Nov. 1, 1966 R. J. BERTI 3,283,146

AUTOMATIC CONTROL MEANS FOR RETARDERS

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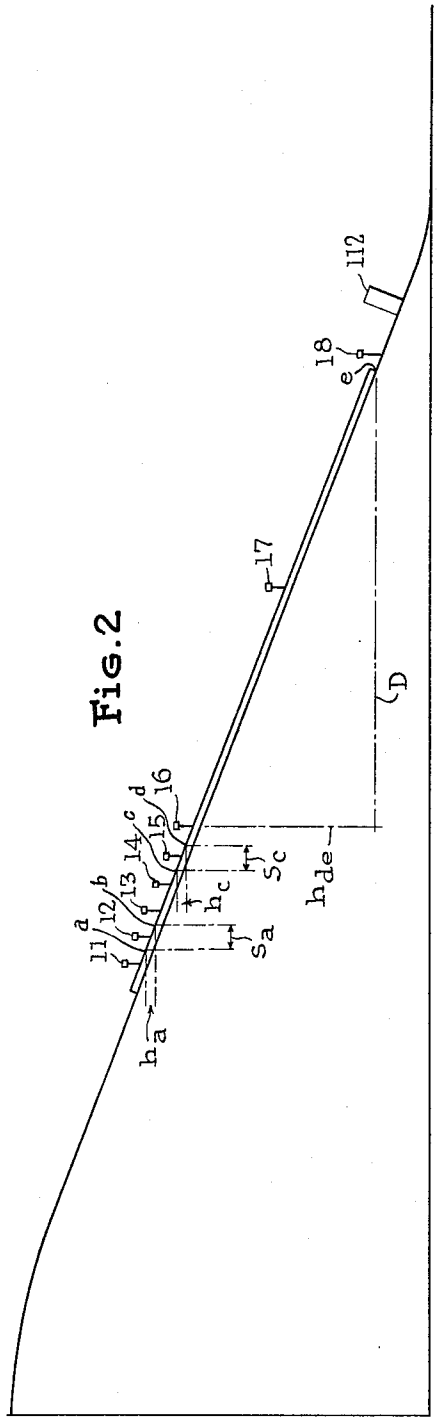


Fig. 2

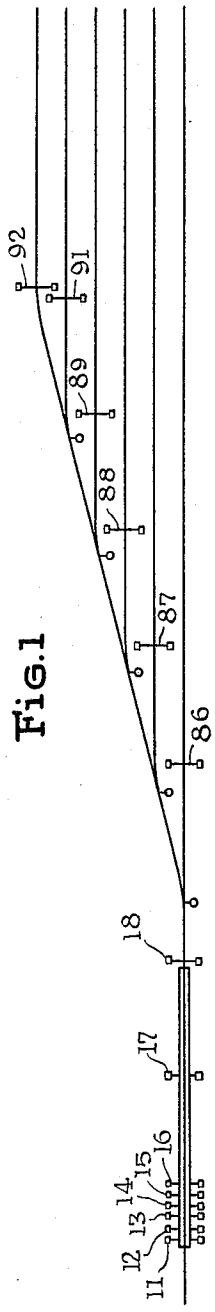


Fig. 1

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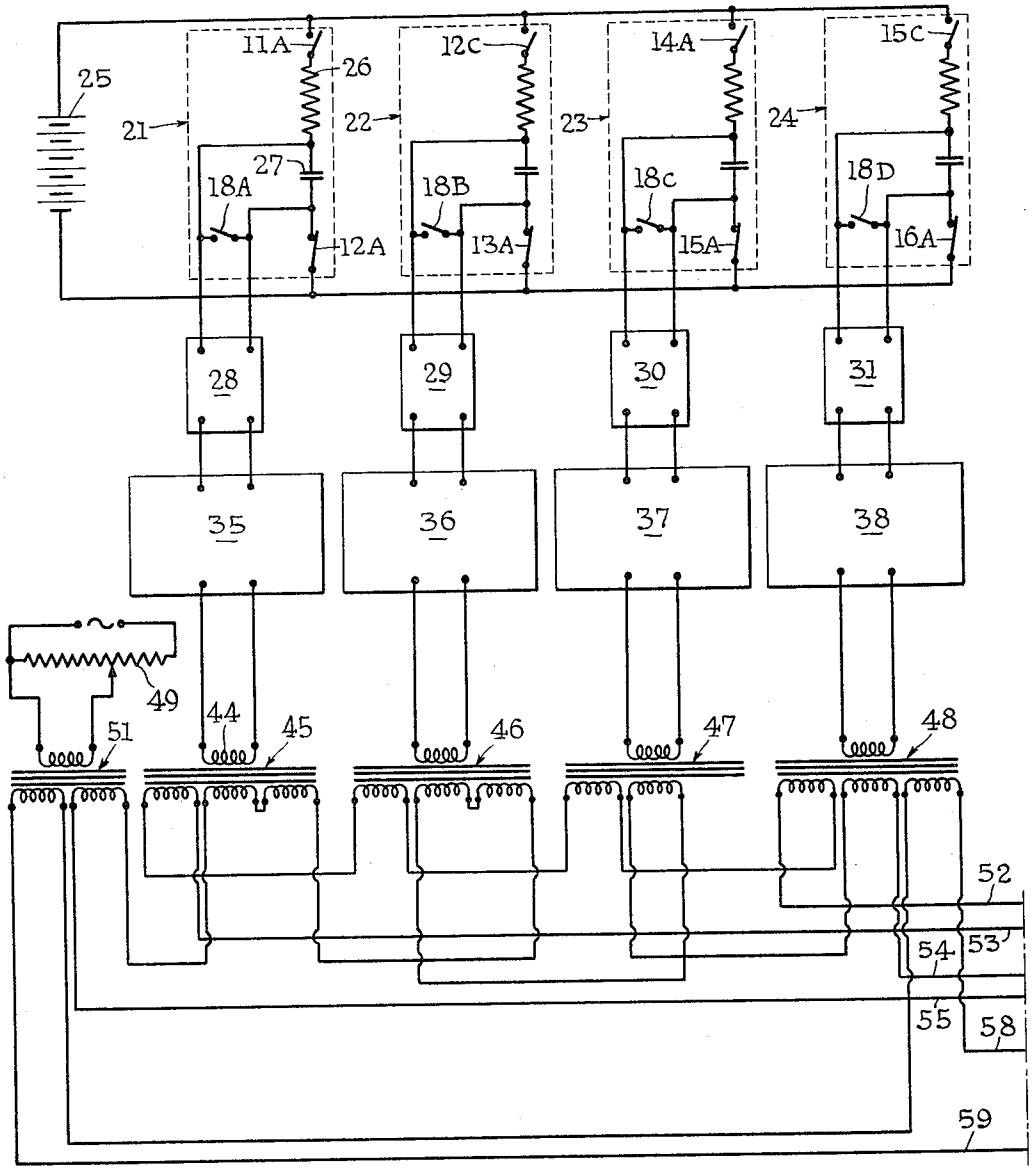
ATTORNEYS

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AUTOMATIC CONTROL MEANS FOR RETARDERS

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Fig. 3



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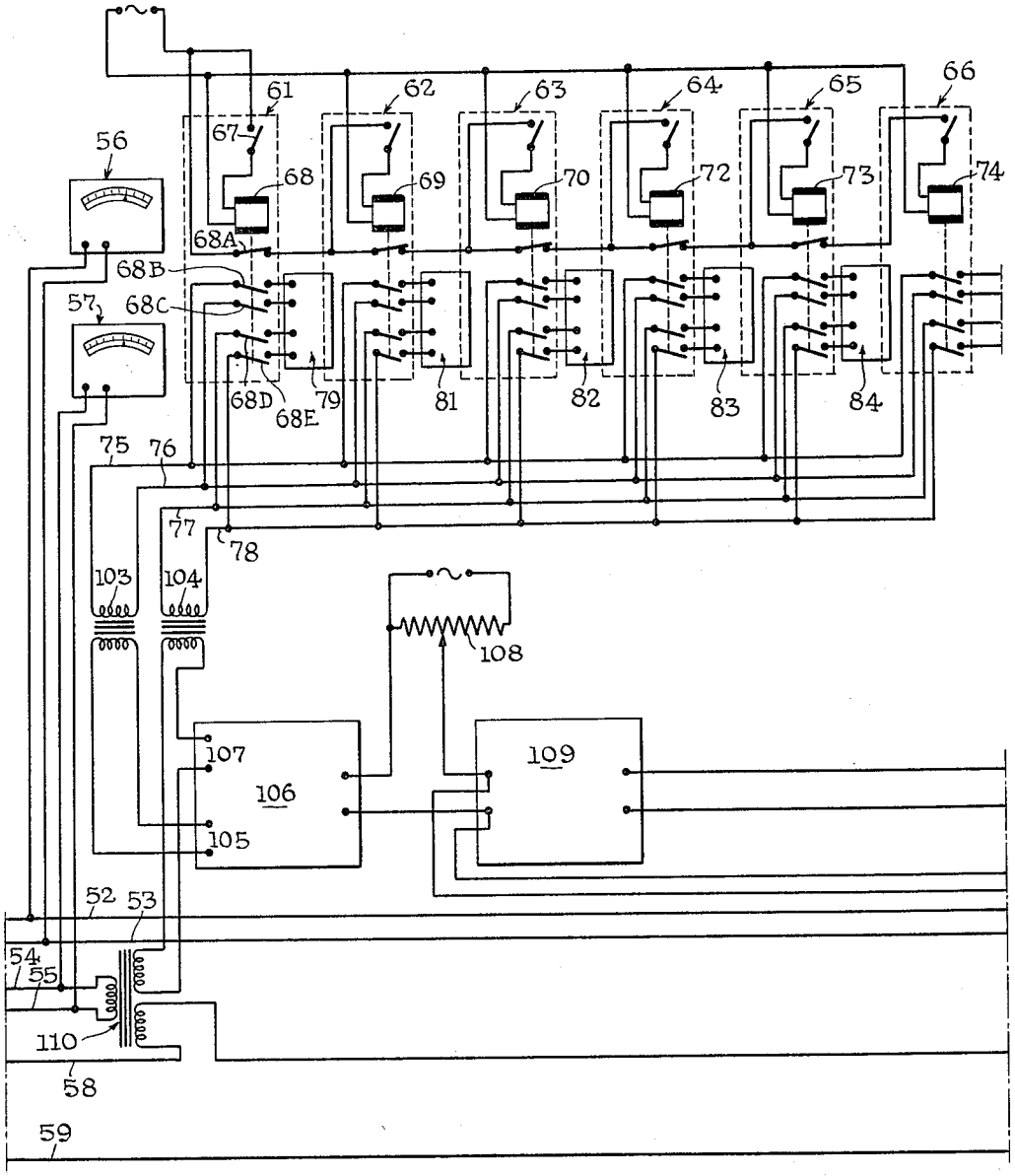
BY Dodge Gill & Jms

ATTORNEYS

AUTOMATIC CONTROL MEANS FOR RETARDERS

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Fig. 4



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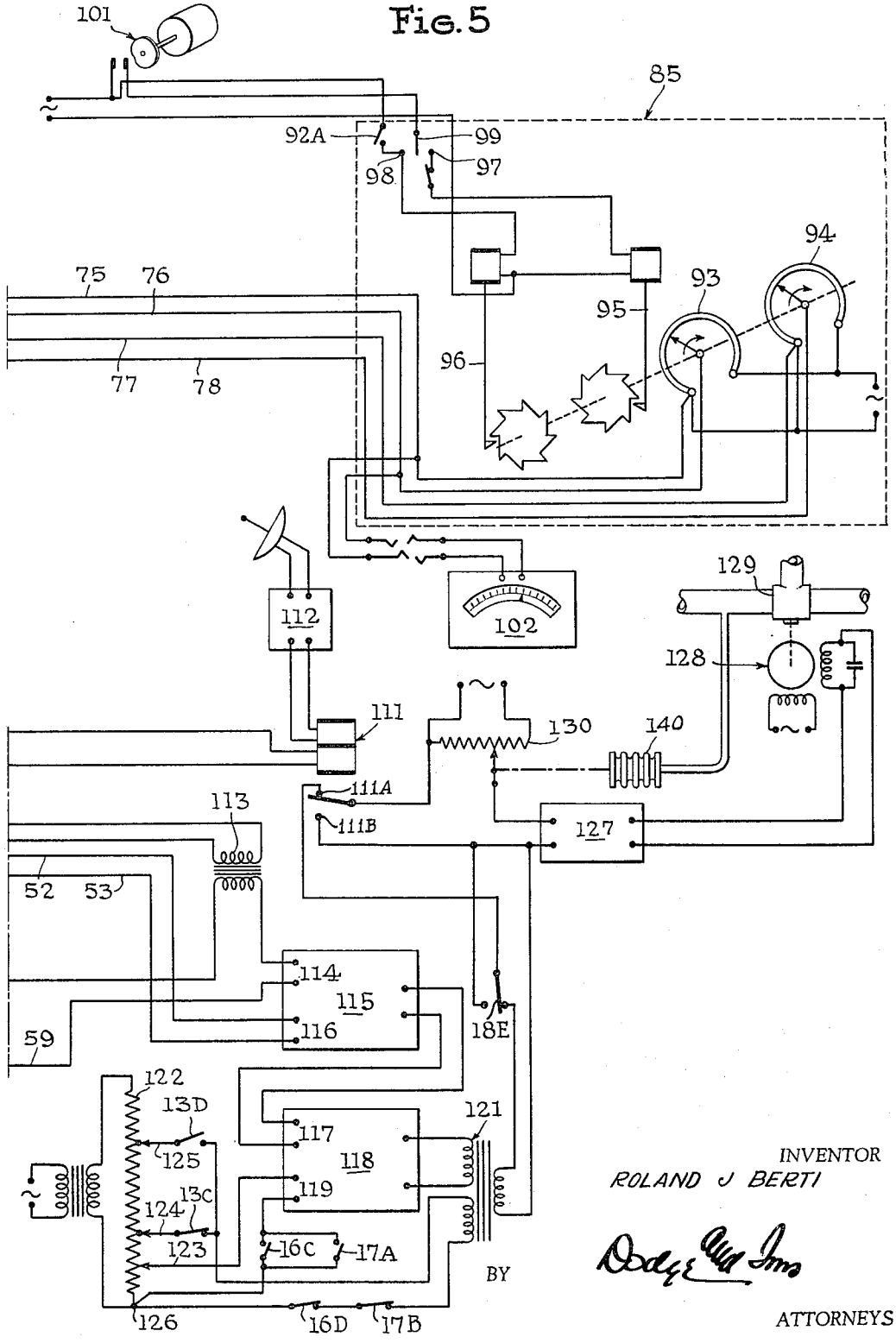
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AUTOMATIC CONTROL MEANS FOR RETARDERS

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Fig. 5



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Fig. 6

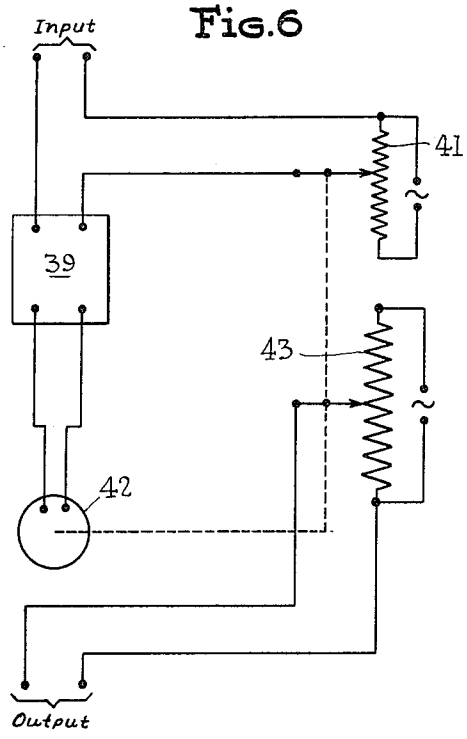


Fig. 7

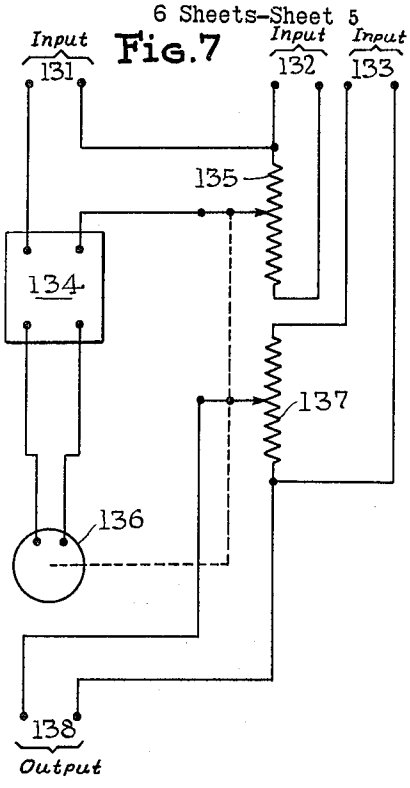
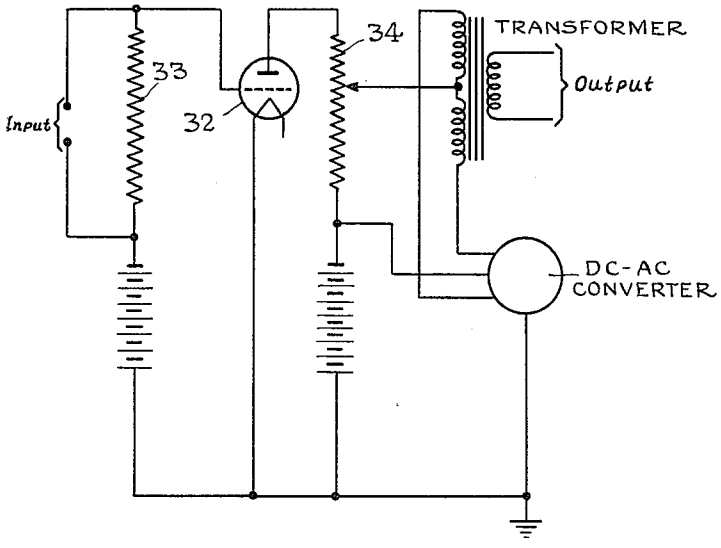


Fig. 8



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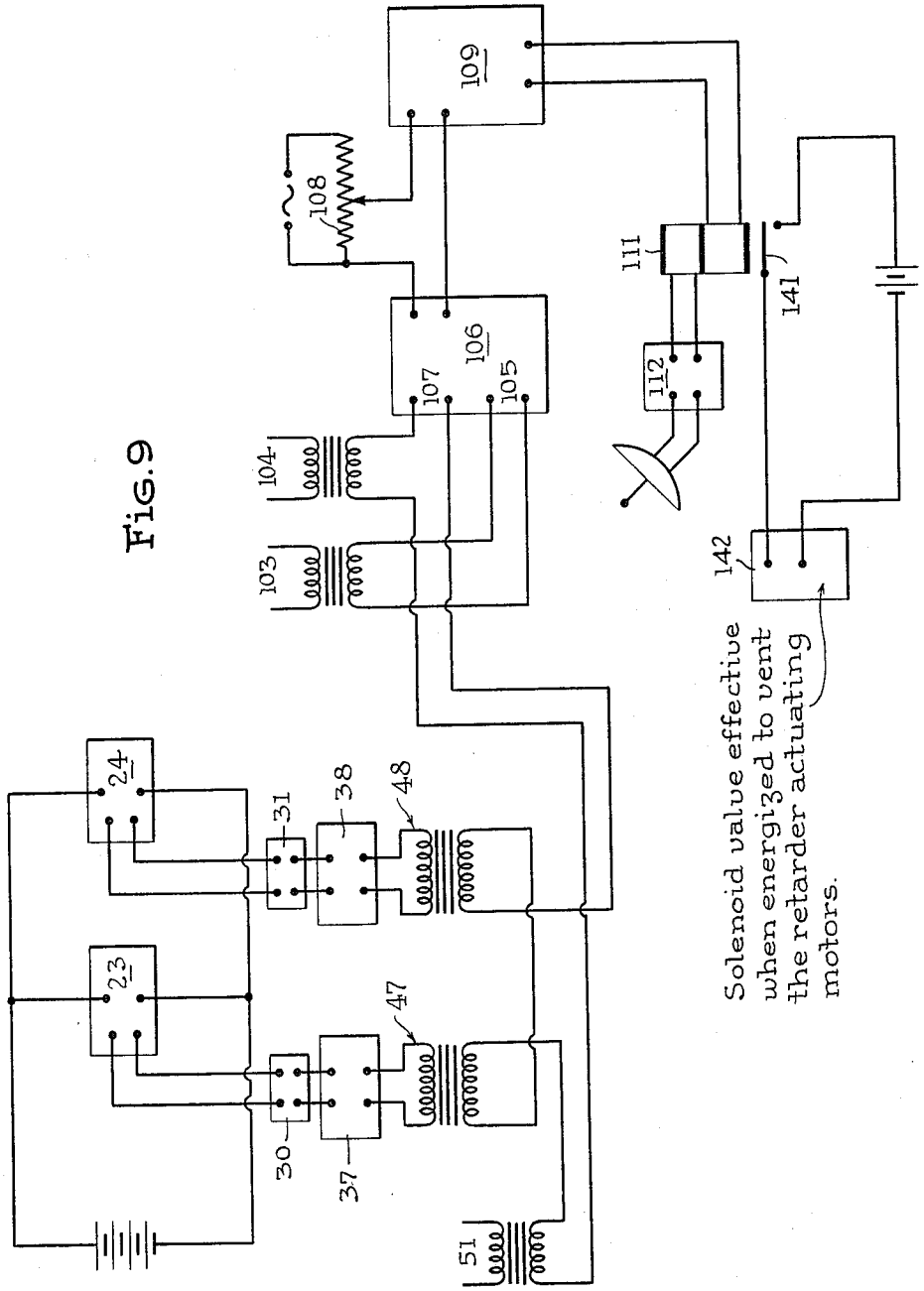
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AUTOMATIC CONTROL MEANS FOR RETARDERS

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Fig. 9



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AUTOMATIC CONTROL MEANS FOR RETARDERS

Roland J. Berti, Omaha, Nebr., assignor to Westinghouse Air Brake Company, Swissvale, Pa., a corporation of Pennsylvania

Filed Jan. 6, 1954, Ser. No. 402,572
10 Claims. (Cl. 246—182)

This invention is concerned with a speed control system for railway cars and finds particular application in freight car classification yards. Present day classification yards are of the well known gravitational type more commonly termed "hump" type and include car retarders for the purpose of appropriately braking the cars to reduce their speed.

Classification yards of this type include a plurality of individual classification tracks that are arranged to receive and store the freight cars that are to be classified according to the destination. The cars are pushed over the hump and permitted to coast down an inclined portion of the main entrance track, through the various retarders, and through the track switches until they reach the particular classification track that corresponds to the ultimate destination of the car.

The principal purpose of the hump is to accelerate the cars, thereby giving the cars sufficient momentum to reach their ultimate destinations, and also introducing sufficient spacing between successive cars to permit the necessary switching operations to be carried out. The retraders cooperate in this operation and assist in maintaining this spacing.

Most classification yards employ three retarders for this purpose, and according to the present invention it is proposed to utilize one or more of these retarders in a system for controlling the coupling speed between successive cars. The term "coupling speed" is used to describe the car speed at the instant that the car, while traveling down its selected classification track, encounters or engages the stationary cars that are already stored on that track. If the cars are not retarded sufficiently, excessive impacts result and frequently cause damage to the cars and the lading, or, on the other hand, if they are retarded too much, excessive spacing between cars on the classification tracks results and this causes inefficient utilization of trackage. In addition the excessive spacing frequently causes the immediately successive cars to strike the spaced car at excessive speeds and results in additional impacts that may be of an even more damaging character. The damage claims arising from excessive impact of the cars during the classification process is one of the major burdens carried by the railroad industry and though many solutions to this problem have been proposed, lading damage remains excessively high. The nub of this lading damage problem is to accurately control the coupling speed of the cars.

Retarders have been employed in speed control systems for classification yards previously but until this time it has not been possible to accurately control the speed of coupling. In these prior art systems there have been various attempts made at regulating the speed based on such factors as the car weight, the condition and type of bearings, the condition of the track, and the climatic conditions, but none of these systems have properly correlated all of these factors.

It is the principal object of the present invention to provide a control system capable of accurately regulating the coupling speeds of the cars being classified. This is accomplished by controlling one of the track retarders, preferably the last one, in a manner so as to cause a car being classified to leave that retarder at a predetermined velocity such that the car will arrive at the coupling point

with an optimum coupling speed. The novel system recognizes that so-called hard running cars must leave the retarder at a higher speed than the so-called easy running cars and there is provision made for determining the rolling characteristic of each car. In regulating the exit speed, it is also necessary to account for the distance the car must traverse in traveling from the exit of the retarder to the coupling point, as well as the gradient of the track over which the car must travel in reaching its destination.

All of the above enumerated factors, with the exception of the rolling characteristic, are functions of the physical layout of the particular classification yard and may be empirically determined. These factors associated with the physical layout of the yard may be conveniently termed the track characteristics and include, for example, range and gradient for the particular track to which the car in question is to be shunted. The rolling characteristics, on the other hand, vary for each car and must be determined in the case of each car. The term "rolling characteristic" as used herein is defined to include all of the factors which affect the travel of the car other than gravity and retarder forces. In positive terms some of the factors that affect the rolling characteristic of a car are its journal friction, its flange friction, its wheel friction, its weight, and the prevailing wind conditions, and though it is next to impossible to determine the individual effect of these various factors, the system of the present invention determines their composite effect with great ease.

According to the present invention this is done by passing the car over a section of track of known grade, and measuring the resultant acceleration of the car during its travel over the section. The rolling characteristic is the difference between the acceleration produced by gravity on this test section and the measured acceleration. The acceleration factor produced by the test section depends upon its slope gradient and upon the condition of the rails. Having determined the rolling characteristic, and knowing the track characteristics of the track to be traversed by the car after leaving the retarder, it is possible to predetermine the exit speed which a car must have when leaving the retarder. It is an important feature of the present invention that though the weight is recognized as one of the factors affecting a car's rolling characteristic, it need not be individually determined.

In controlling the operation of the retarder so as to cause the car to leave at a predetermined speed, two fundamentally different systems are available. In one, a speed monitoring device applies a braking force as required so that the car leaves the retarder at the desired exit velocity.

In the other system the braking characteristic of the car is determined in order to apply an appropriate amount of braking effort to reduce the car speed from the speed at which it is traveling when entering the retarder to the predetermined leaving speed. By "braking characteristic" is meant the retardation effect that is produced on a given car by the application of a known retarder pressure. The braking characteristic of a car depends upon a number of factors including the weight of the car, the contour shape of the wheel flanges (it being assumed that the retarder being employed is the type that grips the wheel flanges), the frictional coefficients of the engaged surfaces, etc., but here again it is not necessary to measure the individual effect of these factors but rather the composite effect.

In the preferred form of the present invention, the system for determining braking characteristics is combined with the system for determining rolling characteristics and a number of possible combinations present themselves. Generally speaking, this composite system contains two unknown, namely the rolling characteristic and the braking characteristic, and hence two test sections capable of

providing two tests are required. There are many ways of running the two tests. The simplest, of course, is to run a first test (test "A") that does not include any braking forces and thereby enable the single remaining unknown, namely the rolling characteristic to be determined immediately. The means for making this determination may be identical with the previously described arrangement. In this form of the invention the second test (test "B") necessarily must include a braking force applied by a retarder in order to determine its effect upon the car. It is also possible to apply a braking force during both test "A" and test "B," the only proviso being that the braking force be different during each test.

According to the present invention, the test sections are located on the hump incline that leads into the main body of classification tracks. This location is chosen in order to insure that the rolling characteristic as determined in the test section remains substantially constant during the travel of the car along the classification track. Certain of the factors making up the rolling characteristic are subject to wide variation and the accuracy of the system depends on eliminating such variations.

One of these is the effect of the winds which can be of varying magnitude and direction, sometimes acting to retard the cars and at other times acting to accelerate them. For this reason it is desirable that the test section closely simulate the wind conditions prevailing in the classification yard and although the proposed location on the hump is at a slightly higher elevation and on a steeper gradient than the location of the classification track, the windage effect on the car is considered to be essentially the same. It is desirable of course, that the test section of track, as nearly as possible be parallel to the classification tracks.

Another highly variable factor is the effect of journal friction which is dependent not only upon ambient temperature but also upon whether the cars being classified are from a recently arrived train and consequently have warm journals or are from a train that has been standing for some time in cold weather. For this reason it is necessary that the test run be made immediatley previous to the classification run in order that no appreciable change in journal friction can occur and the proposed hump location adequately meets this condition.

As heretofore explained, the invention compensates for the progressive shortening of the effective length of the classification tracks that occurs as the successive cars being classified are stored on these tracks and according to the present invention this is accomplished automatically.

Other objects and advantages of the invention will be apparent during the course of the following description.

A preferred embodiment of the invention is shown in the accompanying drawings in which:

FIGURE 1 is a diagrammatic plan view of the hump and the associated classification tracks.

FIGURE 2 is a diagrammatic profile of the hump and an associated classification track.

FIGURES 3, 4 and 5 assembled side by side in the order stated constitute a diagram of an electrical circuit whereby the desired control signal is produced.

FIGURE 6 is a simplified diagram of the circuit of a servo-translator which may be used with the invention.

FIGURE 7 is a simplified diagram of the circuit of a servo-multiplier (or divider).

FIGURE 8 is a simplified diagram of a vacuum tube coupler which may be used with the invention.

FIGURE 9 is a circuit diagram of a modified form of the invention.

In order to best understand that the apparatus of the invention operates in accordance with the general principles of the invention, as expressed hereinbefore, it is helpful to express these principles mathematically and then show that the apparatus conforms to the mathematical relationships.

According to the law of conservation of energy the energy of the car may be stated mathematically as follows:

$$\tfrac{1}{2}mV_0^2+mgh_0=FD+\tfrac{1}{2}mV_1^2+mgh_1$$

where the subscripts "0" and "1" denote respectively the value of that variable at an original or reference point and at some other point, and

V=velocity
m=mass
h=elevation
F=net force (a constant) acting on the car between points 0 and 1
g=acceleration due to gravity
D=distance between points 0 and 1.

Stated in words, the law of conservation of energy tells us that a body which initially possesses a certain kinetic energy ($\frac{1}{2}mV^2$) and a certain potential energy (mgh) will, in moving from one point to another, undergo a change in total energy ($\frac{1}{2}mV^2+mgh$) which is equal to the amount of work done on or by that body while moving between those points. If the forces acting on the body during this motion are constant, the work is equal to the product of the force multiplied by the distance between the points (FD).

Using the subscript e to designate the exit of the main retarder and f to designate a point in the classification yard at which a car being classified will couple with a standing car and using the English system of weights and measures, the following equation may be derived from the equation given above but relating to the car speeds at the points e and f:

$$\tfrac{1}{2}mV_e^2+mgh_e=F_rD_{ef}+\tfrac{1}{2}mV_f^2+mgh_f$$

Substituting h_{ef} for (h_e-h_f) and 32.2 ft./sec.^{2} for g, then solving the above equation for V_e, the following equation results:

(1) $$\sqrt{V_f^2+2D_{ef}\left[\frac{F_r}{m}-32.2\frac{h_{ef}}{D_{ef}}\right]}$$

$100\frac{h_{ef}}{D_{ef}}\approx$ the percent gradient (K) between points e and f.

$$3.22\frac{h_{ef}}{D_{ef}}=0.322K$$

This approximation holds true if the gradient is slight, as it is in a classification yard. Making this substitution in Equation 1, the following may be derived.

(1a) $$V_e=\sqrt{V_f^2+2D_{ef}\left[\frac{F_r}{m}-0.322K\right]}$$

The same equations may be set up for motion of the car during application of the test brake forces while the car is on the hump.

It will be apparent that the net force, F_r in Equations 1 and 1*a*, acting on the car during travel through the yard is the resultant of the forces due to friction, windage, condition of the track and the like. The net force acting on the car at any time during descent along the hump includes these same retarding forces plus the test braking force that is acting.

According to the preferred form of the invention, by measuring the velocity changes which occur as a result of the different forces acting during travel down the hump it is possible to compute the final brakng force necessary to produce an exit velocity at the bottom of the hump such that the car will reach its destination at a proper velocity.

Referring first to FIGURE 1, it will be seen that eight pairs of photoelectric cell relays and associated light sources are employed. These are indicated by reference numerals **11**, **12**, **13**, **14**, **15**, **16**, **17** and **18**. During travel between the photoelectric cells **11** and **13**, a first test brake force F_a is effective, and during travel from photoelectric cell **14** to photoelectric cell **16** a different test brake force F_b is effective.

The photoelectric relays **11**, **12**, **13**, **14**, **15** and **16** are arranged along the track with the light sources on one side of the track and the light sensitive relays on the opposite side, so arranged that as long as no car is occupying the track between, the light sources project into their respective photoelectric cells thus energizing the relays. These light sources and relays are arranged in such a manner so as to provide clearance for any railway vehicle which may occupy the track, and also so that the light beams will be interrupted, and remain interrupted for the entire length of travel of a car or group of cars. A preferred location is to have the light beams normal to the track centerline and at a height so that the beam will be interrupted by the car couplers and connecting underframe. The light source should preferably be lower than the photoelectric relay so that the light beam crosses the track at an angle with the horizontal, thus assuring beam interruption for all types of cars including depressed underframe flat cars.

The spacing of the photoelectric relays **11** to **16** is dependent upon the mechanical and electrical constants of the system and in practice may be a great number of values, depending upon such factors as the speed response of the relays, the speed response of the retarder, the values given to the various circuit components, etc.

It will be understood that while photoelectric relays are used in the illustrated embodiment, these components could also be car actuated treadles, or similar devices.

It has been stated that the test braking forces F_a and F_b are not equal. In other words, F_b is some multiple of F_a. The symbol n will be used to identify this multiple. Stated mathematically, $F_b=nF_a$. Since the forces F_a and F_b are, by definition, unequal, n is some number other than 1. Using the mathematical statement of the law of conservation of energy as set out above, the motion between the points a and b and c and d may be stated according to the following equations wherein F_r=net retarding force other than the test braking force:

$$(2)\quad \tfrac{1}{2}mV_a^2+32.2mh_a=\tfrac{1}{2}mV_b^2+(F_a+F_r)S_a$$

$$(3)\quad \tfrac{1}{2}mV_c^2+32.2mh_c=\tfrac{1}{2}mV_d^2+(F_b+F_r)S_c$$

V_a and V_b respectively represent the average velocity in feet per second during travel from **11** to **12** and from **12** to **13**. V_c and V_d are respectively the average velocity during travel from **14** to **15** and **15** to **16**.

For convenience in explaining the derivation of the basic formulae it will be assumed that $h_a=h_c=h$ and $S_a=S_c=S$. The symbols h_a, h_c, S_a and S_c are defined by the illustration in FIGURE 2.

The following equation may be derived from Equation 2:

$$(2a)\quad \frac{F_a+F_r}{m}=\frac{V_a^2-V_b^2}{2S}+32.2\,\frac{h}{S}$$

Since 100 h/S is approximately equal to the percent gradient of the track between the points a and b, and using the symbol k to represent percent gradient, the following equation may be derived:

$$(2b)\quad \frac{F_a+F_r}{m}=\frac{V_a^2-V_b^2}{2S}+0.322K$$

A corresponding formula for motion from c to d may be derived in the same manner from Equation 3.

$$(3a)\quad \frac{F_b+F_r}{m}=\frac{V_c^2-V_d^2}{2S}+0.322K$$

Since by definition $F_b=nF_a$, nF_a may be substituted for F_b in Equation 3a to obtain the following equation:

$$(3b)\quad \frac{nF_a+F_r}{m}=\frac{V_c^2-V_d^2}{2S}+0.322K$$

Equations 2b and 3b are a pair of simultaneous equations having two unknowns F_a and F_r. To eliminate F_r and

solve for F_a, we subtract Equation 2b from Equation 3b to obtain the following equation:

$$(4)\quad \frac{(n-1)F_a}{m}=\frac{V_c^2-V_d^2-V_a^2+V_b^2}{2S}$$

or

$$(4a)\quad \frac{F_a}{m}=\frac{V_c^2-V_d^2-V_a^2+V_b^2}{2S(n-1)}$$

The solution of simultaneous Equations 2b and 3b for the other unknown F_r is acomplished by multiplying Equation 2b by n and subtracting Equation 3b therefrom to obtain:

$$(5)\quad (n-1)\frac{F_r}{m}=\frac{nV_a^2-nV_b^2}{2S}+(n-1)0.322K-\left(\frac{V_c^2-V_d^2}{2S}\right)$$

or

$$(5c)\quad \frac{F_r}{m}=\frac{nV_a^2-nV_b^2-V_c^2+V_d^2}{2S(n-1)}+0.322K$$

If $n=1$, i.e., if $F_a=F_b$ the solutions of 4a and 5c for F_a/m and F_r/m respectively are indeterminate. Hence n may not equal 1 if a solution is to be obtained. As a practical matter n could equal zero. In this case, we would obtain from Equations 4a and 5c respectively:

$$(4b)\quad \frac{F_a}{m}=\frac{V_c^2+V_d^2+V_a^2-V_b^2}{2S}$$

$$(5d)\quad \frac{F_r}{m}=\frac{V_c^2-V_d^2}{2S}+0.322K$$

Theoretically n could have a value less than zero in which case the force F_b instead of being a braking force would be an assisting force. Practically considered the value of n will usually be positive because of the ease of applying a braking force as contrasted to the application of an assisting force.

If two test forces are used a value of $n>1$ is preferred, because the braking bars of track side retarders are ordinarily pneumatically actuated and air is conserved if the braking force is progressively increased whereby it is unnecessary to vent any air from the retarder actuating means.

It will be assumed for the purposes of convenience in disclosing the illustrated embodiment of the invention that $n=2$. Substituting this value of n, the following formulae are derived from Equations 4a and 5c respectively:

$$(4c)\quad \frac{F_a}{m}=\frac{V_c^2-V_d^2-V_a^2+V_b^2}{2S}$$

$$(5e)\quad \frac{F_r}{m}=\frac{2V_a^2-2V_b^2-V_c^2+V_e^2}{2S}+0.322K$$

Motion of the car from the photoelectric cell relay **16** to the exit of the main retarder may, in accordance with the mathematical statement of the law of conservation of energy, be stated as follows:

$$(6)\quad \tfrac{1}{2}mV_d^2+32.2mh_{de}=\tfrac{1}{2}mV_e^2+(F_r+F_d)D$$

The term F_d represents the main braking force while h_{de} and D are indicated by legend on FIGURE 2. In Formula 6 it is assumed that the difference between the velocities at point d and the photoelectric cell relay **16** can be ignored without introducing a significant error. The following formula can be derived from Equation 6 in a manner generally analogous to the derivation of 2b from Equation 2.

$$(6a)\quad \frac{F_d}{m}=\frac{V_d^2-V_e^2}{2D}+0.322k-\frac{F_r}{m}$$

Multiplying the right hand side of 6a by

$$\frac{F_a/m}{F_a/m}$$

and cancelling we obtain:

$$(7)\qquad F_d=F_a\left[\frac{\frac{V_d^2-V_c^2}{2D}+0.322k-\frac{F_r}{m}}{\frac{F_a}{m}}\right]$$

Since the force F_d is the total applied to both car trucks, and the test braking forces are applied to one truck only, the actual force to produce this braking force is half F_d. This force will be designated F_d'.

$$(7a)\qquad F_d'=\frac{F_a}{2}\left[\frac{\frac{V_d^2}{2D}-\frac{V_c^2}{2D}+0.322k-\frac{F_r}{m}}{\frac{F_a}{m}}\right]$$

The braking force actually acting on the car at any time is equal to the pressure in the retarder motor means, multiplied by the area of the motor element on which that pressure acts, multiplied by the coefficient of friction between the retarder means and the wheels flanges of the car being retarded. Mathematically, this force may be stated as follows:

$$F=PA\mu$$

in which F represents braking force, P represents the pressure then acting, A is the area of the retarder motor means, and μ equals the coefficient of friction.

F_d', by definition, is the main retarding force acting on the car between the points *d* and *e* and therefore may be stated mathematically as follows:

$$F_d'=P_d'A\mu$$

in which P_d' represents the retarder pressure acting on the car as it travels between the points *d* and *e*.

Similarly F_a, the test braking force, may be mathematically stated as:

$$F_a=P_aA\mu$$

wherein P_a represents the retarder pressure acting on the car as it travels between points *a* and *b*.

By substituting the above terms for F_d' and F_a in Equation 7*a*, the following equation may be derived:

$$(7b)\qquad P_d'=\frac{P_a}{2}\left[\frac{\frac{V_d^2}{2D}-\frac{V_c^2}{2D}+0.322k-\frac{F_r}{m}}{\frac{F_a}{m}}\right]$$

The factor $A\mu$, since it would appear on both sides of Equation 7*b*, has been cancelled out from both sides.

Referring now to FIGURE 3, reference numerals **21**, **22**, **23** and **24** indicate generally resistor-capacitor units which are connected in parallel with a battery **25**. Resistor-capacitor until **21** comprises a resistance **26** and a capacitor or condenser **27** connected in series across the battery terminals. Flow through the resistance **26** and capacitor **27** is controlled by relay switch contacts **11A** and **12A**. The relay switch contacts have been numbered according to the convention in which the numeral indicates the photoelectric cell, see FIGURES 1 and 2, and the relay controlled thereby and the reference letter indicates the contact actuated by the relay. These switches are shown in the position assumed when the associated relay is energized, i.e. when no car is on the hump. The opposite sides of the condenser **27** are connected to a high input impedance type vacuum tube coupler **28**, and with this arrangement substantially no dissipation of condenser voltage occurs through the coupler **28**. Deenergization of relay **11** closes contact **11A** whereby a charge is accumulated on the condenser **27**. This charging is terminated by the opening of contact **12A** upon the denergization of relay **12**. A normally open contact **18A** is connected as a shunt between the condenser output leads to the vacuum tube coupler **28** and is effective when closed to dissipate the charge on the condenser **27**, as will be more fully explained. The unit **22** is similar to

unit **21** but charging flow to the condenser is controlled by normally open relay contact **12C** and terminated by the opening of normally closed contact **13A**. The units **23** and **24** are identical to units **21** and **22**. Their serial energization is controlled by the relays associated with the photoelectric cells **14**, **15**, and **16**.

The vacuum tube couplers **28**, **29**, **30** and **31** are identical and their construction will be clear from the diagrammatic showing of coupler **28** in FIGURE 8. It comprises a conventional vacuum triode **32** having a high input impedance obtained by biasing the grid so that it is negative at all times and using a large grid leak resistor **33** in relation to the capacitor **27**. In this way only a small part of the capacitor output is lost during the time the car moves through the retarder. The plate potential in turn is made high enough so that it will be in the conducting range even though the grid is negatively biased. The tube plate and grid potentials are selected so that the plate current flowing through the plate resistor **34** is linearly proportional to the capacitor voltage. A selected portion of this output is impressed on a vibrating reed D.C. to A.C. converter and hence supplied to an output transformer.

The secondary of the output transformer is electrically connected to a servo-translator **35**. Similar servo-translators **36**, **37**, and **38** are respectively connected to couplers **29**, **30**, and **31**. These servo-translators are identical and only a description of translator **35** will be made. See FIGURE 6. The input from the coupler **28** is connected in series to a voltage amplifier **39** and to a variable potentiometer **41**. Amplifier output is supplied to a field winding of a reversible two phase servo-motor **42** which is connected to drive the potentiometer **41** and an output potentiometer **43**. The output from potentiometer **43** is in turn supplied to the primary winding **44** of transformer **45** (see FIGURE 3). Potentiometer **41** is in effect a follow-up device to denergize the servo-motor **42** when the output setting reaches a value corresponding to the input from the coupler **28**. The winding of potentiometer **43** is such that the output is inversely proportional to the square of the input to the translator.

Similar transformers **46**, **47** and **48** are connected to receive the output of translators **36**, **37** and **38** respectively. The charge on capacitor **27** is linearly related to the time it takes the car to travel from photoelectric cell **11** to cell **12**. A signal which is inversely proportional to the square of this charge is proportional to the square of the average velocity of the car while travelling from photo-electric cell **11** to photo-electric cell **12**. Hence the primary windings of transformers **45**, **46**, **47** and **48** are energized by voltages which are respectively proportional to V_a^2, V_b^2, V_c^2 and V_d^2.

A linear potentiometer **49** is connected across an independent A.C. source. The setting of this potentiometer is selected so that it gives an output signal proportional to the percent gradient of the hump which is a constant. This output is connected to the primary winding of transformer **51** and produces a corresponding signal in each of its secondary windings.

The network including leads **52** and **53** and selected secondary windings (as shown in FIGURE 3) produces a voltage signal $E=-V_a^2+V_b^2+V_c^2-V_d^2$ which is proportional to F_a/m (Equation 4*c*) since S is a constant. The term F_a/m is a measure of the braking effectiveness of the retarder for the car in question, and hence the control energy represented by the signal E is proportional to the braking characteristic of the retarder for the car. The network including leads **54** and **55** and the illustrated transformer secondaries produce a voltage signal

$$E2=2V_a^2-2V_b^2-V_c^2+V_d^2+0.322K$$

which is proportional to F_r/m (Equation 5*e*), since S is constant. F_r/m is a measure of the rolling characteristic of the car in question, and hence the control energy represented by the signal E2 is proportional to the rolling

characteristic of the car. Connected across leads 52 and 53 is a voltmeter 56 which may be calibrated to indicate car weight. This indication of car weight is approximate. Similarly a voltmeter 57 is connected across leads 54 and 55 and is calibrated to indicate the net retarding force other than braking forces which is acting on the car.

Two signals corresponding to classification track conditions must be produced and this is accomplished as shown in FIGURES 4 and 5 of the drawings. Associated with the signal transmitting line from each classification track is a selector switch means indicated generally by reference numerals 61, 62, 63, 64, 65 and 66. These switch means are identical and only means 61 will be described in detail. Means 61 includes a normally open main selector switch 67 which may be automatically controlled or manually controlled by the humpmaster. When switch 67 is closed the associated relay 68 is energized whereby associated contacts 68B, 68C, 68D and 68E are closed and contact 68A is opened. Opening of contact 68A prevents energization of relays 69, 70, 72, 73 and 74. It will be noted that each selector switch means is subservient to energization of the relays ahead of it in the series, but dominates those subsequent to it in the series.

Closure of contacts 68B, 68C, 68D and 68E connects signal leads 75, 76, 77 and 78 to the corresponding stepping relay 79. The selector switch means each includes a stepping relay. These relays are indicated by reference numerals 79, 81, 82, 83, 84 and 85.

Stepping relay 85 is identical with the others and is shown in diagram in FIGURE 5. Associated with each classification track at its entrance is a light source and photoelectric cell relay. These are indicated at 86, 87, 88, 89, 91 and 92 in FIGURE 1. Relay 92 controls contact 92A of stepping relay 85. Stepping relay 85 includes two potentiometers 93 and 94. Potentiometer 93 has a winding calibrated so that its output signal is an indication of the distance from the exit of the retarder to the nearest car on the track. Potentiometer 94 is wound so that its signal is an indication of the average gradient (K) between the corresponding point on the classification track and the exit of the retarder. The average gradient is proportional to the change in potential energy which the car undergoes in traveling over the portion of track to which the average gradient corresponds. The potentiometers 93 and 94 are driven from single shaft (indicated by a dotted line). This shaft is driven by either of two ratchet wheels and relay combinations 95 and 96. Assembly 96 is actuated by closure of contact 92A. It acts to adjust the settings of potentiometers 93 and 94 as required by the admission of a single car to the corresponding classification track. This adjustment of 93 and 94 is determined by use of an average car length. An unusual run of long cars or short cars will require that the setting of the potentiometers be adjusted. If a run of long cars occurs the adjustment is made by manually closing contact 99 against contact 98. If a run of short cars occurs contact 99 is closed against contact 97 whereby relay assembly 95 is energized to cause a reverse adjustment of potentiometers 93 and 94. During readjustment, a pulsating current is supplied to relay assemblies 95 and 96, so that the humpmaster may count the number of pulsations and knowing the desired correction and the observed average length of the cars, he may establish the proper settings.

Although the same effect could be had by repeatedly opening and closing switch 99, automatic means such as the cam operated switch 101 is preferred. A single switch 101 can be used to control the readjustment of all the stepping relays 79, 81, 82, 83, 84 and 85.

Potentiometer 93 is connected across leads 75 and 76 and potentiometer 94 is connected across leads 77 and 78. A voltmeter 102 may be connected across leads 75 and 76. This voltmeter can be used as an indication of the range setting, i.e., the indication of the distance from retarder to the nearest car on the corresponding classification track.

The indicated range signal is supplied to the primary winding of transformer 103, and the indicated average gradient signal is supplied to transformer 104. The secondary winding of transformer 103 is designed to produce a signal equal to twice the range ($2D_{ef}$) and is connected to supply this signal to the input connection 105 of the servo-multiplier 106. Input connection 107 receives a signal from transformer 110 and transformer 104 equal to $F_r/m-K$.

The output from multiplier 106 equals $2D_{ef}(F_r/m-K)$. An adjustable potentiometer 108 is connected to the output of multiplier 106. The winding of potentiometer 108 is selected to produce a signal proportional to V_f^2. Servo-translator 109 receives an input equal to

$$V_f^2+2D_{ef}\left(\frac{F_r}{m}-K\right)$$

i.e. V_e^2 according to Equation 1*a*. Servo-translator 109 is similar to to servo-translator 36, but is arranged to produce a modified signal equal to the square root of the input. The square root of the input is equal to V_e (according to Equation 1*a*). This output signal is supplied to one of the coils of differential relay 111. The other coil of relay 111 is connected to the radar speed indicator 112. The purpose of this relay 111 will be explained.

The signal V_e^2 is also supplied to a transformer 113, the secondary winding of which produces a signal $V_e^2/2D$. The secondary windings of transformers 113, 110, 48 and 51 are connected in series and supply to the input 114 of the servo-divider 115 a signal equal to

$$\frac{V_d^2}{2D}-\frac{V_e^2}{2D}+0.322K-\frac{F_r}{m}$$

(See Equation 7*a*). Leads 52 and 53 supply a signal equal to F_a/m to input 116 of divider 115. The output from the servo-divider 115 is equal to

$$\left[\frac{\left(\frac{V_d^2}{2D}-\frac{V_e^2}{2D}+0.322K-\frac{F_r}{m}\right)}{\frac{F_a}{m}}\right]$$

This output is supplied to input 117 of servo-multiplier 118. A signal proportional to $P_a/2$ is supplied to input 119. The output from servo-multiplier is applied to a primary winding of transformer 121.

The signal $P_a/2$ is produced as follows: a fixed potentiometer 122 is provided with three taps 123, 124 and 125. Potentiometer 122 is wound so as to produce a voltage between the points 126 and 123 proportional to $P_a/2$, between points 126 and 124 a signal proportional to P_a and between 126 and 125 a signal proportional to $2P_a$.

A lead extends from 126 to parallel connected contacts 16C and 17A to input connection 119 and back to tap 123. Contact 16C is controlled by the relay associated with photoelectric cell 16. Contact 17A is controlled by the relay associated with photoelectric cell 17. There may be more than one relay such as 17 and these relays act to maintain at least one of the parallel connected contacts closed at all times during a car's descent through the main retarder section.

Contacts 16D and 17B open the circuit to the second primary winding of transformer 121 whenever either relay 16 or 17 is deenergized, as will be the case when a car is in the main retarder. Contacts 13C and 13D act during the car's travel while subject to either of the two test braking forces in a manner such that the input to this second primary winding is either P_a or $2P_a$.

The output of servo-multiplier 118 is a signal proportional the solution of Equation 7*b*, i.e., the desired braking pressure.

The secondary winding of transformer 121 is connected in a series circuit which includes relay contacts 18E,

and front contact 111A, error potentiometer 130 and amplifier 127. The amplifier output is connected to a field winding of motor 128 which operates three-way valve 129. Valve 129 controls the supply and discharge of pressure fluid to and from the operating motors of the retarder. The motor pressure is effective through bellows motor 140 to adjust potentiometer 130.

When the radar speedmeter 112 indicates the speed of the car after the test braking forces have been applied is less than the desired exit velocity from the hump, the circuit through the front contact 111A of the differential relay 111 is opened and a second circuit is established to the retarder-controlling motor through the back contact 111B which is now closed. This causes the retarder operating motors to be vented. The radar speed indicator has a range such that it measures the speed of car only during the interval after it has left the test braking section of the retarder and prior to its exit from the retarder. Contact 18E is closed against its front contact when the photo-electric cell 18 is energized, and closes against its back contact to vent the retarder motors in the same manner that the retarder motor is vented by operation of the differential relay 111. Contact 18E closes its front contact when the photo-electric cell relay 18 is again energized which occurs when the rear end of the car passes that relay. At this same time contacts 18A, 18B, 18C, and 18D are closed to dissipate the charge on the condensers of resistor-capacitor combinations 21, 22, 23 and 24.

A simplified diagram of servo-multiplier 106 and 118 and servo-divider 115 is shown in FIGURE 7. These units comprise three input connections 131, 132, and 133. Input connection 131 is connected in series with a voltage amplifier 134 and error potentiometer 135. Amplifier output is supplied to motor 136 which controls the setting of potentiometer 135 and an output potentiometer 137. When used as a multiplier input 132 is connected to a suitable independent A.C. source, and inputs 131 and 133 are connected to receive the multiplier signal and the multiplicand signal respectively. The output from potentiometer 137 to connection 138 is a signal equal to their product. When used as a divider the dividend signal is connected to 131 and the divisor signal is connected to 132, and the independent A.C. source is connected at 133.

It will be seen that apparatus has been provided whereby equation 7*b* is solved electrically to produce a voltage signal proportional to the braking force required to slow the car to the proper speed when it leaves the hump, so that it will reach its destination and reach it with a desired final velocity.

As has been said only one test braking force need be applied. See Equations 4*b* and 5*d*. However the use of two is preferred, because in this way a braking force is applied to the car at all times during its descent along the hump, whereby the full length of the hump is used to control car speed.

A second variation is also possible. Having solved for the desired exit velocity V_e, a standard main braking force could be employed and its duration determined by the radar speed indicator, for example, by using a differential relay such as 111 connected to vent the retarder acuating motors when the car speed was reduced to the desired V_e. This would result in uneven wear of the braking bars and also the heavy braking force might cause light cars to be derailed. However, this circuit is attractive because of its simplicity and further, because it eliminates the necessity for using a test braking force.

The circuit whereby this embodiment may be used is diagramed in FIG. 9. It includes the servo-translator 109 with its input connected to the outputs of servo-multiplier 106 and of potentiometer 108 connected in series as in the preferred embodiment. The multiplier 106 has its input 105 connected to the secondary winding of transformer 103 which is energized to produce a signal proportional to $2D_{ef}$. The input connection 107 is connected to the secondary winding of transformers 104, 47, 48 and 51 arranged in series to produce a signal

$$\frac{V_c^2-V_d^2}{2S}+0.322k-0.322K$$

The term $.322K$ is fed in through transformer 104 as a voltage signal and it is proportional to the change in poential energy which the car undergoes after leaving the retarder. The balance of the signal fed to the input connection 107 appears as a discrete signal comprising the algebraic sum of the potentials in secondary windings of transformers 47, 48 and 51 and is a signal proportional to the rolling characteristic of the car. The output from servo-translator 109 is connected to one winding of the differential relay 111. The other winding of relay 111 is connected to the radar speedmeter 112. The output from servo-translator 109 is

$$Ve=\sqrt{V_t^2+2D_{ef}\left[\frac{V_c^2-V_d^2}{2S}+0.322k-0.322K\right]}$$

This formula is derived by substituting in Equation 1*a* the value of F_r/m derived from Equation 5*d*. So long as the signal V_e is greater than the signal from the speedmeter 112, contact 141 is open, whereby the solenoid of valve 142 is de-energized which admits pressure fluid to the actuating motors of the retarder to establish therein a predetermined constant pressure. When the signal V_e is equal to or less than the signal from the speedmeter 112, the solenoid valve 142 is energized, thereby causing the retarder motor to be vented.

While a preferred embodiment and one modification of the invention have been described in detail, it will be understood that there are various equivalent arrangements which will occur to those who are skilled in the art. The invention is not limited to the use of a particular type of computer or to a particular type of means for determining the car's velocity. The underlying principle is the fact that it is possible to determine the appropriate car speed at the exit of the retarder in order to produce the optimum coupling speed and also to determine the optimum braking force to be applied in order to produce this exit speed by measuring the velocity changes which occur during descent by the car along an initial portion of the hump and by measuring the car speed at the entrance to the retarder.

What is claimed is:

1. In combination, a classification yard including a retarder having an exit leading into a track section of known track characteristics, said track section extending from the exit of said retarder to a destination in the yard at which a car is to couple at a desired velocity, means for generating control energy corresponding to the rolling characteristic of said car, means for generating control energy corresponding to the track characteristics of the track section to be transversed by said car, computing means for combining all of said control energies to produce a resultant control energy corresponding to the speed at which the car must leave the retarder to arrive at the destination at the desired velocity, said computing means including means representative of said desired coupling velocity and cooperating with said control energies to produce said resultant control energy, and means for generating a control energy representative of the braking characteristic on said car by said retarder, and means jointly responsive to said resultant control energy and to the braking characteristic control energy for controlling the retarder.

2. In combination with a classification yard having a hump, a plurality of classification tracks arranged in parallel relation with each other and each being selectively connectable to the lower end of the hump, and a car retarder disposed along a portion of the length of said hump, a car-controlling system for regulating the velocity of a car as it reaches its destination on a selected classifica-

tion track, said system comprising means for generating a signal proportional to the combined retarding forces acting on said car as it rolls freely down the hump, means for generating a signal proportional to the length of track between the lower end of the retarder and said destination, means for producing a signal proportional to the change in elevation which a car experiences in moving from the lower end of the retarder to said destination, means for producing a signal which is a function of the desired velocity of the car as it reaches said destination, computing means for combining all of said signals to produce a resultant signal corresponding to the velocity the car must have in leaving the retarder to achieve said desired velocity, means for producing a signal proportional to the braking characteristic of said retarder for the car, actuating means for energizing the retarder, and means for regulating said retarder actuating means in accordance with the resultant signal and the braking characteristic signal.

3. In combination with a classification yard having a hump, a plurality of classification tracks arranged in parallel relation with each other and each being selectively connectable to the lower end of the hump, and a main car retarder disposed along a portion of the length of said hump, a car-controlling system for regulating the velocity of a car as it reaches its destination on a selected classification track, said system comprising two sections of test track located on the hump above the entrance to the main retarder, a test retarder associated with each test section, means for actuating each test retarder a known but different amount, means operative as a car traverses said test sections for producing a first signal proportional to the combined retarding forces, other than braking forces, acting on the car, and a second signal proportional to the braking characteristic of said test retarders for the car, means for generating a third signal proportional to the length of track between the exit of the main retarder and the car's destination, means for generating a fourth signal proportional to the average gradient of the track between the retarder exit and said destination, means for producing a fifth signal which is a function of the desired velocity of the car as it reaches said destination, means for producing a sixth signal corresponding to the sum of the products of said first and third signals and said third and fourth signals, means for producing a first resultant signal corresponding to the algebraic sum of said fifth and sixth signals, means for producing a seventh signal which is a function of the velocity at the entrance of the main retarder, means for producing an eighth signal proportional to the gradient of the main retarder, computing means for algebraically adding said first, first resultant, seventh and eighth signals and for dividing the sum by said second signal to produce a final resultant signal corresponding to the quotient, and control means for actuating said main retarder in accordance with the final resultant signal.

4. In combination, a hump-type classification yard having a section of track located forwardly of the exit of a car retarder and a track section extending rearwardly from the exit of said retarder to a destination in said yard at which a car is to couple at a desired velocity, means for measuring the resultant acceleration of the car as it rolls freely over said forward section of track and for producing control energy corresponding to the difference between the measured acceleration and the acceleration due to the velocity-changing effect of said forward section of track, means for generating control energy corresponding to the range of the rearward track section to be traversed by the car, computing means combining all of said control energies to produce a resultant control energy corresponding to the speed at which the car must leave the retarder to arrive at the destination at the desired velocity, means for applying the retarder to the car as it rolls over said forward section of track for measuring the velocity-changing effect of the retarder for the particular car and producing a braking control energy corresponding thereto, and means for combining said resultant control energy and said braking control energy for controlling the retarder.

5. In combination with a classification yard having a hump, a plurality of classification tracks arranged in parallel relation with each other and each being selectively connectable to the lower end of the hump, and a car retarder means disposed along a portion of the length of said hump, a car-controlling system for regulating the velocity of a car as it reaches its destination on a selected classification track, said system comprising means for generating a signal proportional to the combined retarding forces acting on said car as it rolls down the hump, means for automatically generating a signal proportional to the length of track between the exit end of said retarder means and said destination, means for producing a signal proportional to the change in elevation which a car experiences in moving from the exit end of said retarder means to said destination, means for providing a signal which is a function of the desired velocity of the car at its destination, computing means for combining all of said signals to produce a resultant signal which is a function of the velocity the car must have leaving said retarder means to achieve said desired velocity, said car retarder means including a test retarder section for generating a signal proportional to the braking characteristic of said car, means for producing a signal proportional to the velocity of the car at the entrance to said retarder means; means for combining said resultant signal, said braking characteristic signal, and said entrance velocity signal and operable in accordance with the combined signal for actuating said retarder means so that the velocity of the car traversing that retarder means is varied at a constant rate from the velocity represented by said entrance velocity signal to the exit velocity represented by said resultant signal.

6. Apparatus for controlling the speed of a cut of cars leaving a car retarder located at the entrance end of a stretch of track of known characteristics in order to arrive at the end of said stretch at a predetermined terminal velocity, comprising, in combination, means for measuring the rolling characteristic of said cut, means for automatically measuring the length of said stretch, means for generating a signal in accordance with said rolling characteristic and said length proportional to the velocity at which said cut should leave said retarder to arrive at the end of said stretch at said predetermined velocity, means for measuring the speed of said cut in said retarder and producing a signal in accordance therewith, means for measuring the braking characterstic on said cut by said retarder, and means jointly controlled by the difference between said measured speed signal and said desired speed signal and by said measured braking characteristic for controlling said retarder at a constant rate to reduce the leaving speed of said cut from said retarder to said desired value using substantially the entire length of said retarder.

7. Speed control means, comprising, in combination, a car retarder located intermediate a first and a second stretch of track, means associated with said retarder for measuring the rolling characteristics of each car, means automatically adjustable in accordance with the varying length of said second stretch of track, means automatically adjustable in accordance with the varying average grade of said second stretch of track, means for measuring the speed of each car in said retarder, means associated with said retarder for measuring the braking characteristic on each car by said retarder and means jointly controlled by both said measuring means and by both said adjustable means for adjusting the braking force exerted on each car by said retarder to a constant force maintained through substantially the entire length of said retarder so that each car approaches the exit end of said second stretch at a desired speed.

8. In a car retarder control system, a controllable car retarder in a stretch of railway track having an operating

mechanism operable to position the car retarder for selected degrees of retardation, a test area at the entrance end of said car retarder for providing a fixed degree of retardation, speed responsive means for detecting the effect of the fixed retardation in said test area upon the speed of a car, and circuit means for selecting the degree of retardation for said controllable car retarder in accordance with the effect of said fixed retardation in said test area upon the speed of the car as detected by said speed responsive means.

9. In a car retarder control system, the combination of, a car retarder means having a section with a fixed degree of retardation and another section with a controllable degree of retardation, speed responsive means responsive to a car moving through said fixed retardation section for detecting the effect of the retardation upon the speed of said car, and control means controlled by said speed responsive means for controlling the degree of retardation in said controllable section in accordance with the effect of said fixed retardation upon the speed of said car.

10. In combination with a classification yard having a hump, a plurality of classification tracks arranged in parallel relation with each other and each being selectively connectable to the lower end of the hump, and a car retarder disposed along a portion of the length of said hump, a car-controlling system for regulating the velocity of a car as it reaches its destination on a selected classification track, said system comprising means for generating a first signal proportional to the combined retarding forces acting on said car as it rolls down the hump, means for automatically generating a second signal proportional to the length of track between the retarder exit and said destination, means for automatically producing a third signal proportional to the average gradient which a car encounters in moving from the retarder exit to said destination, means for providing a fourth signal which is a function of the desired velocity of the car at its destination, commuting means for multiplying the first and second signals and algebraically adding the product with the third and fourth signals to produce a first resultant signal corresponding to the sum, means for producing a second resultant signal proportional to the square root of said first resultant signal, means for generating a fifth signal proportional to the braking characteristic on said car by said retarder, and control means responsive to said first and second resultant signals and to said fifth signal for controlling the retarder to reduce the velocity of said car at a constant rate throughout substantially the entire length of said retarder to obtain said desired velocity at the destination of said car.

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