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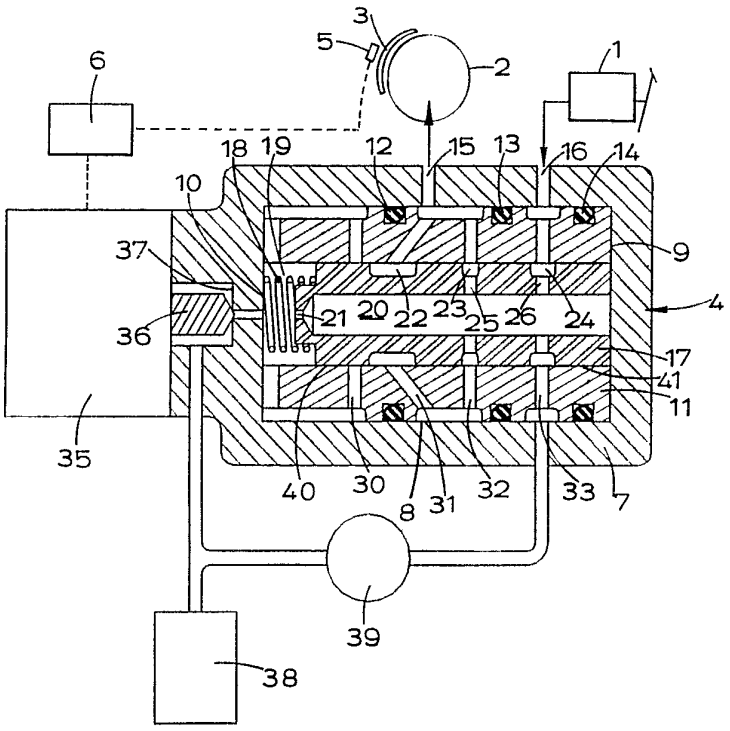
**(54) Title:** IMPROVEMENTS IN HYDRAULIC ANTI-LOCK BRAKING SYSTEMS FOR VEHICLES




**(57) Abstract**

In a hydraulic anti-lock braking system a flow control valve operates with a single-acting solenoid-operated valve (35), and the flow control valve incorporates a spool (17) working in a bore (8) in a housing (7) with the flow directed through a passage (20) passing substantially through the centre of the spool (17). A fixed orifice (21) is located at the one end of the spool which defines a chamber (19) for a control spring (18), and a variable orifice is defined between a port (33) in the housing (7) and a metering edge on the input side of an annular groove (24) in the spool (17) and which communicates with the passage (20) in the spool (17).

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# IMPROVEMENTS IN HYDRAULIC ANTI-LOCK BRAKING SYSTEMS FOR VEHICLES

This invention relates to hydraulic anti-lock braking systems for vehicles of the kind in which the pressure applied to a braked wheel is controlled in response to signals from an electronic control unit, in turn responsive to signals from a speed sensor associated with the wheel.

A system of the kind set forth is disclosed in EP-A-0 202 845. In the system of EP-A-0 202 845 a flow control valve operates with a single-acting normally closed solenoid-operated valve to provide effective control of the pressure in the braked wheel in response to signals from the electronic control unit.

The flow valve of EP-A-0 202 845 embodies a number of novel features namely:-

a) In a first quiescent position, it permits a free flow of fluid between an inlet connected to the input from an hydraulic master cylinder and and outlet connected to the output to the brake;

b) In a first transient position the master cylinder is isolated from the brake;

c) In a second transient position the brake is connected to an expansion chamber by way of the solenoid-operated valve which is open; and

d) In a second quiescent position, the flow valve meters fluid from the inlet to the outlet at a rate determined by a constant pressure drop across an orifice in a spool, which pressure drop is

dependent upon the force of a control spring and the area of the spool.

The constant pressure drop also ensures a constant flow rate irrespective of any excess level of input pressure and because the rate at which the volume of the brake increases as the pressure rises, the flow valve provides a variable re-apply rate with brake pressure level. At low brake pressures, the re-application rate is relatively slow which compensates for the reduced wheel acceleration rate on slippery surfaces. At higher brake pressures, for high friction road conditions, the ability for the wheel to accelerate is increased and the re-application of brake pressure following a skid correction can also be increased.

EP-A-0 344 544 discloses a flow valve having similar features to those of EP-A-0 202 845. In EP-A-0 344 544 however the flow is directed through the centre of the spool. This has the advantage of a longer leakage path between the input and the output whilst the spool is in its control mode, but with the inherent disadvantage of increasing from two to three the number of parasitic leakage paths between a chamber accommodating the control spring and the input/output connections at least when the solenoid-operated valve is actuated. In EP-A-0 344 544 a fixed orifice is located at an intermediate point in the length of the centre of the spool.

According to our invention, in an hydraulic anti-lock braking system of the kind set forth a flow control valve operates with a single-acting solenoid-operated valve, and the flow valve incorporates a spool working in a bore in a housing

with the flow directed through a passage passing substantially through the centre of the spool, a fixed orifice is located substantially at the one end of the spool which defines a chamber for a control spring, and a variable orifice is defined between a port in the housing and a metering edge on the input side of an annular groove in the spool and which communicates with the passage in the spool.

In the skid control or ABS mode the tolerances affecting the clearances between the spool and the bore are relatively non-critical since the flow valve has only one parasitic leak path whilst the spool is in transient mode and with only one extra leakage path whilst the spool is in metering mode.

Our invention retains all the benefits of the flow valves of EP-A-0 202 845 and EP-A-0 344 544 but has a reduced parasitic leakage between the spring chamber and the input/output. This enables larger tolerances to be used between the spool and the bore.

Locating the fixed orifice substantially at one end of the spool with the absence of flow passages beyond the orifice facilitates tolerance free machining, suitably gauge machined using the end face as a datum.

Our invention therefore not only utilises the reduced leakage between input and output, but also reduces the parasitic leakage between the spring chamber and the input/output to one when the solenoid-operated valve is opened.

The flow valve may be provided with an attenuation chamber and orifice to reduce the driver's pedal

reaction. This attenuates the difference between the pump output and the flow being metered to the brake.

Some embodiments in accordance with our invention are illustrated in the accompanying drawings in which:-

Figure 1 is a layout of an hydraulic anti-lock braking system for a vehicle;

Figure 2 is a layout similar to Figure 1 but showing a modified construction;

Figure 3 is a layout of another anti-lock braking system for a vehicle;

Figure 4 is a layout of yet another anti-lock braking system for a vehicle; and

Figure 5 is a layout of still another anti-lock braking system for a vehicle.

The braking system illustrated in Figure 1 of the accompanying drawings comprises a pedal-operated hydraulic master cylinder 1 for applying a brake 2 on a wheel 3 of a vehicle through a modulator assembly 4. The behaviour of the wheel is sensed by a wheel speed sensor 5 which sends signals to an electronic control unit 6, and the signals are differentiated by the unit which, in turn, emits an energising current to control operation of the modulator assembly 4.

The modulator assembly 4 comprises a housing 7 having a longitudinal bore 8 extending between axially spaced faces 9, 10 at opposite ends of the housing 7. A sleeve 11 received in the bore 8 is provided with three annular seals 12, 13, 14 of which the seals 12

and 13 are disposed on opposite sides of an outlet passage 15 leading to the brake 2, and the seals 13 and 14 are disposed on opposite sides of an inlet passage 16 from the master cylinder 1.

A spool 17 works in the bore of the sleeve 11 and is biassed against the face 9 by a spring 18 housed in a chamber 19 between the opposite end of the spool 17 and the face 10. The spool 17 has a central passage in the form of a drilling 20 with a fixed restrictor 21 at or adjacent to the end adjacent to the spring chamber 19. The spool 17 is also provided with three, external, annular grooves 22, 23, 24 of which the two grooves 23, 24 furthest from the spring chamber 19 have radial passages 25, 26 communicating with the drilling 20.

The sleeve 11 has three grooves 27, 28, 29 and four cross passages 30, 31, 32, 33 adapted to connect with the grooves 22, 23, 24 in either a quiescent or transient state.

A single acting solenoid operated dump valve 35 has a valve member 36 which normally engages with a seating 37 in the housing 7 to isolate the spring chamber 19 from an expander chamber 38, and a pump 39 is adapted to withdraw fluid from the expander chamber 38 and return it to the cross passage 33.

In a normal inoperative position for normal brake operation fluid from the master cylinder 1 passes freely through the cross passages 33, the radial passages 26, the central drilling 20, the radial passages 31 and the outlet passage 15 to the brake 2.

Upon receipt of a skid signal from the electronic control unit 6, the solenoid-operated valve 35 opens to connect the spring chamber 19 to the expander chamber 38. At this point fluid flows from the inlet 16 to the spring chamber 19 through the restrictor 21 and leaks through a single leak path defined by a land 40 between the end of the spool 17 and the groove 22.

When the pressure differential across the area of the spool 17 subjects the spool 17 to a force sufficient to overcome the force of the spring 18, the spool 17 moves to:-

a) Isolate the inlet 16 from the outlet 15;

b) Connect the outlet 15 to the expander chamber 19; and

c) Attain its metering position defined by a variable orifice constituted by the co-operation of the groove 24 with the passages 33 with the edge on the input side.

The reduction in pressure permits a recovery of the wheel 3, the skid signal is cancelled, and the solenoid-operated valve 35 is closed. The spool 17, however, remains in its metering position with the outlet 15 and the spring chamber 19 interconnected whilst the output pressure is less than the input pressure. In its metering mode the spool 17 has a leakage past the land 41 at the end of the spool 17 remote from the spool chamber 19. This leakage will be smaller than the metered flow and is directed to the brake 2 through the restricted orifice. Since the

leakage is not between the inlet 16 and the outlet 15, there is no parasitic leakage.

When the solenoid-operated valve 35 is first opened, the initial pressure drop of fluid in the spring chamber 19 provides the differential necessary to cause the spool 17 to move against the spring 18. Ideally, no leakage between the inlet 16 and the spring chamber 19 should occur but, of necessity, flow occurs across the fixed orifice 21. Any other leakage is parasitic but such leakage occurs only at the land 40 immediately adjacent the spring chamber 19. The tolerances controlling clearances in the diameters of the spool 17 and the sleeve 11 can, therefore, be relaxed which means that the components are therefore easier to manufacture.

In the construction described above the pump 39 is adapted to return fluid to the inlet 16 at the same time as the spool 17 is metering fluid into the brake 2. The difference between these two flows, although small, is felt at the brake 2 as a slight pulsation.

In a modified construction as illustrated in Figure 2 of the accompanying drawings, the input from the master cylinder 1 is fed via a steel tube 45 pressed into the housing 7 and the sleeve 11. An annular attenuation chamber 46 is defined between the housing 7 and the sleeve 11 and with which the return from the pump 39 communicates. An orifice 47 in the wall of the tube 45 leads into the annular chamber 46.

The passage 30 is omitted. The portion 48 of the sleeve 11 forward of the seal 12 is increased in diameter to fit the bore 8, and internal bore of the

sleeve 11 is enlarged to provide communication between the passage 31 and the chamber 19 when a land 49 forward of the passage 31 clears the land 40.

In the skid control or ABS mode the pump 39 returns fluid to the enlarged annular attenuation chamber 46 and fluid is metered to the brake 2 via the series of radial passages 33 in the sleeve 11 to the brake 2. Fluid is also metered through the single input defined by the steel tube 45 between the input and the brake 2. The excess flow between the output from the pump 39 and that metered to the brake 2 is attenuated by the fluid in the annular chamber 46 and the orifice 47 in the side-wall of the tube 45.

This improves pedal feel in comparison with the modulator of Figure 1.

The construction and operation of the assembly of Figure 2 is otherwise the same as Figure 1, and corresponding reference numerals have been applied to corresponding parts.

In the modulator assemblies described above the solenoid valve 35 is spring-loaded against the pressure which can be generated at the input. The solenoid valve 35 is positioned adjacent to the spring chamber 19 to reduce to a minimum the volume of the spring chamber 19. This is necessary to avoid premature movements of the spool 17 due to air trapped in the spring chamber 19.

In the modulator assembly 4 illustrated in Figure 3 of the accompanying drawings the solenoid-operated valve 35 is mounted at the opposite end of the housing 7, and the valve member 36 is

extended in length to project with clearance through the centre drilling 20 in the spool 17. A portion 50 terminating at the free end of the valve member 36 is guided in a guide 51 to maintain concentricity between the valve member 36 and the drilling 20.

The fixed orifice 21 is defined by an annular passage between the valve member 36 and an opening of reduced diameter at the inner end of the spool 17 adjacent to the chamber 19.

The solenoid valve 35 is pressure loaded onto the seating 37 and only a light spring is required. This is advantageous since the valve is easy to open at the low pressures encountered on low friction surfaces, and more difficult to open at the high pressures appropriate to braking on high friction surfaces. Consequently the solenoid valve 35 is quicker to act on low friction road surfaces where rapid wheel excursions from true speed are more likely. The solenoid armature is located in the input chamber and does not contribute extra volume to the spring chamber 19.

The construction and operation of the modulator assembly of Figure 3 is otherwise the same as that of Figure 1, and corresponding reference numerals have been applied to corresponding parts.

In the assembly illustrated in Figure 4 of the accompanying drawings the solenoid-operated valve 35 is parallel to the bore 8 with the valve member 36 passing through an output chamber 50 leading to the brake 2.

Although an extra parasitic leak point is added, the leak path disappears when the spool 17 is in its

metering position and the output chamber 50 and the spring chamber 19 are connected together.

The passages 31 are omitted.

The construction and operation of the assembly of Figure 4 is otherwise the same as that of Figure 1 and corresponding reference numerals have been applied to corresponding parts.

The braking system illustrated in Figure 5 of the accompanying drawings comprises two modulator assemblies 40, 41. Reference numerals corresponding to those used in Figure 1 have been applied to corresponding parts of the modulator assemblies 40 and 41. One modulator assembly controls the application of the right hand brake, the other controls the application of the left hand brake.

The spool 17 in the modulator assembly 40 is shown in the normal inoperative position, and the spool 17 in the modulator assembly 41 is shown in its metering position.

Passage 33 is displaced axially towards the wall 9 with respect to the passage 32, to isolate the attenuation chamber from the master cylinder other than through the restrictors 21 in the spools 17 and the sleeves 11 of the modulator assemblies 40, 41.

When solenoid-operated valve 35 is first opened, the initial pressure drop of fluid in the spring chamber 19 provides the differential necessary to cause the spool 17 to move against the spring 18, and isolate the brake 2 from the master cylinder 1 by closing the inner end of passage 33.

Further movement of the spool in the same direction isolates the master cylinder, closes the port at the inner end of the passage 33, and reaches its metering edge of the groove 24 with the passage 32. At this point the brake pressure is held at a constant level and the pump is adapted to return fluid to the inlet 16. As these two flows are substantially equal, the reaction at the brake pedal is minimal. Pump output can only pass to the master cylinder via the restrictors in both spool sleeves 11.

The construction and operation of the assembly of Figure 5 is otherwise the same as that of Figure 1 and corresponding reference numerals refer to corresponding parts.

CLAIMS

1. An hydraulic anti-lock braking system for a vehicle in which the pressure applied to a braked wheel (3) is controlled in response to signals from an electrical control unit (6), in turn responsive to signals from a speed sensor (5) associated with the wheel, characterised in that a flow valve operates with a single solenoid-operated valve (35), and the flow valve incorporates a spool (17) working in a bore in a housing with the flow directed through a passage (20) passing substantially through the centre of the spool, a fixed orifice is located substantially at one end of the spool which defines a chamber (19) for a control spring (18), and a variable orifice is defined between a port (33) in the housing and a metering edge on the input side of an annular groove (24) in the spool and which communicates with the passage (20) in the spool.

2. An anti-lock system according to Claim 1, characterised in that the flow valve is provided with an attenuation chamber (38) and orifice to reduce the driver's pedal reaction.

3. An anti-lock system according to Claim 1 or Claim 2, characterised in that there are no flow passages beyond the fixed orifice (21) at the end of the spool (17).

4. An anti-lock system according to any preceding claim, characterised in that the spool is provided with external annular grooves (22, 23, 24), at least the two (23, 24) furthest from the control spring chamber having radial passages (25, 26) communicating with the passage (20) and the bore has grooves (27, 28, 29) and cross passages (30, 31, 32, 33) adapted to communicate

with the external annular grooves (22, 23, 24) of the spool.

5. An anti-lock system according to Claim 4, characterised in that of the two cross passages furthest from the control spring chamber a first communicates with an input (16) from a master cylinder (1) and a second communicates with the attenuation chamber (38) via a pump (39) which is adapted to withdraw fluid from the attenuation chamber and return it via the second cross passage.

6. An anti-lock system according to any preceding claim, characterised in that the fixed orifice is defined by a valve member (36) of the solenoid-operated valve (35) and an opening (21) of reduced diameter at the inner end of the spool adjacent the control spring chamber (19).

7. An anti-lock system according to claim 5, characterised in that the first cross passage is axially displaced away from the control spring chamber (19) with respect to the second cross passage.

8. An anti-lock system according to claim 5, characterised in that the master cylinder input (16) is fed via a steel tube (45) pressed into the bore.

9. An anti-lock system according to claim 6, characterised in that the valve member (36) of the solenoid-operated valve (35) projects through the passage (20) into the spool (17).

10. An anti-lock system according to claim 9, characterised in that a guide (51) is present to

maintain concentricity between the valve member (36) and the passage (20).

11. An anti-lock system according to claim 6, characterised in that the solenoid-operated valve is parallel to the bore with the valve member (36) passing through an output chamber (50) leading to a brake.

12. An anti-lock system according to claim 6, characterised in that the spool and sleeve assemblies (17, 11) in their rest positions are constructed and arranged to isolate the pump output from the master cylinder other than through the attenuation restrictors (21) located between the master cylinder and pump chamber.

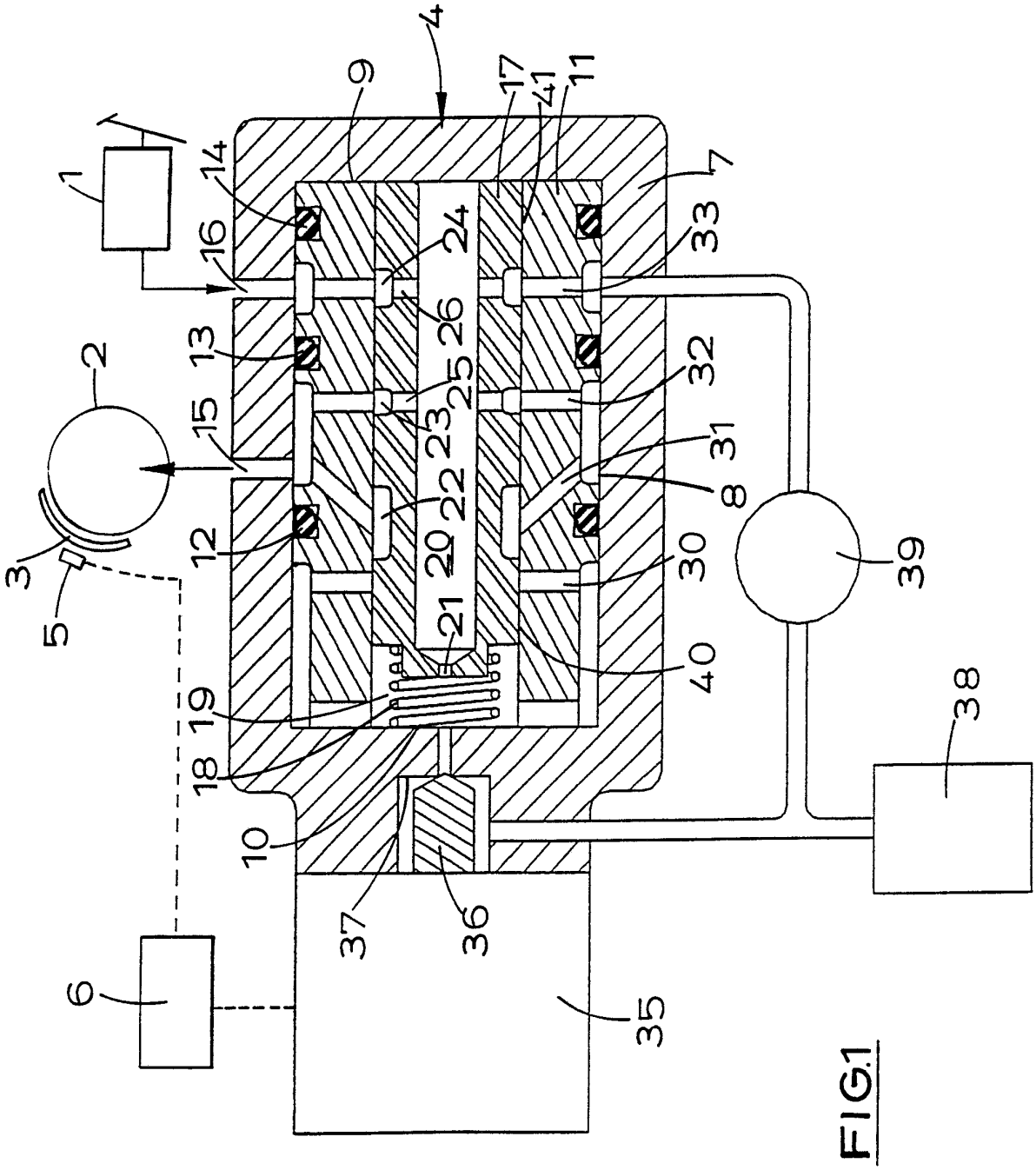
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FIG.1

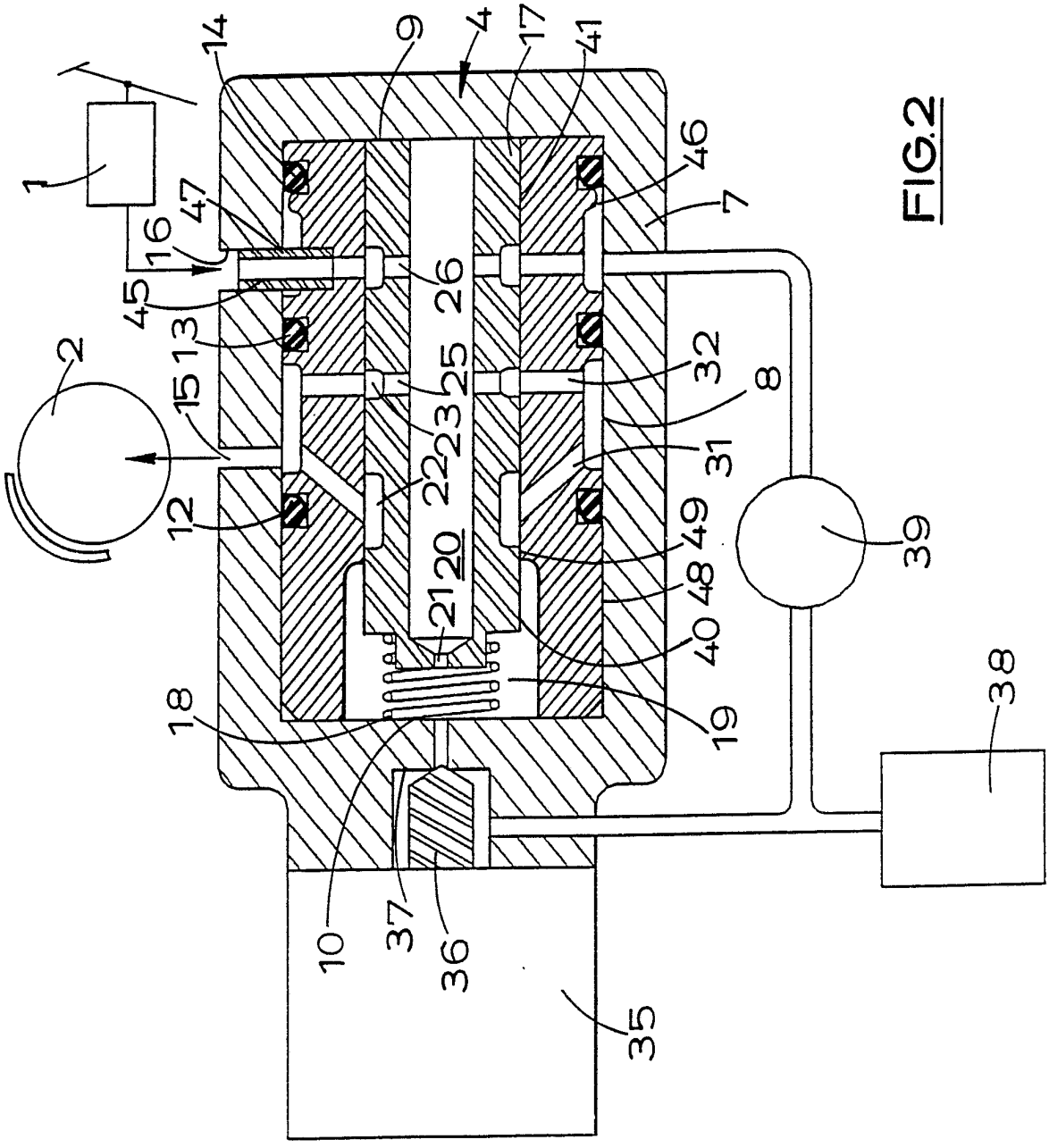
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FIG.2

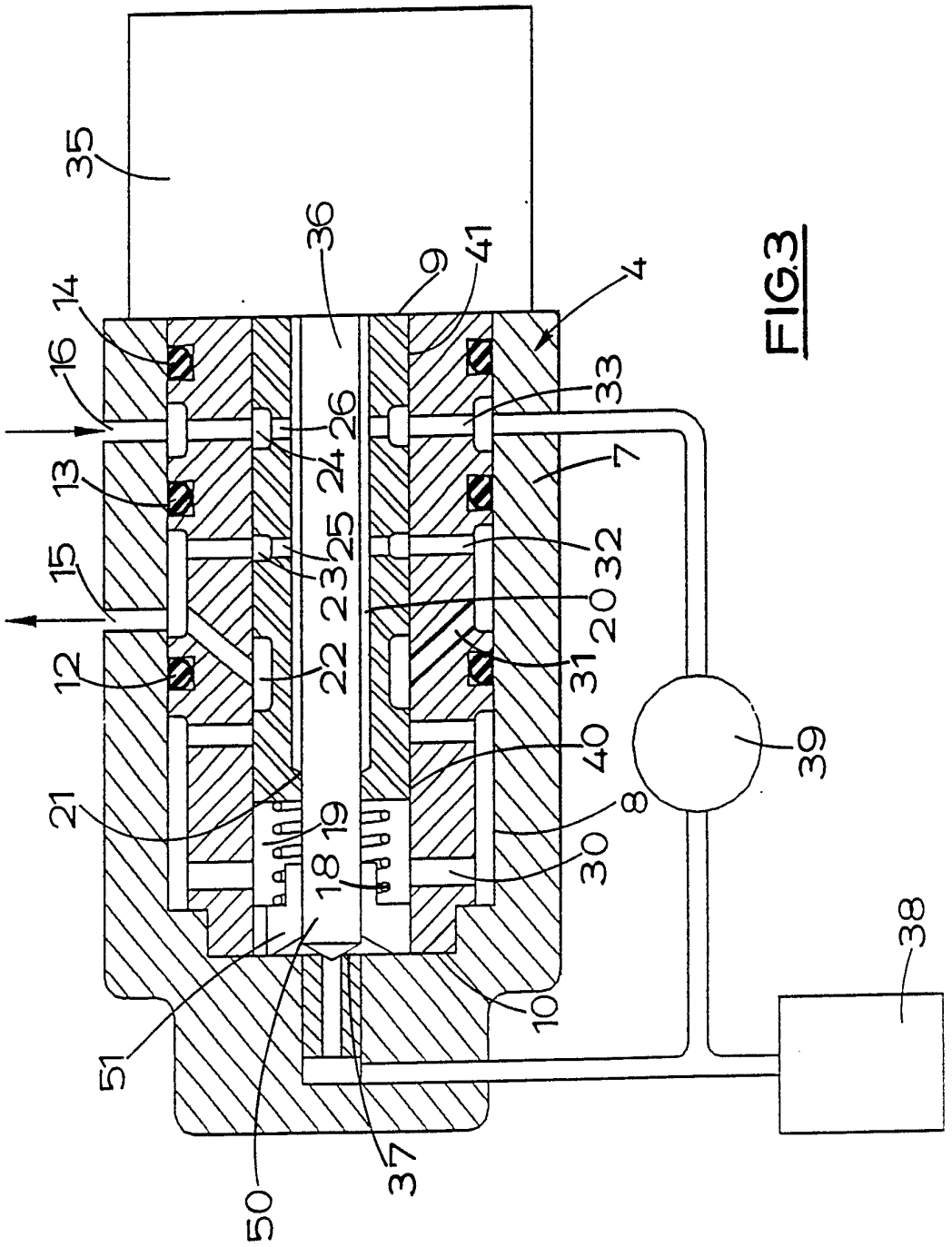
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FIG.3

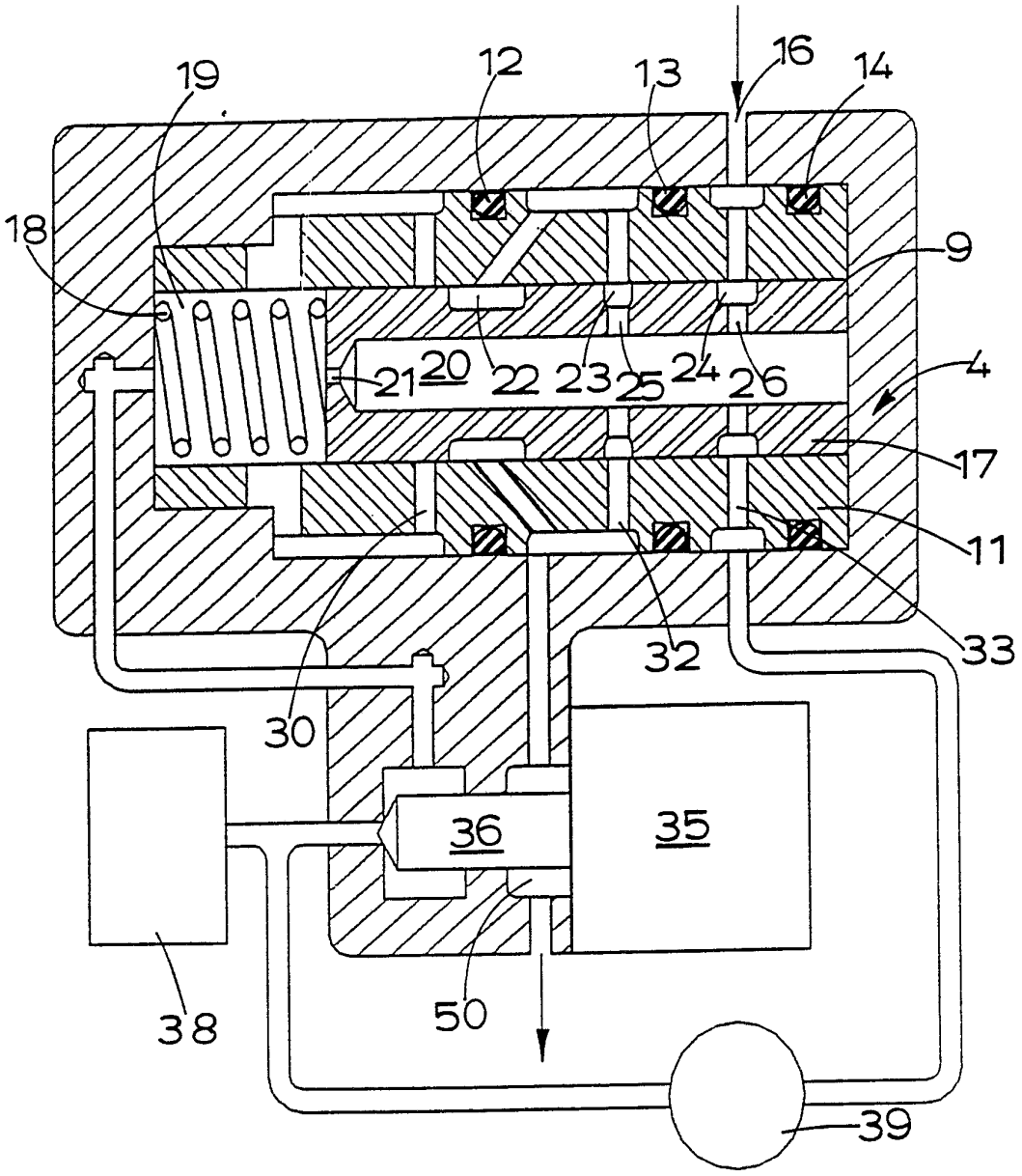


FIG.4

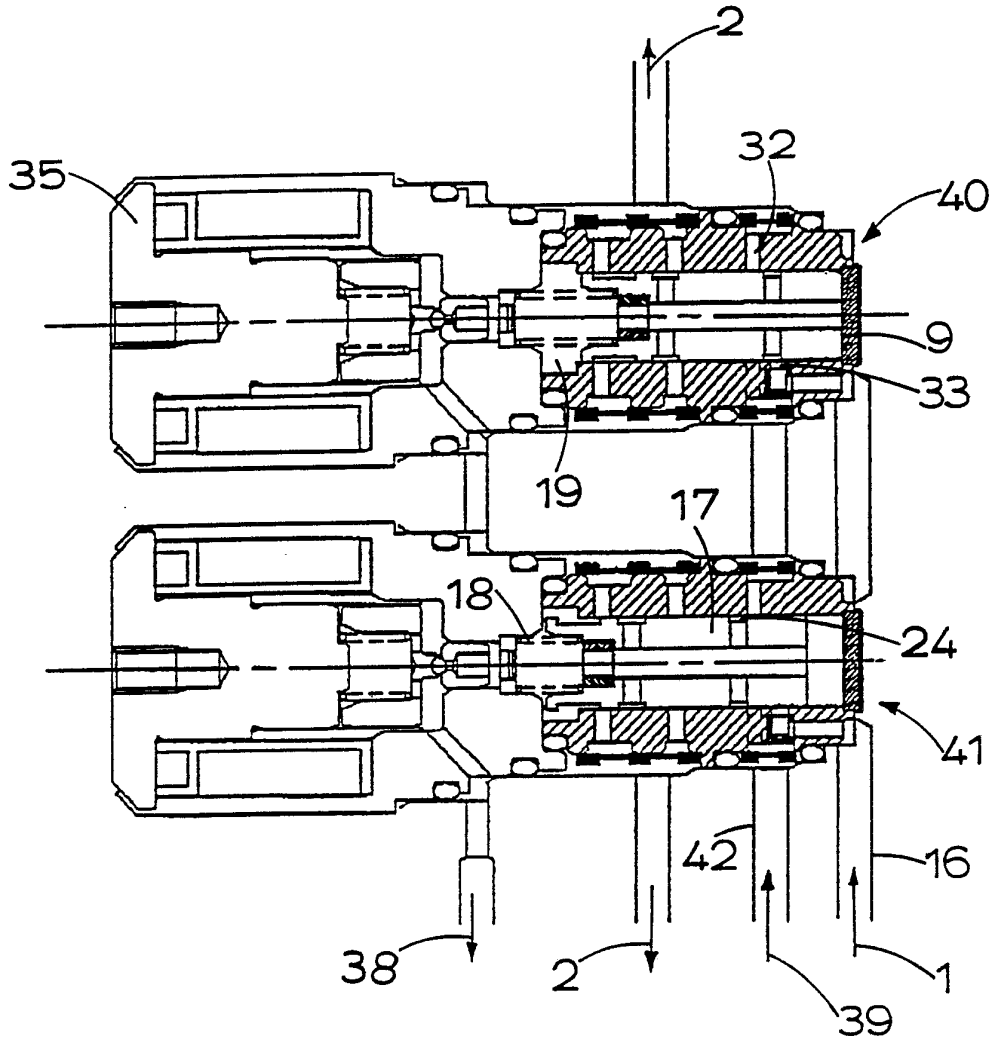


FIG.5

# INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 91/01657

## I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 B60T8/50; B60T8/42

## II. FIELDS SEARCHED

Minimum Documentation Searched[7]

| Classification System | Classification Symbols |
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| Int.Cl. 5 | B60T |

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

## III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

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## IV. CERTIFICATION

| Date of the Actual Completion of the International Search | Date of Mailing of this International Search Report |
|---|---|
| 25 NOVEMBER 1991 | 29. 01. 92 |
| **International Searching Authority** | **Signature of Authorized Officer** |
| EUROPEAN PATENT OFFICE | MEIJS P. |

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

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# ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. GB 9101657 SA 51744

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 25/11/91
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