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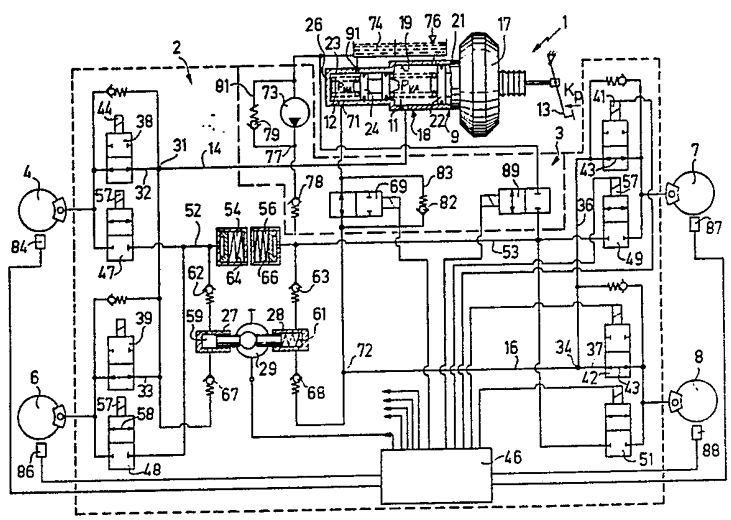
(54) **Drive slip control arrangement**

(57) In a drive slip control arrangement for a road vehicle, with a pump back anti-lock system, the anti-lock return pump 28 of the brake circuit II of the driven rear vehicle wheels 7, 8 is used as the auxiliary pressure source for the drive slip control. When the drive slip control is activated, the main brake pipe II of the driven vehicle wheels is shut off from the master cylinder 9 by a drive slip control valve 69. Initially the return pump 28 is activated and is shut off from the master cylinder 9 when the drive slip of one of the driven vehicle wheels exceeds a threshold value between the drive slip required value and threshold slip value and the driven wheel brake pressure control valves 41, 42 are closed. The high pressure thus building up in the main brake pipe, limited by a pressure relief valve, is then available at the threshold slip valve for an introductory brake pressure build-up phase of the drive slip control on the vehicle wheel requiring it. An additional outlet valve 89, by which the return line can be connected to the brake fluid reservoir, can be provided for controlling the pressure reduction phases of slip control.



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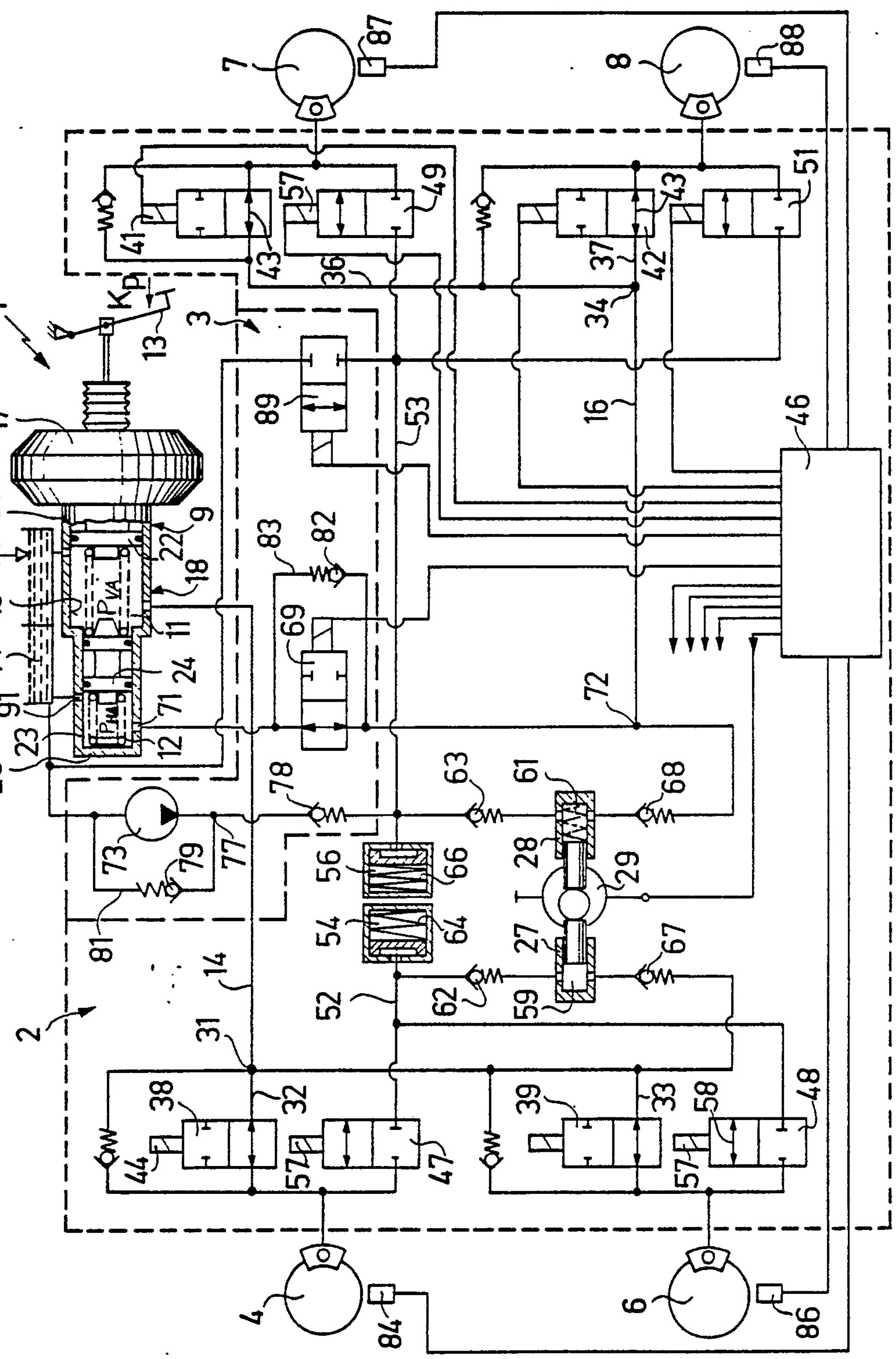

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Drive slip control device

The invention concerns a drive slip control device for a road vehicle having a twin-circuit hydraulic brake installation with front axle/rear axle brake circuit subdivision and having the further generic features A to E quoted in the preamble to Claim 1.

For reasons associated with simplifying a drive slip control device combined with an anti-lock system known from DE 31 37 287 C2, a device of this type was the subject of internal company theoretical and experimental investigations whose objective was to achieve the greatest possible simplification of the anti-lock and drive slip control systems. An interesting possibility considered for simplifying the known drive slip control device (in which - again for the purpose of simplifying the overall construction of a drive slip control device combined with an anti-lock system - the return pump of the anti-lock system was already used as the reservoir charging pump for the pressure reservoir provided as the auxiliary pressure source within the drive slip control device) was to avoid the use of this pressure reservoir and, in its place, to use the return pump associated with the brake circuit of the driven vehicle wheels "directly" as the auxiliary pressure source for the drive slip control device.

The test drive slip control device designed in accordance with this concept was laid out for a vehicle with rear axle drive, the anti-lock system of the vehicle corresponding to the series production type, i.e. the design of the return pumps provided for the two brake circuits involved piston pumps which were "not self-priming". In order, in drive slip control operation, to ensure the functioning of the return pump associated with the rear axle brake circuit as a pressure source, the vehicle was equipped with a booster pump by means of which, in drive-slip control operation, brake fluid was pumped out of the brake fluid reservoir of the brake installation into the pump chamber of the return pump associated with the rear axle brake circuit. The control behaviour achieved in this test-type drive slip control operation, however, was unsatisfactory in that the control was very sluggish, i.e. the build-up of brake pressure occurred relatively slowly after the booster pump and the return pump had been switched on. In order to achieve a response behaviour which was at least approximately comparable with conventional drive slip control, it therefore appeared unavoidable to provide a return pump with a larger pumping capacity - at least for the brake circuit of the driven vehicle wheels. There are, however, design limits to such an increase in size so that, for this reason alone, it did not always appear possible to achieve a sufficiently rapid response behaviour of the control system, particularly since the return pump of the conventional anti-lock system did not appear to be a suitable auxiliary pressure source for drive slip control.

On this basis, therefore, the object of the invention is to produce a drive slip control device of the type mentioned at the beginning, which responds sufficiently rapidly even if a return pump of conventional type is used as the auxiliary pressure source.

The invention achieves this object by means of the features quoted in the characterizing part of Claim 1.

Accordingly, this return pump - including a booster pump possibly provided in association with the return pump - is activated as soon as a driven vehicle wheel - although it is not yet experiencing an excessive drive slip corresponding to the response threshold value of the drive slip control which demands "countering" by the control system - has reached a value of drive slip of this vehicle wheel which is higher - by a specified amount - than the required value specified for the control system so that it can be anticipated that this vehicle wheel will experience a still higher drive slip in the immediate future and will therefore be subjected to a control cycle. With the activation of the return pump, or slightly retarded relative to it, the brake pressure control valves of the driven vehicle wheels are also driven into their closed position and, similarly, the drive slip control valve is driven into its position shutting off the main brake pipe from the brake device. By this means, a higher pressure is already generated in the section of the main brake pipe of the brake circuit of the driven vehicle wheels branching towards the wheel brakes and this pressure can then be connected to the wheel brake "immediately", when control on the vehicle wheel considered has to become effective, by switching the brake pressure control valve of this wheel into its brake pressure build-up position. The section of the main brake pipe branching off to the wheel brakes, and a noise suppressor which is usually connected to it (this noise suppressor being normally provided only to buffer the pressure shocks from the return pump), is then used, so to speak, as a high pressure reservoir. Although the storage capacity of the latter is markedly less than the storage capacity of the pressure reservoir provided as the auxiliary pressure source in a drive slip control device of known type, it still permits the brake pressure build-up phase in the wheel brake of the particular vehicle wheel subjected to the control system, this build-up phase initiating the drive slip control cycle. Although the pressure level is only moderate, there is practically no delay and to this extent the build-up provides a desirably rapid response behaviour to the drive slip control procedure during the further course of which the return pump can "take over" the build-up of the pressure to the necessary brake pressure level.

The control signals necessary for activating the return pump and for switching over the drive slip control valve and the brake pressure control valves are obtained from the electronic control unit of the drive slip control device by processing the output signals of the wheel speed sensors associated with the individual vehicle wheels according to known criteria; the wheel speed sensors generate electrical output signals characteristic of the dynamic behaviour of the vehicle wheels in terms of level and/or frequency. These output signals also permit an assessment in the sense that the - preparatory, so to speak - activation of the return pump, as provided in Claim 2, can be controlled as a function of increasing values of the wheel peripheral accelerations of the driven vehicle wheels.

The type of pump drive control provided by the features of Claim 3 has the advantage that any influence of the pump running-up period is, so to speak, eliminated. The circulatory operation introducing a control cycle in this way generates a - dynamic - pressure which, although smaller, is still sufficient to bring the wheel brakes into contact so that when, subsequently, the brake device is shut off from the brake circuit - by driving the drive slip control valve - the wheel brakes respond with practically no delay, thus improving the sensitivity of the control system.

The arrangement of the drive slip control valve provided by the features of Claim 4 and the inclusion of this valve and the pressure limiting valve provided for brake pressure limitation in the hydraulic unit of the drive slip control device according to the invention provides a particularly simple structure of the hydraulic unit in terms of switching and control.

Pressure loads on the brake device due to the control system are excluded by means of an additional outlet valve with the arrangement and function given in Claim 5 so that, in combination with the drive slip control device of the invention, a series production, simple design of brake device, e.g. a tandem main cylinder of conventional type, can be used.

The drive slip control device of the invention is achievable at substantially less cost than known equipment of this type and has, in addition, the advantage that the interference noises caused by the operation of individual elements of the control device only appear when the control device is activated in accordance with its purpose but not during normal driving - such as can occur during reservoir recharging phases in a conventional control device.

Further details and features of the invention arise from the following description of a special illustrative example using the drawing, to whose details reference is now expressly made.

The drawing shows an electro-hydraulic block circuit diagram of a twin-circuit hydraulic brake installation 1 of a road vehicle substantially represented by the diagram, the road vehicle being equipped with an anti-lock system 2 and also with a system for drive slip control 3.

In the brake installation 1, the front wheel brakes 4 and 6 are combined to a front axle brake circuit I and the rear wheel brakes 7 and 8 are combined to a rear axle brake circuit II.

A brake device designated in total by 9 is provided for the supply of brake pressure to the two brake circuits I and II; this brake device 9 has two outlet pressure spaces 11 and 12, one allocated to each of the two brake circuits I and II, in which output pressure spaces, the -static - brake pressures P_{FA} and P_{RA} can be built up, controlled by the force K_p with which the driver operates a brake pedal 13 and proportional to this force K_p; these brake pressures P_{FA} and P_{RA} can be connected via the respective main brake pipe 14 or 16 of the front axle brake circuit I and the rear axle brake circuit II to their wheel brakes 4/6 or 7/8. A pneumatic or hydraulic brake force amplifier 17 is also provided as part of the brake device as a "braking aid"; the amplification factor of this brake device can have a value between 3 and 6.

The brake device 9 is otherwise so designed that should the brake force amplifier 17 fail, the brake pressure generating element, a stepped tandem main cylinder 18 in the special illustrative example shown, remains operable by the pedal force K_p alone.

The front axle brake circuit I is connected to the primary output pressure space 11, and the rear axle brake circuit II to the secondary output pressure space 12, of this tandem main cylinder 18, the primary output pressure space 11 having a fixed boundary relative to the casing formed by the larger bore step 19 of the main cylinder casing 21 and boundaries which are axially movable formed by, on the one hand, the primary piston 22 guided so as to be displaceable and pressure tight within this larger bore step 19 and, on the other hand, by the secondary piston 24, designed as a floating piston of the tandem main cylinder 18, guided so that it can be displaced and pressure-tight in the - spatially - smaller bore step 23 of the main cylinder casing 21; the secondary output pressure space 12 is movably bounded by the secondary piston 24 and has a boundary fixed relative to the casing provided by the end wall 26 of the main cylinder 21, viewed in the axial direction.

Where there is no express mention in what follows of special arrangements of the main cylinder 18, it is assumed that this is effected as a known type and with a known function.

It is also assumed that the vehicle is effected on conventional design principles, not shown for reasons of simplicity, and has a rear axle drive, the output torque of the vehicle engine being distributed to the two rear wheels of the vehicle via a rear axle differential.

With respect to the drive slip control, 2, it is assumed that it operates on the pump-back principle in both the front axle brake circuit I and the rear axle brake circuit II, in which, in the brake pressure reduction phases of the anti-lock control, brake fluid drained from one of the wheel brakes 4 and/or 6 and 7 and/or 8 is pumped back into the output pressure space 11 or 12 of the main cylinder 18 associated with the particular brake circuit I or II, so that the brake pedal 13 is forced back towards its basic position by a partial stroke correlated with each quantity of brake fluid pumped back and the driver, by this means, receives an obvious feed-back on the activation of the drive slip control system 2, this becoming clearer and clearer as the magnitude of the pressure reduction in the brake(s) subjected to the control becomes greater.

For each of the two brake circuits, a return pump 27 or 28, is effected as a piston pump in the special illustrative example shown, these having a common electrically driven pump drive 29 usually designed as an eccentric drive - and only shown diagrammatically. In a typical design of the return pumps 27 and 28, the volume pumped per piston stroke is approximately 0.2 cm^3, i.e. approximately twenty piston strokes are necessary of, for example, the return pump 27 allocated to the front wheel brake circuit I, to pump back a brake fluid quantity of 4 cm^3 into the primary output pressure space 11 of the tandem main cylinder 18, which corresponds approximately to that quantity of brake fluid which is taken by the brake cylinders of the front wheel brakes 4 and 6 in total during an operation of the brake installation 1 with maximum operating force, i.e. up to a maximum brake pressure build-up of approximately 180 - 200 bar. The corresponding brake fluid volume of the rear axle brake circuit II is approximately half of this, i.e. 2 cm^3. The consequence of this design of the return pumps 27 and

28 is that the brake pedal 13 is not pushed back to its basic position on a single, steadily proceeding stroke but, so to speak, stepwise, the return push of the brake pedal 13 in each of these steps being by a small partial stroke h, this partial step being given by the relationship

$$h = V_{RFP} / F_{Pr}$$

where V_{RFP} is the volume pumped by the return pump 27 or 28 per piston stroke and F_{Pr} is the effective cross-sectional area of the primary piston 22 of the tandem main cylinder 18.

The two brake pipe branches 32 and 33 emerging from a branching position 31 of the main brake pipe 14 of the front axle brake circuit I and the brake pipe branches 36 and 37 emerging from a branching position 34 of the main brake pipe 16 of the rear axle brake circuit II, through which the brake pressure is fed into the wheel brakes 4 and 6 of the front wheel brake circuit I and to the wheel brakes 7 and 8 of the rear wheel brake circuit II during a "normal" braking action, i.e. one not subject to the anti-lock control, are each led via an inlet valve 38 and 39 or 41 and 42 which, when the anti-lock system 2 or the drive slip system 3 has not responded, take up their basic positions 0 shown - their through-flow positions - in which the wheel brake cylinders of the front wheel brakes 4 and 6 and of the rear wheel brakes 7 and 8 are connected to the main brake pipe 14 or 16 of the respective brake circuit I or II via a flow path 43 of each of these inlet valves 38 and 39 or 41 and 21, it being possible either to build up or to reduce brake pressure by appropriate actuation of the brake unit 9 in the basic positions 0 of these inlet valves 38 and 39 or 41 and 42.

These inlet valves 38/39 and 41/42 are designed, in the special illustrative example shown, as 2/2-way solenoid valves which (when their switching solenoids 44 are actuated - individually or severally, depending on which of the vehicle wheel(s) is to be affected by the control - by output signals from an electronic control unit 46 provided for the functional control of both the anti-lock system 2 and the drive slip control 3) can be driven, into their excited position I - their shut-off position - in which the wheel brake(s) 4 and/or 6 and 7 and/or 8 of the front axle brake circuit I and the rear axle brake circuit II subject for the moment to the control is/are shut off from the particular main brake pipe 14 or 16.

In addition, the wheel brake cylinders of the front wheel brakes 4 and 6 and of the rear wheel brakes 7 and 8 are connected via outlet valves 47/48 and 49/51 respectively to a return pipe 52 of the front axle brake circuit I and a return line 53 of the rear axle brake circuit II, respectively, low pressure reservoirs 54 and 56 being respectively connected to these circuits, the storage capacities of these reservoirs being equal to about half the brake fluid volumes which have to be drained from the wheel brakes 4 and 6 of the front wheel brake circuit I and from the wheel brake 7 and 8 of the rear axle brake circuit II in order to permit, in these, a brake pressure reduction to the lowest possible value even when the maximum possible values of the brake pressures p_{FA} and p_{RA} respectively have been connected to the wheel brakes 4/6 and 7/8.

The outlet valves 47/48 and 49/51 are again designed as 2/2-way solenoid valves which can be driven - individually or severally, depending on which of the vehicle wheels the drive slip control responds to - by excitation of their respective control magnets 57 by means of a control output signal of the electronic control unit 46, from their basic position 0, their shut-off position, into their excited position I, their through flow position, in which that or those wheel brake(s) 4 and/or 6 and 7 and/or 8, subjected to the control system so as to produce a reduction of brake pressure, is or are connected via the flow path 58 of the particular outlet valve to the return pipe 52 of the front axle brake circuit I and the return pipe 53 of the rear axle brake circuit II.

The pump chambers 59 and 61 of the two return pumps 27 and 28 are connected, via respective inlet non-return valves 62 and 63 to the return pipes 52 and 53 of the front axle brake circuit I and the rear axle brake circuit II, respectively, these input non-return valves 62 and 63 being subjected in the opening direction to relatively high pressure in their respective return pipes 52 or 53, and the low pressure reservoirs 54 and 56 connected to them, relative to the respective pump chambers 59 and 61 and are held in their shut-off position by relatively high pressure in the respective pump chambers 59 and 61 relative to the return pipes 52 and 53. The closing force of the valve springs of these inlet non-return valves 62 and 63 is, in a typical design, equivalent to a pressure of 2-3 bar. Assuming a piston and spring type of design, the low pressure reservoirs 54 and 56 are typically designed in such a way that the preload of their reservoir springs 64 and 65 is equivalent to a somewhat higher reservoir pressure of, for example, 4-6 bar and, if the acceptance capacity of the low pressure reservoir 54 or 56 is fully exploited, it is approximately equivalent to a pressure of 10 bar.

In addition, the pump chambers 59 and 61 of the two return pumps 27 and 28 are connected via respective outlet non-return valves 67 and 68 to the main brake pipe

14 of the front axle brake circuit I or the main brake pipe 16 of the rear axle brake circuit II, these outlet non-return valves 67 and 68 being subjected in the opening direction to a pressure in the respective pump chambers 59 and 61 which is higher relative to that in the connected main brake pipes 14 and 16 and being held in the shut-off position by a pressure in the respective main brake pipe 14 or 16 which is higher relative to that in the connected pump chamber 59 or 61.

The outlet non-return valves 67 and 68 are also designed in such a way that their closing force is equivalent to a pressure of 2-3 bar.

The elements provided "within" the anti-lock system 2 for the anti-lock control on the rear wheel brakes 7 and 8, i.e. the inlet valves 41 and 42 and the outlet valves 49 and 51, the piston pump 28 associated with the rear wheel brake circuit II and the low pressure reservoir 56, are also used for similar purposes as part of the drive slip control 3, which only acts "on the rear axle".

The return pump 28 is then used for an additional function, i.e. as the pressure generating element for the drive slip control, the outlet pressure of which pressure generating element being connected during a response of the drive slip control to the wheel brake cylinder(s) of the wheel brake(s) 7 and/or 8, on which a spin tendency appears.

The section leading from the secondary outlet pressure space 12 associated with the rear axle brake circuit II to the branching position 34 of the main brake pipe 16 of the rear axle brake circuit II is connected, by means of a drive slip control valve 69 (which is connected "between" the pressure outlet 71 of the secondary outlet pressure space 12 and a connection position 72 of the main brake pipe 16 at which the outlet side of the outlet non-return valve 68 of the return pump 28 is connected to the main brake pipe 16) can be shut off relative to the outlet pressure space 12 of the tandem main cylinder 18 of the brake device 9.

This drive slip control valve 69 is designed as a 2/2-way solenoid valve whose basic position 0 is its through-flow position in which the pressure outlet 71 of the brake device 9 associated with the rear axle brake circuit II is connected to the main brake pipe 16 of the rear axle brake circuit II branching to the wheel brakes 7 and 8.

When the drive slip control system 3 responds, the control magnet 73 of the drive system control valve is switched into its excited position I - the shut-off position - for the duration of the activation of the drive slip control by means of an output signal from the electronic control unit 46, which is also responsible

for actuating the individual control phases of the drive slip control and, by this means, the brake device 9 is disconnected from the rear axle brake circuit II. An electrically driven booster pump 73 is provided as a further, additional functional element of the drive slip control system 3, by means of which booster pump, again controlled by output signals from the electronic control unit 46, brake fluid can be pumped from the chamber 74, associated with the rear axle brake circuit II, of the brake fluid reservoir 76 of the brake installation 1 into the pump chamber 61 of the return pump 28 associated with the rear axle brake circuit II, the pressure outlet 77 of the booster pump 73 being connected via an outlet non-return valve 78 to the inlet side of the inlet non-return valve 63 of the rear axle brake circuit II, to which return pump 28 are also connected the low pressure reservoir 56 of the rear axle brake circuit II and its return pipe 53. This outlet non-return valve 78 of the booster pump 73 is subjected in the opening direction to the pump's outlet pressure which is higher relative to that in the low pressure reservoir 56 and the return pipe 53 of the rear axle brake circuit II and is otherwise closed, the closing force of this outlet non-return valve 78 being again equivalent to a pressure of 2-4 bar.
The outlet pressure and the output of the booster pump 73 are both sufficiently generously dimensioned to ensure

that the low pressure reservoir 56 of the rear axle brake circuit II can be completely charged and that the brake fluid flow from the booster pump 73 and the low pressure reservoir 56 to the return pump 28 cannot "separate" while the return pump 28 is operating as the brake pressure source in drive slip control operation.

The outlet pressure level of the booster pump 73 is around 20 bar and is limited to this value by a pressure limiting valve 79, shown as a non-return valve, which is located in a bypass flow path 81 leading back from the outlet 77 of the booster pump 73 to the brake fluid reservoir 76.

The return pump 28 of the rear axle brake circuit II is, like the return pump 27 of the front axle brake circuit I, assumed to be free piston pump, which, in order that this return pump 28 can pump brake fluid into the brake circuit II, assumes a minimum inlet pressure, which is ensured, in the special illustrative example shown, by the booster pump 73.

Because, assuming a sufficiently powerful drive 29, a piston pump can generate an outlet pressure which can be substantially higher than the maximum pressure of 180-200 bar necessary for subjecting the rear wheel brakes 7 and 8 to a correct brake pressure, limitation of the outlet pressure of the return pump 28 of the rear axle brake circuit II is also necessary. A pressure limiting valve 82 provided for this purpose is inserted, in the special illustrative example shown, in a bypass flow path 83 parallel to the drive slip control valve 69, which bypass flow path 83 leads back from the connection position 73 of the main brake pipe 16 to the pressure outlet 71 of the secondary outlet pressure space 12 of the tandem main cylinder 18.

Since, in a driving situation in which the drive slip control 3 responds, the brake installation 1 is not actuated and the secondary piston 24 of the main cylinder 18 is in its basic position in which the secondary outlet pressure space 12 communicates with the brake fluid reservoirs 74, 76 either via a central valve of the secondary piston 24 or via a follow-up bore, brake fluid can drain (via the pressure limiting bypass path 82, 83 and via the secondary outlet pressure space 12 into the brake fluid reservoir 76 chamber 74, connected to the pressure space 12) if the outlet pressure of the return pump 28 exceeds the maximum permissible limiting value of, for example, 200 bar.

The control devices described up to this point, anti-lock system 2 and drive slip control 3, operate as follows in their respective control operations, the two types of control being explained by a typical control cycle for each, in which the driven rear wheel of the vehicle represented by the wheel brake 7 on the right is considered and reference is first made to the anti-lock control function.

During a braking operation, the drive slip control valve 69 remains in the basic position 0 shown - its through-flow position.

If a tendency to lock occurs on the right-hand rear wheel during the course of the braking operation, action is first taken against this locking tendency by an initial brake pressure reduction phase. For this purpose, the inlet valve of the wheel brake 7 is switched into its shut-off position I and the outlet valve 49 of this wheel brake 7 is switched into its through-flow position I. At the same time or - in anticipation - somewhat earlier, i.e. as soon as the electronic control unit 46 "recognises" the appearance of a tendency to lock, the drive 29 of the return pumps 27 and 28 is also switched on. Brake fluid under the brake pressure achieved up to that point flows away through the now open outlet valve 49 out of the wheel brake 7 via the return pipe 53 and, where it is not - partially - pumped back directly by the return pump 28 of the rear axle brake circuit II into the outlet pressure space 12 of the brake device 9 associated with the brake circuit II, it is first accepted by the low pressure reservoir 56 of the rear axle brake circuit II and subsequently, in further pumping strokes of the return pump 28, it is completely pumped back into the rear axle outlet pressure space 12 of the brake device 9, 18. The resulting pulsating "rearwards motion" of the brake pedal 13 against the actuation force K_p provides the driver with an obvious signal of the activation of the anti-lock system 2.

As soon as the locking tendency ends due to the pressure reduction phase, the outlet valve 49 is switched back into its closed basic position 0 while the inlet valve 41 still remains in its shut-off position I. Because of this, the brake pressure value reached due to the control operation on the wheel brake 7 previously tending to lock is initially maintained. If the locking tendency then reappears, the outlet valve 49 is again switched into its through-flow position I so that the brake pressure in the wheel brake 7 is further reduced.

If the locking tendency has died away, the brake pressure is again built up in steps by switching the inlet valve 41 periodically between its shut-off position I and its through-flow position - the basic position 0 - while the outlet valve 49 remains closed until, finally, the outlet pressure existing in the outlet pressure space 12 of the brake device 9 is again connected, to the full amount, to the wheel brake 7 of the rear wheel previously tending to lock.

The return pumps 27 and 28 also remain in operation during the phase where the brake pressure is building up again at the conclusion of the anti-lock control cycle; they are only switched off after a certain safety period during which there has been no further tendency to lock.

In the brake circuit not subjected to the control system, in the front axle brake circuit I in the explanatory example chosen, the activation of its return pump 27 has practically no effect because its pumping strokes contribute, at most, only to a pulsation of the brake pedal 13 and therefore to signalling the activation of the anti-lock system, but not to an increase in pressure in the front axle brake circuit I.

Although explained as a control cycle of a single-wheel control, the anti-lock control of the rear axle can, of course, also take place according to the so-called select-low principle in such a way that if a locking tendency appears on one of the two rear wheels, the brake pressure in both wheel brakes 7 and 8 of the rear axle is lowered, retained and increased again in the same manner. This type of control is desirable for optimum dynamic stability of the vehicle in the case of a braking procedure subject to the anti-lock control.

In contrast to this, the drive slip control (drive slip control function) naturally requires, a "single wheel control" in the sense that activation of the wheel brakes 7 or 8 only takes place on that wheel which tends to spin or simultaneous activation of both wheel brakes 7 and 8 only occurs when both vehicle wheels tend to spin and, in this case, the output torque of the drive unit of the vehicle 1 is then also lowered.

In order to explain a typical control cycle of the drive slip control 3, a starting situation is now assumed in which the drive slip of the right-hand rear wheel increases substantially more than that of the left-hand rear wheel and, in consequence, a situation may soon be expected in which the right-hand rear wheel will "spin" completely with the result that practically no driving torque can be transmitted to the left-hand rear wheel.

As soon as a lower limiting value of the drive slip of the rear wheel of, for example, 30% is reached or exceeded in this situation - the drive slip λ_D being given by the relationship

$$\lambda_D = (v_W - v_V) / v_W,$$

where the v_W designates the wheel peripheral speed of the vehicle wheel considered and v_V designates the vehicle speed or a reference speed representing it approximately and formed from known algorithms - the booster pump 73 and the drive 29 of the return pumps 27 and 28 are switched on - in preparation, so to speak; the drive slip control valve 69 is directed into its activated position I - its shut-off position - simultaneously or somewhat later and, in addition, the inlet valves 41 and 42 of the rear wheel brakes 7 and 8 are also directed into their shut-off positions I with the result that before brake pressure is connected to the wheel brake 7 of the rear wheel to be subjected - in the immediate future - to the control system, a higher pressure is first built up in the part of the brake installation 1 which includes the main brake pipe 16 and the low pressure reservoir 56 of the rear axle brake circuit II and which then acts to some extent like a pressure reservoir "supercharged" to high pressure from which, as soon as the control system has to become effective, brake pressure is connected to the wheel brake 7 by switching back its inlet valve 41 into its basic position 0.

As soon as the tendency to spin on the correctly "selected" vehicle wheel has decreased because its wheel brake 7 has been subjected to pressure and because of the resulting retardation of this vehicle wheel, the inlet valve is initially driven back once more into its shut-off position I in order to keep the brake pressure connected to the wheel brake 7 for a limited period. This switching of the inlet valve 41 takes place even "before" the spin tendency of the wheel considered has completely died away, i.e. even before its drive slip has decreased to beneath a threshold value below which it can again be assumed that a driving torque can again be transmitted to the vehicle to the desired extent via the vehicle wheel subject to the control system and it can be assumed that good driving stability can be ensured at the same time.

If, despite the brake pressure occurring in the wheel brake 7 and maintained by shutting it off from the main brake pipe 16, the spin tendency of the vehicle wheel subject to the control system again increases, the inlet valve 41 of this wheel brake 7 is again switched back into its through-flow position 0 and the brake pressure in the wheel brake cylinder of the wheel brake 7 is increased by this means.

If, after this, the tendency to spin of the vehicle wheel subject to the control system finally dies away, which the electronic control unit 46 of the anti-lock system 2 and the drive slip control 3 "recognises" from the fact that the drive slip $_D$ of the vehicle wheel considered becomes less than a lower limiting value, which is compatible with both good driving stability and adequate drive torque transmission capability, the drive 29 of the return pumps 27 and 28 and the booster pump 73 are initially switched off and the drive slip control valve 69 switched back to its basic position 0, its through-flow position, and subsequently, after a minimum period t_{min} has elapsed, the inlet valve 41 of the wheel brake 7 is switched back into its basic position 0 - the through-flow position - after which the "neutral control" operating condition of the brake installation 1, overall, is again achieved.

The control signals necessary for the correct control, with respect to anti-lock and drive slip control operation, of the inlet valves 38, 39, 41 and 42, the outlet valves 47, 48, 49 and 51, the return pump drive 29, the drive slip control valve 69 and the booster pump 73, are obtained from the electronic control unit 46 provided in common for both control systems - anti-lock system 2 and drive slip control 3 - from the processing taking place according to criteria, which are assumed to be known, of output signals of wheel speed sensors 84/86 and 87/88 which are associated individually with the non-driven and the driven vehicle wheels and which generate output signal characteristic of the wheel peripheral speeds of the individual vehicle wheels - in level and/or frequency - the changes with time of which output signals also containing the information on the acceleration or retardation behaviour of the individual vehicle wheels.

It is assumed that it is possible for a specialist familiar with the usual control algorithms of an anti-lock control system and a drive slip control system, on the basis of his specialist knowledge and without inventive consideration, to produce an electronic control unit 46 which, as a function of threshold values of the brake slip or drive slip and/or of the wheel peripheral retardations or accelerations, to provide correct control of the functional elements of the anti-lock system 2 and the drive slip control 3 described above so that an explanation of the electronic control unit 46 which goes into the details of the electronic circuit technology is unnecessary.

In a further, special and preferred embodiment of the drive slip control device 3, a drive slip control outlet valve 89 is provided; this is connected "between" the return pipe 53 of the rear axle brake circuit II and the chamber 74, associated with this brake circuit II, of the brake fluid reservoir 76 of the brake installation 1.

This drive slip control valve 89 is designed as a 2/2-way solenoid valve whose basic position 0 is its shut-off position, in which the return pipe 53 of the rear axle brake circuit II is shut off from the brake fluid reservoir 76, and whose excited position I is a through-flow position providing communication between this return pipe and the brake fluid reservoir 76. This outlet valve 89 is used for controlling pressure reduction phases of the drive slip control, i.e. in a function which could also be achieved by switching the drive slip control valve 69 into its basic position 0, in which case the pressure reduction would have to take place via the compensating flow path of the main cylinder 18 associated with the rear axle brake circuit II. In this case, however, the provision of a special design for the main cylinder 18 would be unavoidable, this having, in particular, the effect that a central valve (not shown) of the secondary piston 24 would require an especially wear-resistant design, such as a ball valve with metallic sealing surfaces. This valve is held in its open position in the basic position of the piston 24, in which open position it frees a compensating flow path leading from the secondary outlet pressure space 12 of the main cylinder 18 to its brake fluid reservoir 76, and - after a small initial section of the pressure build-up stroke of the secondary piston 24 - reaches its closed position which has to be reached before the pressure build-up in the secondary outlet pressure space 12 of the main cylinder 18 occurs. Such a design of this type of central valve would be necessary so that the latter cannot be damaged due to the "pressure shocks" in the secondary outlet pressure space 12 of the main cylinder 18 associated with pressure reduction phases of the drive slip control.

If pressure reduction phases of the drive slip control, as described above, are controlled by means of the separate drive slip control outlet valve 89, on the other hand, a main cylinder 18 of conventional type can be used as part of the brake device 9 of the brake installation 1, in which main cylinder 18, the compensating flow path, e.g. as shown, can lead via a so-called snifter hole 91 or via a central valve designed in conventional manner - as a disk valve whose valve body is provided with a flexible rubber seal.

CLAIMS:

1. Drive slip control device on a road vehicle having a hydraulic twin-circuit brake installation with front axle/rear axle brake circuit subdivision and the following features:

A. brake circuits, of which one is associated with the non-driven vehicle wheels and the other is associated with the driven vehicle wheels, are designed as static brake circuits whose brake pressure supply is achieved by providing a brake device with two outlet pressure spaces, one associated with each brake circuit;

B. the vehicle is equipped with an anti-lock system operating on the pump-back principle, which system includes brake pressure control valves associated individually with each of the driven and non-driven vehicle wheels and two return pumps associated one each with the two brake circuits, by means of which return pumps brake fluid is pumped back, during pressure reduction phases of the anti-lock control, out of the wheel brake(s) currently subjected to the control system into the brake device output pressure space associated with the particular brake circuit;

C. the return pump of the brake circuit of the driven vehicle wheels is used as the pressure source in the brake pressure build-up phases of the drive slip control;

D. a drive slip control valve is provided for control process connection of the return pump to the brake circuit of the driven vehicle wheels, which drive slip control valve can be driven (by a drive slip control signal from an electronic control unit controlling the control phases of the drive slip control) from a basic position associated with the normal brake operation and anti-lock control operation, in which position the output pressure space of the brake device associated with the brake circuit of the driven vehicle wheels is connected to the main brake pipe of the brake circuit, into an excited functional position I, alternative to the basic position, in which this output pressure space is shut off from the main brake pipe but the latter continues to be connected to the pressure output of the associated return pump;

E, controlled by a brake pressure build-up control signal from the electronic control unit, pressure can be connected to the brake circuit of the driven vehicle wheels by means of the return pump, a pressure limiting valve being provided to limit the pressure connected to the brake circuit of the driven vehicle wheels during drive slip control operation, by means of which pressure limiting valve brake fluid can flow out of the brake circuit of the driven vehicle wheels to the brake fluid reservoir of the brake installation when the output pressure of the return pump exceeds a specified threshold value, wherein:

F. the electronic control unit generates the output signal for driving the drive slip control valve into its excited position I and the output signal procuring the activation of the return pump of the brake circuit (II) of the driven vehicle wheels and the output signals by means of which the brake pressure control valves of the wheel brakes of the driven vehicle wheels are driven into their shut-off position as soon as the drive slip of at least one of the driven vehicle wheels reaches or exceeds a specified threshold value whose magnitude is between the required slip value and the response threshold value of the drive slip control.

2. Drive slip control device according to claim 1, wherein the electronic control unit generates an output signal for controlling the drive slip control valve, the output signal procuring the activation of the return pump and the output signals driving the brake pressure control valves into their shut-off position as soon as the wheel peripheral acceleration of at least one of the driven vehicle wheels exceeds a response threshold value and/or is greater than the vehicle acceleration by more than a specified difference which is fixed or varies with vehicle speed.

3. Drive slip control device according to claim 1 or claim 2, wherein the output signal of the electronic control unit procuring the activation of the pump drive of the return pump of the brake circuit (II) of the driven vehicle wheels is generated as soon as the drive slip of least one of the driven vehicle wheels reaches or exceeds a specified threshold value which is between 50% and 70% of the threshold value at which the drive slip control valve and the brake pressure control valves of the wheel brakes of the driven vehicle wheels are moved into their shut-off position, and/or when the wheel peripheral acceleration of at least one of the driven vehicle wheels exceeds a response threshold value and/or is greater than the vehicle acceleration by a specified difference which is fixed or varies with the speed of the vehicle.

4. Drive slip control device according to any one of the preceding claims, wherein the drive slip control valve is designed as a 2/2-way solenoid valve which is connected between the brake device pressure output associated with the brake circuit (II) of the driven vehicle wheels and the section of the main brake pipe branching to the wheel brakes of the driven vehicle wheels, and the pressure limiting valve is connected in parallel with the drive slip control valve.

5. Drive slip control device according to any one of the preceding claims, wherein an outlet valve designed as a solenoid valve is provided as a further drive slip functional control valve by means of which the return pipe of the brake circuit (II) of the driven vehicle wheels can be directly connected to the brake fluid reservoirs of the brake installation during the pressure reduction phases of the drive slip control.

6. Drive slip control device on a road vehicle having a hydraulic twin-circuit brake installation with front axle/rear axle brake circuit subdivision substantially as described herein with reference to, and as illustrated in, the accompanying drawing.

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