

Nov. 3, 1970

H. BUHLER ET AL
 DEVICE FOR CONTROLLING THE PNEUMATIC BRAKING
 FORCE OF A RAILWAY TRAIN

3,537,758

Filed May 31, 1968

4 Sheets-Sheet 1

FIG. 1

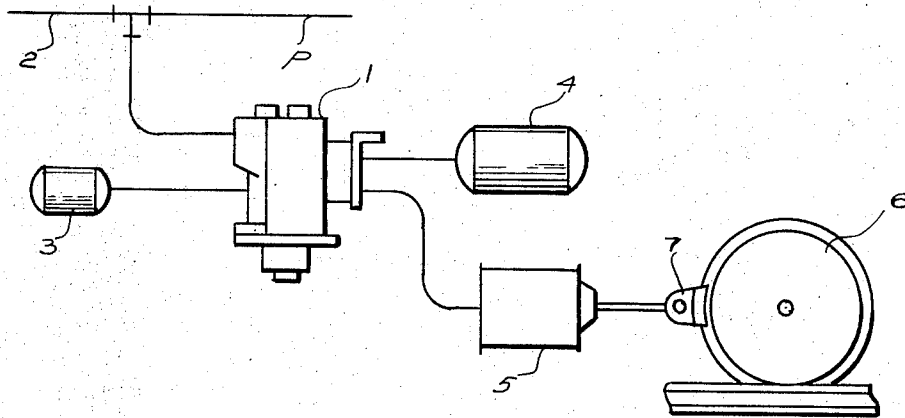


FIG. 2

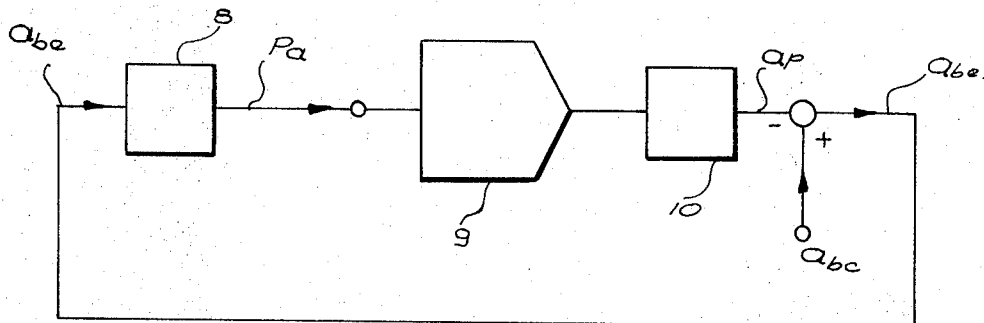
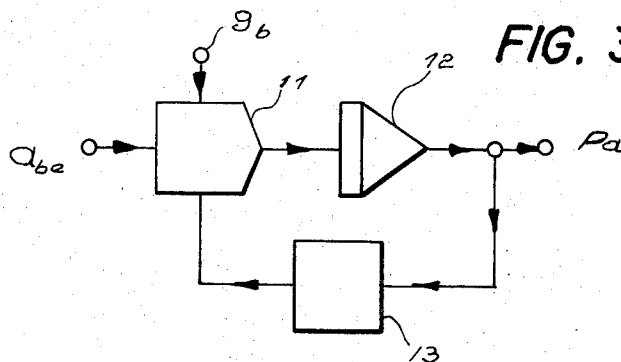


FIG. 3



INVENTORS:

HANSRUDI BUHLER
 HANS PETER WENK

BY

Breitenfeld & Gernie
 ATTORNEYS

Nov. 3, 1970

H. BUHLER ET AL
 DEVICE FOR CONTROLLING THE PNEUMATIC BRAKING
 FORCE OF A RAILWAY TRAIN

3,537,758

Filed May 31, 1968

4 Sheets-Sheet 2

FIG. 4

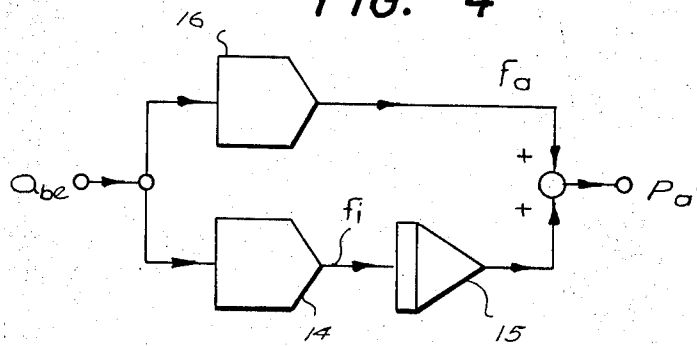


FIG. 5a

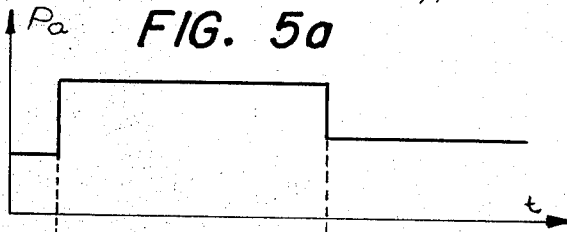


FIG. 5b

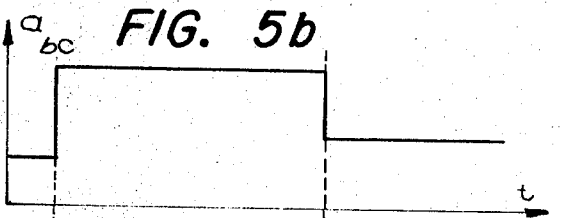


FIG. 5c

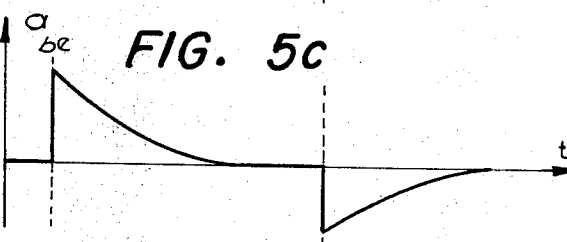


FIG. 5d

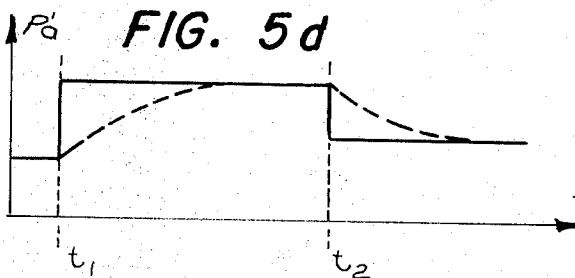


FIG. 6a

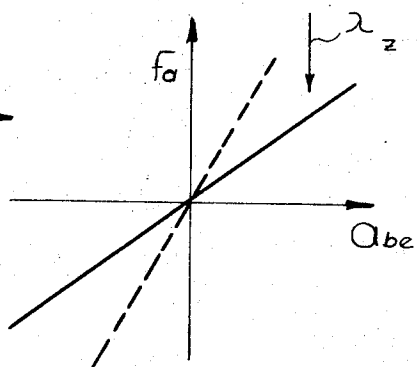
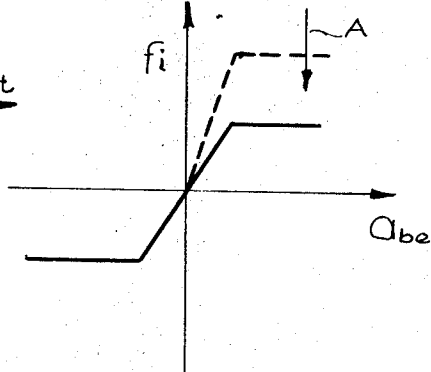


FIG. 6b



INVENTORS:
 HANSRUDI BUHLER
 HANS PETER WENK
 BY
 Breitenfeld & Lennie
 ATTORNEYS

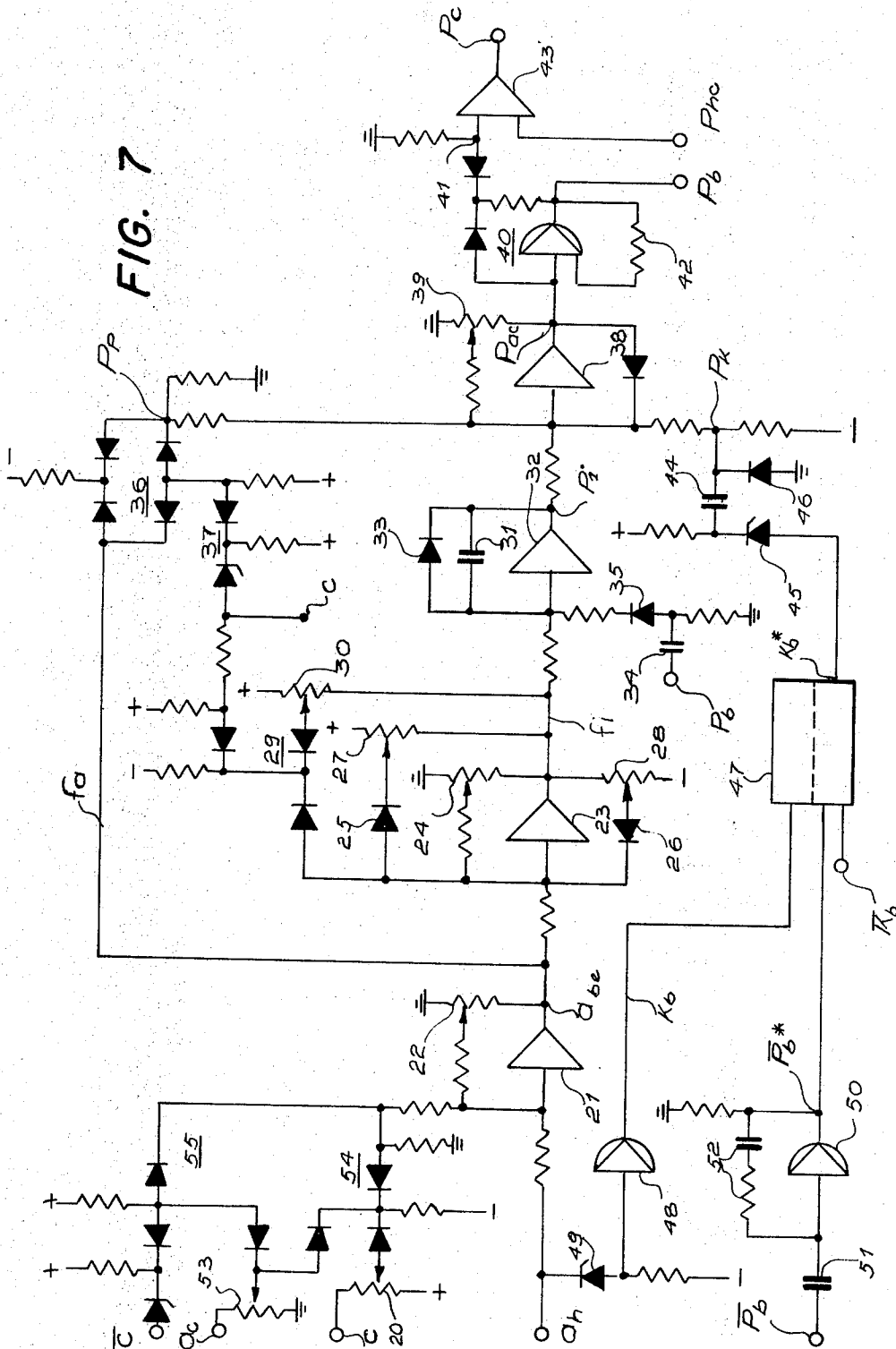
Nov. 3, 1970

H. BUHLER ET AL
 DEVICE FOR CONTROLLING THE PNEUMATIC BRAKING
 FORCE OF A RAILWAY TRAIN

3,537,758

Filed May 31, 1968

4 Sheets-Sheet 3



INVENTORS:
 HANSRUDI BUHLER
 HANS PETER WENK
 BY
Breitenfeld & Lennie
 ATTORNEYS

Nov. 3, 1970

H. BUHLER ET AL
 DEVICE FOR CONTROLLING THE PNEUMATIC BRAKING
 FORCE OF A RAILWAY TRAIN

3,537,758

Filed May 31, 1968

4 Sheets-Sheet 4

FIG. 8

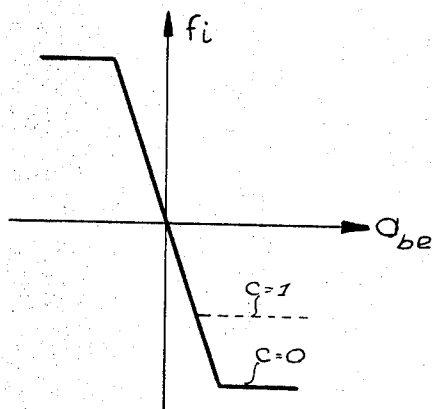


FIG. 9

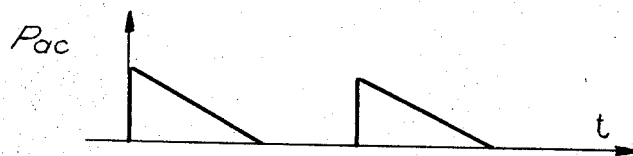
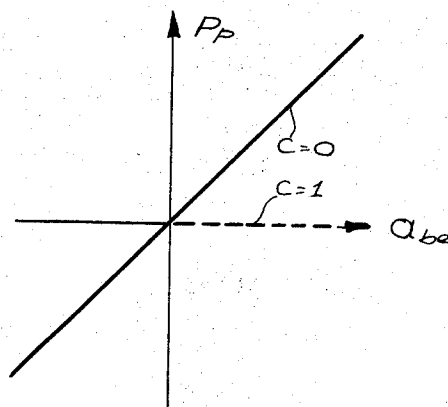


FIG. 10a

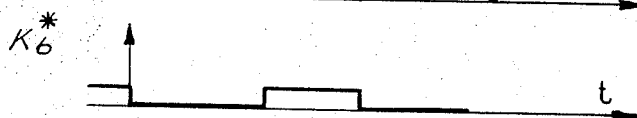


FIG. 10b



FIG. 10c

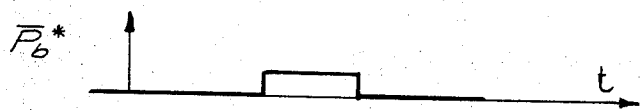


FIG. 10d

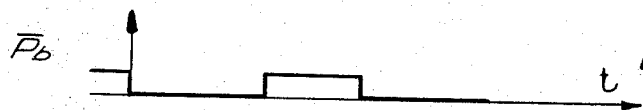


FIG. 10e

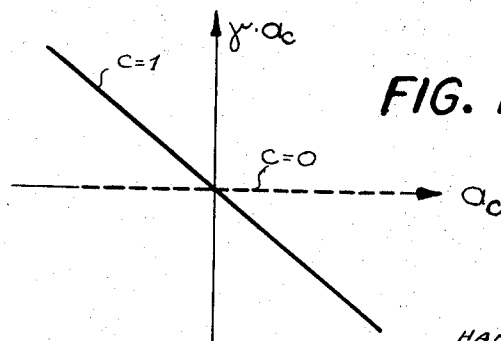


FIG. 11

INVENTORS:
 HANSRUDI BUHLER
 HANS PETER WENK
 BY
Brantenfeld & Leoni
 ATTORNEYS

1

3,537,758

DEVICE FOR CONTROLLING THE PNEUMATIC BRAKING FORCE OF A RAILWAY TRAIN

Hansrudi Buhler, Tessin, and Hans P. Wenk, Zurich, Switzerland, assignors to Oerlikon Engineering Company, a corporation of Switzerland

Filed May 31, 1968, Ser. No. 733,690

Claims priority, application Switzerland, June 1, 1967, 7,778/67

Int. Cl. B60t 13/68

U.S. Cl. 303—20

17 Claims

ABSTRACT OF THE DISCLOSURE

Railway train has braking devices each of which is connected to a main air pressure line, and has a brake cylinder. Pressure within cylinder controlled by pressure in main line. Air pressure in main line controlled by first electric signal which is a function of a second electric signal corresponding to difference between desired deceleration and instantaneous actual deceleration of train. Voltage signal produced which is dependent upon second electric signal, and fed into an integrator whose output controls air pressure in main line. Time constant of integrator is such that change of air pressure in main line with time is about equal to or less than change of air pressure in brake cylinder with time.

The present invention relates to a device for controlling the pneumatic braking force of a railway train. In such trains the locomotive and/or the cars are each provided with a brake device, connected to a main compressed-air conduit, having one or more brake cylinders, the air pressure in each brake cylinder being controlled as a function of the air pressure in the main line. The locomotive, or a control car, has a brake regulator which produces a variable electric control signal for adjusting the air pressure in the main line as a function of another electric signal corresponding to the difference between the desired deceleration and the actual deceleration of the railway train.

It is already known to provide on locomotives of railway trains an automatic travel control, for instance, a speed control, a tractive-force control, or an acceleration control, which also provides a control of the pneumatic braking power. A compressed-air brake in this case becomes active only when the electric brake of the locomotive is no longer sufficient to effect a prescribed deceleration of the train.

Arrangements and methods are known for controlling pneumatic braking force using proportional controllers or proportional-plus-rate action controllers which for reasons of stability have relatively small amplifications. This is disadvantageous because a large deviation of the control is required to activate the compressed air brake, and hence a large difference in speed is necessary, which makes it difficult to maintain a predetermined speed.

On the other hand, with a large amplification of the brake-control circuit, particularly in the case of pure proportional-controllers, strong overshooting takes place which accordingly results in alternate application and release of the brakes and thus in undesired jolts and bumps of the train. In the case of a proportional-plus-rate action controller, overshooting takes place upon an increase in deceleration and an increase in the brake ratio of the train, which is also disadvantageous.

The object of the present invention is to avoid these disadvantages and to create a brake controller which so influences the build-up process upon braking that the necessary brake-cylinder pressure is reached in a short time, without overshooting, and without being dependent

2

on the predetermined deceleration and the brake ratio.

In accordance with the invention, the device is characterized by the fact that in the brake controller a voltage signal dependent on the difference in the actual and desired decelerations, and having at least one adjustable limit value, is fed to an integrator whose output voltage serves to form the electric control variable for adjusting the air pressure. The time constant of the integrator is such that the change with time of the air pressure in the main line is at least approximately equal to or smaller than the maximum change in the air pressure in each brake cylinder.

The invention will be described below by way of example with reference to the drawings, in which:

FIG. 1 shows schematically a known pneumatic brake system of a railway car;

FIG. 2 shows schematically a brake control circuit with a brake controller;

FIG. 3 shows schematically an embodiment of a brake controller in accordance with the invention;

FIG. 4 shows schematically another embodiment of the brake controller;

FIGS. 5a to 5d show the variations with time of the input and output variables of the brake controller of FIG. 4 upon changes in the desired deceleration;

FIGS. 6a and 6b are characteristic curves of circuit parts of the brake controller of FIG. 4;

FIG. 7 is a schematic circuit diagram of another embodiment of the brake controller in accordance with the invention; and

FIGS. 8, 9, 10a to 10e, and 11 show the variations of variables of the circuit arrangement of FIG. 7 as a function of the difference between the actual deceleration and the desired deceleration.

FIG. 1 shows a compressed air brake system, present on each car of a railway train and which is representative of prior art systems. The system shown includes a control valve 1 connected to a main compressed air line 2 extending through the train. In the main line 2 is air under a pressure p which in normal condition, i.e. with the brakes released, is for instance 5 kilograms per square centimeter (kg./cm.^2). Normally, a control tank 3 and an auxiliary air tank 4 are connected, via the control valve 1, with the main line 2 so that the pressure p also prevails in these two tanks. A brake cylinder 5, also connected to the control valve 1, normally communicates with the atmosphere so that brake blocks 7, which can be applied against the wheels 6, are released by the pressure in the brake cylinder 5.

If the pressure p in the main line 2 is reduced, the control valve 1 closes the control tank 3 so that the original pressure, of for instance, 5 kg./cm.^2 is maintained in the tank 5. By means of a regulating valve (not shown) built into the control valve 1, the auxiliary air tank 4 is connected, upon a decrease in pressure p in the main line 2, to the brake cylinder 5, the latter at the same time being closed to the atmosphere. In this way, braking pressure is built up in the brake cylinder 5, the pressure depending, in accordance with the control characteristics of the control valve 1, on the specific decrease in pressure p in the main line 2. If the pressure p in the main line 2 is returned to a higher value, the control valve 1 opens the brake cylinder 5 to the atmosphere, whereupon a condition of equilibrium, with the new pressure in the main line 2 in accordance with the control characteristic, is reached.

Particularly in the case of speed-controlled railway trains, the compressed-air braking system shown in FIG. 1 is combined with a brake regulator which is arranged on the locomotive, or a control car, and supplies the pressure p in the main line 2 to form a brake control circuit.

3

Such a brake control circuit is shown schematically in greatly simplified form in FIG. 2 and constitutes part of the prior art.

A brake regulator 8 produces a decrease in pressure p_a which acts on the braking devices 9. The braking devices 9 in turn enable a deceleration a_p to be measured on the train 10. The deceleration a_p is therefore the instantaneous deceleration value of the train which is compared with a predetermined desired deceleration value a_{be} . The instantaneous deceleration value a_p contains a proportion of deceleration due to the electric brake of the locomotive, as well as a proportion of deceleration due to resistance to forward motion. For the sake of simplicity, these two proportions are combined, as disturbance variables in the schematic showing of FIG. 2, with the instantaneous deceleration value effected by the pneumatic braking force. The deceleration difference a_{be} is fed to the control 8 as an actuating variable to close the control circuit. In FIG. 2 devices for transforming pressure, speed, and deceleration into corresponding electrical variables, and vice versa, such as are known in velocity controls and brake controls on locomotives, are not shown.

FIG. 3 shows diagrammatically a first embodiment according to this invention of the brake controller 8 of FIG. 2, in which the detrimental phenomena mentioned do not occur. Thus, the new and improved brake controller 8 of FIG. 3 includes a switch member 11 which is controlled by the signal of the deceleration difference a_{be} , this signal being an analog signal. In one position of the switching member 11, a constant voltage g_b is applied to the input of an integrator 12. At the integrator output a voltage p_a is taken off which in accordance with FIG. 2 effects a proportional decrease in pressure in the main conduit of the brake system. In the other position of the switch member 11, the constant voltage g_b is disconnected from the input of the integrator 12. However, the output voltage p_a is applied via an ohmic feedback member 13 to the input of the integrator 12.

The two conditions of the switch member 11 correspond to the functions of the brake controller for "braking" and for "release." When braking, the pressure of the brake cylinder must rise as long as the deceleration difference a_{be} is positive and must decrease, for release, when the difference in deceleration a_{be} is negative. Since in the "brake" position of the control valve 1 (FIG. 1) the brake cylinder pressure rises practically linearly with time, and at steady state there is a linear relationship between the decrease in pressure in the main conduit 2 and the brake cylinder pressure, when braking the decrease in the pressure and thus the voltage p_a should rise linearly with time. This result is obtained in the arrangement of FIG. 3 by the integrator 12 to the input of which the constant voltage g_b is applied by the switch member in response to a positive deceleration difference a_{be} . The time constant of the integrator 12 and the value of the constant voltage g_b are so selected that the natural rate of pressure increase within the brake cylinder corresponds to the decrease in pressure in the main line, i.e., to the corresponding output voltage p_a of the integrator.

When the control valve 1 (FIG. 1) is moved to its "release" position, the brake cylinder pressure fades away practically in accordance with an exponential function. If accordingly the reduction in pressure in the main line, or the output voltage p_a of the integrator 12 (FIG. 3) is correspondingly changed exponentially, then upon release also the brake cylinder pressure can, with its natural rate of deceleration, correspond to the negative decrease in pressure, i.e., the increase in pressure. In the arrangement of FIG. 3, this manner of operation is obtained by the feedback member 13 which, in response to a negative deceleration difference a_{be} , is shunted by the switch member 11 across the integrator 12. The value of the feedback member 13 is so selected that the exponential decay of the output voltage p_a corresponds to the natural decay rate of the brake cylinder pressure.

4

The brake controller of FIG. 3 will thus build up the voltage p_a , which produces the decrease in pressure, until the deceleration difference a_{be} is equal to zero. Since the brake cylinder pressure follows the decrease in pressure in the main line, at any moment the brake cylinder pressure necessary to maintain the predetermined deceleration a_{be} (FIG. 2) is present. If the deceleration difference a_{be} is equal to zero, then the switch member 11 (FIG. 3) oscillates continuously between the two switch conditions so that the voltage p_a , which effects the reduction in pressure, remains at least approximately constant at the output of the integrator 12. Therefore, the brake controller described appropriately influences the pressure build up and steady state braking conditions regardless of the desired value of deceleration and the brake ratio of the train, so that the brake cylinder pressure is reached in the shortest time and without overshooting, whereby the control operates with optimum speed. Specifically, the undesired jolts and bumps effected by overshooting the drop in pressure or the brake cylinder pressure are avoided in the case of the brake controller described without impairing the effectiveness of the brakes.

The brake controller described is suitable in particular for short trains having only a few cars or for trains which are equipped with an electro-pneumatic brake. In the case of longer trains having brakes controlled by compressed air, the influence of the length of the main compressed air line which extends along the entire train is present. Consequently, increase in the pressure of the brake cylinder is substantially delayed with an increase in the length of the train as compared with the reaction of the control valve itself. This delay in time of the main-line and brake-cylinder pressure has an unfavorable effect on the stability of the brake control circuit.

FIG. 4 shows schematically another embodiment of the brake controller by means of which the above-mentioned disadvantage in the case of long trains is avoided. In the arrangement of FIG. 4, the brake controller, to the input of which the deceleration difference signal a_{be} is fed in accordance with FIG. 2, has two transmission channels which are brought together again at the output of the brake controller. In the lower channel the deceleration difference a_{be} arrives at the input of an amplifier 14 which amplifies the difference in deceleration and limits both the positive and negative voltage values to an adjustable limit value. The output signal f_1 of the amplifier 14 is a positive or negative direct voltage depending upon the sign of the difference in deceleration a_{be} , and it is fed to an integrator 15 whose output signal forms a part of the voltage p_a which serves to produce a proportional main-line pressure.

In the upper channel the deceleration difference a_{be} is applied to the input of a transmission member 16 which has a non-linear or at least approximately linear characteristic, and may for instance be an ohmic resistance. The output signal f_a of the transmission member 16 is added, with proper sign, to the output signal of the integrator 15 and forms, with the latter, voltage p_a' which corresponds to the voltage p_a of FIG. 3.

The construction of the brake controller described and its manner of operation are based on the following consideration: In order that the transfer process take place as rapidly as possible upon braking but nevertheless proceed without undesired jolts and bumps, it is advantageous when a change of the desired deceleration a_{be} (FIG. 2) occurs that the decrease in pressure at the start of the main-line, or the corresponding output voltage p_a of the brake controller, assume as rapidly as possible the value necessary to maintain the desired delay. In FIG. 5a the desired variation with time of the pressure reduction, or the voltage p_a' , is shown when the desired deceleration a_{be} in accordance with FIG. 5b is suddenly increased at the time t_1 and suddenly reduced at a later time t_2 . In FIG. 5c, the corresponding path of the deceleration difference a_{be} is shown. From FIGS. 5c and 5d it can be seen that the voltage p_a' corresponding to the

desired pressure drop must be composed of two portions, namely, a portion which depends directly upon the deceleration difference a_{be} , and a portion, shown in broken lines in FIG. 5d, in connection with which a function of the deceleration difference a_{be} is integrated, since the $a_{be} \leq 0$ the pressure decrease must assume a specific value. A good approximation of these signal portions is produced by the simple circuit arrangement of FIG. 4.

In FIGS. 6a and 6b, the characteristics of the transmission member 16 and of the limiting amplifier 14 of FIG. 4 are shown. As a result of the amplification and the limiting character of the amplifier 14 the voltage f_1 , shown in FIG. 6b with a steep slope, assumes the maximum or minimum value upon braking or release respectively. At the output of the integrator 15 (FIG. 4) there accordingly occurs, beginning at time t_1 , a linearly increasing voltage and, beginning at time t_2 , a linearly decreasing voltage which proceeds only quasi-exponentially when the deceleration difference a_{be} tends towards zero. Due to the substantially linear characteristic of the transmission member 16 (FIG. 6a) and the approximately linear path of the deceleration difference a_{be} beginning with the times t_1 and t_2 , the output voltage f_a also changes correspondingly linearly. The sum of the output voltage f_a of the amplifier 16 and the output voltage p_a of the integrator 15 accordingly has the desired path shown in FIG. 5d when the attenuation factor of the transmission member 16 and the time constant of the integrator 15 are properly selected. In this connection, the lower channel shown in FIG. 4 having the limiting amplifier 14 and the integrator 15 corresponds to the embodiment shown in FIG. 3 when braking, i.e., when the difference in deceleration a_{be} is positive.

It is advantageous to select the slope of the straight line shown in FIG. 6a as a function of the brake ratio λ_z of the train, and, as indicated in FIG. 6a, the slope should be smaller than the greatest brake ratio λ_z of the train. The limiting value of the positive branch of the characteristic of the amplifier 14 shown in FIG. 6b, which corresponds to the braking, is advantageously made lower than the highest the number of axles A of the train, as indicated in FIG. 6b. The negative branch, which corresponds to release of the brakes, can on the other hand have a constant limiting value even with larger numbers of axles, for instance 60 axles.

The brake controller of FIG. 4, which has been described, makes it possible to obtain optimum degrees of pressure variation in the main line and in the brake cylinders upon rapid changes in deceleration even in the case of long trains. In order, in actual practice, to minimize the expense in connection with the arrangement of adjustment members (not shown in FIG. 4) for the characteristics of the transmission member 16 and of the amplifier 14, it may be advisable to adjust the characteristics only for, for instance, two values of the brake ratio λ_z and the number of axles A, and to tolerate a slight deviation from optimum control behavior for other values.

The brake controllers described in connection with FIGS. 3 and 4 do not require great expenditures for circuit elements. Furthermore the required variables for controlling the brake controller, particularly the difference in deceleration a_{be} , are already present in the apparatus provided on locomotives for controlling speed, i.e., the automatic travel control.

Referring to FIG. 7, there will be described below a circuit arrangement for a brake controller of the type shown schematically in FIG. 4. In addition, the circuit of FIG. 7 has further features which permit two operating conditions, namely, deceleration at a lower speed, and travel at constant speed on a grade. The circuit elements or groups of circuit elements used in the circuit arrangement of FIG. 7 are arranged in customary manner so that a detailed description thereof can be dispensed with.

In accordance with FIG. 7, a signal a_k is applied to the input of an amplifier 21 the gain of which is adjustable

by means of a potentiometer 22. The signal a_k is the correction voltage for the desired acceleration of the locomotive, i.e., an analog voltage corresponding to the derivative with respect to time of the speed, dv/dt , upon response to the brake-current limiting of the locomotive.

The difference in deceleration to be applied by the pneumatic brake or the corresponding voltage a_{be} which is at the input of the brake controller according to FIG. 4 is proportional to said analog voltage. The difference in deceleration a_{be} is therefore the deceleration value which cannot be supplied by the electric brake of the locomotive. The analog voltage a_k is taken from the speed controller present on the locomotive. Since, when braking, dv/dt and thus a_k are negative, while the difference in deceleration a_{be} is to be positive when braking, a change in sign is effected by the amplifier 21. Accordingly, the desired difference in deceleration c_{be} is present at the output of the amplifier 21 as the input variable of the brake controller.

From the deceleration difference a_{be} there is derived by the circuit arrangement of FIG. 7, and in accordance with the basic diagram of FIG. 4, an integral portion f_i and p_i as well as a proportional portion f_a and p_p , the two portions p_i and p_p being summed to obtain the desired voltage p_{ac} of the pressure reduction at the main line of the brake system, corresponding to the voltage p_a of FIG. 4.

For this purpose the deceleration difference a_{be} is applied to the input of another amplifier 23 whose gain is also adjustable by means of a potentiometer 24. Furthermore the positive and the negative voltage values of the amplified deceleration difference a_{be} are limited by a limiter circuit which contains diodes 25 and 26 whose bias is adjustable by the potentiometers 27 and 28, respectively, in order to determine the limiting level. Connected in parallel with the diode 25 is a further arrangement 29 of several diodes which can be brought by a logic signal c into conductive condition and thereby effect a decrease in the limiting level of the diode 25 to a lower level when the signal c has the value 1 as shown in FIG. 8. The value of the lowered level can in this connection be adjusted by means of a potentiometer 20. The interpretation and derivation of the logic signal c will be explained later.

At the output of the amplifier 23, is the signal f_1 which corresponds to the similarly designated signal f_1 of FIG. 4 and is subsequently also fed to an integrator. The integrator has, in known manner, an amplifier 32 provided with a feed-back loop including a condenser 31. Another feed-back loop including diode 33 permits only a positive output voltage p_i of the integrator such as intended for the braking process. By a logic signal p_b , whose derivation will be explained later and which is fed to the input of the integrator 31, 32 via a capacitor 34 and a diode 35, the integral portion, i.e., the output voltage p_i of the integrator, can be set to zero.

The proportional portion f_a is equal to the deceleration difference a_{be} and is fed to a diode arrangement 36 which is so constructed that the output voltage p_p has a linear relationship to the deceleration difference a_{be} , i.e., the diode arrangement is normally conductive. Another diode arrangement 37, controlled by the logic signal c , acts on a part of the diode arrangement 36 making it possible to block the positive branch of the proportional portion f_a so that for the value 1 of the logic signal c the voltage p_p has only a negative branch, as is shown in FIG. 9.

The proportional portion p_p and the integral portion p_i are combined at the input of an amplifier 38 whose gain is adjustable by means of a potentiometer 39. The output signal p_{ac} of the amplifier 38 accordingly represents the desired voltage for production of the decrease in pressure in the main line.

In order to prevent, in the main line of the compressed air brakes, a very slight decrease in pressure less than a minimum value required for the proper operation of the control valves arranged on the cars a measurement trigger 40 is provided behind the amplifier 38. The trigger 40

forwards the voltage p_{ac} to the point 41 of its output only when the voltage p_{ac} has reached a given minimum value which corresponds for instance to a pressure drop of 0.4 kg./cm.² in the main line. However, the flipping back of the measurement trigger 40 should take place at a smaller value, i.e., the measurement trigger 40 should have a relatively large hysteresis which is obtained by a feedback resistor 42. When the measurement trigger responds, a logic signal p_b appears at its output, this signal being fed via a connecting line (not shown) to the capacitor 34 and thus, as a dynamic signal, to the input of the integrator 31, 32.

The desired voltage p_{ac} of the pressure drop which is passed by the measurement trigger is finally deducted in a differential amplifier 43 from the reference voltage p_{hc} which corresponds to the normal pressure in the main line and therefore for instance to a pressure of 5 kg./cm.². There thus appears at the output of the amplifier 43 a desired voltage p_c for the actual required pressure in the main line. The voltage p_c is fed as a control voltage to an electro-pneumatic pressure amplifier, not shown in the drawing.

A positive decreasing voltage signal portion p_k is applied to the input of the amplifier 38 at which the proportional portion p_p and the integral portion p_i are brought together. To produce the portion p_k a capacitor 44 is employed, the charge of which is reversed with the time constant of the circuit by a logic signal k_b^* which is fed via a diode 45. A diode 46 prevents the occurrence of a negative voltage portion.

The logic signal k_b^* fed to the capacitor 44 is produced by a bistable member 47 when the latter effects the transition 1→0. For bringing about this transition a logic signal k_b is fed to an input of the member 47. The signal k_b is produced by a measurement trigger 48. The correction voltage a_k for the desired acceleration of the locomotive is present, via a diode 49, at the input of the measurement trigger 48 in such a manner that the measurement trigger 48 responds to a very low negative value of a_k and therefore to a small correction of the desired deceleration. The measurement trigger 48 furthermore has the smallest possible hysteresis.

The other two inputs of the member 47 are connected as "OR" inputs. The logic signal $\bar{p}_b^*$ and $\bar{k}_b$ applied to them shift the member 47 to 1 and therefore effect the transition 0→1 of the bistable member. The signal $\bar{k}_b$ is the inverse of signal k_b which is the output signal of the measurement trigger 48. The signal $\bar{p}_b^*$ is the dynamic signal of $\bar{p}_b$, which is the inverse of the logic signal p_b , appearing at the output of the measurement trigger 40, and has a predetermined minimum duration. For the production thereof there is provided another measurement trigger 50 to whose input the signal $\bar{p}_b$ is applied via a capacitor 51 and which has a feedback loop including a resistor-capacitor arrangement 52. The processes at the member 47 will be explained later on with reference to FIGS. 10a to 10e.

The circuit arrangement of FIG. 7 finally has a circuit part, for reducing the input a_k of the amplifier 21 for specific operating conditions, which will be described in further detail later on. From the tap of a potentiometer 53 receiving an analog signal a_c , a partial voltage γa_c is fed via a diode arrangement 54, 55 to the input of the amplifier 21 so that the voltage $a_k - \gamma a_c$ is present at the input. The diode arrangement 54, 55 represents a contactless switch for the analog signal γa_c and is composed of a "greater than" member and a "smaller than" member. For controlling this switch, the aforementioned logic signal c and its inverse signal $\bar{c}$ are used. The switch is conductive for $c=1$ and $\bar{c}=0$ and blocks for $c=0$ and $\bar{c}=1$. This switch function is shown in FIG. 11.

The manner of operation of the circuit arrangement of the brake controller shown in FIG. 7 will now be described.

Assuming that $c=0$ and that feeding of the portion p_k to the input of the amplifier 38 has been interrupted, the circuit arrangement of FIG. 7 has the same manner of operation as that of the brake controller described above with reference to FIG. 4. In addition to this, the brake controller of FIG. 7 has two different operating conditions namely:

(I) The condition for deceleration to a lower speed, and

(II) The condition for obtaining travel with constant speed on a grade.

In operating condition I, the logic signal c is equal to zero, so that in this condition of operation the brake controller of FIG. 7 has substantially the same manner of operation as that of FIG. 4. The influence of the portion p_k , fed in addition to the integral portion p_i and the proportional portion p_p , is generally negligibly small in the operation condition I since the difference in deceleration a_{be} is greater than the value for a minimum desired reduction p_{ac} which actuates the measurement trigger 40, as will be evidence from the following discussion.

In operating condition II (travel on grade), the logic signal c has the value 1 and is therefore controlling for the instantaneous condition of operation of the brake controller. The logic signal c can be derived, for instance, from the desired-value transmitter for the speed (not shown) which is located on the locomotive, i.e., from the criterion whether the preselected speed is reached or not, and from the position of the reversing switch on the locomotive.

In operating condition II ($c=1$), the logic signal c via the diode arrangements 37 and 36 blocks the positive branch of the proportional portion p_p , which branch is controlling for braking, so that this proportion has the path shown in broken lines in FIG. 9 as a function of the deceleration difference a_{be} . By this suppression of the proportional portion p_p , an overbraking of the train is avoided when traveling on a grade. On the other hand, release of the brakes takes place with unchanged speed, since the negative branch of the proportional portion p_p is not blocked even when $c=1$.

In operating condition II ($c=1$), the logic signal c also connects the negative limiting level of the amplifier 23 via the diode arrangement 29 to a value of the signal f_1 less than the maximum, for instance, to $0.54 \cdot f_{1 \max}$, as can be noted from FIG. 8. In this way, when travelling on a grade, overbraking of the train is also avoided, since with reduced limiting level, the integral portion p_i increases more slowly. Release of the brake, however, takes place with unchanged speed, since the positive limiting level of the amplifier 23 is not affected. Upon release of the brake, the integral portion p_i is set to zero as in operating condition I via the capacitor 34 and the diode 35 by means of the transition 1→0.

In order to maintain the increase in speed within suitable limits when travelling on a grade, and particularly when entering a grade, the brake controller should respond as early as possible. Since in operating condition II, in accordance with what has been stated above, the voltage p_{ac} is built up only via the integral portion p_i , a minimum drop in pressure must be effected by other means as soon as the desired acceleration correction a_k becomes negative. For this purpose, the decreasing base portion p_k is connected, which portion is of such value that the measurement trigger 40 just responds whereby a minimum drop in pressure of, for instance, 0.4 kg./cm.² is produced. This drop in pressure must however be reduced, particularly in the case of those grades which lie slightly above the limit case at which the electric brake of the tractive vehicle is by itself sufficient, before the full braking action is reached. For this reason, the base portion p_k decreases in time, for instance, to half its value within 4 seconds. With larger grades, the decrease of the base portion p_k is at least partially compensated for by

the increase in the integral portion p_i so that the resultant drop in pressure at most decreases slightly.

As soon as the voltage a_k reaches a negative value which corresponds to a desired deceleration of, for instance, -0.05 m./sec.², the measurement trigger 48 responds and produces the logic signal k_b which effects the transition 1→0 of the member 47. At the member output there therefore appears the logic signal k_b^* which subsequently reverses the charge of the capacitor 44 via the resistors connected with it so that the decreasing signal p_k is produced. In FIGS. 10a, 10b and 10c, the variations with time are shown for the signal p_{ac} of the desired deceleration which appears at the output of the amplifier 38 and corresponds to the portion p_k upon the absence of the integral portion p_i , and for the output signal k_b^* of the member 47, and for the output signal k_b of the measurement trigger 48.

The transition 0→1 of the member 47, i.e., the resetting of the member to condition 1, is effected in one case by the inverse signal $\bar{k}_b$, namely, when the signal k_b is equal to zero, i.e., the analog signal a_k has become positive, which corresponds to a positive correction of the desired acceleration. In the other case, the transition 0→1 of the member 47 is effected by the signal $\bar{p}_b^*$ in which p_b^* is the dynamic signal, produced by the measurement trigger 50, of the inverse signal $\bar{p}_b$ and has a minimum duration of, for instance, 5 seconds. The variation with time of the signals $\bar{p}_b^*$ and $\bar{p}_b$ is shown in FIGS. 10d and 10e respectively. By the alternative possibility of setting the member 47, the base portion p_k is stepped up again even if after an accidental release of the brakes, for instance, as a result of a stabilizing measure, the signal k_b is continuously present and accordingly the signal $\bar{k}_b$ for setting the member 47 to 1 never becomes 1.

In the case of travel on a slight grade, in order to avoid disconnecting of the electric brake of the locomotive as a result of overbraking of the car by the compressed air brake, and in order to obtain a uniform variation of the speed, it is advantageous to effect a corresponding stabilizing of the brake control circuit. Such stabilizing is obtained in the case of the brake controller of FIG. 7 by reducing the desired deceleration correction a_k by a component consisting of the factor γ times the desired acceleration a_c so that the effective deceleration difference a_{be} at the input of the actual controller is given by the value $a_{be} = a_k - \gamma \cdot a_c$. The reduction portion $\gamma \cdot a_c$ is, as described above, tapped off from the potentiometer 53. In operating condition II ($c=1$, $\bar{c}=0$), the reduction portion $\gamma \cdot a_c$ arrives at the input of the amplifier 21, while in the operating condition I ($c=0$, $\bar{c}=1$), at which a reduction of a_k is undesired, the analog signal $\gamma \cdot a_c$ is blocked by the switch formed by the diode arrangements 54 and 55 respectively.

What is claimed is:

1. Apparatus for controlling the pneumatic braking force in a railway train having a main compressed air line, a brake device on each car connected to said main line, each brake device having at least one brake cylinder, means for controlling the air pressure in each brake cylinder as a function of the air pressure in said main line, a brake controller for producing an electric variable control signal serving to adjust the air pressure in said main line, said variable signal being a function of another electric signal corresponding to the difference between the desired deceleration of the train and its instantaneous actual deceleration, wherein the improvement comprises an integrator forming a part of said brake controller, means for feeding a voltage dependent upon said difference signal to said integrator, said dependent voltage having at least one adjustable limit value, the output of said integrator serving as said variable control signal, and the time constant of said integrator being such that the rate of air pressure change in said main line is at least about equal to the rate of air pressure change in each of said brake cylinders.

2. Apparatus as defined in claim 1 wherein said brake controller includes a switch member having a "braking" position and a "release" position and being responsive to said difference signal, and a feedback loop connected to the output of said integrator, said switch when in its braking position connecting a constant voltage to said integrator input and when in its release position connecting said feedback loop to said integrator input.

3. Apparatus as defined in claim 2 wherein said feedback loop includes an ohmic resistor.

4. Apparatus as defined in claim 1 wherein said brake controller includes a limiting amplifier adapted to receive said difference signal, the output of said limiting amplifier being connected to the input of said integrator, and a transmission member arranged in parallel with said amplifier and integrator and also adapted to receive said difference signal, and means for combining the output voltages of said integrator and said transmission member with the same sign.

5. Apparatus as defined in claim 1 including a circuit arranged to receive the output signal of said brake controller, said circuit becoming conductive when the output signal of said brake controller exceeds a value corresponding to a predetermined minimum pressure drop in said main line.

6. Apparatus as defined in claim 5 wherein said circuit includes a measurement trigger, and a feedback loop between the output and input of said trigger, said loop containing a resistor for providing hysteresis.

7. Apparatus as defined in claim 6 including means for transmitting the output logic signal of said trigger to the input of said integrator, to set the latter at zero upon release of the brakes, said means including a capacitor.

8. Apparatus as defined in claim 4 including means for adjusting the limiting levels of said limiting amplifier.

9. Apparatus as defined in claim 4 including a diode switch responsive to a logic signal for varying the limiting level of said limiting amplifier which controls braking.

10. Apparatus as defined in claim 4 including a diode switch responsive to a logic signal for blocking the branch of the characteristic of said transmission member which controls braking.

11. Apparatus as defined in claim 1 including a diode switch responsive to a logic signal for adding said difference signal and a reduction signal derived from an analog signal corresponding to the desired deceleration.

12. Apparatus as defined in claim 9 including means for producing said logic signal when said brake controller is set to maintain constant speed when the train is travelling on a grade.

13. Apparatus as defined in claim 4 including means for applying to the output of said integrator a base voltage which decreases with time, whereby when the train is travelling on a grade a rapid increase of the integrator output signal is obtained corresponding to a predetermined minimum drop in pressure in said main line.

14. Apparatus as defined in claim 13 including means for producing said base voltage, said means including a bistable member, a rechargeable capacitor arranged to receive a logic signal from the output of said bistable member when the latter switches from one of its conditions to the other, and means for applying to one input of said bistable member a logic signal derived from said difference signal when the latter reaches a predetermined minimum value.

15. Apparatus as defined in claim 14 wherein the other inputs of said bistable member are connected as an OR circuit, and including means for applying to said other inputs for resetting said bistable member a signal inverse to said logic signal derived from said difference signal and a logic signal produced upon release of the brakes.

16. Apparatus as defined in claim 14 including a measurement trigger arranged to receive the output signal of said brake controller, said trigger becoming conductive

11

when the output signal of said brake controller exceeds a value corresponding to a predetermined minimum pressure drop in said main line, means for applying a signal inverse to the logic signal from said trigger to another measurement trigger and means for connecting the output of said other trigger to one of the other inputs of said bistable member, for feeding said logic signal produced upon release of the brakes.

17. Apparatus as defined in claim 16 including means for adjusting the minimum duration of said logic signal produced upon release of the brakes.

12

References Cited

UNITED STATES PATENTS

3,398,995 8/1968 Martin.

DUANE A. REGER, Primary Examiner

U.S. Cl. X.R.

303—21