CONTROL FOR HELPER LOCOMOTIVE

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The present invention relates to a method and system for operating a train of railroad cars by more than one locomotive, and more particularly to a method and system for controlling the operation of a helper locomotive that is used for assisting the main or lead locomotive in pulling a train of railroad cars.

Specifically, the present invention relates to a method and system for controlling a helper locomotive in accordance with the amount of pulling or pushing force to which a helper locomotive is subjected when connected in a train of cars.

It is a common practice to provide a helper locomotive unit which is connected directly behind the main locomotive unit and has controls interconnected therewith to provide the necessary tractive effort and power for operating a long train. Although this multiple directly connected locomotive unit has enough power theoretically to pull substantially twice as many railroad cars over a certain terrain as a single locomotive unit, the number of cars that are able to be included in such a train is limited, from a practical standpoint, by the strength of the drawbars and couplings, and the individual cars. A train having a number of cars in excess of this practical limit results in damaged drawbars, couplings, and not infrequently damage to the frames of the individual cars.

Herein is an attempt to overcome this practical limit of the length of a train pulled by more than one locomotive, and to more evenly distribute the force exerted on the couplings of the individual cars, it has been proposed to position the helper locomotive in the train remotely from the main locomotive. The operation of the helper locomotive is then controlled from the main locomotive by communication link, such as by radio communication, to effectuate a multiple locomotive unit. However, such a system has many disadvantages. For example, it is necessary to install and maintain remote control apparatus on both the main and helper locomotives. Also, in radio frequency systems, the communication link is unreliable in that it may be disrupted by extraneous electrical influences. Because of the impracticability of obtaining an isolated radio frequency for such a system, the prior proposed system was rendered even less reliable by using the same frequency as that used for voice communication.

One object of this invention is to provide an improved method and system for controlling the operation of a helper locomotive that is used to assist the main locomotive in pulling a train of railroad cars.

Another object of the invention is to provide an improved method and system for operating a helper locomotive which insures that the helper locomotive is carrying its proportionate share of the train load.

Another object of the invention is to provide a method and system for controlling the operation of a helper locomotive wherein the amount of force in tension or compression to which the helper locomotive is subjected determines the proper control of the helper locomotive.

Another object of this invention is to provide a locomotive control system wherein the actual speed of the controlled locomotive modifies the control provided by the forces in tension or compression to which the controlled locomotive is subjected.

Another object of this invention is to provide a helper locomotive control system that utilizes the force at the coupling to control the locomotive, and which system has means for locking out the control equipment of the helper locomotive in the event of malfunction.

A further object of this invention is to provide a system for operating a helper locomotive wherein the helper locomotive is properly controlled upon the application of the emergency brakes of the main locomotive.

A further object of this invention is to provide a system of the character described for the operation of a helper locomotive which is effective to provide the proper control for the locomotive in both directions of travel.

A further object of this invention is to provide a system for controlling the operation of a helper locomotive in accordance with the amount of tensile or compressive force that is present at one of the drawbars of the helper locomotive when the locomotive is placed intermediate the ends of a train remote from the main locomotive.

Other objects of this invention will become apparent from the drawings, the specification, and the appended claims.

In the drawings:

FIGS. 1A, 1B and 1C, when placed side by side illustrate schematically the apparatus and circuitry of a helper locomotive control system constructed according to one embodiment of the invention.

FIG. 2 schematically illustrates, by way of example, one of the trigger circuits used in this embodiment of the invention for controlling, in effect, the throttle of the helper locomotive.

FIG. 3 schematically illustrates, by way of example, one of the trigger circuits used in this embodiment of the invention for controlling the braking of the helper locomotive.

According to the present invention, the helper locomotive is coupled to the train remotely from the main locomotive in accordance with individual requirements of practice. The force in tension or compression to which the helper locomotive is subjected when the main locomotive applies tractive effort is sensed and converted into an electrical signal, the value and character of which corresponds to the amount of and direction of this force. The character and value of this electrical signal is then caused to select and operate the throttle or brake control apparatus of the helper locomotive to cause the helper locomotive to move with a predetermined power and speed to reduce this force to a predetermined value. The actual speed of the helper locomotive provides another electrical signal which modifies the throttle control as provided by the electrical signal which is caused by the heretofore mentioned force. With this method, the helper locomotive is controlled to travel at the proper speed and provide the proper tractive effort so that it assumes its proportionate share of the train load.

In the illustrated embodiment of the invention, the helper locomotive is placed intermediate the ends of a train with cars coupled to the front drawbar or coupling of the helper locomotive and cars coupled to the rear coupling or drawbar of the helper locomotive. The actual position of the helper locomotive relative to the number of cars located either ahead of, or behind the locomotive, in this embodiment of the invention, depends on the proportionate share of the power that the helper locomotive is to provide. Thus, in a train of 100 cars, for example, if the helper locomotive has sixty cars in front and forty cars coupled to the rear, it is required to provide approximately 40% of the total power or operating the train.

When the helper locomotive is pulling its proportionate share of the train load, there is little or no force applied to the front coupling or drawbar of the locomotive. When
the helper locomotive is operating in a forward direction and pulling a disproportionate share of the train load which is due to the fact that the helper locomotive is operating in a forward direction on the front drawbar of the helper locomotive; and when this disproportionate share is greater than that required, there is a force in compression on the front drawbar.

In the illustrated embodiment of the invention, the locomotive motor is controlled by the force that is on the front drawbar of the helper locomotive in such a way that the locomotive is constantly operating to bring this force to substantially zero. If there is a force in tension at the front drawbar, the system operates to increase the tractive effort of the locomotive to decrease this force. If this force is in compression the system operates to decrease the tractive effort to reduce the force. Also, the system is so arranged to modify the effect of this force in controlling the motor control apparatus depending upon the speed that the helper locomotive is actually traveling. Moreover, the system further modifies the effect of this coupling force when the helper locomotive is traveling at a low rate of speed such as would occur when it first starts moving to prevent wheel slippage and provide smooth operation; and also provide for proper operation of the helper locomotive to share the proportionate share of the load when traveling in a reverse direction.

Referring to the drawings, and more particularly to FIG. 1A, a train of cars is diagrammatically illustrated fragmentarily, which includes a helper locomotive 5 that is connected by its front drawbar or coupling 6 to a plurality of cars 7. Connected to the front of the car 7 is a main or lead locomotive 8. A plurality of cars 9 are connected to the rear of the helper locomotive 5. A plurality of cars 9 may be any conventional locomotive, which is equipped with a prime mover control system in which effect advances the throttle in response to the selective energization of the motor control apparatus. In the illustrated embodiment, the prime mover control system is selectively operated by applying energy to one of a plurality of wires to slow down, speed up, or brake the helper locomotive.

A force responsive device, or so-called strain gauge 10 is connected to the coupling 6 so as to be responsive to the forces either in tension or compression that are present on the coupling 6. The strain gauge 10 may be any well known type which operates to supply a distinctive output signal, the value of which corresponds to the degree of force at the coupling 6, and is distinctive to the direction of force at the coupling 6, that is, whether the force is in tension or compression. In the present embodiment, the strain gauge 10 comprises a strainable element 12 which is connected in a bridge circuit 11 with resistors 13, 14 and 15. A source of potential, such as a battery 16 supplies energy to opposite diagonals of the bridge circuit 11. When the element 12 is comparatively free of any force either in tension or compression, the bridge circuit 11 is balanced thereby producing no output potential across wires 17 and 18 which are connected to the opposite diagonals of the bridge circuit 11. A force in tension exerted on the element 12 unbalances the bridge circuit 11 to produce an output voltage of one polarity across the output wires 17 and 18, the value of which corresponds to the degree of tensile force. A force in compression on the element 12 unbalances the bridge circuit 11 in an opposite manner to produce an output voltage of opposite polarity across the wires 17 and 18. In describing the present embodiment of the invention, it is assumed that a force in tension will produce an output voltage of positive polarity across the wires 17 and 18, that is, wire 17 is positive relative to wire 18. A force in compression will cause a negative output voltage across the wires 17 and 18, that is, the wire 17 is negative relative to the wire 18. The gauge 10 and wires 17 and 18 are connected through pole changing connections to the input of an amplifier 20. These pole changing connections are contacts 22 and 24 of a relay RD, which contacts are which either in an energized position or a de-energized position depend upon the input 21 which is connected through a line 26 to the relay rod 20. Each relay it is energized, thereby closing the contacts 22 and 24 when the locomotive is connected through a forward direction; and causes the upper winding of the relay RD to be energized, thereby closing the front contacts 22 and 24 when the helper locomotive is traveling in a reverse direction.

The output of the amplifier 20 is connected to the input of an integrator 30. This integrator 30 is connected through a resistor 32, a capacitor 34, and an amplifier 35, which are connected in a well known circuit arrangement, to integrate the value of the output potential from the amplifier 20, regardless of its polarity.

The integrated output potential of the integrator 30 is applied over wire 45 to the detection trigger by the closing of a contact 36. The integrated potential in the integrator 30 is periodically cleared by the closing of a contact 38, which completes a circuit for discharging the capacitor 34 and dispelling the voltage.

The opening and closing of the contacts 36 and 38 are controlled by a conventional timing mechanism 40 through cams 41 and 42. These cams 41 and 42, which are rotated at a predetermined rate of speed in a clockwise direction as viewed in FIG. 1A, are so arranged to cause the contact 38 to be opened for a predetermined period of time, such as ten seconds, for example, and then is closed momentarily to reset the integrator to zero. The cams 41 and 42 are further so arranged that the contact 36 is closed momentarily just prior to the closing of the contact 38. Thus, during operation, while contact 38 is open, cam 41 first closes and then opens contact 36, and cam 42 then closes contact 38. Thus, the integrator 30, the integrator 30 and the timer 40 so cooperate with the strain gauge 10 that a pulse of integrated potential is provided to the trigger circuits periodically. The value of this pulse is that which has been integrated during the ten second period since the last output pulse from the integrator 30 when contact 36 was open.

During the momentary closing of the contact 36, the output voltage from the integrator 30 is applied over wire 45 to a voltage dividing resistor 50. The resistor 50 is provided with spaced taps 51, 52, 53, 54 and 55. Each tap of the resistor 50 connects a switch 56, 57, 58, 59, 60 to the input of respective throttle trigger circuits 1T, 2T, 3T, 4T, and 5T. The trigger circuits 1T through 5T are so constructed and connected to the resistor 50 through its respective taps, that a relatively weak integrated pulse of predetermined value and positive potential causes trigger circuit 1T only to fire. A slightly stronger pulse of predetermined potential and positive value causes trigger circuits 2T and 2T to fire. Similarly, a still stronger positive pulse of integrated voltage causes the additional firing of trigger circuit 3T, and so on until the maximum integrated positive pulse of predetermined value applied to the resistor 50 results in the firing of all the trigger circuits 1T through 5T. Each of the trigger circuits 1T through 5T when fired, operate a respective relay 1T through 5T. These relays are held picked up only long enough to permit the hereinafter mentioned stepping switches to move from one limit position to another, if required, whenever its respective associated trigger circuit is fired. Connected to the trigger circuit 1T is a repeater relay 1TP which is energized when the relay 1T is picked up.

The trigger circuits 1T through 5T for operating their respective relays 1T through 5T are identical circuit configurations, and a typical circuit arrangement for the operation of relay 1T by the trigger circuit 1T is illus-
treated schematically in FIG. 2 by way of example. The typical trigger circuit ITC for operating the relay IT is comprised of NPN transistors 62 and 63. These transistors are connected by a common emitter connection through a resistor 64 to a source of positive biasing potential. The collector terminal of transistor 62 is connected through a resistor 65 to the base of the transistor 63. The collector of the transistor 62 is also connected through a resistor 67 and the winding of a relay IT to the collector of the transistor 63. The base of the transistor 62 is connected to a wire 68 which constitutes the input of the trigger circuit from the tap 51 of the resistor 50. The positive emitter-bias maintains the transistor 62 in a normally conductive state which causes the transistor 63 to be normally nonconductive or cut off. When a positive voltage pulse is applied to the base of the transistor 62 over the wire 68, the transistor 62 is cut off during the pulse, which causes the transistor 63 to conduct at this time. The momentary conducting of transistor 63 energizes the relay IT.

In the trigger circuit ITC only of the trigger circuits ITC through IT5, there is a contact 70 which moves from back to front and then back. Each time the contact 70 is closed at its front during this movement, a capacitor 72 is charged through a circuit which extends from (+) and includes the front contact 70, and the capacitor 72 to (−). The capacitor 72 is discharged each time the contact 70 is closed at its back through a wire 74 and the winding of the relay ITP (FIG. 1B), and a capacitor 76 to (−). The capacitor 76 serves to maintain the relay constantly picked up during the time interval between the pulses from the integrator 30.

Also connected to the taps 51, 52 and 53 respectively of the resistor 50 through isolating resistors 80, 81, and 82 are brake trigger circuits IBT, 2BTP, and 3BTP respectively. The brake circuits IBT, 2BTP and 3BTP are so constituted and connected to the divider 50 that a relatively weak integrated potential of negative value causes the trigger circuit IBTC only to fire. A stronger negative pulse will cause both the trigger circuits IBT and 2BTP to fire and the maximum integrated negative pulse from the resistor 50 causes all three trigger circuits IBT, 2BTP and 3BTP to fire. Connected to the output of each of these trigger circuits is a repeater relay IBTP, 2BTP and 3BTP, respectively.

The trigger circuit IBTC in trigger circuit 3BTP are identical circuit configurations, and a typical circuit arrangement for the trigger circuit IBTC is illustrated schematically in FIG. 3 by way of example. This trigger circuit is comprised of NPN transistors 92 and 93. The emitters of the transistors 92 and 93 are connected through a resistor 94 to a common source of negative biasing potential. The collector of transistor 92 is connected through a resistor 95 to the base of the transistor 93. The collector of the transistor 92 is also connected through a resistor 97 and the winding of a relay IBT to the collector of the transistor 93. The base of the transistor 92 is connected by a wire 98 to the tap 51 of the resistor 50 through the resistor 80 to constitute the input of the trigger circuit. The negative emitter bias maintains the transistor 92 in a normally conductive state which causes the transistor 93 to be normally nonconductive. When a negative voltage pulse is applied to the base of the transistor 92 over the wire 98, the transistor 92 becomes nonconductive which causes the transistor 93 to conduct during the pulse period. The conducting collector transistor 93 in response to the negative voltage pulse energizes the relay IBT which causes a movement of contact 100 of the relay IBT from back to front to back. Similar to the operation of the contact 70 in the trigger circuit ITC, the operation of the contact 100 causes a capacitor 102 to charge and then discharge through the front and back contacts 100, respectively. Also, as the capacitor 102 charges the relay IBTP to be energized over a wire 104 at the output of the trigger circuit. A capacitor 106 also main-
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tains the relay energized during the time interval of ten seconds since the previous pulse from the integrator 30 picked up the 1BT relay. The repeater relays 2BT and 3BT operate in the same manner.

A slow drop away relay ZS is provided to be deenergized upon the picking up of relay ITP or 1BTP. This relay will stay picked up for a longer period rather than the relays IT through ST, but shorter than the time interval between output pulse from the integrator 30. The trigger relays IT through ST, IBT and 2BTP, and the relay ZS are each provided with a respective contact 110 through 117 which are so connected in a circuit organization to control the operation of a stepping switch which will be described hereinafter. The ZS relay is normally energized from (+) energy through a contact 118 of relay ITP, contact 119 of relay IBTP to negative energy. Thus, the ZS relay is energized whenever the conditions are such that neither ITC or IBTC are triggered at the end of a time period, for example when the coupler stress is in the range of 7 to 9.

The stepping switch is comprised of three mounting discs or so called wafers W1, W2, and W3. Positioned on each of these wafers are a plurality of angularly spaced contact terminals C1, C2, C3, C4, C5, C6, and C7. On the wafer W1, the contact terminals are referred to at IC1, IC2, etc. through IC7. On the wafer W2, the contact terminals are referred to at 2C1, 2C2, etc. through 2C7; and on the wafer W3, the contact terminals are referred to at 3C1, 3C2, etc. through 3C7. Rotatably mounted on each wafer is a contact arm which is adapted to engage each one of the associated terminals C1 through C7. A contact arm 121 is mounted on wafer W1, a contact arm 122 is mounted on wafer W2; and a contact arm 123 is mounted on wafer W3.

The contact arms 121, 122 and 123 are so connected mechanically to operate in synchronism step-by-step either upwardly to engage the next adjacent higher numbered contact terminal or downwardly to engage the next adjacent lower numbered contact terminal. The contact arms 121, 122, and 123 may be connected by any well known ratchet type mechanism which will advance the arms simultaneously to the next adjacent terminal. A relay 125 (FIG. 1C) operates the ratchet mechanism to accomplish the aforesaid results. The relay 125 is provided with a down step winding D, which when energized causes the mechanism to move the arms 121, 122, and 123 downwardly as viewed in FIGS. 1B and 1C to engage the next lower adjacent contact terminal, and an up step winding U, which when energized causes the mechanism to move the arms 121, 122 and 123 upwardly to engage the next higher adjacent contact terminal.

The contact terminals IC on the wafer W1 and the contact terminals 2C on the wafer W2 are connected electrically to selectively complete a distinct circuit through either the arm 121 or 122 to the winding U or D, respectively, of the relay 125 depending upon the condition of the relays ST through IT and ITP, and the relay ZS in accordance with the positions of the arms 121 and 122. The contact terminal 1C1 is connected by a wire 130 and diodes as shown to the contact terminal 2C3. The terminal 1C3 is connected by a wire 132 and diodes as shown to the terminal 2CS. The terminal 1C4 is connected by a wire 133 and diodes as shown to the terminal 2C6. The terminal 1C5 is connected by a wire 134 and diodes as shown to the terminal 2C7. The terminal 1C6 is connected by a wire 135 to the front contact 116 of the relay ST. The terminal 1C7 on the wafer W1 has no circuit connection and merely constitutes the limit of upward movement of the arm 121. The terminal 2C1 on the wafer W2 has no circuit connection and merely constitutes the limit of downward movement of the arm 122.

Relays BR, ZS and 2BTP through their respective front contacts 120, 117 and 113 apply positive energy to the
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130 line. Positive energy is applied to the 132 line through the BR and ZS relay contacts 120 and 117 respectively. When the relays BR, ZS, 2T and 3T are energized. Energy is applied to the wire 133 through the back contact 115 of the relay 4T when the relays BR, ZS, 2T and 3T are energized. Positive energy is applied to the wire 135 through the back contact 116 of the relay 5T when the relays 2T, 5T, 4T, BR and ZS are picked up. When any of the relays BR, ZS and 2T through 3T are picked up, energy is applied to the wire 135. A plurality of unidirectional current conducting devices or diodes 141 through 145, respectively, are connected across adjacent contact terminals 1C1 through 1C6 to the wires 130 through 135. These diodes 141 through 145 permit positive energy applied to one of the wires 130 through 135 to be applied to the lower numbered contact terminals adjacent the terminal connected to this wire. For example, when positive energy is applied to the wire 135, the diodes 141 through 145 conduct this energy to all of the contacts 1C5 down to 1C1. When positive energy is applied to the wire 133, for example, positive energy is conducted not only to the terminal 1C4 but also through the diode 143 to the terminal 1C3, and the diode 142 to the terminal 1C2, and the diode 141 to the terminal 1C1. A plurality of diodes 146 through 149 are each connected in a respective wire 136, 137, 138 and 139 to prevent positive energy from being conducted to the other wires 130, 132, 133, and 134.

Similarly, a plurality of unidirectional current conducting devices or diodes 151 through 155 are each connected across adjacent ones of the contact terminals 2C2 through 2C7 to the wires 136 through 137. These diodes are arranged opposite to that of diodes 141 through 145 so that when positive energy is applied to the wire 133 for example, this energy will be conducted to the higher numbered terminals, such as 2C7 and terminal 2C6 of the wafer 2B but blocks any conduction of current to the lower numbered contact terminals mounted on the wafer 2W. Diodes 156 through 159 are each connected in one of the wires 136, 137, 138, and 139 to prevent the flow of energy from adjacent wire to the other, similar to the diodes 146 through 149.

Thus, when energy is applied to the wire 130, it will be conducted to the contact terminals 2C3 through 2C7 of the wafer 2W through the diodes 145 through 155, and will be blocked from the terminal 2C2 by the diode 151. This energy will also be applied to the contact terminal 1C1 of the wafer W1 but will be blocked from any of the other terminals of the wafer 1W because of the diode 141. Assuming that the arms 131 and 132 of the wafer W1 and W2 are in their extreme downward position, and positive energy is applied to the wire 132, this positive energy will be conducted through diodes 147, 142, 141 and terminal 1C1 of the wafer W1, arm 121, wire 161, back contact 126 of the winding U of the relay 12S and the winding U, to (—).

Back contact 162 and 163 of the stepping relay 125 are arranged so that they are closed until the stepping stroke is almost completed. After opening they remain open until the ratchet mechanism has returned to its latching position. This operation is repeated as long as there is energy at 161 or 162. When the relay ZS is dropped away energy is applied to either the D or U coil of the relay 125 over wires 110' or 119'. Since this energizing circuit does not include either back contact 162 or 163, the relay will stay energized until the potential is removed from the wires 110' or 119', permitting energy stop for each energization.

Since there is no external connection to terminal 2C1, this pulse of positive potential does not affect the wafer W2. Because the energizing circuit for the winding U of the relay 125 is through its back contact 162 the relay operates the ratchet mechanism to advance the contact arms 121 and 122 one step from 1C1 and 2C1 to 1C2 and 2C2, and is then deenergized and returns to its latching position and close contact 162. Positive energy is now applied to the winding U of the relay 125 through 147 and 163 and closed contact 162. Another step is taken with contact 162 opening during the completion of the step and reclosing after the ratchet mechanism operates. Arms 121 and 122 rest on contacts 1C3 and 2C3 respectively. Positive energy through diode 145 causes another step so that arms 121 and 122 rest on contacts 1C4 and 2C4. Now a blocking action of diodes 143 and 153 no positive energy is applied to either the U coil or D coil of the stepping switch relay 125 so the switch remains in this position. Therefore, from the previous description of the stepping switch and its connecting circuitry it is apparent that the contacts 131 and 132 of the wafer W3 are controlled step-by-step, or in multiple steps except upwardly or downwardly depending upon the position of the arms 121 and 122 on the energized or deenergized position of the relays ZS, 1T through 1T, 1BT, and 2BT. As previously mentioned the contact arm 123 of the wafer W3 moves one step upwardly or downwardly simultaneously with the arms 121 and 122.

The arm 123 and the contacts 3C1 through 3C7 are so connected as to distinctively condition the circuitry for operating the throttle and brake control system of the locomotive. The energy applied to the arm 123 of the relay 125 from the wafer 1W is controlled by contacts of relays 3R and 3BR. The relay 3R is operated by an air brake emergency detector valve 165, which operates a switch 166. The valve 165 is sensitive to a rapid loss of air pressure in the braking system of the locomotive, such as would occur if a section of the train should accidentally become uncoupled, other sudden failure of the air brake system, or an emergency brake application were made at the lead locomotive. Under normal conditions, the switch 166 is closed and the relay ER is normally energized by a stick circuit which extends from (—) and includes the contact 166, front contact 164 of the relay 125 through the winding of the relay to (—). If the relay 165 should drop away because of a sudden loss of pressure, a reset button 168 is provided to reestablish the stick circuit after the condition is corrected. The relay 3BR is controlled through a contact 170 of an air brake pressure valve 172. When there is air in the braking system of a predetermined value the contact 170 is closed and the relay 3BR is energized. Thus, when both relays ER and 3BR are energized positive energy is supplied to the arm 133 through front contact 173 of the relay ER and front contact 174 of the relay 3BR. Either the other of the relays ER and 3BR is deenergized, this energy is applied to the terminal 3C2 of the wafer W3.

The contacts 3C1 through 3C7 of the wafer W3 are connected in a circuit arrangement to the various throttle and brake control wires of the helper locomotive for exerting respective distinctive controls for the locomotive. The terminal 3C1 is connected to a brake control wire 175, which when energized applies the dynamic brakes of the locomotive. The terminal 3C2 is connected to a wire 176 which when energized causes the locomotive engine and control circuits to assume the idle condition. The terminal 3C3 is connected by a wire 177, which when energized controls the locomotive at a slow rate of speed. When wire 175 is energized the locomotive motor is controlled to a medium slow rate of speed through terminal 3C4 or 3C5 depending upon the position of contact 180 of a speed relay 4R. The terminal 3C2 is also connected to apply energy to a wire 175 to cause the system to operate at a medium rate of speed. When energy is applied to a wire 174 the locomotive engine is controlled to operate at a medium fast rate of speed through the terminal 3C6 when front contact 185 of a relay 6R is closed. Energy is also applied to the wire 184 from the terminal 3C7 when a back contact 186 of a relay 10R is closed and the front contact 185 is closed. The locomotive engine is controlled to a fast rate of speed by apply-
ing energy to a wire 187. Energy is applied to this wire from terminal 3C7 when the front contact 186 is closed. It should be noted, that energy may be applied to the wire 176 to cause the locomotive motor to idle through a circuit which extends from (+) and includes back contact 173 of relay ER and the terminal 3C2, or includes the front contact 173 of relay ER and the back contact 174 of the relay BR.

Associated to the helper locomotive 8 is a tachometer generator TG which provides output energy to amplifiers 200 and 202, the potential value and frequency of which depends on the speed that the helper locomotive 8 is traveling. The output of the amplifier 202 is applied over a wire 203 to a plurality of high pass filters 204, 205, and 206. When the locomotive is detected by the tachometer generator TG as traveling at four miles per hour, for example, the frequency of this potential is such as to cause the high pass filter 204 to energize the relay 4R. When the locomotive is traveling at a speed of six miles per hour, for example, the frequency passed by the high pass filter 205 causes the relay 6R to be energized in addition to the relay 4R. When the locomotive is traveling at a speed of ten miles or more per hour, the high pass filter 206 passes a frequency to cause the relay 10R to be energized in addition to both the relays 4R and 6R.

The output from the amplifier 200 is applied to the input of a well known voltage shaping unit or device 210 which will change the output frequency of the amplifier to a voltage proportional to the frequency, in any well known manner. The output voltage is rectified by a bridge rectifier 212, and the D.C. output voltage from the rectifier 212 is stored in a capacitor 213. The output from the capacitor 213 is conducted over wires 214 and 215 to opposite ends of a voltage dividing resistor 220. In the illustrated embodiment of the invention, the wire 214 is assumed the wire 215 is negative. The central point of the resistor 220 is connected to ground. The (+) side of the resistor between the wire 214 and ground is provided with a plurality of spaced taps 221, 222, 223, 224 and 225. The tap 221 is connected to an isolating resistor 230 to the input 68 of the terminal trigger circuit 1TC. The tap 222 is connected through a resistor 226 to the input of the trigger circuit 2TC. Also, the taps 223 and 224 of the resistor 220 are connected through respective resistors 227 and 228 to the input of the trigger circuits 3TC and 4TC respectively. A tap 225 of the resistor 220 is connected through a resistor 229 to the trigger circuit 5TC.

The negative side of the divider 220 is provided with spaced tap connections 232, 233 and 234. The tap 232 of the resistor 220 is connected to the input 98 of the brake trigger circuit 1BTC through a resistor 235. The taps 233 and 234 are connected through respective resistors 236 and 237 to the trigger circuits 2BTC and 3BTC respectively.

Thus, the positive D.C. energy from the rectifier 212 is applied through the voltage divider 220 to the throat trigger circuits 1TC through 4TC, and the negative potential is applied to the braking trigger circuits 1BTC through 3BTC. The amplitude of the biasing voltage from the divider 220 is governed by the speed of the locomotive; the greater the speed, the greater the amplitude of the biasing voltage. Therefore, it is apparent that the voltage output of the tachometer generator TG modifies, through the voltage dividing network 220, the effect of the pulse output of the integrator 39 in a manner so that both the braking trigger circuit inputs and the throat trigger circuit inputs are modified by the speed of the locomotive. Moreover, because the bias voltage is of the same polarity that is required to fire the trigger circuits by a pulse from the divider 50, the greater the amplitude of the biasing voltage, the less pulse amplitude required to fire the trigger circuits from the divider 50. For example, if the coupling 6 is subjected to a strain which is sufficient to produce a pulse amplitude that will fire the trigger circuits 1TC and 2TC only when the locomotive is stopped, this same pulse amplitude is sufficient, perhaps, to fire the trigger circuit 3TC also, when the locomotive is traveling at a certain speed. In the event the locomotive is traveling at a predetermined high rate of speed, a predetermined strain on the coupling 6 which would only be sufficient to fire the trigger circuit 1TC when the locomotive is stopped may be sufficient perhaps to fire all the trigger circuits at the rate of speed that the locomotive is traveling.

The locomotive motors which are shown diagrammatically have armatures generally referred to at M1 and M2. These armatures are interconnected in series across a plurality of series connected resistors 240, 241, 242, 243, and 244 when the locomotive control circuits are set for dynamic braking. Also, in parallel with these resistors and connected across the motor armatures M1 and M2 when connected for dynamic braking are two dissipation grids 245 and 246. The field winding 247 of the motor M1 and 248 of the motor M2 are connected in series across the main generator armature 250. The field 252 of the main generator is connected at opposite ends between the resistors 243 and 244, and 240 and 241 respectively. As shown in FIG. 1B, when the relays 1BTC, 2BTC, and 3BTC are deenergized, all the relays 1BTC and 2BTC are shunted out by back contacts 253, 254 and 255. When front contact 255 of relay 1BTC is open only the relays 241 and 242 are shunted out. Similarly, when the relay 2BTC is energized, the closure of front contact 254 results in the shunting out of only the resistor 241. When all the relays 1BTC are energized none of the relays are shunted out. Thus, the operation of the relays 1BTC through 3BTC provides dynamic braking in increasing degrees depending upon the condition of these relays 1BTC. A more detailed description of this embodiment of the invention will be given in connection with its operation. The helper locomotive is coupled into the train under manual control by a hostler. The motor control switch is then set to automatic. The timer 40 is started to rotate. Because there is no air pressure in the braking system at this time, the relay 1R is deenergized, and the engine is started to idle by energizing the idle control wire 176 through a circuit which extends from (+) and includes front contact 173 of the relay ER, back contact 174 of the relay BR, the terminal 3C2 of the wiper W3 of the stepping switch, and the idle control wire 176. When the brake line is pumped up, the idle control wire 176 is maintained energized through the circuit which extends from (+) and includes the front contacts 173 and 174 of the relays ER and BR, arm 123 and contact terminal 3C2 of the wiper W3, and the idle wire 176. When the lead or front locomotive starts to move forward, a force in tension is placed on the coupler 6, which unbalances the bridge circuit 10 to render the output wire 17 more positive than the output wire 18. Since the helper locomotive is not moving when the tension is first applied and will move forward when it gets underway, the lower winding of the relay RD which is energized remains energized so that its back contacts 22 and 24 are closed. Thus, the input to the amplifier 20 is such that the integrator 30 provides positive energy. The integrator 30 begins integrating the potential from the bridge 11 when contact 38 is open, and when the cam 41 of the timer 40 causes the contact 36 to close, the integrated positive pulse is applied to the voltage dividing network 50 over the wire 45.

In starting the train, it may be that this positive integrated pulse is of sufficient amplitude to cause the trigger circuits 1TC through 4TC to fire because the tension on the coupler 6 would be substantial at this time. It should be recalled that, because the pulse is positive, it has no effect on the trigger circuits IBTC through 3BTC. Because the helper locomotive is not yet under motion when this tension is applied in starting, the tachometer generator TG does not provide any output biasing potential. All the relays IT through 4T are energized upon the
firing of the trigger circuits ITC through 4TC. The relay 1TP is held energized by its shunting capacitor 76 so that it was main picked up until the timer 40 causes the contact 36 to again close for applying the next subsequent pulse of potential if any. Upon the picking up of the relays 1T through 4T, energy is applied to the wire 134 of the stepping switch by a circuit which extends from (++) and includes front contacts 129, 117, 111, 114 and 115 of the relay 1BR, 2ST, 3T, 4T and 4T respectively. The energizing of the wire 134 applies potential to the upper coil U of the relay 125 through the diodes 149, 144, 143, 142, the arm 121 of the wafer W1, wire 161, back contact 162 of the winding U and the winding U of the relay 125 to (——) causing arms 131, 132, and 133 to step up to contacts 1C6, 2C5 and 3C6 in the manner as previously described.

When the arm 121 engages the terminal 1C6, the arm 123 of the wafer W3 is engaging the terminal 3C6 of the wafer W3, but energy is still being applied to the medium slow wire 170 of the motor control circuit through the back contacts 185 and 180 of the speed indication relays 6R and 4R respectively. This prevents the wheels from slipping under conditions of great tension when the locomotive is starting, by not permitting the locomotive motor to assume a full speed or throttle control condition.

As the speed increases relays 4R, 6R and 10R pick up successively to increase gradually the throttle setting and horsepower developed by the diesel engine.

Before the timer 40 permits the next pulse of energy to be applied to the divider 50, the 2S relay drops away. The relay 1TP remains picked up during this interval. Assuming that the next pulse of energy is positive and is of sufficient force to again fire the trigger circuits ITC through 4TC, the stepping switch only moves one step. This is caused by the deenergized position of the relay 2S which closes a circuit to energize the coil U of the relay circuit which extends from (++) and includes front contact 120 of the relay 1BR, back contact 117 of the relay 2S, front contact 110 of the relay 1T, wire 109 and the winding U of the relay to (——). Thus as long as there is a force on the coupling, each time the contact 36 of the timer 40 closes to permit the firing of the trigger circuit ITC, the stepping switch will advance only one step, regardless of the degree of force. In the present example, however, on the second pulse of potential, the stepping switch engaged the contact 1C7 which is the limit of its travel, and the throttle is advanced only because the increase of speed of the locomotive causes the relay 4R to pick up successively.

Assuming that the train has been traveling for some time with little or no force in tension or compression at the coupling 6, and the lead or main locomotive slows down, a force in compression will occur at the coupling 6. The force in compression unbalances the bridge circuit 10 to cause the wire 17 to be negative thereby producing an integrated pulse over wire 45 when the contact 36 closes which is of negative potential. The trigger circuits 1BTC through 3BTC will fire, depending upon the amplitude of this negative pulse as modified by the biasing potential from the divider 228. Assuming that this negative pulse is of sufficient value to cause both the trigger circuits 1BTC and 2BTC to fire, thus energizing the relays 4BTC and 2BTC, the stepping switch will step downwardly until arm 121 engages the contact 1C2. The circuit for stepping the switch in multiple under these conditions extends from (++) and includes front contact 120 of the relay 1BR, front contact 117 of the relay 2S, front contact 115 of the relay 2BTC, the wire 130, diode 156, the diodes 152 through 155, terminal 2C7 of the wafer W2, arm 122, back contact 163 of the relay 125 and the winding D of the relay to (——). Arm 123 of the wafer W3 also moves downwardly to energize the idle wire 176 through back contact 174 of the relay. Similarly a sudden loss of air pressure, which denotes a malfunction of the braking system, will cause the relay ER to drop away which energizes the idle control wire 176 by the closing of back contact 173 of the relay.

Thus, from the preceding description of the operation, it is apparent that the system will cause a stepping of the stepper switch to a position which will tend to make the force in the coupling 6 which is insufficient to cause the firing of either the trigger circuit ITCT or 1BTC. Only one corrective step is taken at a time unless a period of little or no strain has existed prior to the triggering of the trigger circuits TC or BTC. In the event a period of little or no force has existed prior to the triggering, multiple steps can be taken depending upon the position of the arms of the stepping switch and the amount of the force at the coupling.

If the train should reverse its direction of travel, the lead locomotive would cause a force in compression against the coupler 6 of the helper locomotive. This at first would force the locomotives to move rearwardly which would cause the relay RD to pick up to close its front contacts 22 and 24. This force in compression thus causes a positive signal to be integrated in the integrator 30 for controlling the triggers ITCT through 5BTC to operate the helper 5 locomotive in a reverse direction. Also, under these circumstances, a force in tension would provide a negative pulse in the integrator 30 thus applying the brakes of the helper locomotive. The foregoing examples of the operation of this embodiment of the invention under a set of typical operating conditions will render obvious the operation of the system under other given sets of traffic or operating conditions.

It is understood, that more or less trigger circuits TC or BTC may be used in accordance with the requirements of practice. The trigger circuits TC or BTC are shown herein as being transistor multivibrator circuits which are preferred because of their resistance to shock. However, any suitable type of trigger circuits may be used in practicing this invention.

Although the helper locomotive herein illustrated is positioned intermediate the ends of a train, it is understood that a method and system according to the present invention is adaptable to properly control the helper locomotive regardless of its position in the train. This embodiment of the invention controls the locomotive motor to constantly bring the force at the forward coupling to substantially zero. However, it is understood that a system according to the present invention could be arranged to respond to a force on any other coupling of
the locomotive on the train, and constantly attempt to bring the force at this coupling to some predetermined force either in tension or compression.

Thus, I have provided an improved system for operating a locomotive that is coupled to a train which will at all times control the locomotive at the proper speed and tractive effort. Further, I have provided a system which comprises for and "sorts out" any time shocks to which the drawbar or coupling of the locomotive will be subjected during operation, and a system which modifies the control of the locomotive motor in accordance with the actual speed of the locomotive, and causes the helper locomotive to respond practically instantaneously to electrical signals to the main or lead locomotive or in a change of proportion of the load that the helper locomotive is to pull. It is apparent, that this system not only improves the operation of a helper locomotive to aid in providing additional tractive effort for pulling a train, but it also provides additional dynamic braking.

Having thus described one specific embodiment of the present invention, it is to be understood that various adaptations, modifications, and alterations may be made in accordance with the requirements of practice, without in any manner departing from the spirit or scope of the present invention.

With reference to the drawings:

1. A system for operating a helper locomotive that is coupled to a train of cars to which a main locomotive is also coupled, said system comprising means for selectively operating the throttle and braking control of the helper locomotive, train responsive means mounted to detect the degree of force between the helper locomotive and a coupled car of the train, electrical means operatively connected to said strain responsive means to produce an electrical signal proportional to the detected force, control means responsive to said electrical signal to selectively operate the throttle and braking means to maintain said detected force within limits such that the helper locomotive is providing the power for a predetermined portion of the train.

2. A system according to claim 1 wherein said electrical means is operative to produce an output signal of one polarity when said strain responsive means detects a force in compression and an output signal of opposite polarity when said strain responsive means detects a force in tension.

3. A system according to claim 1 wherein said control means includes an integrating means connected to the output of said electrical means effective to integrate said electrical signal, and timing means operatively connected to said integrating means to periodically produce an output pulse from said integrating means to vary the operation of the throttle and brake control selection means periodically in response to said output pulse.

4. A system according to claim 1, wherein said strain responsive means is mounted on a drawbar which connects the helper locomotive to an adjacent car.

5. A system according to claim 1 wherein said helper locomotive has speed responsive means effective to detect the speed of the helper locomotive, means connected to said speed responsive means for producing a second electrical signal proportional to the speed of the helper locomotive, and circuit means operatively connecting said last named means to said control means effective to modify the control of said throttle and brake selections by said first named electrical signal.

6. A system according to claim 1 wherein said throttle and brake selection means includes a stepping switch for selecting said throttle and brake settings, and circuit means effective to selectively operate said stepping switch a predetermined number of steps as governed by the amplitude of said output pulse from the integrating means and the actual position of said stepping switch.

7. A system for controlling a helper vehicle having a plurality of speed and brake selection means for operating the helper vehicle selectively at distinctive speeds and degrees of braking, said helper vehicle being coupled in a train of cars with a control vehicle without a prime mover at a point in the train remote from a main control vehicle, comprising means operatively positioned to detect the degree of force present between said helper vehicle and a portion of the train of cars, means responsive to the degree of said detected force to produce a first electrical signal having characteristics in accordance with the degree of said force, means to produce a second electrical signal corresponding to the velocity of the helper vehicle, and means responsive to both said first and second electrical signals to selectively operate said speed and brake selection means to maintain said force within predetermined limits.

8. A system for controlling the operation of a helper locomotive coupled in a train of cars with a main locomotive, said helper locomotive being equipped with apparatus for selecting various plurality of speed and brake selection means for operating the helper vehicle selectively at distinctive speeds and degrees of braking, said helper vehicle being coupled in a train of cars with a control vehicle without a prime mover at a point in the train remote from a main control vehicle, comprising means operatively positioned to detect the degree of force present between said helper vehicle and a portion of the train of cars, means responsive to the degree of said detected force to produce a first electrical signal having characteristics in accordance with the degree of said force, means to produce a second electrical signal corresponding to the velocity of the helper vehicle, and means responsive to both said first and second electrical signals to selectively operate said speed and brake selection means to maintain said force within predetermined limits.

9. A system according to claim 1 including a direction detection means connected operatively between strain detecting means and the integrating and timing means effective to change the polarity of said output signal when said helper locomotive reverses direction.

10. A system according to claim 1 wherein said stepping switch has a first and second plurality of spaced terminals and a first and second movable contact adapted to electrically connect to each one of each said plurality terminals in succession, an up-step means and a down-step means operatively connected to said movable contacts, said up-step means being effective to operate said movable contacts in one direction and said down-step means being effective to operate said movable contacts in the other direction, said circuit selection means including means connecting preselected ones of said first plurality of terminals to preselected ones of said second plurality of terminals, unidirectional current conducting circuit means connected across adjacent ones of each plurality of terminals to conduct current in one selected direction across ones of said first and second plurality of terminals, and said circuit selection means being effective to apply energy selectively to said connecting means to selectively operate said up-step and down-step means through said
movable contacts and the terminal that it is engaging as governed by said unidirectional circuit means.

11. A system for operating a helper locomotive having speed and brake control means and coupled to a train of cars remote from a controlling vehicle, said system comprising a transducer disposed for detecting and translating a mechanical force existing between the coupled car and the train and caused by the effort of the control vehicle into an electrical signal characteristic of the direction of said mechanical force, a speed sensitive device connected to said helper vehicle for providing an electrical signal proportional to the speed of said helper vehicle, circuit means electrically connecting operatively the electrical signals from said transducer and from said speed sensitive device to said speed and brake control means to operate selectively the speed and brake control means of said helper vehicle as governed by the characteristic of said signals to maintain said force within predetermined limits.

12. A system for controlling a helper locomotive coupled to a train of cars remote from a main locomotive and having a throttle and brake control selection means to operate the helper locomotive at a selected speed and degree of braking respectively, a transducer connected to the coupling of said helper locomotive having a plurality of throttle settings, circuit means operatively connected to said throttle generator for separating said second electrical signal into two polarities, a throttle trigger circuit means responsive to one of said two polarities from said integrating means and a like one of said two polarities from said circuit means for selectively operating said throttle control selection means, brake trigger circuit means responsive to the other of said two polarities from said integrating means and the like other of said two polarities from said circuit means for selectively operating said brake control, thereby controlling said throttle and brake of said helper locomotive in accordance with the force in said coupling, and the speed of said helper locomotive to maintain the force of said coupling within predetermined limits.

13. A control system for a helper locomotive that is connected in a train of cars remote from a main locomotive, said helper locomotive having a plurality of throttle settings, said system comprising a transducer mounted on a coupling of said helper locomotive connecting it to the train for translating tensile forces in said coupling into signals of one polarity and compressive forces in said coupling into signals of opposite polarity, speed responsive means connected to said helper locomotive effective to provide an electrical output signal proportional to the speed of the helper locomotive, an integrator operatively connected to said transducer effective to eliminate peak voltages from said transducer by integrating said peaks over a predetermined time period, timing means operatively connected to said integrator for gating the output of said integrator at the end of said predetermined time period, circuit means operatively connected to said timing and the output of said integrator for accepting said gated signals from said timing and combining said signals with said output signal from said speed responsive means, and locomotive motor control means operatively connected to said circuit means for selectively varying said throttle settings as governed by said combined signals to maintain the force of said helper locomotive to the desired force within predetermined limits.

14. A method of controlling the operation of a helper locomotive coupled to a train of cars to which a main locomotive is coupled remote from said helper locomotive comprising measuring the force exerted on said helper locomotive by a car coupled directly to the helper locomotive when the train is urged in one direction by the main locomotive, measuring the velocity of the helper locomotive, and employing the actual measured velocity of the helper locomotive and the detected force to vary the control of said helper locomotive to cause it to maintain substantially within predetermined limits the force exerted on said helper locomotive or said helper locomotive by a car coupled directly to said helper locomotive when the train is urged in one direction by the main locomotive, converting said detected force into an electric signal having distinctive characteristics depending upon the degree and direction of said force, measuring the velocity of the helper locomotive, converting said measured velocity into an electrical signal corresponding to the velocity of the helper locomotive, and varying the control of said helper locomotive in accordance with the characteristics of both said signals to cause its power to maintain substantially within predetermined limits the force exerted on said helper locomotive by said coupled car, thereby to cause the helper locomotive to provide a predetermined effort in urging the train in said one direction.

15. A method of controlling the operation of a helper locomotive coupled to a train of cars to which a main locomotive is coupled remote from said helper locomotive, comprising measuring the force exerted on said helper locomotive by a car coupled directly to said helper locomotive when the train is urged in one direction by the main locomotive, converting said detected force into an electric signal having distinctive characteristics depending upon the degree and direction of said force, measuring the velocity of the helper locomotive, converting said measured velocity into an electrical signal corresponding to the velocity of the helper locomotive, and varying the control of said helper locomotive in accordance with the characteristics of both said signals to cause its power to maintain substantially within predetermined limits the force exerted on said helper locomotive by said coupled car, thereby to cause the helper locomotive to provide a predetermined effort in urging the train in said one direction.

16. A system for controlling a helper vehicle coupled to a train of cars to which a main vehicle is coupled, said helper vehicle having a plurality of distinct throttle selections for operating the vehicle at distinct speed, comprising means operatively positioned to detect the degree of existence between said helper vehicle and a portion of the train, means responsive to the degree of said existence force to produce a first electrical signal proportional to the degree of existence force connected to the output of said first electrical signal to cause said signal to be effective at predetermined specified intervals of time, means for advancing the throttle through a plurality of settings in accordance with said first electrical signal, and means responsive to said periodic signal effective to advance the throttle setting by one increment only in response to each output signal.

17. A method of controlling the operation of a train of coupled railroad cars by a pair of locomotives, comprising coupling according to said locomotives between adjacent ones of said railroad cars remote from the other locomotive, measuring the force to which said one locomotive is subjected by the movement of the train as caused by the effort of the other locomotive, converting said force into an electrical signal, the value of which is dependent upon the amount of force and characteristic of the direction of force, and controlling the motor and braking power of said one locomotive in accordance with the values and characteristics of said electrical signal to maintain said force within predetermined limits.

18. A method of controlling a helper locomotive adapted to be connected in a train of cars with a main locomotive, comprising means effective to detect the force to which the helper locomotive is subjected when the train is in motion, means for detecting an operating condition of the helper locomotive, and control means responsive to said conditions of said locomotives to control the speed of said helper locomotive to the desired speed within predetermined limits.

19. A system for controlling a helper locomotive comprising measuring the force exerted on said helper locomotive by a car coupled directly to the helper locomotive when the train is urged in one direction by the main locomotive, measuring the velocity of the helper locomotive, and employing the actual measured velocity of the helper locomotive and the detected force to vary the control of said helper locomotive to cause it to maintain substantially within predetermined limits the force exerted on said helper locomotive or said helper locomotive by a car coupled directly to said helper locomotive when the train is urged in one direction by the main locomotive, converting said detected force into an electric signal having distinctive characteristics depending upon the degree and direction of said force, measuring the velocity of the helper locomotive, converting said measured velocity into an electrical signal corresponding to the velocity of the helper locomotive, and varying the control of said helper locomotive in accordance with the characteristics of both said signals to cause its power to maintain substantially within predetermined limits the force exerted on said helper locomotive by said coupled car, thereby to cause the helper locomotive to provide a predetermined effort in urging the train in said one direction.

20. A system according to claim 18 wherein said control means includes a step-by-step means operated from one step to the next step at time spaced intervals for
selecting controls for governing said helper locomotive.

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