this output voltage analog from the Frequency To Speed Converter 75 is indicative of the locomotive speed only. Therefore, during starting, this voltage analog from converter 75 is then fed along wire 76, between FIGS. 1A and 1B, to the input of a suitable integrating circuit 77, for picking up

relay DIST provided the current output from the integrator 77 is greater in magnitude than the preset current energizing the lower or knockdown winding of relay DIST and thus detects when the distance travelled by the locomotive is greater than the known train length, to indicate that the entire train is moving. Obviously, however, the minimum distance that the train locomotive must travel, before the entire train will be in motion, and, for which relay DIST should be preset, is dependent upon the known amount of slack that must be taken up. When relay DIST thus picks up, the stick circuit for relay START is then interrupted, at back contact 50 of relay DIST, so that relay START then drops away to change the demand speed from two to twenty-five miles per hour. This dropping of relay START then shorts out the input to integrating circuit 77, to drop relay DIST, by a circuit including wire 78 between FIGS. 1B and 1A, and back contact 79 of relay START. Obviously, once the entire train is in motion, the analog voltage output from the Frequency To Speed Converter 75 is the analog of the actual train speed S_a .

During starting of the locomotive, the desired or demand speed S_d is converted to two miles per hour by connecting the right-hand side of torque motor TM of FIG. 1A to the 2 m.p.h. tap on resistor 80, through front contact 81 of relay START. The analog of the actual train speed S_a is then applied to the left-hand side of torque motor TM, via wire 76, and the armature of the torque motor TM assumes a position which is proportional to the difference between the actual and desired speeds.

Associated with torque motor TM, is a plurality of cam operated switches $D\pm$ selectively energized in accordance with the aforementioned comparison between the actual and desired speeds. More specifically, the switches $D+\frac{1}{4}$, $D+1$ and $D+4$ open their back contacts when the actual train speed is one-quarter mile per hour, one mile per hour, and four miles per hour, respectively, above the demand speed, while switches $D-1$ and $D-4$ close their front contacts when the actual speed is below the demand speed, by these amounts. Thus, with the train at standstill and the demand speed S_d equal to two miles per hour, cam operated switch $D-1$ is actuated to close its front contact 82, for energizing the associated relay $D-1R$ of FIG. 1B over wire 83 and front contact 84 of relay $D+1R$, to register that the actual speed is less than the demand speed minus one mile per hour.

When relay START drops away, as previously described, the demand speed S_d is then increased from two to twenty-five miles per hour, due to the connection of the right-hand side of torque motor TM to the 25 m.p.h. tap on resistor 80, through back contact 85 of relay START, back contact 86 of repeater relay 75RP, and front contact 87 of repeater relay 120RP. Since the demand speed S_d has been increased to twenty-five miles per hour, cam operated switch $D-4$ is now operated to close its front contact 88 and thereby cause energization of its associated relay $D-4$ of FIG. 1B by a circuit including front contact 88 of cam operated switch $D-4$, wire 89 between FIGS. 1A and 1B, front contact 90 of relay $D+4R$, and to (-). This picking up of relay $D-4R$ then completes a direct energizing circuit to up-step the reversible motor RM1 (control taken away from micropositioner MP1), so that the movable contact arm 26 can be up-stepped towards the +8 position on control resistor 27; i.e. the locomotive throttle is advanced towards the eighth power setting. More specifically, this direct energizing circuit for reversible motor RM1 includes wire 61 extending between FIGS. 1D and 1B, front contact 91 of relay $D-4R$, and wire 92 extending between FIGS. 1B and 1D to the up-step side of motor RM1.

As mentioned previously, because of the wheel slip considerations, it is desirable to limit the stepping rate of the locomotive throttle in accordance with the actual

train speed S_a . This is accomplished by controlling the energization of the motor control wires WAV, WBV, WCV, and WDV of FIG. 1C through certain front and back contacts on the relays SR of FIG. 1C which are selectively energized in accordance with the actual speed at which the train is moving. Thus, these speed registering relays SR, of FIG. 1C, are assumed to be selectively energized by a suitable plurality of cam operated switches, actuated by the cams represented by the dotted rectangle CS3 in FIG. 1C. This selective energization of the speed registering relays ST is accomplished by comparing the voltage analog of the actual train speed S_a , appearing on wire 76 in the accompanying drawings, with a reference voltage supplied by potentiometer 93 of FIG. 1C, at micropositioner MP4. Thus, micropositioner MP4 selectively closes its associated front and back contacts to control reversible motor RM4, in such a manner that the voltage picked-off by contact arm 94 is balanced with the actual speed analog voltage, on wire 76. Motor RM4 then operates the cams represented by the rectangle CS3, and thereby selectively energizes the speed registering relays SR in accordance with the actual train speed. In the selected embodiment, it is intended that each of the speed registering relays will be picked up when the actual speed of the train is above the numerical designation associated with that particular speed registering relay; e.g., relay 2.5SR will be picked up as long as the actual speed of the train is above two and one-half miles per hour, while speed registering relay 8SR will be picked up as long as the train speed is above eight miles per hour, etc.

Recalling now that the reversible motor RM1 of FIG. 1D is being directly energized, over front contact 91 of relay D—4R of FIG. 1C, the contact arm 26 is then operated to the +4 position on control resistor 27 (assuming of course that back repeater relay EVEN—BP is dropped away). However, in order to prevent slippage of the wheels it is desirable to delay the fourth power setting of the locomotive throttle until the actual speed of the train has increased above two and one-half miles per hour. Thus, when cam operated switch TC4 of FIG. 1D is closed to register that contact arm 26 is on the +4 position of control resistor 27, wire 95 between FIGS. 1D and 1C is now energized to call for the fourth throttle power setting. If the actual speed of the train is above two and one-half miles per hour, this energization of wire 95 causes motor control wire WAV to be energized over front contact 96 of speed registering relay 2.5SR. Control wires WAV, WEX and WCV are thus energized to provide the fourth throttle power setting (see FIG. 2). However, if the actual train speed is below two and one-half miles per hour (relay 2.5SR dropped away), when the contact arm 26 is operated to the +4 position on resistor 27, the third throttle power setting will be retained, until actual train speed does exceed two and one-half miles per hour.

Depending upon the dropaway time of back repeater relay ODD—BP of FIG. 1D, the reversible motor RM1 will subsequently be energized to up-step contact arm 26 to the +5 position on control resistor 27, to energize wire 97 between FIGS. 1D and 1C which calls for the fifth power setting of the locomotive throttle. When this occurs, the third power setting will be retained until the actual speed of the train exceeds two and one-half miles per hour (front contact 96 of relay 2.5SR closes), the fourth power setting will be maintained between two and one-half and four miles per hour, while the fifth power setting, now being called for by the cam operated switch TC5 of FIG. 1D, will not be obtained until the actual speed of the train is above four miles per hour (front contact 99 of relay 4SR closed). In a similar manner, as the contact arm 26 continues its up-stepping toward the +8 position on control resistor 27, to finally call for the eighth power setting, the sixth power setting will not be obtained until the actual

speed is above six miles per hour, the seventh power setting will not be obtained until the actual speed is above eight miles per hour, and the eighth power setting will not be obtained until the actual speed is above eleven miles per hour. After the train exceeds eleven miles per hour, so as to permit the eighth throttle power setting, the train then rapidly accelerates towards its desired speed of twenty-five miles per hour.

If the reversible motor RM1 attempts to drive the contact arm 26 above the +8 position on control resistor 27, the upper limit switch ULS is operated to open its contact 64 in the energizing circuit for reversible motor RM1, and therefore, reversible motor RM1 will be stopped with contact arm 26 at the +8 position on control resistor 27.

When the actual train speed increases past twenty-one miles per hour, front contact 88 of cam operated switch D—4 of FIG. 1A now opens to interrupt the energizing circuit for relay D—4R of FIG. 1B, and, the control of reversible motor RM1 is shifted from direct up-stepping to control by the micropositioner MP1, in accordance with the computed required horsepower HP_r necessary to maintain the desired speed S_d , as computed in accordance with the train dynamic Equations 1 through 4, previously set forth.

Maintaining desired speed

The actual horsepower HP_a being developed by the locomotive traction motors is detected by measuring the voltage and current outputs from the main generator MG of FIG. 1C. More specifically, the voltage output from the main generator MG appears across resistor 100, and, a preselected portion of this generator output voltage is applied to the left-hand side of micropositioner MP2 for comparison with the reference voltage appearing on resistor 101. Micropositioner MP2 then controls the reversible motor RM2, in such a manner as to balance the voltage being picked off resistor 101 by adjustable tap 102 with the preselected portion of the generator output voltage, i.e. the voltage appearing on wire 103 is directly proportional to the generator output voltage. Similarly, the generator output current is detected by utilizing shunt 104 connected in the output circuit of the main generator MG. The voltage thus applied to the left-hand side of micropositioner MP3 is directly proportional to the voltage developed across shunt 104, and therefore to the generator output current. Micropositioner MP3 then controls reversible motor RM3 to move adjustable tap 105, on resistor 106, until the voltages on either side of micropositioner MP3 are balanced, so that the voltage appearing on wire 107 is directly proportional to the generator output current.

These voltage analogs of the generator output voltage and current are simultaneously applied to a multiplier 108 of FIG. 1C, having an operational amplifier 109 and a resistor 110 connected to its output. The tap 111 on resistor 110 is preset in accordance with the known constant relating the product of the generator output voltage and current to the actual horsepower HP_a being developed by the traction motors so that the voltage picked off by tap 111 is the analog of this actual horsepower HP_a .

This voltage analog of the actual horsepower HP_a is then fed along wire 112 to the input of adder 113, connected in a dividing circuit arrangement with multiplier 114 and operational amplifier 115, in such a manner that the output voltage from this circuit arrangement (appearing across resistor 116) is proportional to the quotient of the actual horsepower HP_a divided by the actual train speed S_a (applied to multiplier 114 via wire 76). The tap 117 on resistor 116 is then preset in accordance with the known constant relating to the actual horsepower HP_a being developed by the traction motor to the actual tractive effort TE_a being developed by the motors.

The voltage analog of the actual tractive effort being developed, is then fed along wire 118, between FIGS. 1C

and 1B, as one input to adder 119, while the other input to this adder 119 is a voltage analog of the inertial force of the train; i.e. the product of the mass M of the train multiplied by the actual train acceleration Aa .

The actual acceleration Aa of the train is detected by differentiating the actual speed analog voltage output from the Frequency To Speed Converter 75, of FIG. 1A, by means of a conventional differentiating circuit 120. The output of this differentiating circuit 120, a voltage analog of the actual train acceleration Aa , is then fed along wire 121, between FIGS. 1A and 1B, to the input of operational amplifier 122. The output resistor 123 of the operational amplifier 122, is provided with an adjustable tap 124 which is preset in accordance with the known mass of the train, so that the voltage picked off by tap 124 is the analog of the inertial force of the train; i.e. the product of the train mass M multiplied by the actual train acceleration Aa . This inertial force analog voltage is then applied to a Sign Changer 125, so that the voltage appearing on wire 126 is the negative analog of the train mass M multiplied by the actual acceleration Aa .

Referring to Equations 1 and 2 previously set forth, when the voltage analog appearing on wire 126 is added to the tractive effort analog voltage appearing on wire 118, as is accomplished by the adder 119, the voltage appearing at the output of adder 119 on wire 127, is the voltage analog of the rolling resistance Fr being encountered by the train. This voltage analog of the rolling resistance Fr is then applied along wire 127, as one input to multiplier 128 in order to compute the required horsepower HP_r necessary to maintain the desired speed S_d , in accordance with the foregoing Equation 4. The other input to multiplier 128 is a voltage proportional to the demand or desired speed S_d multiplied by the known constant C relating horsepower to tractive effort. More specifically, the voltage analog of the demand speed S_d is picked off resistor 80 in FIG. 1A and appears on wire 129 in FIGS. 1A and 1B. This demand speed analog voltage is then applied to operational amplifier 130 having resistor 131 connected across its output with an associated tap 132 which is preset in accordance with the known constant C . The resulting voltage analog of this product of the demand speed analog voltage and the known constant C is then fed along wire 133 in FIG. 1B as the second input to multiplier 128.

In accordance with the Equation 4, the output of multiplier 128 is therefore the voltage analog of the required horsepower HP_r necessary to maintain the train at the desired speed S_d . This analog voltage of the computed required horsepower HP_r is then fed along wire 134 between FIGS. 1B and 1A, through back contact 135 of relay START, along wire 136 between FIGS. 1A and B, through front contact 137 of relay D—1R, and along wire 28 between FIGS. 1B and 1D which is connected to the left-hand side of micropositioner MP1 controls the reversible motor RM1 to down-step contact arm 26 to the proper position on control resistor 27 (to call for the proper throttle power setting or dynamic braking) necessary to maintain the desired speed S_d .

With the contact arm 26 at the +8 position of control resistor 27, and assuming that the computed required horsepower HP_r calls for a power reduction from the eighth to the third power setting of the locomotive throttle (+3 position on resistor 27), micropositioner MP1 is now energized with a current flowing from right to left through its winding, so that back contact 138 of micropositioner MP1 is now closed. The down-step side of reversible motor RM1 is now energized to decrease the throttle setting called for by contact arm 26; i.e. contact arm 26 is moved downwardly on resistor 27, by circuit extending from (+) in FIG. 1D through front contact 59 of back repeater relay ODD-BP, back contact 60 of back repeater relay EVEN-BP, wire 61 between FIGS. 1D and 1B, back contact 62 of relay D—4R, wire 63 between FIGS. 1B and 1D, back contact 138 of micro-

positioner MP1, contact 139 of the lower limit switch LLS, and to (—).

When the contact arm 26 is now lowered to the +7 position on control resistor 27, the back repeater relays EVEN-BP and ODD-BP are again reversed, as previously described, but since the actual train speed S_a is above twenty miles per hour, the dropaway times of these back repeater relays ODD-BP and EVEN-BP have been substantially reduced since capacitors C2, C3, C5 and C6 are no longer connected across the respective windings of these relays; e.g. back contacts 67 and 68 of speed registering relays 15SR and 20SR respectively are now both open, so that the dropaway time of relay ODD-BP is reduced. Thus, the locomotive throttle setting can be reduced at a relatively faster rate, than the stepping rate maintained during acceleration, as previously described.

In substantially the same manner as was previously discussed, when considering the up-stepping of contact arm 26 during acceleration, the locomotive power setting is now reduced in steps determined by the back repeater relays ODD-BP and EVEN-BP until the control arm 26 is lowered to the +3 position on control resistor 27 to call for the third power setting of the throttle, as required by the computed horsepower HP_r , to maintain twenty-five miles per hour.

Assuming now that contact arm 26 is properly located at the +3 position on control resistor 27, when the actual train speed S_a exceeds twenty-four miles per hour, cam operated switch D—1, of FIG. 1A, opens its front contact 82 and therefore deenergizes the associated relay D—1R of FIG. 1B. This dropping away of relay D—1R opens its front contact 137, and thereby disconnects the voltage analog of the computed required horsepower HP_r from the left-hand side of the micropositioner MP1 which in turn subsequently assumes its centered position, wherein its front and back contact are both opened. The load regulator of FIG. 1B, comprising resistor LLR and adjustable tap 34, then provides the fine control of the train speed, around the throttle power setting called for by the computed required horsepower HP_r .

Generally speaking, the load regulator of FIG. 1B attempts to maintain a constant generator load on the diesel engine for a given throttle setting. However, in accordance with the present invention, this load regulator is controlled to operate below the so-called "balance point" for a particular throttle setting and speed, and therefore, the adjustable tap 34 is continually attempting to move to the right along resistor LLR, but, is prevented from reaching its "balance point" by the overriding solenoid ORS.

Assuming that the train is traveling at twenty-five miles per hour, as the adjustable tap 34 moves to the right, on resistor LLR, towards its "balanced point" for the third throttle position, the actual train speed gradually increases. However, as soon as the actual train speed exceeds the demand speed by one-quarter mile per hour, back contact 24 of cam operated switch D+¼ of FIG. 1A is opened, to drop its associated relay D+¼R of FIG. 1B. This dropping of relay D+¼R now energizes relay ORSR of FIG. 1B by a circuit including a back contact 140 of relay D+¼R, and with relay ORSR now picked up, overriding solenoid ORS of FIG. 1B is now energized from (+) energy, over back contact 140a of minimum field repeater relay FRP and front contact 141 of relay ORSR, and causes the adjustable tap 34 to gradually move to the left along resistor LLR of the load regulator towards the minimum field position, so as to decrease the magnitude of the current flowing through the battery field winding BF of the main generator MG (see FIG. 1C). This then gradually decreases the generator output voltage and the loading on the diesel engine so that engine speed governor calls for less fuel and the current to the traction motors is decreased, with the result that the actual speed of the train will be properly reduced. This movement of adjustable tap 34 to the left along resistor LLR

continues until the train speed decreases to within one-quarter mile per hour of the demand speed S_d , at which time, relay $D+\frac{1}{4}R$ is again picked up to deenergize relay ORSR and therefore also overriding solenoid ORS, which releases the load regulator and allows adjustable tap 34 to move to the right on resistor LRR, towards its "balanced point."

If the actual train speed should again exceed twenty-five and one-quarter miles per hour, the overriding solenoid is once again energized to reduce the generator battery field current towards its minimum. In this manner, the train speed is accurately held between twenty-five and twenty-five and one-quarter miles per hour.

If for some reason, the actual train speed stays above the demand speed plus one-quarter mile per hour, for example, because of a downgrade or the like, the overriding solenoid ORS of FIG. 1B will remain energized and cause the adjustable tap 34 to move to its extreme left-hand position on resistor LRR (as shown), wherein relay MIN-FR will be picked up to cause an automatic down-step of the locomotive throttle setting from the third to second power setting as shown in FIG. 2. More specifically, if relay MIN-FR is picked up, reversible motor RM1 is now energized to cause an automatic down-step of contact arm 26 to the +2 position on control resistor 27 (second throttle power setting called for) by a circuit extending from (+) in FIG. 1D, through the closed back contact 141a of "idle" cam switch TCC, along wire 141b extending between FIGS. 1D and 1B through back contact 142 of relay D-4R, front contact 143 of relay $D+4R$, front contact 144 of relay MIN-FR, along wire 145 between FIGS. 1B and 1D, front contact 146 of relay CAM-O, back contact 147 of relay CAM-E, along the down-step wire 148 through contact 139 of the lower limit switch LLS, and to (-).

During the down-stepping operation, from the third to the second throttle setting, the relay CAM-O is stuck in its picked up position by a stick circuit including its own front contact 149, wire 150 extending between FIGS. 1D and 1B, and front contact 151 of relay MIN-FR. As soon as the down-stepping of contact arm 26 has been completed, the relay CAM-E is also stuck in its picked up position, over front contact 152, to prevent more than one such automatic down-stepping each time relay MIN-FR picks up.

Referring to FIG. 1B, when the minimum field relay MIN-FR and its repeater relay FRP are picked up, by the movement of tap 34 to its minimum field position on resistor LRR, the overriding solenoid ORS is automatically deenergized, by the opening of back contact 140a of repeater relay FRP, and therefore the tap 34 is again permitted to move to the right along resistor LRR to shunt the winding of relay MIN-FR and thereby cause relay MIN-FR and its repeater relay FRP to drop away. Therefore, if the aforementioned down-stepping of the locomotive throttle setting fails to properly reduce the train speed to below twenty-five and one-quarter miles per hour, within the predetermined time interval set by the slow-drop-away time of relay FRP, the overriding solenoid ORS is again energized to move tap 34 towards its minimum field position, wherein relays MIN-FR and FRP are again energized, so that another down-step of the throttle setting is called for, if required, to properly hold the desired speed.

Similarly, if the train speed should begin to drop below the twenty-five miles per hour demand speed, the adjustable tap 34 is permitted to gradually move to the right along resistor LRR, i.e., solenoid ORS not energized, so as to increase the generator output voltage which causes the traction motor current to increase with the result that the train speed be properly increased. However, if the actual train speed remains below the demand speed, for example because of an up-grade or the like, the tap 34 will be able to move far enough to the right on resistor LRR in order to drop relay MAX-FR. This

relay MAX-FR is connected to load regulator LRR in such a manner that it will be dropped away, to call for an up-stepping of the throttle, just before the adjustable tap 34 reaches its so called "balance point."

Assuming now that relay MAX-FR drops away when contact arm 26 (of FIG. 1D) is located at the +2 position on control resistor 27, the contact arm 26 would be actuated from the +2 to the +3 position on control resistor 27 by a direct up-stepping circuit now completed to reversible motor RM1 extending from (+) in FIG. 1D, through back contact 141a of cam switch TCC, wire 141b extending between FIGS. 1D and 1B, through back contact 142 of relay D-4R, front contact 143 of relay $D+4R$, back contact 153 of relay MAX-FR, along wire 154 between FIGS. 1B and 1C, back contact 155 of relay CAM-O, front contact 156 of relay CAM-E, and along the up-step wire 157, and to the reversible motor RM1. With the relay MAX-FR dropped away, a common stick circuit is then provided for relays CAM-E and CAM-O at back contact 158 of relay MAX-FR, so that only one up-stepping of contact arm 26 results for each dropaway of relay MAX-FR. Thus, after control arm 26 is up-stepped to the +3 position on control resistor 27, the direct up-stepping circuit, just described, is then interrupted because both the CAM-O and CAM-E relays are picked up.

It should be pointed out at this time that the traction motors of the vehicle may be required to be connected for dynamic braking, in accordance with the computed required horsepower HP_r , in order to maintain the desired speed S_d . Thus, if the computed required horsepower HP_r calls for dynamic braking, the contact arm 26 is operated downwardly on control resistor 27 to select one of the dynamic braking positions -1 to -5, wherein the dynamic braking control contactors DB1, DB2, and DB3 of FIG. 1D are selectively energized to provide the desired degree of braking in accordance with the dynamic braking portion of the chart of FIG. 2. As mentioned previously, during dynamic braking of the traction motors, the cam operated switch TCBG of FIG. 1D is also closed to energize wire 160 extending between FIGS. 1D and 1C and connected to the dynamic braking control wire WBG of FIG. 1C which, when energized causes the traction motors to be connected for dynamic braking as shown in FIG. 1D.

Referring now to FIG. 1D, during the dynamic braking, dissipating grids DG are connected across the traction motor armatures TMA to dissipate the rotational energy of the traction motors. In order to vary the dynamic braking, a resistor DBR is then connected in multiple with the traction motor armatures TMA and supplies selected amounts of voltage across the battery field winding BF of the main generator MG in accordance with the selective operation of the dynamic braking control contactors DB1, DB2, and DB3. The traction motor field windings TMF are then connected across the main generator MG so that as the voltage applied to the battery field winding BF increases, the magnetic flux produced by the traction motor field winding TMF also increases to produce increased dynamic braking effort on the traction motor armatures TMA.

More specifically, the dynamic braking resistor DBR is connected in a voltage divider network, as diagrammatically illustrated in FIG. 1D, whereby the selective operation of the dynamic braking control contactors DB1, DB2, and DB3 applies varying voltages across the battery field winding BF of the main generator MG. As illustrated, the dynamic braking contactors DB1, DB2 and DB3 are all unactuated, and therefore, substantially no voltage is applied across the battery field winding BF. However, if the first degree of dynamic braking is called for (contact arm 26 is located in the -1 position on control resistor 27), back contact 161 of contactor DB3 and front contact 162 of contactor DB2 are closed for selecting (see FIG. 2) a predetermined amount of the voltage across resistor DBR for energization of the battery

field winding BF. This then causes a predetermined degree of dynamic braking effort on the traction motor armatures TMA. If the second degree of dynamic braking is called for (contact arm 26 is located in the -2 position on resistor 27), a somewhat larger voltage is applied across the battery field winding, via front contact 163 of contactor DB3 and back contacts 164 and 165 of contactors DB2 and DB1 respectively, to increase the dynamic braking effort at the traction motor armatures TMA. Referring to FIG. 2, in the fifth dynamic braking position, control contactors DB1, DB2 and DB3 are all operated to close their associated front contacts 163, 166 and 167 respectively so that a maximum voltage is applied to the battery field winding BF, to provide the maximum degree of dynamic braking at the traction motor armatures TMA.

From the above discussion, it is seen that between twenty-one and twenty-four miles per hour, the computed required horsepower HP_r automatically adjusts the locomotive throttle power or dynamic braking to that setting required to just maintain the desired speed S_d , while the load regulator of FIG. 1B provides the fine or vernier control of the locomotive speed, if necessary, in order that the actual speed of the train be maintained within one-quarter mile per hour of the demand speed.

If for some reason, the actual speed of the train increases past twenty-six miles per hour, cam operated switch D+1 of FIG. 1A opens its back contact 22 and thereby deenergizes the associated relay D+1R of FIG. 1B. This dropping away of relay D+1R then reconnects wire 134 from multiplier 128 of FIG. 1B (the analog voltage of the computed required horsepower HP_r) to the left-hand side of micropositioner MP1, over back contact 168 of relay D+1R, so that the contact arm 26 is once again adjusted on control resistor 27, in accordance with the horsepower required to maintain the twenty-five miles per hour demand speed.

If the actual train speed should exceed twenty-nine miles per hour, even though the load regulator has previously caused an automatic down-step of the locomotive throttle setting, relay D+4R of FIG. 1B is now deenergized, to drop the train brake control relay EPVR-T of FIG. 1B, by the opening of front contact 10 of relay D+4R. This dropping away of brake control relay EPVR-T causes a service application of the train air brakes to be initiated (electro-pneumatic valve EPV-T is deenergized), while the left-hand side of micropositioner MP1 (wire 28) is now connected to ground, through back contact 53 of relay EPVR-T, so that the reversible motor RM1 moves the contact arm 26 to the IDLE position on control resistor 27 (as shown), to cause the traction motors to "idle" during this brake application. The dropping of the train brake control relay EPVR-T also causes timer T1 to begin its timing operation, due to the closing of back contact 169 over relay EPVR-T, while timer T2 is reset over back contact 170 of relay EPVR-T, and drops its repeater relay T2P.

If this service brake application is properly made, pressure switch PS1 of FIG. 1B closes its front contact 171 within a predetermined time interval and thereby retains relay SUPP picked up, so as to prevent drop away of the emergency brake control relay EM of FIG. 1B. This predetermined time interval is dependent upon the slow dropaway time of repeater relay D+4RP of FIG. 1B which is deenergized when relay D+4R drops away, to indicate that the train speed is above twenty-nine miles per hour, by the opening of front contact 172 of this relay D+4R. With reference to FIG. 1B, front contact 173 of repeater relay D+4RP is included in the normal energizing circuit for relay SUPP. Therefore, if repeater relay D+4RP drops away before the service brake application is properly made (pressure switch PS1 closes), relay SUPP will drop away, to open its front contact 15 connected in the normal stick circuit for emergency brake control relay EM. Obviously, this will cause the emer-

gency brake control relay EM to drop away, to call for an emergency application of the vehicle air brakes, provided, of course, that the overspeed relay C is also dropped away, indicating that the actual speed of the train is above thirty miles per hour, assuming a 120 received code rate. In the above, pressure switch PS1 is assumed to be connected in the air braking system of the vehicle in such a manner that it closes its front contact 171 only after the air braking system is properly conditioned to supply the desired service brake application; e.g. pressure switch PS1 might close its front contact 171 when the pressure of the air brake equalizing reservoir is sufficiently below the pressure of the air brake feed valve to indicate that a service brake application has been enforced.

Assuming now that the train speed has been reduced to within four miles per hour of the demand speed so that the relay D+4R is once again picked up to close its front contact 10, the train brake control EPVR-T is again energized for releasing the air brakes, by a circuit including front contact 10 of relay D+4R, wire 174 between FIGS. 1B and 1C, front contact 175 of speed registering relay 8SR (assuming that switch TLS is in the illustrated position), wire 176 between FIGS. 1C and 1B, front contact 177 of timer T1 (which closes after timer T1 has completed its timing operation to insure a predetermined minimum brake application time) and to (-). When the train brake control relay EPVR-T now picks up, timer T1 is reset over front contact 17 of relay EPVR-T, while timer T2 initiates its timing operation over front contact 18 of relay EPVR-T, to insure that the train brakes are fully released before the locomotive throttle can be up-stepped from the present "idling" condition.

More specifically, after timer T2 completes its timing operation (contact 19 closes) repeater relay T2P is picked up to open its back contact 54 and thereby disconnects wire 28 from ground. The micropositioner MP1 of FIG. 1D is now operated, in accordance with the computed required horsepower HP_r , to adjust the locomotive throttle or dynamic brake setting to that necessary to maintain the desired speed. As soon as the actual speed of the train decreases to within one-quarter mile per hour of the demand speed, the load regulator of FIG. 1B again operates, as previously described, to provide the fine control of the train speed, by varying the generator output voltage to the traction motors.

Certain overspeed control apparatus is provided in the selected embodiment of the present invention to call for an emergency application of the train air brakes whenever the actual speed of the train is greater than five miles per hour above the demand speed and a service brake application has not been properly initiated, as previously described; i.e. upon the dropping away of the relay D+4R of FIG. 1B.

More specifically, oscillator 178 of FIG. 1A provides an output signal, to amplifier 179 whose frequency is high enough to pass through whichever of the high-pass Over-Speed Filters is connected thereto, for energizing the relay D of FIG. 1B over wire 180 extending between FIGS. 1A and 1B. Under the assumed conditions (120 code rate received), the 30 m.p.h. overspeed filter is connected to amplifier 179, over back contact 181 of relay 75R and front contact 182 of relay 120R. This picking up of relay D completes the energizing circuit for its repeater relay DP, at front contact 183 of relay D and the picking up of repeater relay DP then opens wire 184 extending between FIG. 1B and 1A to the oscillator 178, to terminate the operation of the oscillator 178, which then causes relay D to drop away. This in turn, causes repeater relay DP to drop away and causes the oscillator 178 to again provide its normal output to pickup relay D. Thus, under the illustrated normal conditions, the relays D and DP are each in a coding condition wherein the over-speed relay C is maintained in a picked up position by the alternate charging and discharging of capacitor 185.

As mentioned previously, the axle-driven frequency generator ADFG of FIG. 1A provides an output frequency analog of the actual train speed S_a . Thus, as soon as the actual speed of the train increases above five miles per hour over the demand speed (under the assumed conditions, when the train exceeds thirty miles per hour), the output of the axle-driven generator ADFG can pass through the connected over-speed filter and the relays D and DP are kept picked up, and therefore, the relay C drops away to indicate that the actual speed is five miles per hour greater than the demand speed. This dropping away of relay C will cause an emergency brake application; i.e. drop the emergency brake control relay EM unless relay SUPP is retained in a picked up position by pressure switch PS1 which detects that a service brake application has been properly enforced when the actual speed exceeded the demand speed by four miles per hour.

Accelerating to higher desired speed

With the train traveling at twenty-five miles per hour, in response to the 120 code rate presently being received it will now be assumed that traffic conditions are such that the received code rate is changed from 120 to 180 to increase the demand speed from twenty-five to fifty miles per hour.

Decoding relay 180R of FIG. 1A is now picked up, to energize its repeater relay 180RP, by a circuit extending through front contact 13 of decoding relay 37R, back contacts 36 and 186 of decoding relays 75R and 120R respectively, front contact 187 of decoding relay 180, and to (-). The demand speed S_d is now increased to fifty miles per hour, by connecting the right-hand side of torque motor TM to the 50 m.p.h. tap on resistor 80 of FIG. 1A through back contacts 85, 86, and 188 of relays START, 75RP and 120RP respectively, and front contact 189 of relay 180RP.

In substantially the same manner as was previously described, when accelerating from standstill to the desired speed of twenty-five miles per hour, the contact arm 26 of FIG. 1D is first up-stepped to the +8 position on control resistor 27, as to call for the eighth power setting of the locomotive throttle. When the actual speed is between forty-six and forty-nine miles per hour, the computed required horsepower HPr adjusts the contact arm 26 to call for the proper throttle power or dynamic brake setting necessary to maintain the desired fifty miles per hour, and, the load regulator of FIG. 1B then provides the fine control around the throttle of dynamic brake setting called for by the computed required horsepower HPr, to hold the actual speed to within one-quarter mile per hour of the fifty mile per hour demand speed.

Computing proper brake release speed

With the train now traveling at fifty miles per hour, in response to the 180 code rate now being received, it will be assumed that the traffic conditions become more restrictive so that a 120 code rate is once again received by the receiver coils RC of FIG. 1A, to call for a speed reduction to twenty-five miles per hour. Obviously, when the 30 m.p.h. over-speed filter is connected to the output of amplifier 179, over speed relay C will drop away after its predetermined delay, while the relays $D+\frac{1}{4}R$, $D+1R$, $D+4R$ and its repeater $D+4RP$ will all be dropped away to indicate that the actual speed is well above the demand speed of twenty-five miles per hour. The dropping of relay $D+4R$ then initiates a service application of the train air brakes, by dropping the train brake control relay EPVR-T as previously described. This service brake application then remains in force until the actual speed of the train has been decreased to the proper release speed then computed by the apparatus of the accompanying drawings, in accordance with the aforementioned Equations 5 through 10, associated with the deceleration of the train during the brake application, so that the air

brakes will be fully released at substantially the same time that the actual train speed reaches twenty-five miles per hour.

More specifically, the voltage analog of the actual acceleration A_a , appearing on wire 121 at the output of differentiator 120 in FIG. 1A, is multiplied by one-half of the known time t_1 required for full brake release, by a circuit including operational amplifier 190 and resistor 190a, the adjustable tap on which is set in accordance with the known train length. The voltage analog of this product of the actual train acceleration A_a and the time t_1 is then fed along wire 191 between FIGS. 1A and 1B, to the Sign Changer circuit 192, and, from there to Adder 193, along with the voltage analog of the desired speed S_d (appearing on wire 129 in FIGS. 1A and 1B), so that the voltage appearing on wire 194 is the analog of the proper brake release speed V_o .

The voltage analog of the actual train speed S_a , appearing on wire 76 in the accompanying drawing, is then compared to the voltage analog of the computed release speed V_o by micropositioner MP5 of FIG. 1B in such a manner that when the actual speed S_a has been properly reduced to the computed speed V_o , back contact 195 of micropositioner MP5 closes to energize brake release relay BR of FIG. 1B by a circuit extending from (+), through back contact 196 of the train brake control relay EPVR-T, back contact 195 of micropositioner MP5, and to (-). This picking up of the brake release relay BR then causes the train brake control relay EPVR-T to be energized by a circuit extending from (+), through front contact 197 of relay BR along wire 174 between FIGS. 1B and 1C, through front contact 175 of speed registering relay 8SR which is selected in accordance with the illustrated setting of switch TLS for reasons to be considered in detail hereinafter, along wire 176 between FIGS. 1C and 1B, front contact 177 of timer T1, and to (-), so that the train air brakes can begin their release, assuming of course that timer T1 has completed its timing operation so that it closed its front contact 177. In accordance with this computed brake release speed V_o , the air brake on the train will be fully released at substantially the same time that the actual train speed reaches twenty-five miles per hour, and after repeater relay T2P picks up, as previously described, the throttle control apparatus will then assume control to maintain this desired speed.

While the train air brakes are releasing, relay BR is maintained in its picked up position over front contact 197a of pressure switch PS2 which is closed as long as the brakes are applied; i.e. pressure switch PS2 might be closed when the brake pipe pressure is below the pressure of the air brake feed valve. This picking up of brake release relay BR also retains relay SUPP in its picked up position, by the closing of front contact 198 of relay BR, to prevent an emergency brake application, while the brakes are releasing.

If for some reason, the actual train speed S_a is greater than the demand speed plus five miles per hour, when the train air brakes are fully released, the dropping away of brake release relay BR at the end of the brake release (pressure switch PS2 opens its front contact 197a) causes deenergization of train brake control relay EPVR-T, to call for a reapplication of the train brakes. If this second braking application is not enforced, relay SUPP will not be maintained in its picked up position over front contact 171 of pressure switch PS1, and therefore relay SUPP will open its own front contact 15, to drop the emergency brake control relay EM for causing an emergency application of the vehicle air brakes. Once an emergency brake application is made, the manual RESET push button of FIG. 1B must be depressed to remove this emergency application.

In the above discussion, it should be noted that front contact 175 of speed registering relay 8SR must be closed (to register that the train speed is above eight miles per

hour) before the train brake control relay EPVR-T can be energized to initiate a release of the train air brakes. As mentioned previously, this critical speed value; i.e., below which a brake release is not permitted, is selected by a switch TLS which is preset in accordance with known length of the train connected to the locomotive. This restriction is desirable because of the observed rapid increase in the coefficient of braking friction which takes place particularly during the low speed braking of relatively long trains. Thus, if a brake release is initiated on a relatively long train traveling at a low speed, the train brakes on the railway cars towards the head end of the train may be fully released while the brakes on the cars towards the rear of the train may be providing very heavy braking action which, under extreme conditions, could cause separation of the train.

Stopping train

It will now be assumed that a 37½ code rate is received on the vehicle to call for a normal service stop of the train; i.e., the demand speed is decreased from twenty-five miles per hour to zero speed. Obviously, the train brake control relay EPVR-T is now deenergized, due to the opening of front contact 10 of relay D+4R and thereby causes the train air brakes to apply and the locomotive throttle to be automatically set to "idling" condition by the operation of contact arm 26, of FIG. 1D, to the IDLE position on control resistor 27, wherein cam switch TCC closes its front contacts 29a to selectively energize wire 30 which extends between FIGS. 1D and 1C and which, when energized, causes energization of control wire WPY and the associated control contactor PY (not shown) for controlling the traction motors to their "idling" condition. This operation of cam switch TCC (opening of its back contact 141a) furthermore interrupts the direct upstepping and down-stepping circuits for reversible motor RM1 which are controlled by relays MIN-FR and MAX-FR, as previously described, so that an automatic downstep of the throttle will not take place when the idle throttle setting is called for and the overriding solenoid ORS of FIG. 1B is subsequently energized, as previously described, to return the adjustable tap 34 to the minimum field position on resistor LRR (as shown), wherein the minimum field relay MIN-FR and its repeater relay FRP are both picked up.

When the actual train speed decreases below two and one-half miles per hour, speed registering relay 2.5SR of FIG. 1C is dropped away, to pick up the train brake control relay EPVR-T for initiating a release of the air brakes on the train, whereas the locomotive brake control relay EPVR-L of FIG. 1B is now dropped away, to call for an application of the independent locomotive brakes.

More specifically, the train brake control relay EPVR-T will be energized, when the actual train speed decreases below two and one-half miles per hour, by a circuit extending from (+) through front contact 10 of relay D+4R (which closes below four miles per hour), along wire 174 between FIGS. 1B and 1C, back contact 199 of speed registering relay 2.5SR, along wire 176 between FIGS. 1C and 1B, front contact 177 of timer T1, and to (-). At the same time, the locomotive brake control relay EPVR-L is now dropped away since wire 200 extending between FIGS. 1B and 1C is now deenergized by the opening of front contact 201 of the speed registering relay 2.5SR, so that the vehicle comes to a standstill with its train brakes released and its locomotive brakes applied. The circuit apparatus shown in the accompanying drawings has thus been returned to its illustrated normal condition, previously described.

From the above discussion, it will be noted that the system of the present invention generally provides for computing the proper throttle power or dynamic braking setting required on the locomotive in order to maintain a desired speed for the train, and which further provides for automatically adjusting the locomotive traction motors

to supply this computed required driving power or dynamic braking during the automatic train operation.

Furthermore, the system of the present invention also provides for computing the proper speed at which to initiate a brake release, when slowing down from a higher to a lower desired speed, so that the brakes will be fully released at substantially the same time that the actual train speed is reduced to the lower desired speed, and which further provides for automatically releasing the air brakes on a train, during automatic train operation, in accordance with this computed brake release speed.

Having thus described one specific embodiment of the present invention, it is desired to be understood that this form is selected to facilitate in the disclosure of the invention rather than to limit the number of forms which it may assume; and, it is to be further understood that various modifications, adaptations and alterations may be applied to the specific form shown to meet the requirements of practice, without in any manner departing from the spirit or scope of the present invention.

What I claim is:

1. In a system for controlling the driving unit on a vehicle desired to travel at a predetermined desired speed, the combination of,
 - (a) first means for measuring the resultant of forces tending to accelerate said vehicle above said desired speed,
 - (b) second means measuring the resultant of forces tending to decelerate said vehicle below said desired speed,
 - (c) computing means responsive to said first and second measuring means for computing a signal characteristic of the horsepower required of said driving unit to make the resultant of said accelerating forces substantially equal to the resultant of said decelerating forces in order to maintain the desired speed, and
 - (d) means governed by the horsepower signal computed by the computing means for regulating the driving unit accordingly.
2. In a system for controlling the driving unit on a vehicle desired to travel at a predetermined desired speed, the combination of,
 - (a) means for developing a first signal which is substantially the analog of said desired vehicle speed,
 - (b) means for developing a second signal which is substantially the analog of the actual vehicle speed,
 - (c) means for developing a third signal which is substantially the analog of the actual horsepower being developed by said driving unit at said desired speed,
 - (d) means for dividing said third analog signal by said second analog signal to obtain a fourth signal which is substantially the analog of the actual tractive effort being developed by said driving unit at said desired speed,
 - (e) means for developing a fifth signal which is substantially the analog of the inertial force of said vehicle at said desired speed,
 - (f) means for subtracting said fifth analog signal from said fourth analog signal to obtain a sixth signal which is substantially the analog of the rolling resistance to vehicle movement at said desired speed,
 - (g) means for multiplying said sixth analog signal by said first analog signal to obtain a seventh signal which is substantially the analog of the horsepower required of said driving unit to maintain the vehicle at said desired speed, and
 - (h) means for controlling the driving unit of the vehicle in accordance with the seventh signal.
3. In a system for controlling a locomotive at the head of a train when getting under way, the combination of,
 - (a) means at the head end of the train for registering whether or not the entire train is in motion, and

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- (b) means responsive to said registering means for limiting the driving power developed by said locomotive until the entire train is in motion.
4. The invention according to claim 3 wherein the means for registering whether or not the entire train is in motion comprises,
- (a) means for measuring the actual distance travelled by said locomotive from standstill, and
- (b) means preset in accordance with the length of the train and responsive to said measuring means for registering when the entire train is in motion.
5. In a system for controlling a train locomotive when getting underway from a standstill to a desired running speed, the combination of,
- (a) means for supplying a first signal indicative of the horsepower required of the locomotive driving unit to accelerate the locomotive to said desired running speed,
- (b) means for supplying a second signal indicative of a predetermined horsepower limit proper for the locomotive driving unit until the entire train is in motion when getting underway,
- (c) means for registering when the entire train is in motion, and
- (d) means responsive to said first and second signals and said registering means for adjusting the actual horsepower delivered by said driving unit in accordance with said signal until the entire train is in motion and thereafter in accordance with said first signal.
6. In a system for controlling the locomotive of a train when getting underway, said locomotive being required to travel a predetermined distance from standstill before the entire train will be in motion, the combination of,
- (a) means for generating a first signal proportional to the actual speed of said locomotive,
- (b) means for integrating said first signal to produce a second signal proportional to the actual distance travelled by said locomotive from standstill,
- (c) means for generating a third signal proportional to a third distance at least as great as said predetermined distance,
- (d) control means responsive to said second and third signals for registering when the actual distance travelled by said locomotive is greater than said third distance, and
- (e) means governed by the control means for increasing the tractive effort of the locomotive when the locomotive has travelled sufficient distance to insure that the entire train is in motion.
7. The combination specified in claim 6 wherein said registering means includes a relay having
- (a) a knockdown winding energized in accordance with said third signal, and
- (b) a pickup winding energized in accordance with said second signal.
8. In a system for controlling the operation of the throttle on a train locomotive when accelerating said train, the combination of,
- (a) means for advancing said throttle in distinct steps during said acceleration, and
- (b) timing means responsive to the actual speed of said train for causing said throttle advancing means to advance said throttle at a predetermined time rate when the actual speed of the train is above a predetermined speed and at a relatively slower time rate when the actual speed of the train is below said predetermined speed.
9. The combination specified in claim 8 wherein said timing means includes a relay whose operating time is dependent upon the actual speed of said train.
10. A speed control system for a locomotive desired to operate at a predetermined speed and having at least one driving traction motor, a generator for supplying electrical output power to said motor, a throttle controlled engine

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- for driving said generator, and a load regulator for controlling the generator loading on said engine, said load regulator including current varying means which control the amount of current supplied to a field winding for said generator and which has a minimum current position and a predetermined balance current position for each setting of the locomotive throttle towards which said current varying means is automatically operated to increase the field current to said generator and the actual locomotive speed, said speed control system comprising,
- (a) first circuit means controlled in accordance with the desired speed of said locomotive for selecting a predetermined throttle setting on the locomotive whereby said current varying means is operated towards the balance current position for said predetermined throttle setting to increase said generator field current and the actual locomotive speed towards said desired speed,
- (b) second circuit means responsive to the position of said current varying means for advancing the locomotive throttle setting if said current varying means reaches a second predetermined current position below said balance current position before the actual locomotive speed has increased to said desired speed, whereby said current varying means is prevented from reaching said balance position,
- (c) third circuit means responsive to the actual and desired speeds of said locomotive for actuating said current varying means towards its minimum current position to decrease the generator field current and the actual locomotive speed when the actual speed of the locomotive increases above the desired locomotive speed, and
- (d) fourth circuit means responsive to the position of said current varying means for reducing the locomotive throttle setting if said current varying means reaches said minimum current position before the actual locomotive speed has reduced to said desired speed.
11. The speed control system according to claim 10 wherein said current varying means is a rheostat connected in series with the field winding for said generator and a source of electric current.
12. In a system for controlling a locomotive equipped with a power unit to operate at a desired running speed, said power unit being controllable to a plurality of distinct settings spaced from one another on a predetermined output power scale, the combination of,
- (a) performance detecting means for detecting the actual performance of said locomotive and including means to detect the actual speed of said locomotive,
- (b) computing means responsive to the desired speed of said locomotive and to said performance detecting means for computing a value indicative of the setting of said power unit required to cause said locomotive to operate at said desired speed,
- (c) first power unit control means responsive to said computing means for controlling said power unit to said computed setting,
- (d) second power unit control means responsive to said performance detecting means and to said desired speed effective while said power unit is in said computed setting for adjusting the output power of said power unit as necessary to provide a vernier control of said actual locomotive speed to maintain said locomotive in substantial agreement with said desired speed, and
- (e) third power unit control means responsive to said performance detecting means and to said desired speed for controlling said power unit to the next higher or next lower setting as required if said second power unit control means is unable to maintain said actual locomotive speed in substantial agreement with said desired speed while said power unit is in said computed power setting.

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13. In a system for operating a locomotive having a driving unit at a desired running speed, the combination of,

- (a) means for computing a signal characteristic of the horsepower required of the locomotive driving unit to operate the locomotive at said desired running speed, 5
- (b) means governed by the signal for adjusting the actual horsepower developed by said locomotive driving unit in accordance with said computed required horsepower, 10
- (c) said driving unit having at least one electric driving motor and means rendered effective when said locomotive is to accelerate toward said desired speed for conditioning said driving motor to develop driving power output and rendered effective when said locomotive is to decelerate toward said desired 15

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speed for conditioning said driving motor to develop dynamic braking action, and

- (d) said adjusting means being effective to adjust the amount of driving power and dynamic braking action developed by said motor.

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