

(19)



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(11)

EP 0 828 946 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:

11.07.2001 Bulletin 2001/28

(21) Application number: **95929784.7**

(22) Date of filing: **28.08.1995**

(51) Int Cl.7: **F15B 13/043**

(86) International application number:
PCT/DK95/00345

(87) International publication number:
WO 96/07029 (07.03.1996 Gazette 1996/11)

(54) **HDYRAULIC ACTUATING UNIT**

HYDRAULISCHE ANTRIEBSEINHEIT

BLOC DE COMMANDE HYDRAULIQUE

(84) Designated Contracting States:
DE FR GB IT

(30) Priority: **01.09.1994 DE 4431103**

(43) Date of publication of application:
18.03.1998 Bulletin 1998/12

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US-A- 3 954 046 **US-A- 4 416 187**

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Description

[0001] The invention relates to a hydraulic actuating unit with a positioning motor which is arranged in a diagonal of a bridge circuit having four electromagnetic valves, the other diagonal being arranged between a pressure source and a pressure sink.

[0002] Such an actuating unit is known from DE 39 01 475 A1. There, in each of the two parallel double branches which connect the pressure source to the pressure sink, a normally-open and a normally-closed electromagnetic valve are connected in series. The positioning motor is in the form of a double-acting piston which is additionally loaded on each side by a spring.

[0003] A similar arrangement is known from DE 38 04 744 C2. Here too, in each double branch a respective normally-closed electromagnetic valve is connected in series with a respective normally-open electromagnetic valve.

[0004] US 4 416 187 discloses a servo system with four valves, which are illustrated in the normally-closed state. These valves are in the form of pulse-controlled electromagnetic valves.

[0005] All the arrangements operate satisfactorily in most cases of application. Occasionally, however, the response behaviour is unsatisfactory, in particular as regards the response of the positioning motor to signals for changing its position.

[0006] The invention is based on the problem of providing a hydraulic actuating unit with a rapid response behaviour.

[0007] This problem is solved in a hydraulic actuating unit of the kind mentioned in the introduction in that all four electromagnetic valves are in the form of normally-open electromagnetic valves.

[0008] Normally-open electromagnetic valves are electromagnetic valves which remain open in the no-current or unenergized state. They are not moved into their closed position until they are energized or a current is supplied to them. By using normally-open electromagnetic valves, in the unenergized state there is a permanent flow of fluid from the pressure source to the pressure sink. Since this flow of fluid is distributed uniformly over the two double branches of the bridge circuit, the pressure on each side of the piston of the positioning motor is the same. If the fluid flow in one double branch of the bridge is changed by actuating one or more valves, the pressure on the corresponding side of the piston of the positioning motor also changes automatically, and the piston is correspondingly displaced, until equilibrium is established again. Displacement of the piston of the positioning motor by pressure changes that have been caused by means of the electromagnetic valves in the bridge branches is known per se from the publications mentioned in the introduction. In the known cases, however, to change the position a certain volume of fluid, which was at rest before the change signal appeared, always has to be accelerated. This acceleration

time has an adverse effect on the response behaviour of the positioning motor. An added difficulty is that the build-up of energization to open the electromagnetic valve likewise requires a certain amount of time, so that in all cases there is some delay between the appearance of a change signal and the actual changing of the position of the positioning motor. This delay time can assume considerable values in unfavourable circumstances. The use of four normally-open electromagnetic valves does have the disadvantage that there is permanently a certain flow of fluid through the bridge circuit. But that fluid flow is largely without pressure, so that, apart from certain internal losses, the energy balance is not noticeably impaired. The improved response behaviour of the positioning motor in many cases cancels out the disadvantage of the energy loss. Moreover, it has been shown that with the four normally-open electromagnetic valves it is also possible to achieve a better control of the position of the positioning motor. This is presumably connected to the fact that with small flows it is primarily the magnetic forces which determine the degree of opening, which is attributable to correspondingly smaller air gaps in the magnetic circuits of the valves. The valves are therefore less sensitive to external influences, for example, pressure fluctuations resulting from forced movements of the positioning motor. In the case of normally-closed electromagnetic valves, with small flows the air gaps are larger, with correspondingly smaller magnetic influencing forces, so that the sensitivity to external forces is increased. Apart from that, with a permanent flow of fluid the ability to exclude air is improved.

[0009] In a preferred embodiment, a throttling device is arranged between the pressure sink and the electromagnetic valves adjacent to the pressure sink. The connecting line from the electromagnetic valves to the pressure sink, for example, a tank, can in some cases assume considerable lengths. For reasons connected with cost, the tank connections of further hydraulic units are often fed into these tank lines so that in combination with the throttling caused by the long line lengths there is also a risk of pressure peaks occurring (water hammer). Such pressure peaks are moderated by the throttling device to such an extent that they are unable to have an adverse effect on the position of the positioning motor.

[0010] It is here especially preferred for the throttling device to be formed by a throttle common to both electromagnetic valves. This measure ensures in a simple manner that the flow path on each side of the positioning motor can be kept substantially equal. No additional matching of the throttles to one another needs to be undertaken.

[0011] As a further feature, a non-return valve arrangement opening in the direction towards the pressure sink can be arranged between the pressure sink and the electromagnetic valves adjacent to the pressure sink. Such a non-return valve arrangement, which can also be in the form of a non-return valve common to both

electromagnetic valves, not only damps the pressure peaks but with greater reliability keeps them away from the electromagnetic valves.

[0012] The positioning motor is preferably connected to a position sensor, which is in signal connection with a control unit which activates the electromagnetic valves, the electromagnetic valves, the position sensor and the control unit being received in a hermetically sealed unit which is connected by way of a hydraulic interface to the positioning motor. Electrical, mechanical and hydraulic components can thus on the one hand be kept strictly separate from one another, but on the other hand can be combined to afford a conveniently operable control.

[0013] The positioning motor is preferably directly connected to an activation device of a hydraulic pump. Particularly in the case of pumps, a rapid response is desirable, in order to be able to follow the pressure and volume requirement of a hydraulic system supplied by the pump as rapidly as possible. In addition to advantages connected with control engineering, this also has the advantage of saving energy. The rapid response and the relatively large forces that can be generated using four normally-open electromagnetic valves means that the activation can be effected directly at the pump without further servo elements being required. Avoiding further auxiliary elements in turn improves the stability, since with fewer elements fewer deviations and thus also fewer potential errors are to be feared. In addition, each additional element causes an increased time delay, which can quickly lead to instability in the case of control loops. Moreover, such a control is naturally more expensive.

[0014] The pump preferably forms the pressure source. The pump therefore itself delivers the output for its adjustment. In this manner, routes can be kept short, with the result that energy losses can be kept low and the response behaviour can be improved.

[0015] It is here especially preferred for the hydraulic interface to be mounted directly on the pump. The sealed unit can therefore be assembled together with the pump as a modular item.

[0016] In an especially preferred construction, two bridge circuits are provided, the diagonals of which between pressure source and pressure sink are connected parallel to one another and the diagonals of which containing the positioning motor likewise being connected parallel to one another. With such a construction, the advantage of normally-open electromagnetic valves is very clear. The two bridge circuits connected in parallel provide a relatively large flow-through capacity and thus a relatively large output, so that larger positioning motors, for example, in the case of larger pumps, can also be reliably served without introducing further servo stages. Moreover, the system is more fault-tolerant because it has built-in redundancy. Even if one bridge should fail because of a fault in the electromagnetic valve or the associated control system, the system will merely be-

come slower and the monitoring function will not be completely lost. Moreover, with two bridges connected in parallel the response behaviour can be improved. Errors occurring during control can be compensated for more quickly. This is attributable to the fact that the piston is normally held fixedly in its position only when the positional error is less than a given reference value. If, however, the positional error, that is, the deviation between the actual position and the desired position, is larger than the given reference value, the control arrangement normally activates two electromagnetic valves lying diagonally opposite one another in the bridge, namely, with a duty factor that is proportional to the error in order to reduce the error. Where there are two parallel bridges, the two bridges can now have different reference values assigned to them. If the error is small, only one bridge becomes active. If the error is larger, both bridges will attempt to reduce the error.

[0017] Preferably, provision is made for each bridge circuit to have its own throttling and non-return valve arrangement. This allows the bridges to be well isolated from one another, that is to say, allows a largely independent control.

[0018] It is also preferred for the two bridge circuits to be identical with one another. In this manner several bridge circuits can be connected in parallel without too much consideration having to be given to their dimensions. The bridges are largely equally loaded and deteriorate to a correspondingly uniform extent.

[0019] It is advantageous to provide two position sensors. This increases the redundancy of the system.

[0020] The invention is described hereinafter with reference to preferred embodiments in combination with the drawings, in which

- Fig. 1 shows a first embodiment of a hydraulic actuating unit,
- Fig. 2 is a diagrammatic view of the actuating unit from the outside and
- Fig. 3 shows a second embodiment of the hydraulic actuating unit.

[0021] A hydraulic actuating unit 1 comprises a positioning motor 2 which is arranged in one diagonal of a hydraulic bridge circuit 3. The other diagonal of the bridge circuit 3 lies between a pressure source in the form of a pump 4 and a pressure sink in the form of a tank 5.

[0022] The hydraulic bridge circuit 3 has four branches. In each branch there is a respective electromagnetic valve 6, 7, 8, 9. All the electromagnetic valves 6, 7, 8, 9 are normally-open, that is to say, they are open in the no-current or unenergized state and do not close until a current is applied. The signal wave-form of a corresponding control current is illustrated diagrammatically by respective square-wave pulse trains, that is to say, the valves are pulse-controlled. This pulse train is supplied from a control unit 11 by way of a control line 10

which has four paths each for actuating a respective electromagnetic valve 6, 7, 8, 9. The control unit 11 is connected on one side to an electrical adjusting device 12. That device produces a desired value for the positioning motor 2. On the other side, the control unit 11 is in signal connection with a position sensor 13. The position sensor 12 produces an actual value for the setting of the positioning motor 2. For that purpose a diagrammatically shown arm 14 is connected to a piston 17 of the positioning motor 2.

[0023] Between the tank 5 and the hydraulic bridge circuit 3 there is a throttle 16. This throttle 16 damps any pressure surges that might occur between the tank 5 and the bridge circuit 3. Pressure surges are therefore kept away from the two electromagnetic valves 8, 9 adjacent to the tank 5. Alternatively, a non-return valve opening in the direction towards the tank 5 could be used in place of the throttle 16.

[0024] The pump 4 produces a flow of liquid through the two double branches, each of which is provided with the electromagnetic valves 6, 8 and 7, 9 respectively. Since the two double branches are substantially of identical construction, on both sides of the piston 17 of the positioning motor 2 the pressure is also equal. By throttling one of the electromagnetic valves 6, 7, 8, 9 or even by throttling two diagonally opposite valves 6, 9 or 7, 8, the pressure conditions on the two sides of the piston 17 of the positioning motor 2 can be changed so that the piston 17 of the positioning motor 2, and with its also the arm, is displaced. Relatively rapid reaction times can be produced here, since on the one hand there are no amounts of fluid to be accelerated, merely a flow of fluid to act upon, and on the other hand only small energizing outputs are required to produce the necessary influencing of the electromagnetic valves 6, 7, 8, 9.

[0025] Beyond that, using the normally-open electromagnetic valves 6, 7, 8, 9 a relatively precise adjustment of the setting of the piston 17 of the positioning motor 2 can be achieved. With normally-open electromagnetic valves, it is primarily the magnetic forces that determine the degree of opening with small flows. But with small flows the forces acting from the outside on the electromagnetic valves, that is to say, by way of the fluid, are greatest. Because of the small air gaps the valves are less sensitive to these disruptions than in the case of the large air gaps occurring with normally-closed valves in the same open position.

[0026] Fig. 2 shows the use of such an actuating unit on a pump 4. The pump can be the same one as that acting as pressure source for the actuating unit. In that case the electromagnetic valves 6, 7, 8, 9 are combined in a hermetically sealed unit 18 which is connected to the pump 4 by way of a hydraulic interface 19. On the sealed unit 18, or integrated in it, there may be an electronics module 20 with the control unit 11. If desired, the position sensor 13 can also be arranged in the electronics module.

[0027] The use of the illustrated actuating unit in a

pump 4 is advantageous. With pump actuation there is in principle always an adequate flow quantity present. Since the valves are open, this flow can be produced without particularly large losses. Certain internal losses cannot be avoided, of course. These internal losses are compensated, however, by the pump's responding substantially more quickly so that it pumps more closely to the requirement of an attached hydraulic system and therefore keeps the losses there small.

[0028] Fig. 3 shows a further construction. Here, identical parts have been provided with identical reference numbers. Here, in addition to the bridge circuit 3 illustrated in Fig. 1, parallel with this bridge circuit there is connected a further bridge circuit which can be of more or less identical construction. To distinguish between them the corresponding reference numbers have therefore been marked **a** and **b**. Two position sensors 13a and 13b are also provided. With the construction illustrated, the system is more tolerant of errors because it has built-in redundancy. If, for example, one bridge circuit should fail because of malfunction of a valve, the system can still continue to function even if with poorer results. The actuation of the piston 17 is effected more slowly.

[0029] Ordinarily, with the arrangement illustrated in Fig. 3 a rapid response can be achieved even with relatively large units. By doubling the flow capacity by means of the two bridges connected in parallel, relatively large positioning motors 2 can also be operated without difficulty.

[0030] Furthermore, an improved control concept can be achieved with the two parallel bridges. The individual electromagnetic valves are actuated, as illustrated diagrammatically, by pulse trains. The pulse duty factor of these pulse trains is normally dependent on the magnitude of the error, that is, on the size of the deviation of the desired value preset by the adjusting device 12 with respect to the actual value detected by the position sensors 13a, 13b. The piston 17 of the positioning motor 2 is displaced only when the difference between the desired value and the actual value is less than a preset tolerance or reference value. This reference value can be made smaller for one bridge circuit 3a than for the other bridge circuit 3b. If the positional or setting error is greater than the reference value of the two bridge circuits 3a, 3b, the two bridge circuits are used to compensate for the error. If, on the other hand, the error is greater than the reference value of one bridge circuit 3b, but smaller than the reference value of the bridge circuit 3a, only the bridge circuit 3b is used to reduce the error.

[0031] The pump 4 can alternatively be replaced by any other pressure source, for example, a low-pressure pump or a pressure accumulator.

Claims

1. A hydraulic actuating unit (1) with a positioning mo-

tor (2) which is arranged in a diagonal of a bridge circuit (3) having four electromagnetic valves (6,7,8,9), the other diagonal being arranged between a pressure source (4) and a pressure sink (5), characterized in that all four electromagnetic valves (6, 7, 8, 9) are in the form of normally-open electromagnetic valves.

2. An actuating unit according to claim 1, characterized in that a throttling device (16) is arranged between the pressure sink (5) and the electromagnetic valves (8, 9) adjacent to the pressure sink. 10
3. An actuating unit according to claim 2, characterized in that the throttling device (16) is formed by a throttle common to both electromagnetic valves (8, 9). 15
4. An actuating unit according to one of claims 1 to 3, characterized in that a non-return valve arrangement opening in the direction towards the pressure sink is arranged between the pressure sink (5) and the electromagnetic valves (8, 9) adjacent to the pressure sink (5). 20
5. An actuating unit according to one of claims 1 to 4, characterized in that the positioning motor (2) is connected to a position sensor (13), which is in signal connection with a control unit (11) which activates the electromagnetic valves (6, 7, 8, 9), the electromagnetic valves (6, 7, 8, 9), the position sensor (13) and the control unit (11) being received in a hermetically sealed unit (18) which is connected by way of a hydraulic interface (19) to the positioning motor (2). 30
6. An actuating unit according to one of claims 1 to 5, characterized in that the positioning motor (2) is directly connected to an activation device of a hydraulic pump (4). 35
7. An actuating unit according to claim 6, characterized in that the pump (4) forms the pressure source. 40
8. An actuating unit according to claim 6 or 7, characterized in that the hydraulic interface (19) is mounted directly on the pump (4). 45
9. An actuating unit according to one of claims 1 to 8, characterized in that two bridge circuits (3a, 3b) are provided, the diagonals of which between pressure source (4) and pressure sink (5) are connected parallel to one another and the diagonals of which containing the positioning motor (2) likewise being connected parallel to one another. 50
10. An actuating unit according to claim 9, characterized in that each bridge circuit (3a, 3b) has its own 55

throttling and non-return valve arrangement (16a, 16b).

11. An actuating unit according to claim 9 or 10, characterized in that the two bridge circuits (3a, 3b) are identical with one another.
12. An actuating unit according to one of claims 9 to 11, characterized in that two position sensors (13a, 13b) are provided.

Patentansprüche

1. Hydraulische Betätigungseinheit (1) mit einem Stellmotor (2), der in einer Diagonalen einer vier Magnetventile (6, 7, 8, 9) aufweisenden Brückenschaltung (3) angeordnet ist, wobei die andere Diagonale zwischen einer Druckquelle (4) und einer Drucksenke (5) angeordnet ist, dadurch gekennzeichnet, daß alle vier Magnetventile (6, 7, 8, 9) als normalerweise offene Magnetventile ausgebildet sind.
2. Betätigungseinheit nach Anspruch 1, dadurch gekennzeichnet, daß zwischen der Drucksenke (5) und den der Drucksenke benachbarten Magnetventilen (8, 9) eine Drosseleinrichtung (16) angeordnet ist.
3. Betätigungseinheit nach Anspruch 2, dadurch gekennzeichnet, daß die Drosseleinrichtung (16) durch eine für beide Magnetventile (8, 9) gemeinsame Drossel gebildet ist.
4. Betätigungseinheit nach einem der Ansprüche 1 bis 3, dadurch gekennzeichnet, daß zwischen Drucksenke (5) und den der Drucksenke (5) benachbarten Magnetventilen (8, 9) eine in Richtung zur Drucksenke hin öffnende Rückschlagventileinrichtung angeordnet ist.
5. Betätigungseinheit nach einem der Ansprüche 1 bis 4, dadurch gekennzeichnet, daß der Stellmotor (2) mit einem Positionssensor (13) verbunden ist, der signalmäßig mit einer Steuereinheit (11) verbunden ist, die die Magnetventile (6, 7, 8, 9) ansteuert, wobei die Magnetventile (6, 7, 8, 9), der Positionssensor (13) und die Steuereinheit (11) in einer hermetisch gekapselten Einheit (18) aufgenommen sind, die über eine hydraulische Schnittstelle (19) mit dem Stellmotor (2) in Verbindung steht.
6. Betätigungseinheit nach einem der Ansprüche 1 bis 5, dadurch gekennzeichnet, daß der Stellmotor (2) direkt mit einer Aussteuereinrichtung einer hydraulischen Pumpe (4) verbunden ist.

7. Betätigungseinheit nach Anspruch 6, dadurch gekennzeichnet, daß die Pumpe (4) die Druckquelle bildet.
8. Betätigungseinheit nach Anspruch 6 oder 7, dadurch gekennzeichnet, daß die hydraulische Schnittstelle (19) unmittelbar auf der Pumpe (4) montiert ist. 5
9. Betätigungseinheit nach einem der Ansprüche 1 bis 8, dadurch gekennzeichnet, daß zwei Brückenschaltungen (3a, 3b) vorgesehen sind, deren zwischen Druckquelle (4) und Drucksenke (5) angeordnete Diagonalen parallel zueinander geschaltet sind und deren den Stellmotor (2) aufweisenden Diagonalen ebenfalls parallel zueinander angeordnet sind. 10
10. Betätigungseinheit nach Anspruch 9, dadurch gekennzeichnet, daß jede Brückenschaltung (3a, 3b) eine eigene Drossel- bzw. Rückschlagventileinrichtung (16a, 16b) aufweist. 15
11. Betätigungseinheit nach Anspruch 9 oder 10, dadurch gekennzeichnet, daß beide Brückenschaltungen (3a, 3b) einander gleich sind. 20
12. Betätigungseinheit nach einem der Ansprüche 9 bis 11, dadurch gekennzeichnet, daß zwei Positionsensoren (13a, 13b) vorgesehen sind. 25

Revendications

1. Un bloc de commande hydraulique (1) avec un moteur de positionnement (2) qui est agencé dans une diagonale d'un circuit en pont (3) ayant quatre soupapes électromagnétiques (6, 7, 8, 9), l'autre diagonale étant agencée entre une source de pression (4) et un réservoir de pression (5), caractérisé en ce que toutes les quatre soupapes électromagnétiques (6, 7, 8, 9) sont sous la forme de soupapes électromagnétiques normalement ouvertes. 35
2. Un bloc de commande selon la revendication 1, caractérisé en ce qu'un dispositif d'étranglement (16) est agencé entre le réservoir de pression (5) et les soupapes électromagnétiques (8, 9) près du réservoir de pression. 40
3. Un bloc de commande selon la revendication 2, caractérisé en ce que le dispositif d'étranglement (16) est formé par un papillon commun aux deux soupapes électromagnétiques (8, 9). 45
4. Un bloc de commande selon l'une des revendications 1 à 3, caractérisé en ce qu'un agencement de soupape de non-retour débouchant dans la direc-

tion vers le réservoir de pression est disposé entre le réservoir de pression (5) et les soupapes électromagnétiques (8, 9) adjacentes au réservoir de pression (5).

5. Un bloc de commande selon l'une des revendications 1 à 4, caractérisé en ce que le moteur de positionnement (2) est relié à un capteur de position (13) qui est en liaison par signal avec un ensemble de commande (11) qui active les soupapes électromagnétiques (6, 7, 8, 9), les soupapes électromagnétiques (6, 7, 8, 9), le capteur de position (13) et l'ensemble de commande (11) étant reçus dans un ensemble hermétiquement étanchéifié (18) qui est relié au moyen d'une interface hydraulique (19) au moteur de positionnement (2). 50
6. Un bloc de commande selon l'une des revendications 1 à 5, caractérisé en ce que le moteur de positionnement (2) est relié directement à un dispositif d'activation d'une pompe hydraulique (4).
7. Un bloc de commande selon la revendication 6, caractérisé en ce que la pompe (4) constitue la source de pression.
8. Un bloc de commande selon la revendication 6 ou 7, caractérisé en ce que l'interface hydraulique (19) est montée directement sur la pompe (4).
9. Un bloc de commande selon l'une des revendications 1 à 8, caractérisé en ce que deux circuits en pont (3a, 3b) sont prévus, dont les diagonales entre la source de pression (4) et le réservoir de pression (5) sont reliées parallèlement l'une à l'autre et dont les diagonales contenant le moteur de positionnement (2) sont reliées de la même façon parallèlement l'une à l'autre.
10. Un bloc de commande selon la revendication 9, caractérisé en ce que chaque circuit en pont (3a, 3b) présente son propre agencement de soupape de non-retour et d'étranglement (16a, 16b). 55
11. Un bloc de commande selon la revendication 9 ou 10, caractérisé en ce que les deux circuits en pont (3a, 3b) sont identiques l'un avec l'autre.
12. Un bloc de commande selon l'une des revendications 9 à 11, caractérisé en ce que deux capteurs de position (13a, 13b) sont prévus.

Fig.1

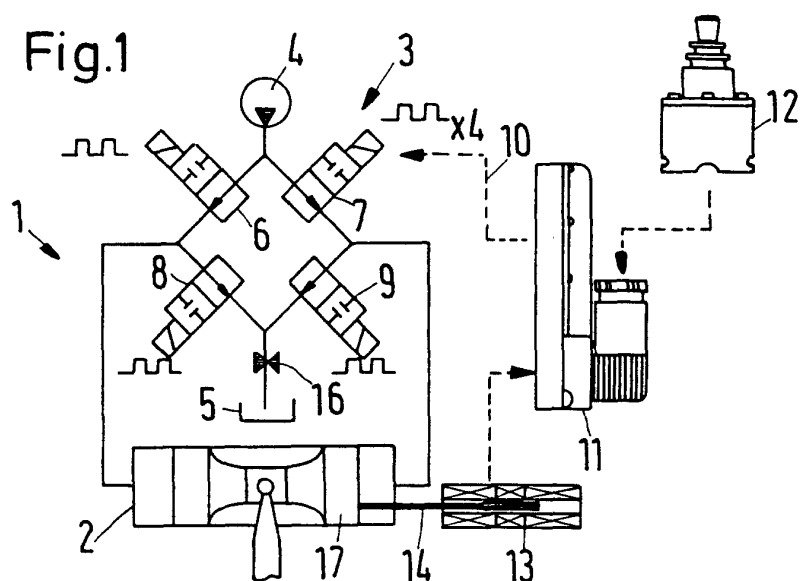


Fig.2

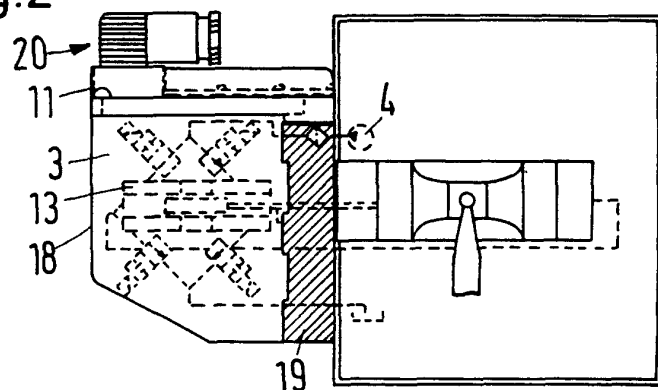


Fig.3

