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EUROPEAN PATENT APPLICATION

⑰ Application number: **80302580.8**

⑸ Int. Cl.³: **F 16 H 39/44, F 15 B 21/04**
// B64C27/54

⑱ Date of filing: **28.07.80**

⑳ Priority: **30.07.79 GB 7926500**

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④③ Date of publication of application: **11.02.81**
Bulletin 81/6

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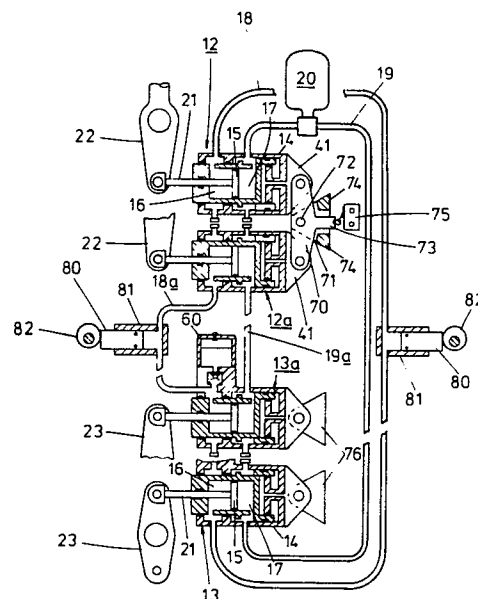
⑧④ Designated Contracting States: **DE FR GB IT SE**

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⑤④ **Fluid power transmission system.**

⑤⑦ A fluid power transmission system comprises a fluid power transmitting unit (12) having a mechanical power input provided by movement of a piston (15) relative to a body portion (14) of the transmitting unit (12) and a fluid power receiving unit (13) having a mechanical power output provided by movement of a piston (15) relative to a body portion (14) of the receiving unit (13). The piston (15) divides a space within the body portion (14) of each unit (12, 13) into first (16) and second (17) chambers. The first chambers (16) of the units (12, 13) are interconnected by a liquid and the second chambers (17) of the units (12, 13) are interconnected by a gas.

Means are disclosed which compensate for changes in the volume of the liquid interconnection due to temperature changes so that a mechanical output from the receiving unit (13) is not affected by such volume changes.



Description of Invention

Title: "Fluid Power Transmission System"

THIS INVENTION relates to fluid power transmission systems particularly, although not exclusively, suited for use in aircraft flying control systems.

Power applied to a control system by a manually operated
5 mechanical input may be transmitted to a remote mechanical output of the system by hydraulic means comprising an incompressible fluid, in practice a liquid, interconnecting between one cylinder space of a piston and cylinder assembly at the input and a corresponding cylinder space of a piston and cylinder assembly at the output. In
10 one such system return to a neutral position is provided by a liquid interconnecting corresponding cylinder spaces on the opposite faces of the pistons. In application to aircraft flying control systems, particularly when a number of controls are to be operated by such fluid power transmission systems, the weight of liquid in
15 the return interconnections is a considerable disadvantage.

In an alternative system having hydraulic power transmission between a mechanical input and a mechanical output, return is provided by operating the piston of a piston and cylinder assembly at the output and against a spring. As well as introducing a risk
20 of system failure due to breakage of the spring in fatigue, this means of return is complicated by the fact that a spring having a constant rate must be provided so as to ensure constant linear output movement is obtained from the system. This latter point is particularly important when effecting movement of aircraft control
25 surfaces.

According to the present invention a fluid power transmission system comprising a fluid power transmitting unit having a mechanical power input provided by a piston arranged for sliding movement relative to a body portion of the power transmitting unit and dividing
30 a space within the body portion into first and second chambers, and a fluid power receiving unit having a mechanical power output provided by a piston arranged for sliding movement relative to a body portion of the fluid power receiving unit and dividing a space



within the body portion into first and second chambers, is characterised in that a liquid interconnects the first chambers of the transmitting and receiving units and a gas interconnects the second chambers of the transmitting and receiving units.

5 Preferably, a fluid power transmission system in accordance with the present invention has temperature compensating means provided in at least one of said fluid power transmitting or receiving units for accommodating changes in volume of the liquid due to temperature change.

10 Such temperature compensating means may be provided by the piston of either one or both of the transmitting and receiving units being slideable within a cylinder which is slideably housed within the body portion of the unit so that mechanical input to the transmitting unit and mechanical output from the receiving unit is
15 by relative movement between the piston and the body portion and temperature compensation is provided by relative movement between the cylinder and the body portion.

At least a part of the area of one end surface of the cylinder is adapted for reaction with a temperature responsive medium
20 contained within a chamber at one end of the body portion of the unit.

The area of the cylinder end surface may comprise an annular surface arranged for entry into the chamber between an internal surface of the bore of the body portion of the unit and a circumferential
25 surface of a fixed piston supported from the end of the body portion.

A reservoir may be provided for the liquid interconnecting the first chambers of the units and is preferably incorporated in the receiving unit.

A reservoir for gas interconnecting the second chambers of the
30 units may be incorporated in a gas line providing the gas interconnection between the second chambers.

The system may be duplicated by an additional power transmitting unit and an additional power receiving unit having their respective first and second chambers interconnected by a
35 liquid and a gas, respectively.

Means may be provided for indicating loss of liquid in one of the liquid interconnections between the pair of transmitting units

and the pair of receiving units. One such indicating means comprises a rocker arm having one of said pair of power transmitting units attached at each end thereof and adapted intermediate its ends for pivotal attachment on support structure
5 so as to actuate signal means when the rocker arm pivots due to an out of balance force applied by one of the transmitting units.

A second mechanical power input may be incorporated in the liquid connection between the first chambers of the transmitting and receiving units so that the mechanical output from the
10 receiving unit may be varied whilst the mechanical input to the transmitting unit is held in a fixed position.

The second mechanical power input may comprise a plunger adapted for movement in cylinder connected in a liquid line providing the liquid connection between the first chambers of the
15 transmitting and receiving units.

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

Figure 1 is a partly sectioned diagrammatic illustration of a fluid power transmission system in accordance with one embodiment
20 of the invention;

Figure 2 is a cross-section taken along the longitudinal centre-line of a fluid power transmitting unit used in the system shown in Figure 1;

Figure 3 is a partly sectioned end view taken along line
25 II - II of Figure 2;

Figure 4 is a cross-section through a liquid reservoir incorporated in a fluid power receiving unit used in the system shown in Figure 1;

Figure 5 is a diagrammatic illustration of a helicopter flying
30 control system incorporating fluid power transmission systems in accordance with the present invention.

A fluid power transmission system, as shown in Figure 1, is duplicated by the provision of two fluid power transmitting units 12, 12a and two fluid power receiving units 13, 13a. Each
35 transmitting and receiving unit comprises a hollow body portion 14 and a piston 15 disposed within the body portion and arranged for sliding movement relative thereto. The piston 15 divides a space



within the body portion 14 into first and second chambers 16 and 17, respectively. Liquid in the respective first chambers 16 of the transmitting units 12, 12a interconnects with liquid in the corresponding first chamber 16 of each of the receiving units 13, 13a by pipe lines 18, 18a, and a gas in the respective second chambers 17 of the transmitting units 12, 12a interconnects with gas in the corresponding second chamber of each of the receiving units 13, 13a by pipe lines 19, 19a.

The pipe lines 18, 18a, 19, 19a, are formed by small bore plastics tubing manufactured from nylon or P.T.F.E. material, the tubing for the gas pipe lines having a maximum internal diameter in the order of 3.5 m.m. (0.125 inch) and the tubing for the liquid pipe line having a maximum internal diameter in the order of 8 m.m. (0.3 inch). The liquid should have a viscosity in the order of $\frac{1}{2}$ 1.96 centistokes at 20°C and 6.16 centistokes at minus 40°C so as to provide a reasonable rate of response at low operating temperatures when using small bore tubing. It is considered that a liquid being a mixture of methanol and water in the range of 55 to 65 per cent VV methanol to water will provide adequate response characteristics. A suitable gas is air or nitrogen contained in the system at a pressure in the order of 250 p.s.i.g. A gas reservoir 20, is provided in the gas pipe line 19 to accommodate variations in gas pressure and leakages of gas from the pipe line 19. A similar reservoir (not shown) is provided in the gas pipe line 19a.

A mechanical power input to the transmitting units 12, 12a is provided by movement of their respective pistons 15 relative to their body portion 14. Each piston 15 projects a piston rod 21 externally of one end of the body portion for connection with a lever 22. Mechanical power output from the receiving units 13, 13a is also accomplished by movement of their respective pistons 15 relative to their body portions 14, the pistons of the receiving units also projecting piston rods 21 externally of the receiving unit body portions for connection with pivotal links 23.

One of the fluid power transmitting units 12, 12a will now be described in detail and with reference to Figures 2 and 3 of the accompanying drawings. The transmitting unit 12 as briefly

described with reference to Figure 1 comprises a hollow body portion 14 and a piston 15 arranged for sliding movement relative to the body portion 14, the piston 15 dividing a space within the body portion into first and second chambers 16 and 17, respectively.

5 The piston 15 is slideable in the bore of a first cylinder 25 of a cylinder assembly 24 which is slideably housed in the bore of the body portion 14. Seals 26 are provided on the piston 15 to prevent leakage between the chambers 16 and 17. One end 27 of the cylinder 25 projects from one end 28 of the body portion 14 sealing being
10 provided by a sealing ring 29 provided in the body portion 14. The piston rod 21 projected by the piston 15 extends externally of the end 27 of the first cylinder 25 through a gland 30 which closes the first cylinder end 27. The gland 30 is retained by a nut and locking washer combination 31. A sealing ring 32 permitting sliding
15 movement of the piston rod 21 is provided in the bore of the gland 30. The piston rod end is provided with an end fitting 33 housing a spherical bearing 33a.

The other end 34 of the first cylinder 25 is located within and attached to an annular flange 35 projecting from the base of a
20 second cylinder 36 which forms a part of the cylinder assembly 24. The external circumferential surface of the second cylinder 36 is a sliding fit in the bore of the body portion 14 of the transmitting unit 12. A fixed piston 37 is housed within the bore of the second cylinder 36 so that the second cylinder 36 is slideable with
25 respect thereto. The fixed piston 37 is carried on a stem projected by a plug 38 which closes the other end 39 of the body portion 14, the plug 38 being held in position by a threaded ring 40. The plug 38 is provided with a lug 41 which projects outwardly with respect to the end 39 of the body portion 14, a spherical
30 bearing 42 being housed in the lug 41. A chamber 43 is formed between that end surface of the plug 38 which is internal of the bore of the body portion 14 and the back face of the fixed piston 37. The second cylinder 36 projects an annular end surface 44 into this chamber 43 between the bore of the body portion 14 and the
35 circumferential surface of the fixed piston 37. A charging connection 45 in the plug 38 provides means for filling the chamber 43 with a temperature responsive medium the purpose of which will

be described later in this specification. A chamber 46 defined by the second cylinder 36 and the fixed piston 37 is vented to ambient atmosphere by a vent-duct 47 having one end opening at the inner-face of the fixed piston 37 and the other end opening at the

5 outwardly disposed end surface of the plug 38 (reference Figure 3).

Referring to Figure 3, the liquid and gas pipe lines 18 and 19, respectively, are connected to the body portion 14 at ports 48 and 49, respectively, by a threaded union 50 and an olive 51 in a known manner. The port 49 connects with a space 52 between the
10 bore of the body portion 14 and the outer circumferential surface of the first cylinder 25, and this space 52 communicates with the second chamber 17 by way of passages 53 in the annular flange 35 of the second cylinder 36, the passages 53 extending radially with respect to the longitudinal axis of the cylinder assembly 24. The
15 port 48 connects with a space 54 between the bore of the body portion 14 and the outer circumferential surface of the first cylinder 25, the spaces 52 and 54 being sealed with respect to each other by a sealing ring 55 provided in the bore of the body portion 14. The space 54 communicates with the first chamber 16 by way of passages
20 56 in the wall of the first cylinder 25.

In operation of the transmitting unit 12 the first chamber 16 is filled with liquid and the second chamber 17 is filled with gas, as has been previously described with reference to the system shown in Figure 1. The chamber 43 is filled with a temperature
25 responsive medium which is a gel obtained by adding a thixotropic filler to liquid as is used for filling the first chamber 16. The null length of the transmitting unit 12 is set by wholly filling the chamber 43 with the gel and then moving the cylinder assembly 24 to expel excess gel through the charging connection 45 until the
30 end 27 of the first cylinder 25 is at a predetermined distance relative to the end 28 of the body portion 14 of the unit 12.

An input of mechanical power to the transmitting unit 12 is provided by movement of the piston 15 relative to the body portion 14; the liquid in the first chamber 16, the pipe line 18 and the
35 corresponding first chamber of a receiving unit 13, forming a liquid strut which moves to effect an equal movement of the piston of the receiving unit 13 relative to the body portion thereof so that there

is an output of mechanical power from the receiving unit 13. The pressurised gas in the second chamber 17 of the transmitting unit 12, the pipe line 19 and the corresponding second chamber of the receiving unit 13 forms a gas strut to provide return of the

5 receiving unit piston when the transmitting unit piston is moved in the opposite direction towards its original position relative to the body portion 12. Should the volume of the liquid in the first chamber 16 of the transmitting unit 12 change due to it absorbing heat from the body portion 14 which has itself been subject to a

10 change in ambient temperature, this will tend to move the piston 15 with respect to the body portion 12 of the transmitting unit 12. In the event of the piston 15 being held fixed, say by an aircraft pilot holding the lever 22 (reference Figure 1), this movement will tend to be effective upon the piston of the receiving unit 13 and,

15 unless compensated for, there will be an uncalled for output from the receiving unit 13. Such a volume change in the liquid due to temperature change is compensated for by movement of the cylinder assembly 24 relative to the body portion 14 to vary the volume of the first chamber 16, such movement to increase the volume of the

20 first chamber 16 being effected by an increase in the volume of the gel in chamber 43. The gel also absorbs heat from the body portion 14 and as the volume of the gel expands it exerts a pressure on the annular end face 44 of the second cylinder 36 which moves the cylinder assembly 24 and hence the first cylinder 25 relative to the

25 body portion 14 in a direction with respect to the piston 15 which increases the volume of the first chamber 16 so as to accommodate the change in volume of the liquid contained therein without effecting movement of the piston 15 with respect to the body portion 14. The effects of temperature changes on the gas in the second

30 chamber 17 are accommodated by pressure changes with the volume of the gas remaining constant. When the body portion 14 of the transmitting unit 12 gives up heat and the volume of the liquid in the first chamber 16 decreases, the pressurised gas in the second chamber 17 acts on the base of the second cylinder 36 to effect

35 movement of the cylinder assembly 24 so as to provide an appropriate volume for the liquid in the first chamber 16. Appropriate movement of the cylinder assembly 24 is achieved by predetermination

of a suitable volume to volume ratio of the liquid containing first chamber 16 and the gel containing chamber 43, in conjunction with a suitable area to area ratio of the piston 15 and the annular end surface 44 of the second cylinder 36.

5 Each fluid power receiving unit 13, 13a of the fluid power transmission system shown in Figure 1 is generally of similar construction to the fluid power transmitting unit 12 which has been described with reference to Figures 2 and 3, and its principle of operation is also similar with the exception that movement of the
10 receiving unit piston 15 is in a direction opposite to that of the transmitting unit piston by which it is produced. However, each receiving unit 13 incorporates on its body portion a liquid reservoir 60 (reference Figure 1 and 4) comprising a cup-like body 61 which engages with an annular groove 62 in the body portion 14
15 of the receiving unit 13. The body 61 of the reservoir 60 is drawn into sealing contact with a soft seal in the groove 62 by means of a breather bolt 63 threaded into the body portion 14 centrally of the annular groove 62. A filler-port and plug 64 is provided in the body 61 of the reservoir 60. A non-return valve
20 65 is secured to the body portion 14 so as to align with a port 66 which extends through the body portion 14 to provide for passage of liquid from the reservoir 60, by way of a slotted recess 67 in the body portion 14 and a port 68 in the wall of the first cylinder 25, to the first chamber 16.

25 Generally the receiving units 13, 13a of the system shown in Figure 1 will be at a position remote from the transmitting units 12, 12a so that each of the transmitting and receiving units will incorporate temperature compensating means because the receiving units may be subject to temperature change independent of the
30 transmitting units and, conversely, the transmitting units may be subject to temperature change independent of the receiving units. However, in a system where both the transmitting and receiving units are so disposed as to ensure they are subject to the same temperature changes, temperature compensating means need be provided in only the
35 transmitting units or the receiving units.

In the duplicated system shown in Figure 1 each of the transmitting units 12, 12a are pivotally connected by their lugs 41

to opposite ends of a rocker arm 70 which is mounted intermediate its ends on support structure 71 by a friction pivot 72. A tongue 73 projected by the rocker arm 70 extends between two stops 74 to engage with a micro-switch 75. This arrangement provides simple means for visual indication of the state of balance between the two systems by observation of the position of the tongue 73 between the stops 74, and for remote indication by any suitable means, for example, a warning light (not shown), arranged for electrical operation by the micro-switch 75. Should a leakage of liquid occur in one of the systems during operation, the other system will continue to operate but will become slightly out of phase such that operation of the lever 22 will be about a slightly displaced null position. Assuming the system developing a leak is that containing the transmitting unit 12 and receiving unit 13, then in a static condition the respective pistons 15 of each of the transmitting units 12, 12a and receiving units 13, 13a are constrained against movement relative to their respective body portions 14 by the lever 22 being firmly held. As the leak continues a pressure gradient develops across the pistons of the transmitting unit 12 and receiving unit 13 allowing the pressurised gas in the second cylinders 17 of the units 12 and 13 to exert a driving force. This force is ineffective towards moving the pistons of the units 12 and 13, and the gas is unable to expand in the second chamber 17 of the receiving unit 13 because the body portion of the unit 13 is firmly anchored to structure 76. However, the gas is able to expand in the second chamber 17 of the transmitting unit 12 by moving the body portion 14 relative to the piston 15 to an extent limited by the tongue 73 of the rocker arm 70 contacting one of the stops 74 as the rocker arm 70 rotates about the pivot 72. This rotation of the rocker arm 70 causes the body portion 14 of the other transmitting unit 12a to be moved a corresponding extent with respect to its piston 15 but in an opposite direction. This reduces the volume of the second chamber 17 of the transmitting unit 12a so that the gas pressure in the system containing the units 12a and 13a is slightly increased which causes the piston 15 in the receiving unit 13a to move to a position in which it is again pressure balanced and in so moving the piston moves the link 23. This movement of the link 23 is

countered by a controller of the system, for example a pilot in an aircraft application, adopting a new null position for the lever 22.

In the fluid power transmission system shown in Figure 1, a
5 plunger 80 and cylinder 81 assembly is provided in each of the liquid lines 18, 18a, the plunger 80 being adapted for movement in the cylinder 81 under control of a cam 82. These plunger and cylinder assemblies permit the mechanical output of the receiving units 13, 13a to be varied independently of any mechanical input
10 from the transmitting units 12, 12a. In operation rotation of the cams 82 to move the plungers 80 into the cylinders 81 will effect movement of the liquid struts formed by the liquid interconnecting the transmitting units 12, 12a and the receiving units 13, 13a. However, because the pistons 15 in the transmitting units 12, 12a,
15 are firmly held by manual control of the lever 22, movement of the liquid struts is effective to move only the pistons 15 of the receiving units 13, 13a relative to their respective body portions 14 by compression of the gas interconnecting the transmission units 12, 12a and the receiving units 13, 13a so that there is a mechanical
20 power output from the receiving units 13, 13a. When the cams 82 are further rotated to permit return movement of the plungers 80 in the cylinders 81 the increase in the gas pressure brought about by its compression is effective to return the pistons 15 of the receiving units 13, 13a towards their original positions relative to the body
25 portions 14 of the units 13, 13a.

The duplicated fluid power transmission system described with reference to Figure 1 finds particular application in a helicopter flying control system as shown in Figure 5. The three main flying controls for a helicopter comprise a collective pitch control
30 system 90 for collectively changing the pitch of main rotor blades 91 attached to a main rotor hub 92, a cyclic pitch control system 93 for cyclic variation of the pitch of the main rotor blades 91, and a tail rotor pitch change system 94 for changing the pitch of tail rotor blades 95 so as to vary the thrust of the tail rotor
35 whereby torque produced by the main rotor is reacted and the helicopter is caused to yaw for directional control. In the collective pitch and cyclic pitch control systems 90 and 93,

respectively, mechanical power input to the fluid power transmitting units 12, 12a is by the pilot manually moving a collective pitch change lever 96 and a cyclic pitch change lever 97. As previously described with reference to Figure 1 the liquid in the fluid power transmission systems transmits this movement to produce a corresponding mechanical output at the fluid power transmitting units 13, 13a which for the collective and cyclic pitch control systems are located near to the rotor hub 92. Output from the receiving units 13, 13a of the collective pitch control system 90 operates a collective pitch change jack 98 which changes the pitch of the main rotor blades 91 by a mechanism that is well known in the art of helicopter engineering. The cyclic pitch change lever 97 is adapted for providing mechanical input to the transmitting units 12, 12a of two fluid power transmission systems, the receiving units 13, 13a of one system providing a mechanical output for operation of a fore-and-aft cyclic pitch change jack 99, and the receiving units of the other system providing a mechanical output for operation of a lateral cyclic pitch change jack 100. In the tail rotor pitch change control system 94 mechanical input to transmitting units 12, 12a is by a foot operated pedal arrangement 101, and mechanical output from receiving units 13, 13a operates a pitch change jack 102 positioned at the tail rotor.

The plunger 80 and cylinder 81 assemblies described with reference to and shown in the fluid power transmission system of Figure 1 provide means for "control mixing" in the helicopter application. For example, should the pilot of the helicopter desire to increase the collective pitch of the main rotor blades in order to climb, he will operate the collective pitch change lever 96. At the same time he will have to operate the foot pedal arrangement 101 so as to increase tail rotor thrust to counteract an increase in main rotor torque which will occur as the collective pitch is increased. To counter the tendency of the helicopter to move laterally in response to the increase in tail rotor thrust, it will be necessary to increase the cyclic pitch so as to produce a lateral component of main rotor thrust opposed to the tail rotor thrust. This may be input to the cyclic pitch change system 93 by the movement of the collective pitch lever 96 being arranged to



operate the plunger and cylinder assemblies of the fluid power transmission systems associated with the cyclic pitch control system 93 so that the pilot is not required to make any movement of the cyclic pitch change lever 97 for this purpose.

- 5 Compared with conventional totally mechanical or totally hydraulic flying control systems a system in accordance with the present invention provides a considerable saving in weight because of the use of gas in the return side of the system. Furthermore, the system is able to tolerate small leakages of gas by changes in
- 10 gas pressure. Also, temperature changes are compensated for in the gas side of the system by changes in gas pressure without affecting the mechanical output of the system so that it is necessary to provide temperature compensating means for only one side of the system.

CLAIMS

1. A fluid power transmission system comprising a fluid power
5 transmitting unit having a mechanical power input provided by a
piston arranged for sliding movement relative to a body portion of
the power transmitting unit and dividing a space within the body
portion into first and second chambers, and a fluid power receiving
10 unit having a mechanical power output provided by a piston arranged
for sliding movement relative to a body portion of the fluid power
receiving unit and dividing a space within the body portion into
first and second chambers, characterised in that a liquid interconnects
the first chambers of the transmitting and receiving units and a gas
interconnects the second chambers of the transmitting and receiving
15 units.

2. A fluid power transmission system as claimed in Claim 1,
characterised in that means are provided in at least one of said
fluid power transmitting unit or said fluid power receiving unit for
20 accommodating changes in volume of the liquid due to temperature
change.

3. A fluid power transmission system as claimed in Claim 2,
characterised in that the piston is slideable within a cylinder
25 which is slideably housed within the body portion so that mechanical
input or output of said respective transmitting unit or receiving
unit is by relative movement between the piston and the body portion
and temperature compensation is provided by relative movement
between the cylinder and the body portions.

30

4. A fluid power transmission system as claimed in Claim 3 wherein
at least a part of the area of one end surface of the cylinder is
adapted for reaction with a temperature responsive medium contained
within a chamber at one end of the body portion of the unit.

35

5. A fluid power transmission system as claimed in Claim 4, wherein
the area of the cylinder end surface comprises an annular surface



arranged to enter the chamber between an internal surface of the bore of the body portion of the unit and a circumferential surface of a fixed piston supported from the end of the body portion.

- 5 6. A fluid power transmission system as claimed in any preceding claim, characterised in that a reservoir for the liquid interconnecting the first chambers of the units is incorporated in the receiving unit.
- 10 7. A fluid power transmission system as claimed in any preceding claim, characterised in that a reservoir for gas interconnecting the second chambers of the units is incorporated in a gas line providing the interconnection.
- 15 8. A fluid power transmission system as claimed in any preceding claim, characterised in that the system is duplicated by an additional power transmitting unit and an additional power receiving unit having their respective first and second chambers interconnected by a liquid and a gas, respectively.
- 20 9. A fluid power transmitting system as claimed in Claim 8, characterised in that means are provided for indicating a loss of liquid in one of the liquid interconnections between the pair of transmitting units and the pair of receiving units.
- 25 10. A fluid power transmitting system as claimed in Claim 9, characterised in that the means for indicating liquid loss comprises a rocker arm having one of said pair of transmitting units attached at each end thereof and adapted intermediate its ends for pivotal attachment on support structure so as to actuate signal means when the rocker arm pivots due to an out of balance force applied by one of the transmitting units.
- 30 11. A fluid power transmitting system as claimed in any preceding claim, characterised in that a second mechanical power input is incorporated in the liquid connection between the first chambers of the transmitting and receiving units so that the mechanical output
- 35

from the receiving unit may be varied whilst the mechanical input to the transmitting unit is held in a fixed position.

12. A fluid power transmitting system as claimed in Claim 11, characterised in that the second mechanical power input comprises a plunger adapted for movement in cylinder connected in a liquid line providing the liquid connection between the first chambers of the transmitting and receiving units.

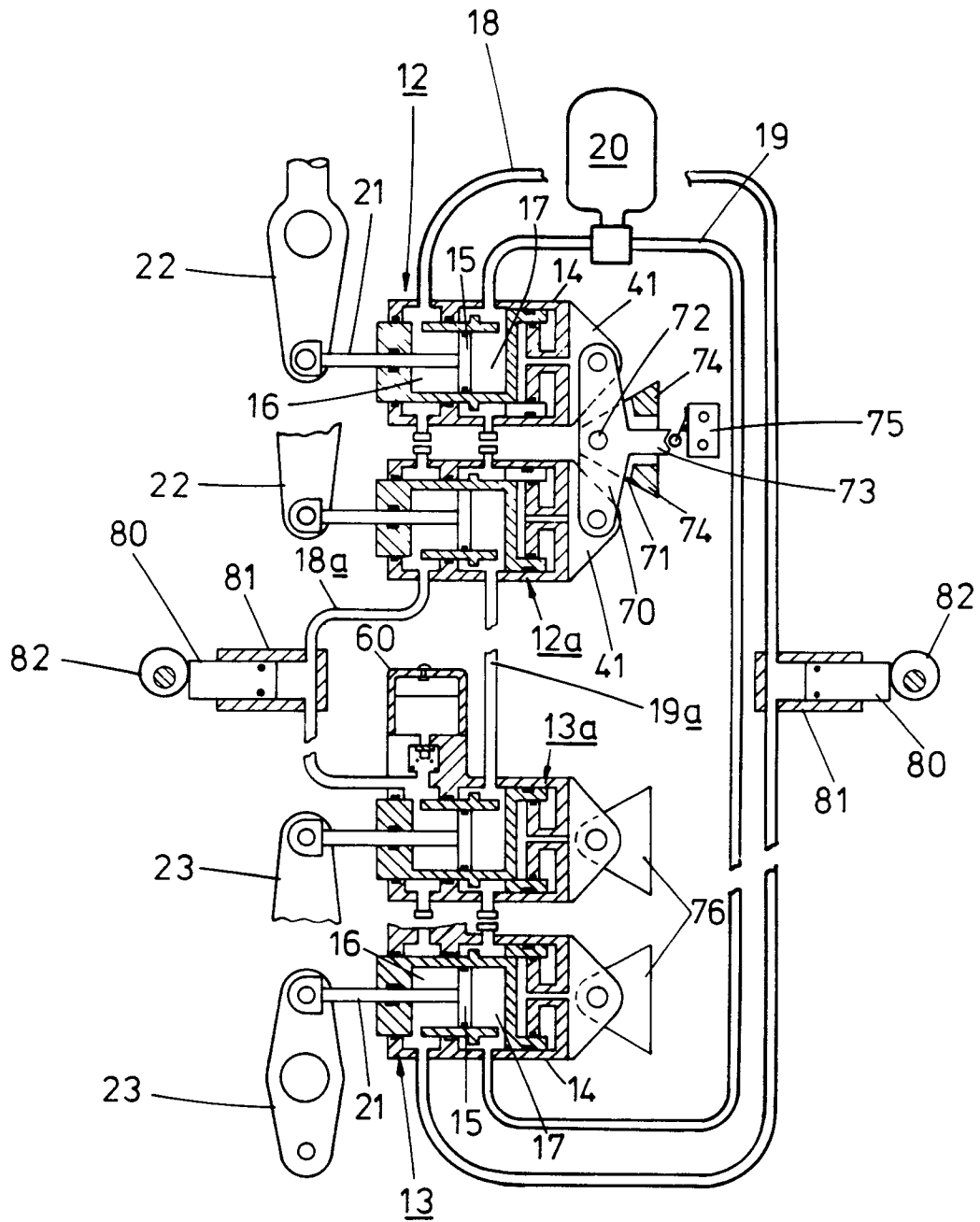


FIG. 1

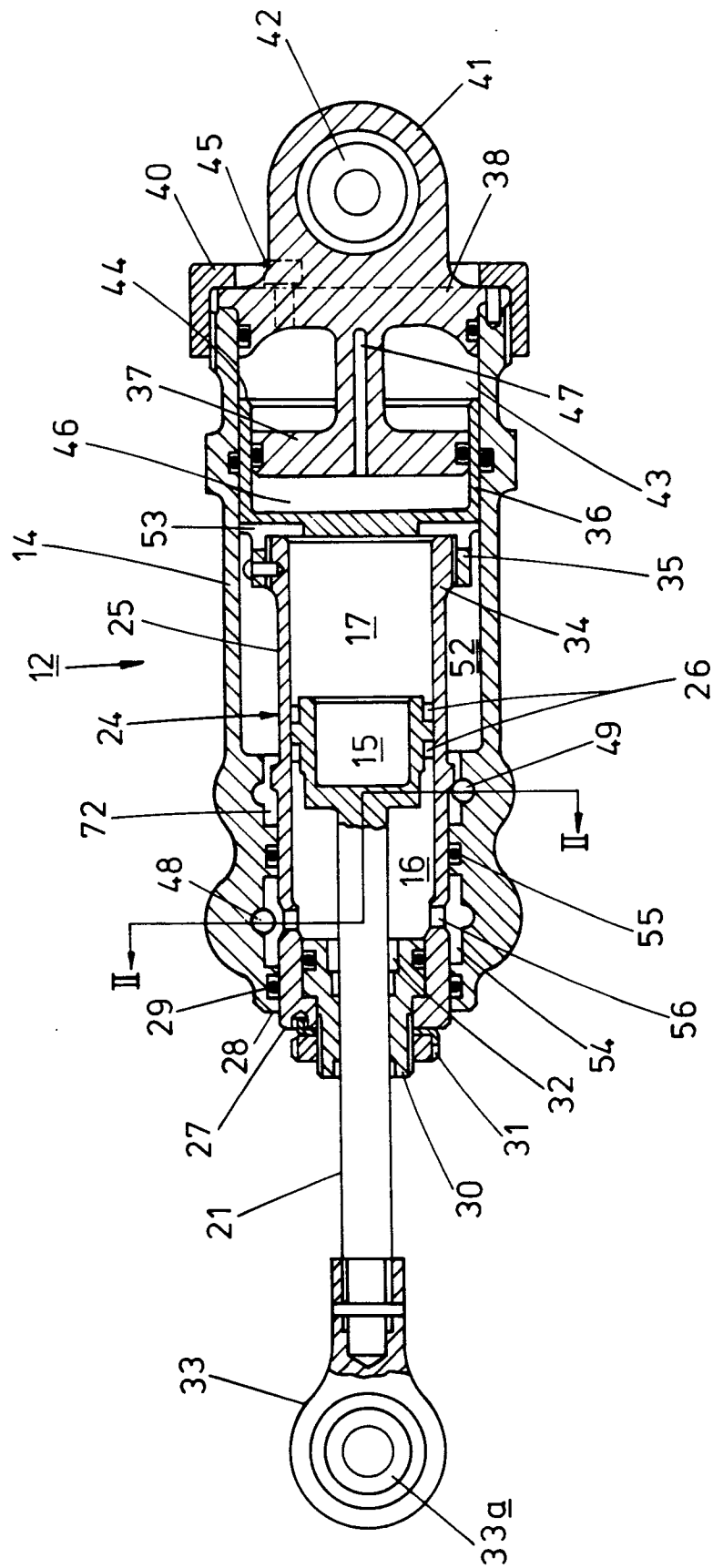


FIG. 2

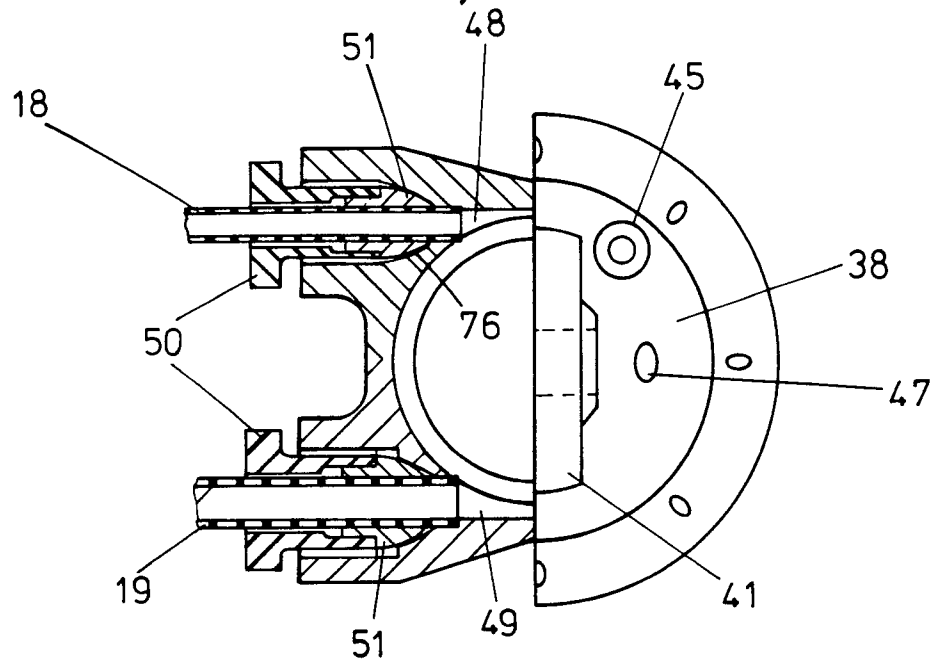


FIG. 3

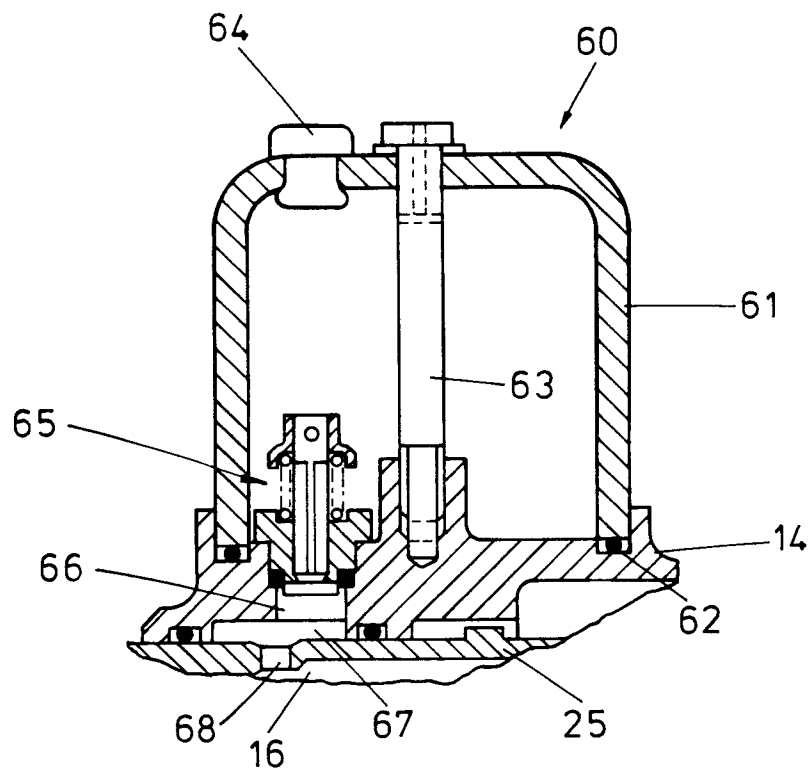


FIG. 4

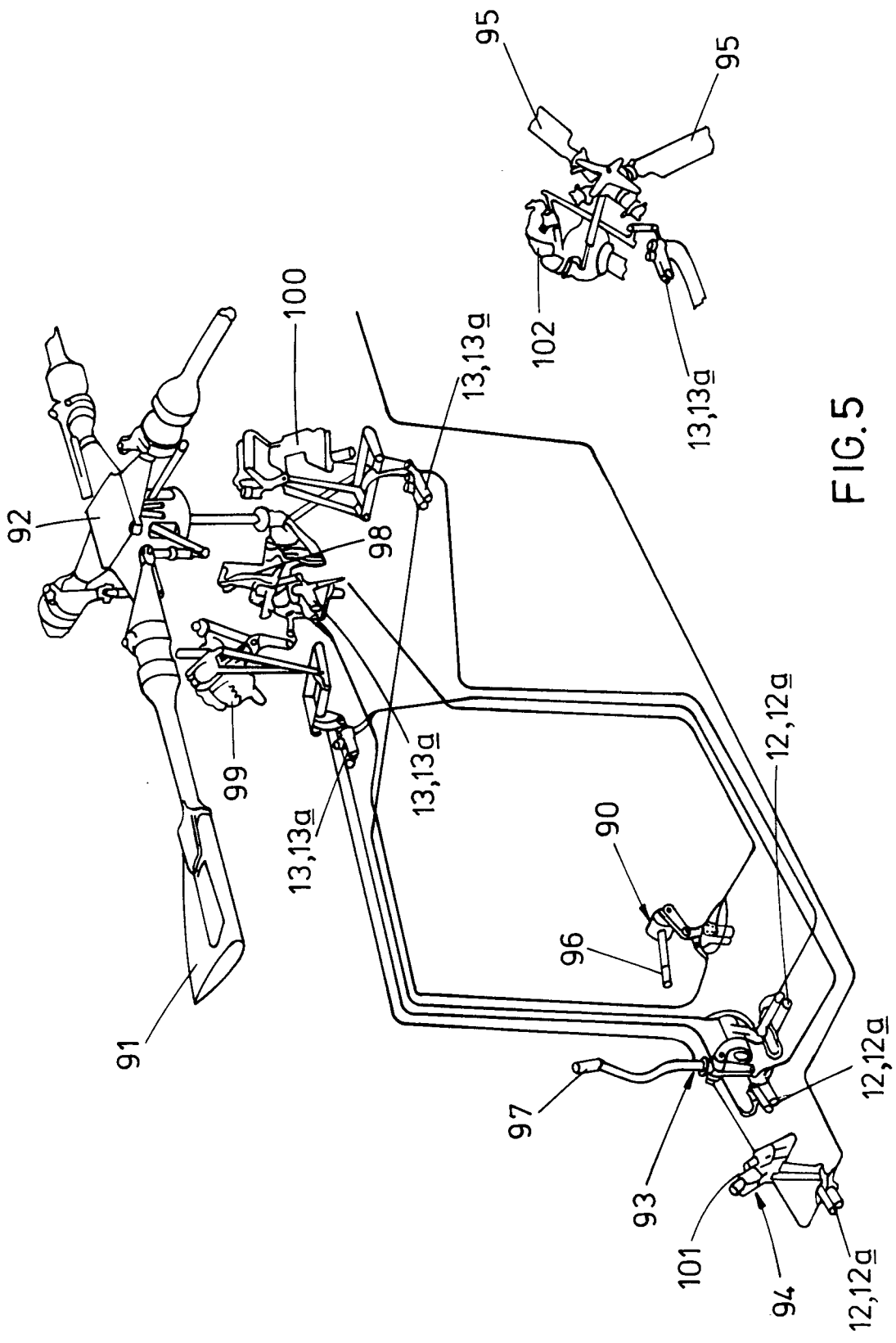


FIG.5