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(54) **Anti-skid vehicle braking systems**

(57) An anti-skid braking system has individual modulating valves (5, 7), (6, 8) for the brakes of two wheels. The valves are located near the junction of the brake lines, and are controlled as shown in Figure 1*b* so that the pressure in one circuit cannot rise while it is falling in the other, and so that a pulsed increase in pressure in one circuit is matched by a corresponding increase in the other circuit. The system is also so arranged that the flow resistance in the common line from the master cylinder 1 is at least as great as the resistance between the junction and each brake.

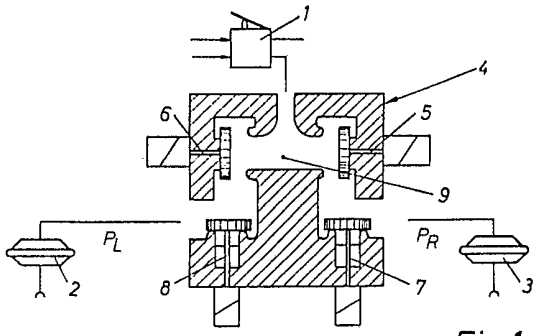


Fig. 1a

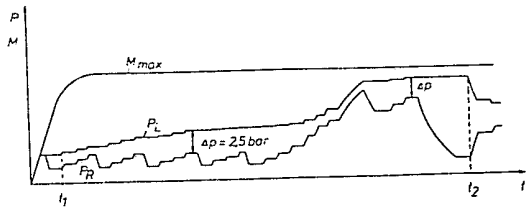


Fig. 1b

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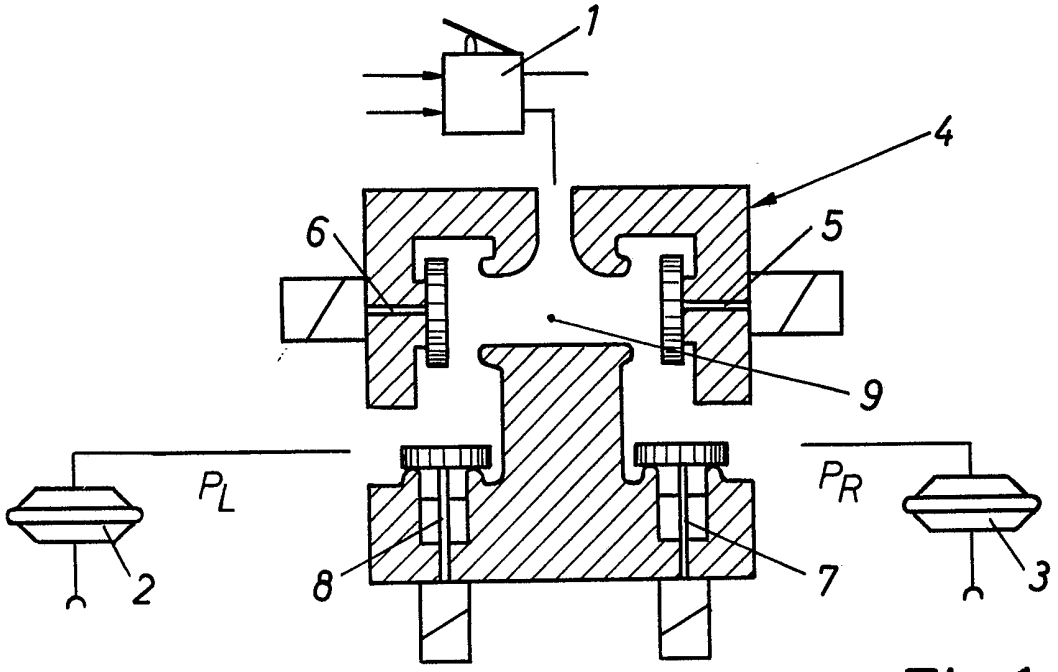


Fig. 1a

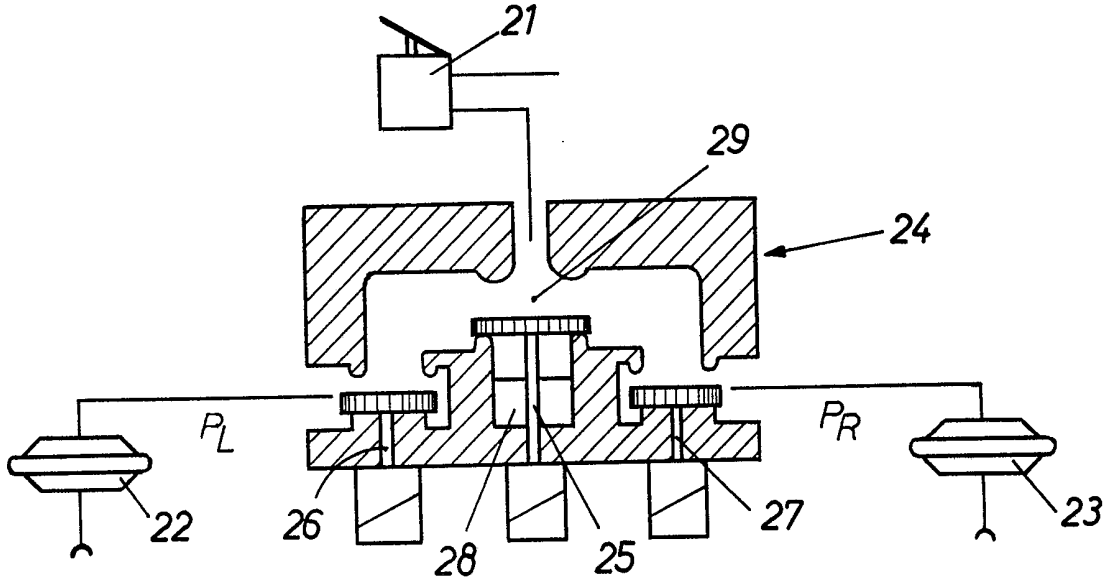


Fig. 2

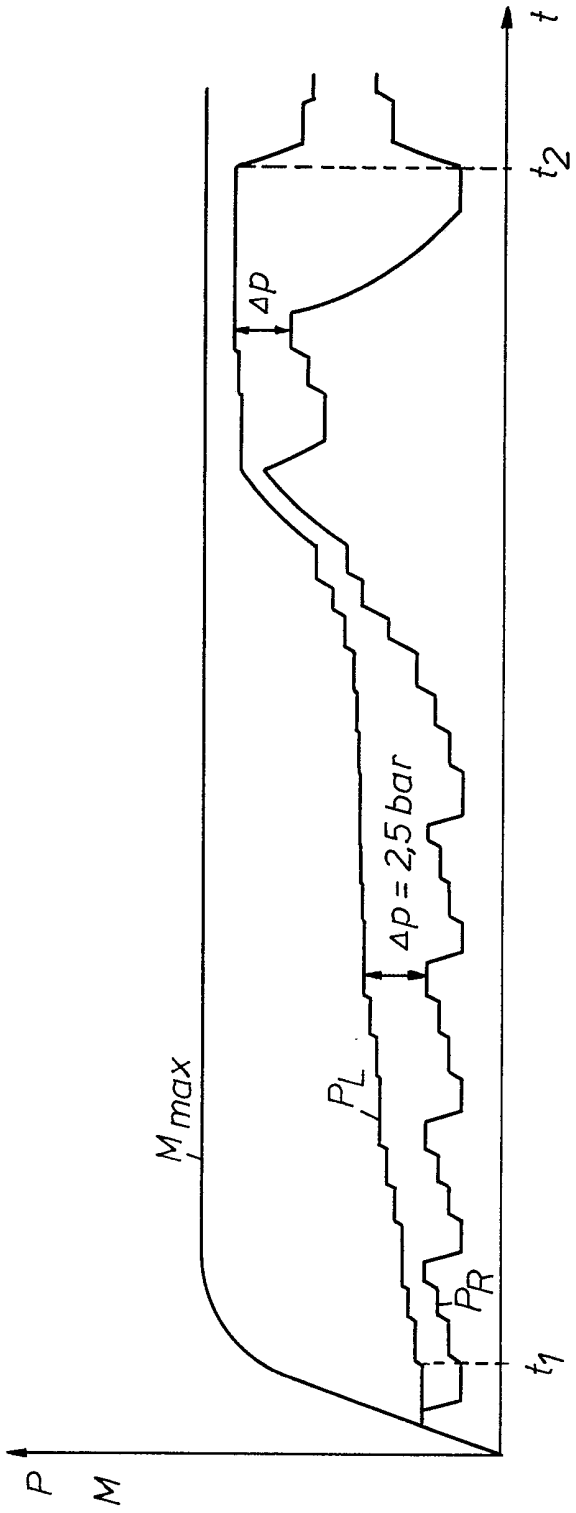


Fig. 1b

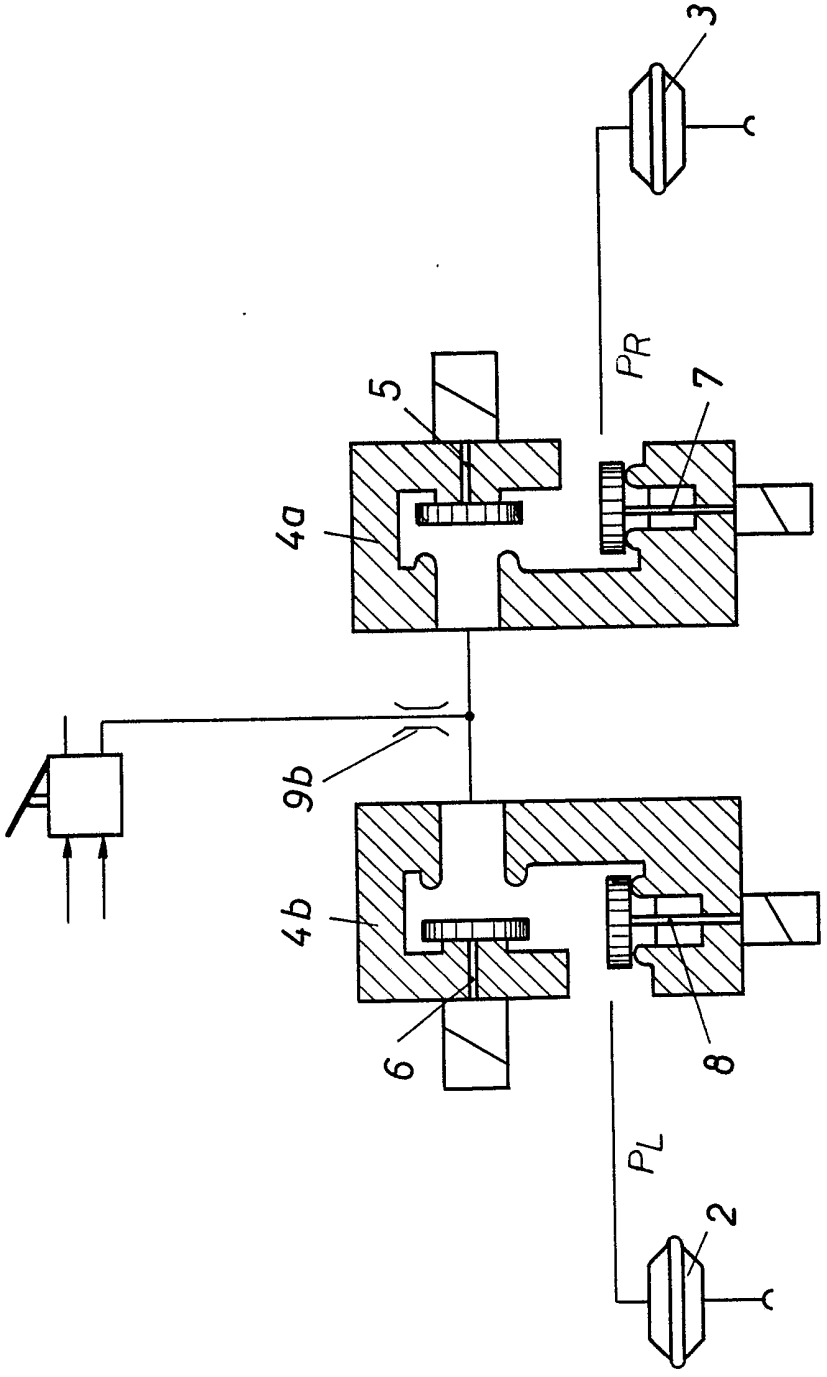


Fig.3

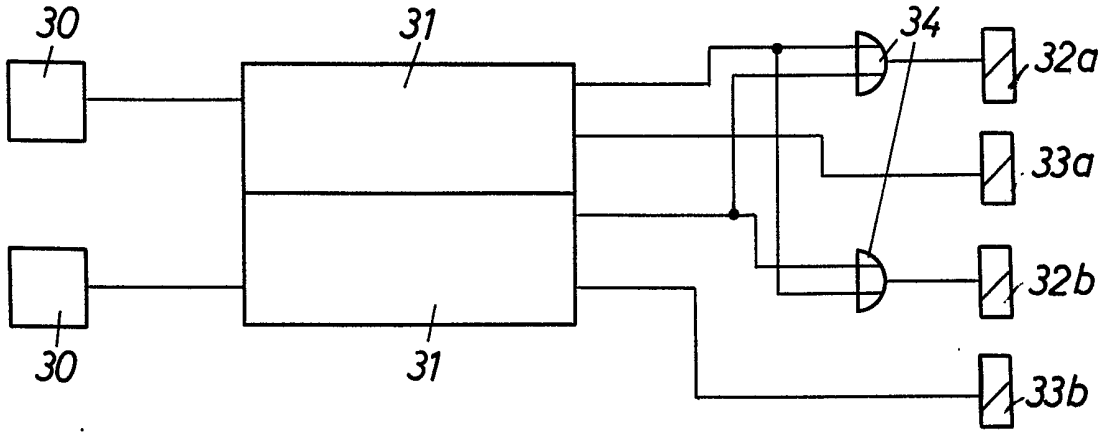


Fig.4a

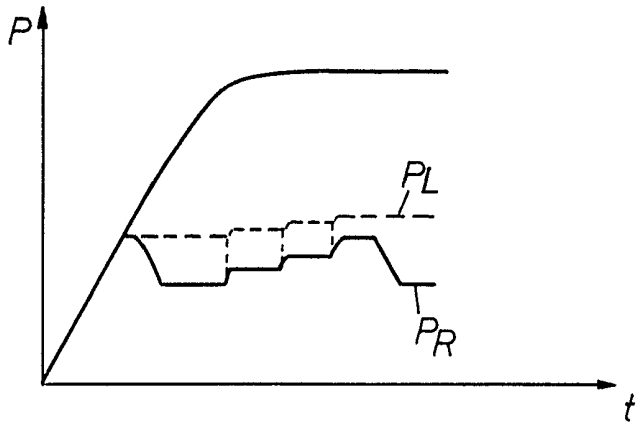


Fig.4b

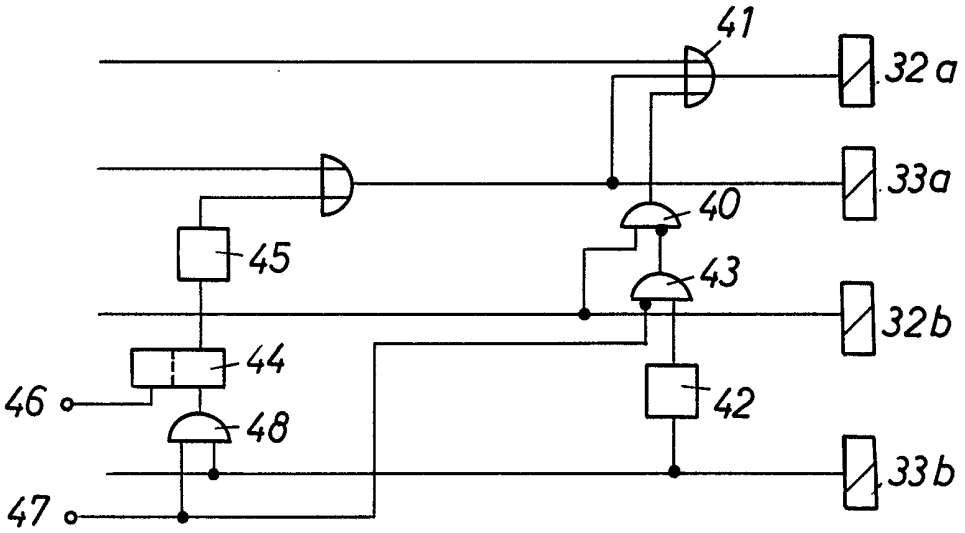


Fig.5a

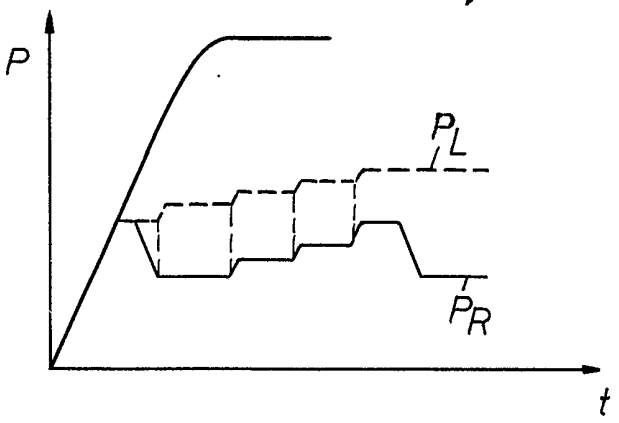


Fig.5b

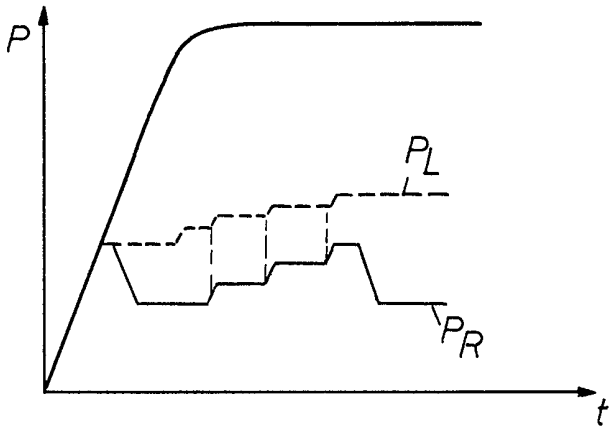


Fig.5c

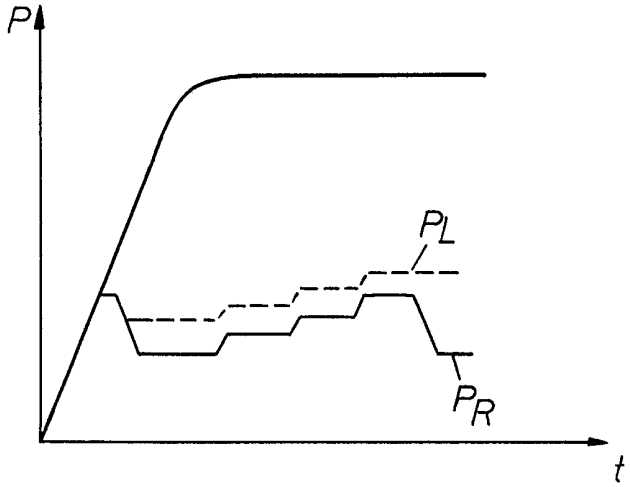


Fig.5d

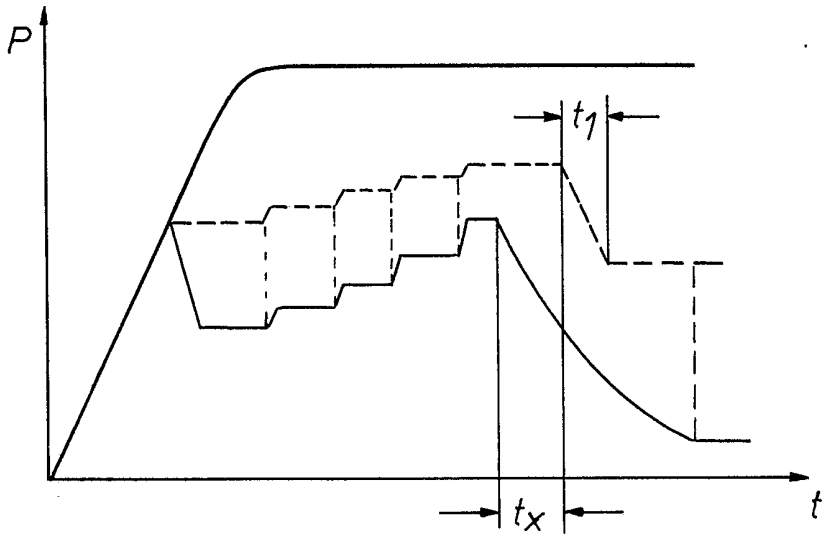


Fig. 5e

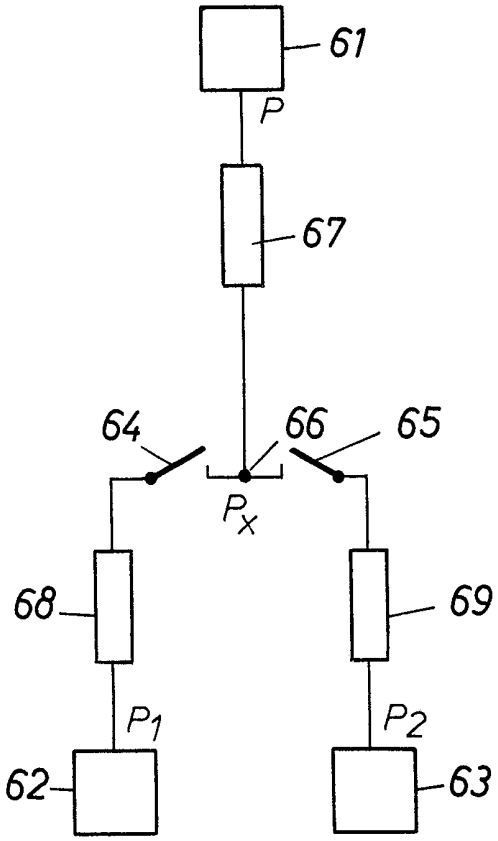


Fig. 6

SPECIFICATION

Improvements in or relating to anti-skid regulating systems for vehicle brakes

The present invention relates to anti-skid regulating systems for pressure-medium-operated vehicle brakes.

In one form of anti-skid regulating system each wheel of an axle has an associated signal generator for obtaining a signal characterising the behaviour of the movement of that wheel; these signals are fed to an evaluation circuit which, on the basis of these signals, produces brake pressure control signals which are fed to brake pressure control devices for separately influencing the brake pressure at the two wheels, the evaluation circuit including control means which, upon a reduction of pressure at one wheel, prevents a substantial buildup of pressure at the other wheel and, upon a pulsed increase in pressure thereafter at one wheel, also only permits a synchronous pulsed increase of pressure at the other wheel.

An anti-skid regulating system of this kind is described in German Offenlegungsschrift, 2,320,559 in which the measures mentioned are used to avoid large yawing moments upon the commencement of braking when the brakes are fully applied and the wheels of one axle run on a roadway having a greatly differing coefficient of friction. With this arrangement, however, great pressure differences and consequently great yawing moments occur after a long braking time.

According to the present invention there is provided an anti-skid regulating system for pressure-medium-operated vehicle brakes, in which each wheel of an axle has an associated sensor for providing a signal characterising the rotational behaviour of that wheel, and the signal from the sensors are fed to an evaluation circuit which, on the basis of these signals, produces brake pressure control signals which are fed to brake pressure control devices for separately influencing the brake pressure at the two wheels, the evaluation circuit including control means which, upon a reduction of pressure at one wheel, prevents substantial build-up of pressure at the other wheel and, upon a pulsed or step-wise increase in pressure thereafter at one wheel, also permits a synchronous pulsed or step-wise increase of pressure of the other wheel, and a junction from which branch lines leading from a source of brake pressure to the two wheel brakes is disposed in the immediate vicinity of the brake pressure control devices or in the brake pressure control devices themselves.

In a system embodying the present invention the brake pressure at one wheel during a build-up of pressure can only exceed the brake pressure at the other wheel by a specific pressure difference. Since this pressure difference is dependent upon the flow resistance in a common position of the brake line, the pressure difference can be inlfuenced by corresponding throttling of the cross section of this podrtion of the line, or by corresponding selection of flow resistances of the branch portions downstream of the junction relative to that of the common portion. Preferably, the flow resistance of the common portion is at least as great as the flow resistance of a branch portion downstream of the junction. Since conduits exceeding a certain length can be regarded as pressure reservoirs, it is necessary to define the position of the junction in the manner described above.

When the brakes are fully applied on a roadway having greatly differeing coefficients of friction between the two wheels of an axle, the higher braking force on one side, with full utilisation of the brake forces transmissible on both sides, causes a large yawing moment which considerably reduces the braking stability particularly in the case of vehicles having a short wheel base.

The asymmetric brake forces then occurring can be so great that the vehicle cannot be controlled even with a rapid steering reaction on the part of the driver of the vehicle, thus resulting in side-slipping and skidding.

Even in the case of self-stabilising steering, such as in vehicles having a negative camber it would be difficult for a driver to control a vehicle having a short wheel base and a low load on the rear axle.

Track-stabilised braking under critical roadway conditions and when travelling on sharp bends can only be ensured by limited utilization of the higher brake force on one side in the case of asymmetric brake forces.

By embodying the present invention and using a special valve arrangement, and dimensioning, and synchronous control of the brake pressure devices, the required limited utilization of the higher brake force on one side can be automatically provided by a self-establishing, maximum obtainable difference between the brake pressures in the individual brake cylinders.

The desired limiting of the pressure difference in the individual brake cylinders is obtained, by virtue of the special valve arrangement and dimensioning, in that momentary pressure-increase pulses, which are controlled synchronously by the brake pressure control devices associated with the individual brake cylinders, lead to an increase in pressure in the individual brake cylinders in inverse ratio to the particular pressure level. That is to say, the larger increase in pressure is effected proportionately in the brake cylinder in which the lower brake pressure level has been introduced.

When a difference between the individual pressures in the brake cylinders, determined substantially by the selection of flow resistances provided by throttles, is obtained, a further pressure rise in excess of this pressure difference cannot be obtained in the brake cylinder having the higher pressure level. Consequently, adjustment to this pressure difference is also automatically effected when the asymmetric brake forces are reversed as a result of changes in the coefficient of friction.

The present invention can be applied both to compressed air operated brakes and to hydraulic brakes, although it is of particular interest for the first-mentioned brakes.

In one embodiment of the present invention in

inlet valve and an outlet valve are used for each wheel brake. It is then necessary for a combined valve arrangement to be disposed in the immediate vicinity of the junction between common and branch portions of the brake line. In another embodiment there is incorporated in the brake line up-stream of the junction leading to the two wheel brakes a valve which, when in one position, connects a source of brake pressure to the wheel brakes and, when in its second position, interrupts this connection and establishes communication between the wheel brakes and a return or relief line, and there is incorporated in each of the two branch lines leading to the wheel brakes, a two port, two way valve which keeps the line open when in one position and closes the line when in its other position, and in this embodiment the junction can be disposed directly in the valve arrangement.

In both these embodiments the valves can be integrated in a single unitary valve arrangement.

It has been mentioned above that, during a pressure drop at one wheel brake, the pressure at the other wheel brake is to be maintained substantially constant when a regulating signal for the second wheel brake does not exist. The term "maintained substantially constant" can, on the one hand, be interpreted to mean simply stabilization of pressure or, on the other hand, a momentary pressure drop and otherwise maintaining the pressure constant. This momentary drop in pressure can be made dependent upon the vehicle speed. It will only be used particularly in a first regulating cycle. It is also possible only to effect the pressure drop for a predetermined period of time when a pressure drop has previously been effected at the regulated wheel over a predetermined period of time.

The control means are preferably adapted to operate such that, with the pressure maintained constant at the wheel brake having pressure regulation, the pressure at the wheel brake of the other wheel is either maintained constant likewise or, alternatively, is increased in a pulsed or step-wise manner and is otherwise maintained constant. The abovementioned momentary increase in pressure can be effected at the end of a phase of pressure decrease at the other wheel or, alternatively, after a predetermined period of time after the end of a decrease in pressure. Alternatively, the abovementioned possibilities can be combined and, for example, a short build-up of pressure can be permitted up to a predetermined vehicle speed and, when the vehicle speed exceeds the predetermined speed, the pressure can be momentarily reduced during the reduction of pressure at the regulated wheel.

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

Figure 1a shows a pneumatic brake system incorporating one embodiment of the present invention,

Figure 1b shows graphically an associated pressure characteristic at the wheel brakes of the system of Figure 1*a*,

Figure 2 shows a different pneumatic brake system incorporating a second embodiment of the present invention,

Figure 3 shows an embodiment of the system of Figure 1*a* with an individual valve arrangement,

Eigure 4a is a block circuit diagram of an antiskid regulator in accordance with the invention,

Figure 4b shows graphically the pressure characteristic associated with the regulator of Figure 4*a*,

Figure 5a is a further block-circuit diagram of an anti-skid regulator,

Figures 5b to *5e* show pressure characteristics associated with the regulator of Figure 5*a*, and

Figure 6 is an equivalent circuit diagram for explaining the predetermined pressure difference.

Figure 1 shows a brake control valve 1 by means of which compressed air can be introduced through brake lines into the brakes 2 and 3 of the wheels of one axle of a vehicle. In order to regulate the brake pressure when there is a tendency for the wheels to lock, there is provided an integrated valve arrangement 4 which comprises two inlet valves 5 and 6 and two outlet valves 7 and 8. The valve arrangement is constructed such that the junction between a common leading position of the brake line and branch brake line position leading to the wheel brakes is disposed in the valve itself. In this instance, the inlet cross section 9 is in the form of a throttle.

Let it be assumed that the right hand wheel has moved onto a surface with a low coefficient of friction μ and that the pressure of this brake is regulated upon braking. Figure 1*b* shows that, during a reduction of pressure and stabilization of pressure at the right hand wheel (curve P_R), the pressure P_L at the other wheel is maintained constant (up to the time t_1), and that the two pressures P_L and P_R are thereafter increased together step-wise in a pulsed manner. As a result of the throttling ratios which have been chosen between each of the branch brake line portions and the common brake line poertion, the heights of the pressure steps of the right hand wheel are greater than those of the left hand wheel, so that the pressure curves P_R and P_L in each case approach one another up to a differential pressure $\triangle$ p of, for example, 2.5 bar. In this instance, it is also of interest that, with a large pressure difference (for example at t_2) occasioned by regulation, the pressure at the left hand wheel is relieved towards the pressure at the brake of the right hand wheel during the following pressure rises at the right hand wheel owing to the throttle ratios, that is to say, a counter-acting pressure change takes place, although only the inlet valves 5 and 6 are actuated and no outlet valve is actuated.

Figure 2 shows a valve arrangement 24 which is modified relative to the valve arrangement 4 Figure 1*a* in that only three valves are provided, of which the valve 25 when actuated, prevents the flow of compressed air from the brake valve 21 to the wheel brakes and connects the latter to an outlet 28, and the valves 26 and 27 are shut-off valves which, when actuated, can interrupt the pressure drop and pressure rise at the individual wheel brakes. Here also, the inlet 29 is throttled.

By using this valve arrangement, it is possible to obtain the same pressure characteristic as that obtained by the valve arrangement of Figure 1*a*.

The embodiment of Figure 3 differs from that of

Figure 1*a* only in that the valves 5 to 8 are accommodated in two valve arrangements 4*a* and 4*b* and that, in the present instance, a line throttle 9*b* is indicated.

It has been assumed in Figures 1*a* and 2 and 3 that the brakes are air brakes. Alternatively, however, hydraulic circuits can be used, it being entirely immaterial whether these circuits are full power circuits or some other type of hydraulic circuits. Alternatively, as already mentioned, the throttles can be disposed in the lines (and not in the valves) as is shown in Figure 3. This is particularly necessary when valves are only fitted downstream of the junction.

Figure 4*a* shows a block circuit diagram of the control means of an anti-skid regulator required to control the valve 4 of Figure 1*a*. The sensors associated with the two wheels for the purpose of monitoring the rotational behaviour thereof are designated 30, and the evaluation circuits for the signals from them are designated 31. The evaluation circuits 31 control inlet valves 32*a* and 32*b* (coressponding to, for example, valves 5 and 6 of Figure 1*a*) and outlet valves 33*a* and 33*b* (corresponding to, for example, valves 7 and 8 of Figure 1*a*) by way of OR gates 34. The inlet valves 32*a* and 32*b* are interconnected by way of the OR gates 34, so that (as is shown in Figure 4*b* and corresponding to Figure 1*a*), during pressure stabilization and reduction of pressure at the regulated wheel (P_R) the pressure at the other wheel is also built-up in steps, although with a reduced height of the steps.

Only the four leads connected to the valves 32*a* and 32*b* and 33*a* and 33*b* are shown in the embodiment of Figure 5*a*, these leads being interconnected in another way. In the combination shown on the right, the signals on the lead connected to the inlet valve 32*b* are fed to the inlet valve 32*a* by way of an AND gate 40 and an OR gate 41, similarly to the OR gate 34 shown in Figure 4*a*, that is to say, the valve 32*a* in general follows the signals of the valve 32*b* (as in Figure 4*a*). However, it may be advisable to increase the pressure once in a step-like manner at the other wheel after a reduction of pressure and during stabilization at the regulated wheel. For this purpose, a timing circuit 42 is provided which responds to the trialing edge of a pressure-drop signal fed to the valve 33*b* and thereafter, for a predetermined period of time, produces a signal which blocks the AND gate 40 (inversion) by way of the AND gate 43 and thereby does not allow the valve 32*a* to respond for the pre-determined period of time and thereby allows the pressure to rise for this period of time. This is shown in the pressure graph of Figure 5*b*. When the timing circuit 42 has a time lag, a pressure build-up stage occurs at a later instant, as is shown in Figure 5*c*.

The second combination illustrated also effects a short reduction of pressure at the non-regulated wheel when pressure is reduced at the other wheel. This is shown by the pressure curve of Figure 5*d*. In this instance, the pressure drop signal fed to the valve 33*b* sets a bistable circuit 44 and its leading edge triggers a monostable circuit 45 which triggers the valve 33*a* (and 32*a*) for a short period of time and thus reduces the pressure for a short period of time. After the bistable circuit 44 has been set once, a pressure drop signal fed to the valve 33*b* can no longer trigger the monostable circuit, that is to say, the pressure drop is only permitted during a first regulating cycle. The bistable circuit 44 is reset at the end of a braking operation by way of terminal 46. When the bistable circuit 44 is set with a time lag, pressure is only reduced at the non-regulated wheel when the pressure drop at the regulated wheel exceeds a minimum period of time (pressure curve 5*e*).

The two combinations of Figure 5*a* can be used alternatively, although, as is shown in Figure 5*a*, they can also be used jointly, wherein a signal appearing at the terminal 47 at, for example, a vehicle speed > 30 km/h, blocks the build-up of pressure by way of the AND gate 43 (that is to say, a build-up of pressure is only permitted at a low speed), while this signal permits the reduction of pressure corresponding to Figure 5*d* by way of the AND gate 48.

For the sake of simplicity, only the interconnection between the leads connected to the valves 32*b*, 33*b* and the leads connected to the valves 32*a*, 33*a* are illustrated, and not the reverse, similar interconnection.

The principle of the invention will be explained with reference to Figure 6 which shows an equivalent circuit diagram for the pressure ratios during the buildup of pressure. The brake valve is designated 61, the wheel brakes are designated 62 and 63, and the inlet valves are designated 64 and 65. The flow resistance of the line between the valve 61 and the branch point 66 is illustrated in a lumped (as opposed to distributed manner and is designated 67, and the flow resistances of the lines from the junction 66 onwards are similarly illustrated and designated 68 to 69. The pressure at the outlet of the valve 61 is designated P, the pressure at the brake 62 is designated P_1, and the pressure at the wheel brake 63 is designated P_2, it being assumed that $P_1 < P_2 < P$ owing to a preceding pressure drop at the brake 62. If the valves 64 and 65 are now opened (that is to say, the illustrated switches are closed), there is established at the junction 66 a pressure P_X determined by the pressure difference $P - P_1$ and the ratio of the flow resistances 67 and 68. Since

$$P_X - P_1 > P_X - P_2,$$

it is ensured that, with the inlet valves 64 and 65 open for a short period of time, the inflow of pressure medium into the brake 63 will be less than that at the brake 62. Finally, P_2 might approach so closely to P_X that virtually no pressure increase occurs at the second wheel brake 63.

CLAIMS

1. An anti-skid regulating system for pressure-medium-operated vehicle brakes, in which each wheel of an axle has an associated sensor for providing a signal characterising the rotational behaviour of that wheel, and the signals from the

sensors are fed to an evaluation circuit which, on the basis of these signals, produces brake pressure control signals which are fed to brake pressure control devices for separately influencing the brake pressure at the two wheels, the evaluation circuit including control means which, upon a reduction of pressure at one wheel, prevents a substantial build-up of pressure at the other wheel and, upon a pulsed or step-wise increase in pressure thereafter at one wheel, also only permits a synchronous pulsed or stepwise increase of pressure at the other wheel, and a junction from which branch lines leading from a source of brake pressure to the two wheel brakes is disposed in the immediate vicinity of the brake pressure control devices or in the brake pressure control devices themselves.

2. An anti-skid regulating system as claimed in claim 1, in which the flow resistance of a common line from the pressure source to the junction is at least as great as the flow resistance between the junction and a wheel brake, and in which a predetermined flow resistance can be obtained by throttling.

3. An anti-skid regulating system as claimed in claim 1 or 2, in which an inlet valve and an outlet valve are provided as the brake pressure control device for each wheel brake.

4. An anti-skid regulating system as claimed in claim 1 or 2, in which there is incorporated in a common brake line upstream of the junction from which the branch lines lead to the two wheel brakes, a valve which, when in one position, connects the source of brake pressure to the wheel brakes and, when in its second position, interrupts this connection and establishes communication between the wheel brakes and a return or relief line, and in which there is incorporated in each of the two branch lines leading from the junction to the wheel brakes a two port, two way valve which keeps the line open when in one position and closes the line when in the other position.

5. An anti-skid regulating system as claimed in claim 3 or 4, in which the valves are integrated into a unitary valve arrangement.

6. An anti-skid regulating system as claimed in any of claims 1 to 5, in which the control means is adapted to operate such that, during a pressure drop at one wheel brake (without a regulating signal derived from the outer wheel), the pressure at the other wheel brake is maintained constant.

7. An anti-skid regulating system as claimed in claim 6, in which the control means is further adapted to operate such that, when the pressure is being maintained at one wheel brake, it also maintains the pressure at the other wheel brake (without regulating signal) constant.

8. An anti-skid regulating system as claimed in claim 6, in which the control means is further adapted to operate such that, whilst the brake pressure is being maintained constant at one wheel brake following a pressure drop, it increases the pressure at the other wheel brake (without regulating signal) for a short time and otherwise also maintains it constant.

9. Anti-skid regulating systems for vehicle brakes, constructed and arranged and adapted to operate substantially as hereinbefore particularly described with reference to and as illustrated in Figures 1*a* and 1*b* of Figures 2 and 1*b*, or Figures 3 and 1*b* of the accompanying drawings.

10. Anti-skid regulating system as claimed in claim 9, including control means constructed and arranged and adapted to operate substantially as hereinbefore particularly described with reference to and as illustrated in Figures 4*a* and 4*b*, or Figure 5*a* and Figure 5*b* or Figure 5*c* or Figure 5*d* or Figure 5*a* of the accompanying drawings.

11. Anti-skid regulating systems as claimed in claim 9 or 10 adapted to operate substantially as hereinbefore particularly described with reference to Figure 6 of the accompanying drawings.

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