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(54) **MEDICAL PUMP**

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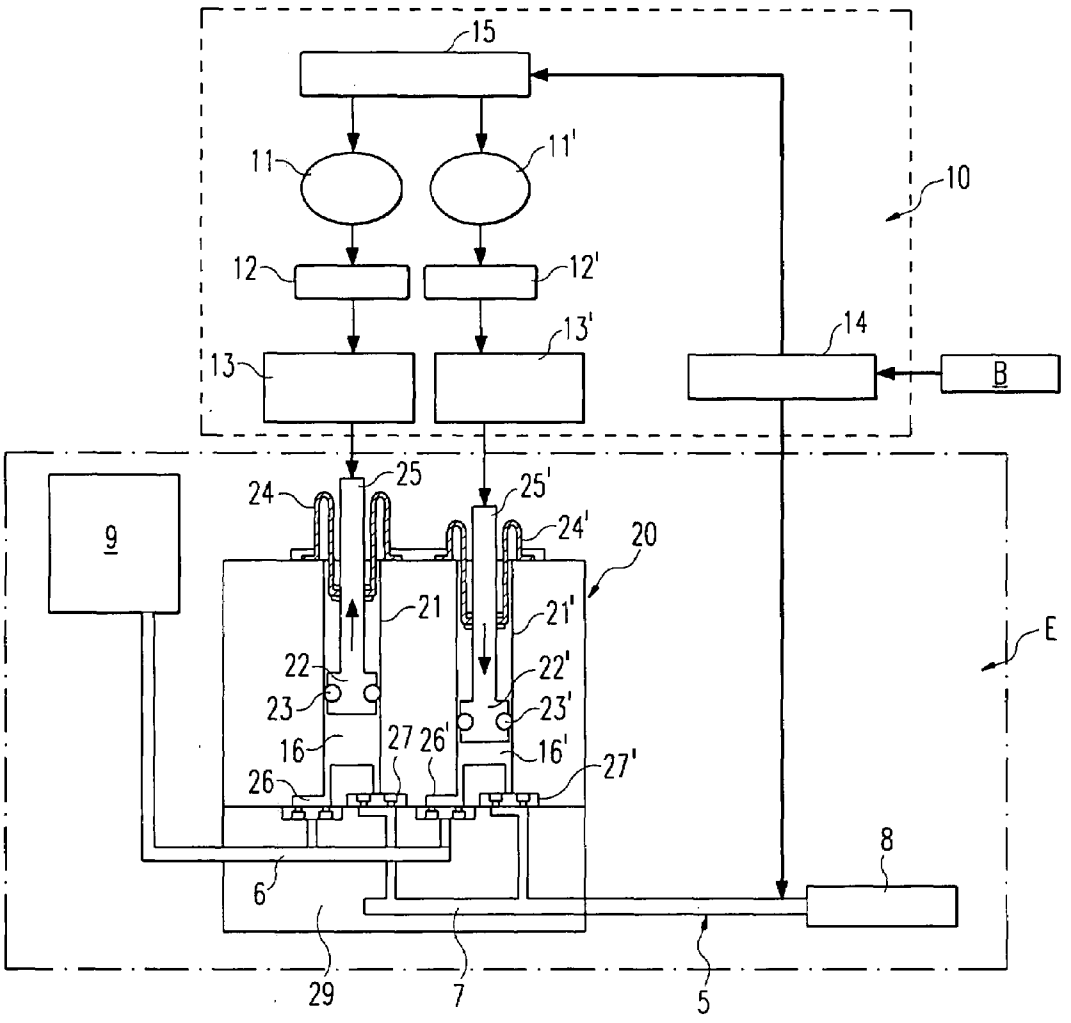
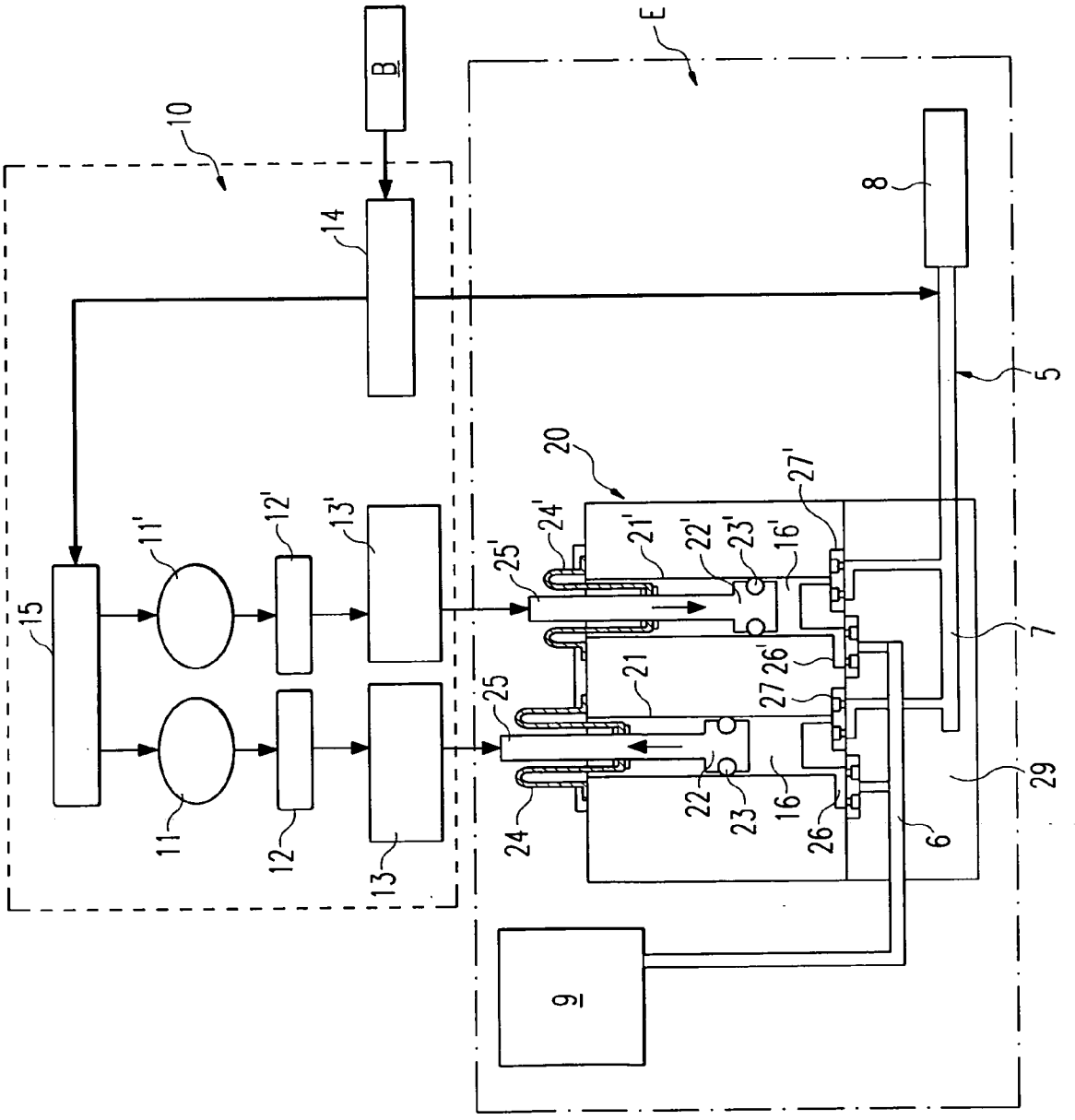
(57) **ABSTRACT**

Medical pumps for water jet surgery are known. The invention relates to a pump comprising at least two pistons provided with piston rods for displacing the pistons in cylinders and for coupling to a pump actuation device, a cylinder head for closing the cylinders, and valve means for respectively connecting a pressure chamber in the cylinder to at least one fluid inlet and at least one fluid outlet. Said fluid outlet is connected to the fluid inlet in a communicating manner by means of an adjustable pressure regulating valve, in such a way that the pressure in the fluid outlet can be limited to a predetermined maximum value so that operation of the pump can be.

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14
8
5
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27'
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21'
22'
23'
16'
25'
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26'
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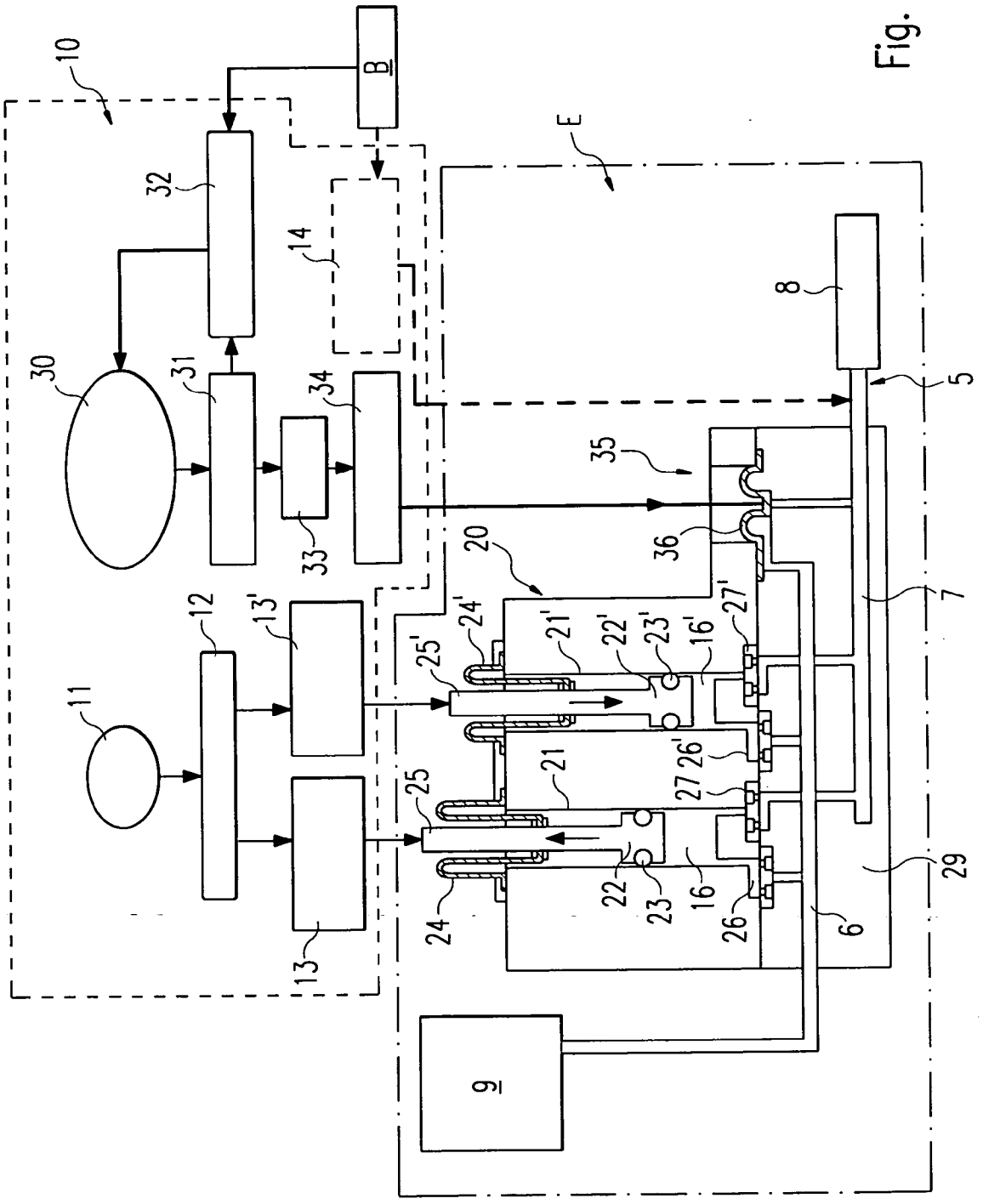
12
13
6
29
9

Fig. 1


10
B
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32
14
30
31
34
8
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35
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36
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12
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24'
21'
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23'
16'
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11
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27
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22
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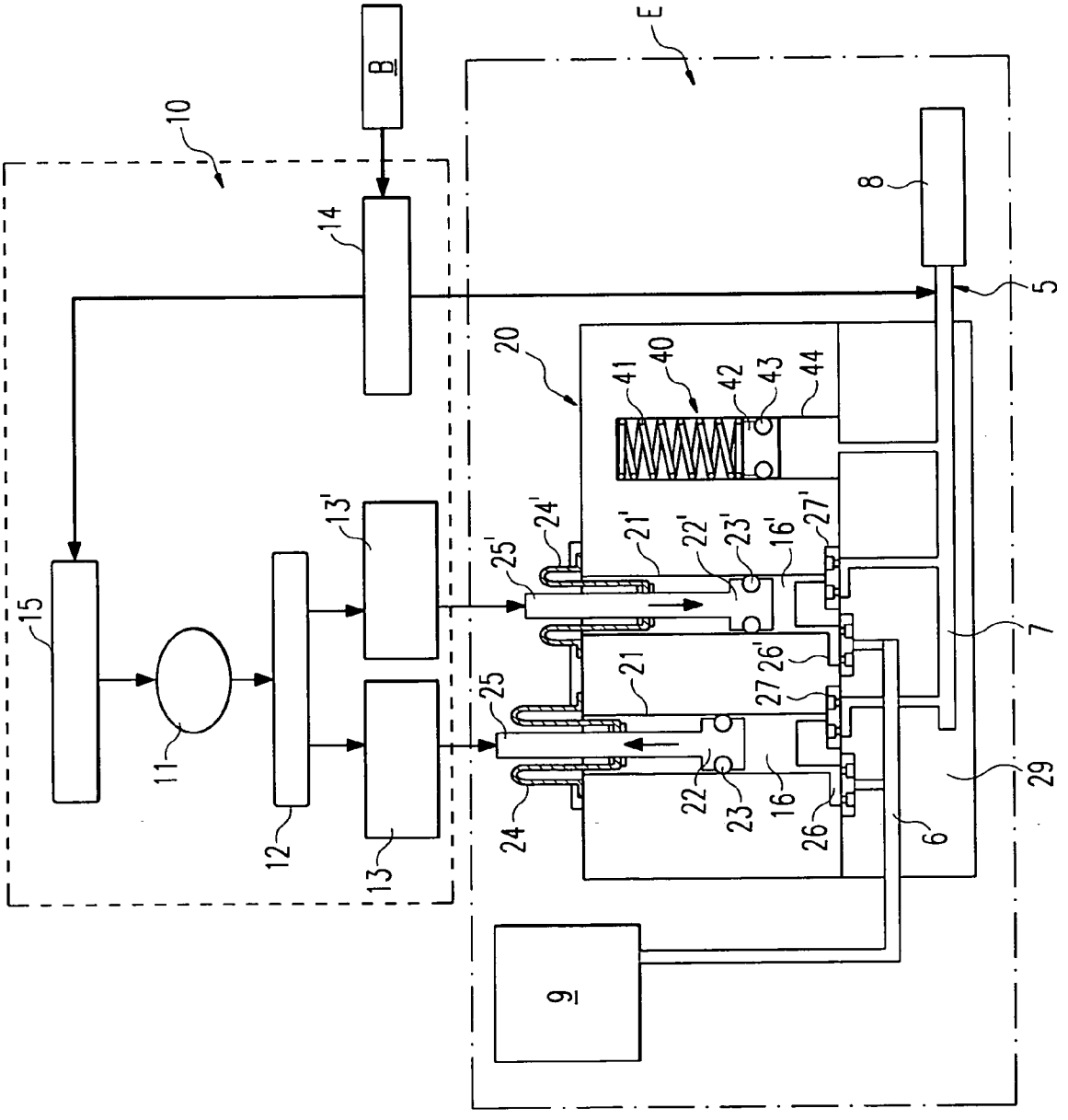
16
26
24
29
6
13
9

Fig. 2


B
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14
8
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27'
25'
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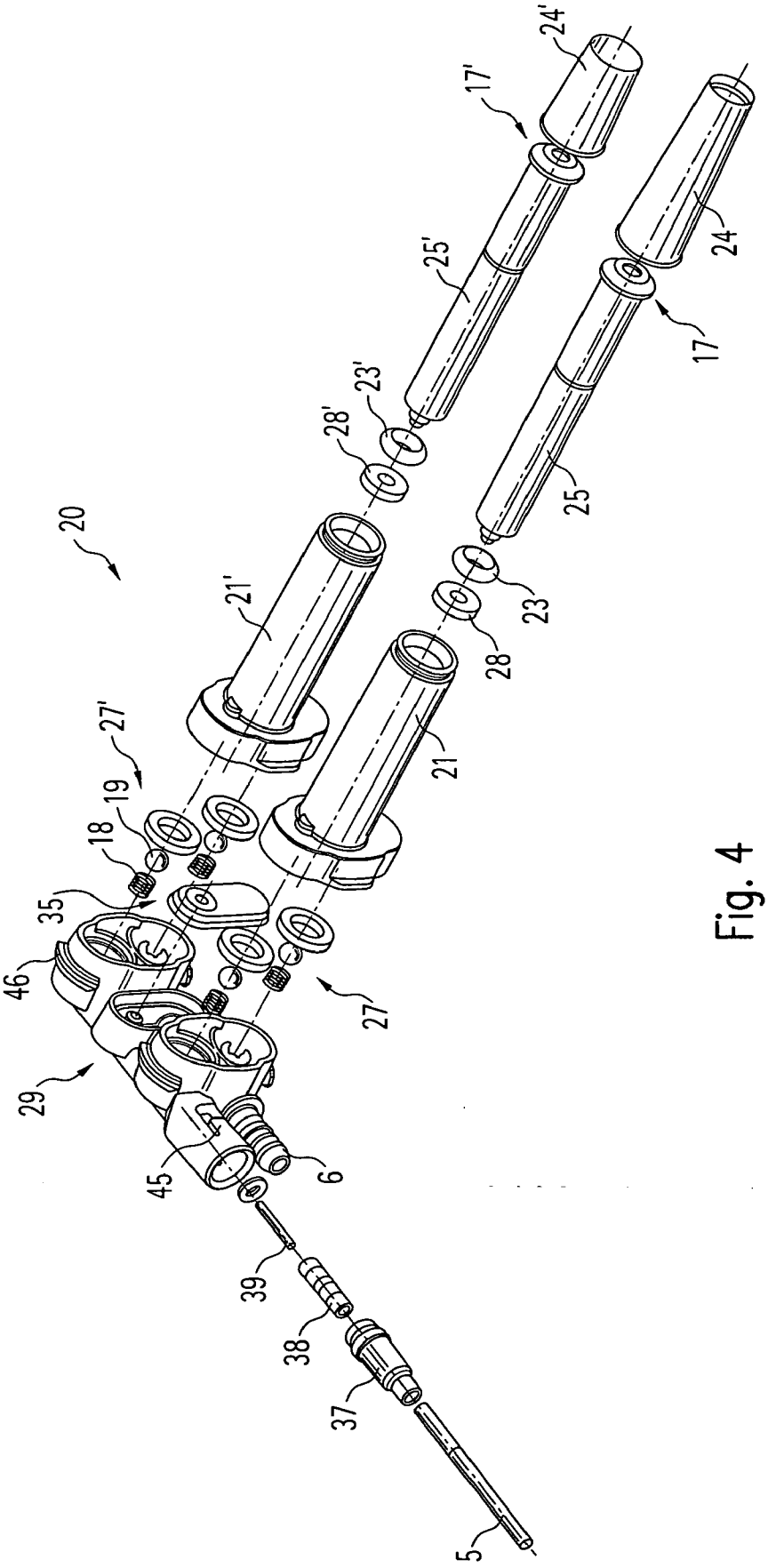
29
9

Fig. 3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17'
25'
23'
28'
20
21'
27'
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18
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46
29
45
6
39
38
37
5
27
21
28
23
25
17
24

Fig. 4

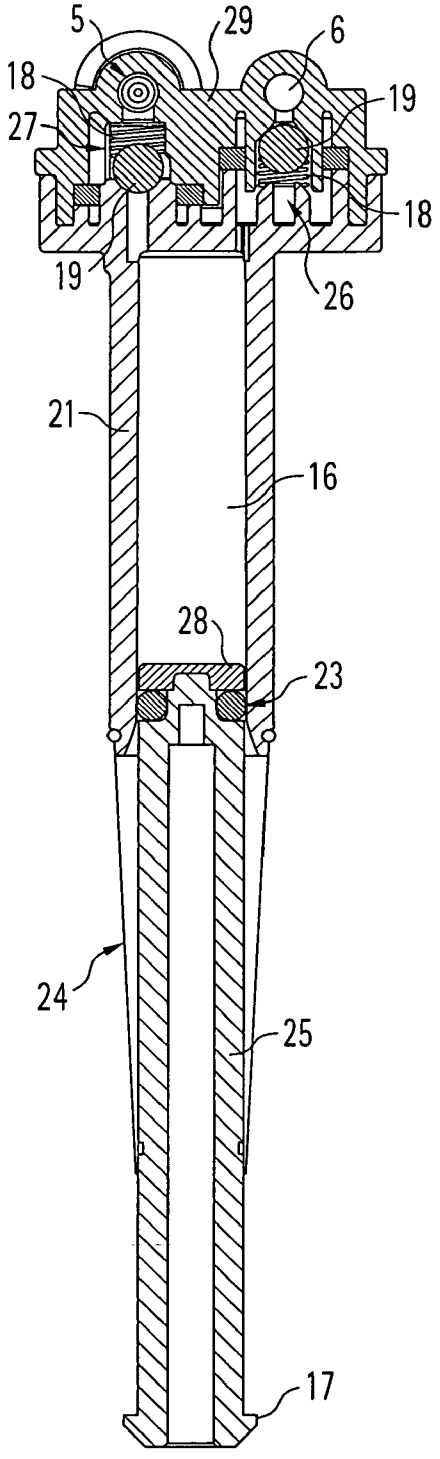
5
29
6
18
19
27
18
19
26
21
16
28
23
24
25
17

Fig. 6

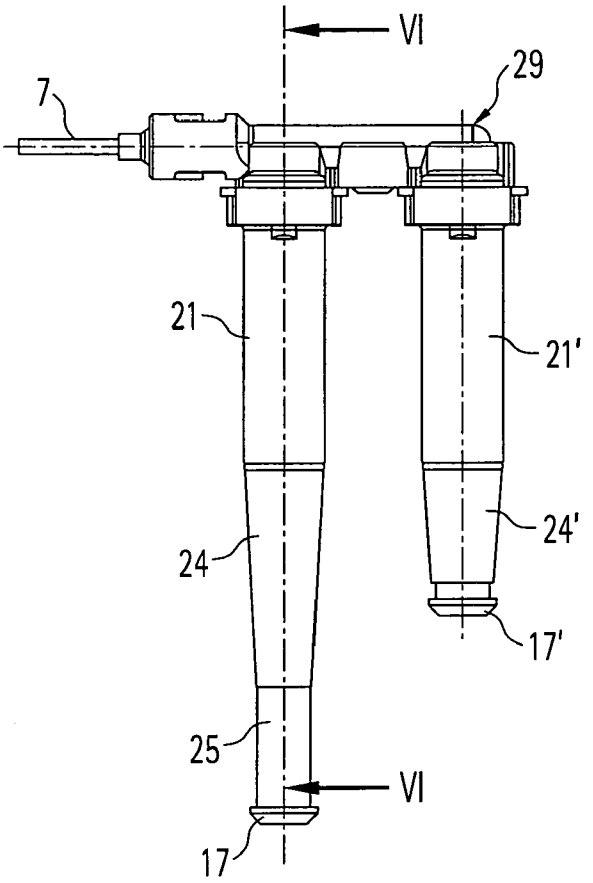
VI
29
7
21
21'
24'
24
17'
25
VI
17

Fig. 5

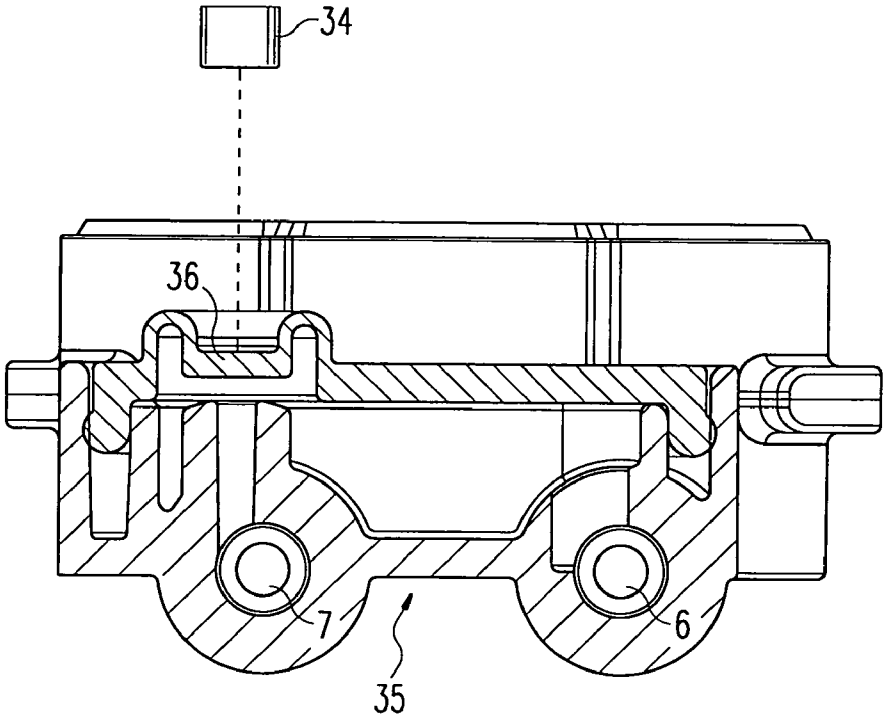

Fig. 7

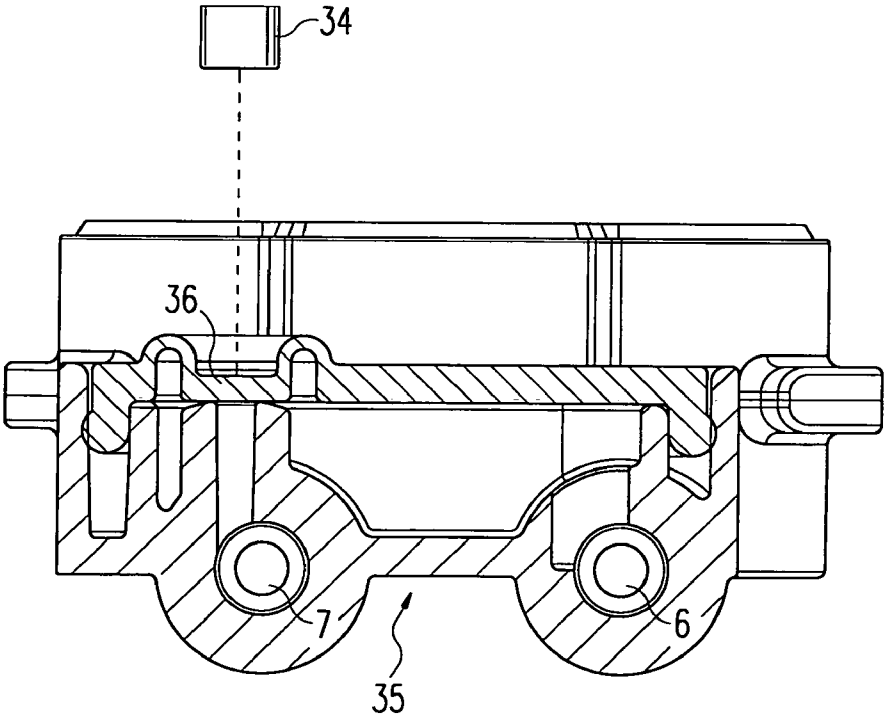

Fig. 8

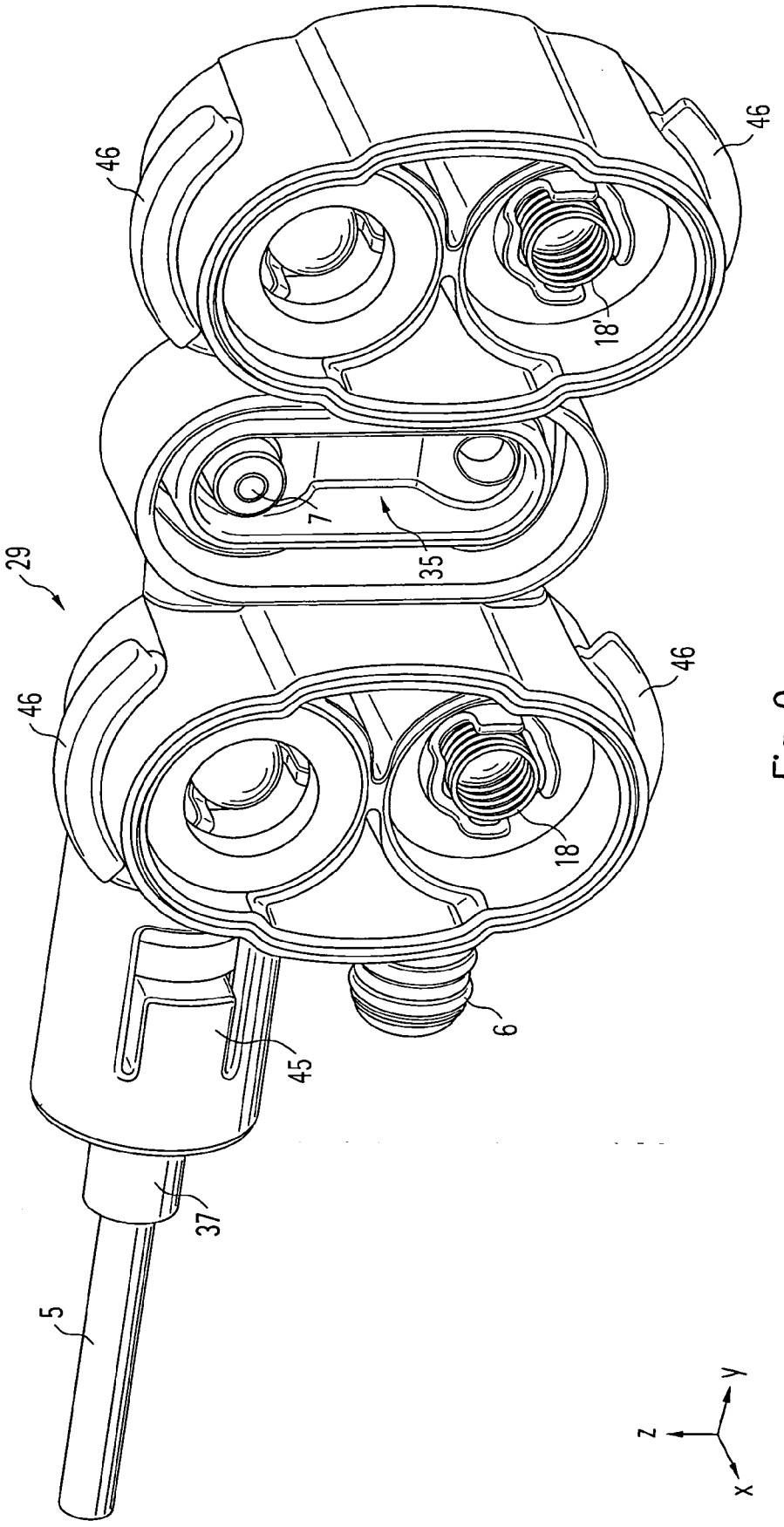

Fig. 9

MEDICAL PUMP

RELATED U.S. APPLICATIONS

[0001] Not applicable.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not applicable.

REFERENCE TO MICROFICHE APPENDIX

[0003] Not applicable.

FIELD OF THE INVENTION

[0004] The invention relates to a medical pump, in particular for water jet surgery.

BACKGROUND OF THE INVENTION

[0005] Water jet surgery has been used for some time in liver surgery as this organ, like no other, has tissue structures of different firmness (parenchyma, blood vessels and bile ducts) and the applied water jet separates the tissue being cut, yet leaves the blood vessels and bile ducts undamaged. Naturally, a precise control of the cutting pressure is required for this.

[0006] A further problem of water jet surgery is that the cutting medium must be totally sterile (e.g. Ringer solution) as the liquid comes into contact with body tissue in the closest and most intensive way possible. Ordinary problems such as high reliability, simplicity and economic manufacture must also be considered.

[0007] A medical pump for water jet surgery is described in U.S. Pat. No. 6,216,573 B1, as well as DE 203 09 616 U1, which is disposable and thus used only once. The pump efficiency as well as its adjustment, however, are unsatisfactory.

BRIEF SUMMARY OF THE INVENTION

[0008] The invention provides a medical pump, in particular for water jet surgery, which despite simple construction and suitability for single use facilitates improved cutting performance.

[0009] According to the invention a medical pump comprises at least two pistons with piston rods for displacing the pistons in the cylinders and for coupling to a pump actuation device, a cylinder head for closing the cylinders in relation to the pistons, valve means for connecting the pressure chamber with at least one fluid outlet and at least one fluid inlet, whereby the fluid outlet interacts with the fluid inlet via an adjustable pressure control valve in such a way that the pressure in the fluid outlet can be limited to a predetermined maximum value.

[0010] As the pump is operated with two piston/cylinder units, an improved and smoothed out pump capacity can be achieved. The construction is simple so that economic manufacture is possible. The already improved pumping of the working fluid is further improved by the pressure control valve as it can be smoothed out and at the same time be adjusted to the application requirements.

[0011] The valve means and/or the pressure control valve comprise an elastic or elastically pressurized valve membrane. This enables very economic manufacture and high operational safety.

[0012] The valve devices can also comprise two spring-loaded ball check valves, which again are simple to produce.

[0013] The pressure control valve is preferably constructed as a power driven valve in such a way that the maximum value is adjustable by means of actuating power on a regulator of the pressure control valve. This special form facilitates coupling of the medical pump to the pump actuation device in an advantageous manner, where a particular specific spatial positioning of the pump in relation to the pump actuation device is not required. Because the pressure adjustment is not proportional to the travel but proportional to the force, coupling of the pressure control valve to a regulating unit is not position-dependent (which would require accurate adjustment of the pump), it is rather the position independent force with which the regulator activates the pressure control valve which is important.

[0014] The pressure control valve is preferably arranged between fluid inlet and fluid outlet in such a way, that on exceeding the maximum value, fluid from the fluid outlet can be directed back to the fluid inlet. In this way the pressure can be adjusted independently of the quantity of pumped fluid.

[0015] The pistons or pistons rods are preferably connected securely and in a sterile way via bellows, cup seal or similar non-slip seals to the cylinders. Germs can thus not be introduced despite sterile working fluid and sterile transmission pipes, which can be the case with pumps known hitherto. This danger is particularly great as due to piston displacement in the cylinders their back ends (in relation to the pressure chambers) are subjected to streams of ambient air and thus cylinders can be contaminated therewith in this area.

[0016] The valve devices and/or pressure control valve are preferably housed in the cylinder head. This results in a simpler setup containing fewer parts.

[0017] It is preferred that the cylinders are connected independently to the cylinder head. This simplifies manufacture.

[0018] The outlet preferably has fittings for irreversible connection to a pressure hose. This avoids a faulty installation of the pump and also non-permissible re-use of the pump.

[0019] The cylinder head preferably comprises holding devices, in particular lugs into which the catches engage, which are attached to the pump actuation device. No special measures are thus needed for mounting the pump to the pump actuation device.

[0020] An accumulator is provided in a preferred embodiment and is connected to the fluid outlet in such a way that fluid pressure fluctuations at the fluid outlet are smoothed out due to a low pass function. This results in a further smoothing of the cutting jet and thus an improvement of the equipment cutting function desired. The accumulators are preferably situated in the cylinder head or connected therewith which simplifies the assembly of the entire arrangement.

[0021] Embodiments of the invention will now be described by way of example with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] FIGS. **1** to **3** are schematic block diagrams of different embodiments of the medical pump arrangements according to the invention.

[0023] FIG. **4** is an exploded view of an embodiment of the pump.

[0024] FIG. **5** is a side view of the pump shown in FIG. **4**.

[0025] FIG. **6** is a section along line VI-VI in FIG. **5**.

[0026] FIGS. **7** and **8** are partial sectional views through the medical pump in the pressure control valve area in two respective control positions.

[0027] FIG. **9** is a perspective view of a cylinder head of the pump.

DETAILED DESCRIPTION OF THE INVENTION

[0028] The same reference numbers will be used for the same parts and parts with the same function.

[0029] A pump actuation device **10** is intended for the embodiment of the invention shown in FIG. **1**, which encompasses a motor control **15** for the control of two motors **11**,**11'**, which are connected via gearing **12**, **12'** and clutch devices **13**, **13'** to the piston rods **25**,**25'**. One operator B can operate the motor control **15** with suitable switches (foot switch or finger switch), so that the motors **11**, **11'** displace the piston rods **25**, **25'** and thus the pistons **22**, **22'** in the cylinders **21**, **21'** of pump unit **20** alternately via the described train, so that the volume of the pressure chambers **16**, **16'** of the pump unit **20** is alternately enlarged and reduced.

[0030] In order to seal the pressure chambers **16**, **16'** and the pistons **22**, **22'** in relation to the cylinders **21**, **21'** seals **23**, **23'** are provided at the pistons **22**, **22'**. Moreover, the piston rods **25**, **25'** maintain sterility with cup seals **24**, **24'**, which are firmly fixed to the cylinders **21**, **21'** on the one hand and to the pistons rods **25**, **25'** on the other. In this way germs from the ambient air, which without these cup seals **24**, **24'** would settle on the internal walls of the cylinders **21**, **21'** and pass through the seals **23**, **23'**, can neither mix with the working fluid nor find their way into the same.

[0031] Suction valves **26**, **26'** as well as pressure valves **27**, **27'** are connected to the pressure chambers **16**, **16'**. The suction valves **26**, **26'** are connected via a fluid inlet **6** to a reservoir **9** for the working fluid. The pressure valves **27**, **27'** are connected to the pressure hose **5** via a fluid outlet **7**, which leads to an applicator **8**. The pump unit **20** forms a disposable part E together with the reservoir **9** including its contents, pressure hose **5** and applicator **8**, which is disposed of after each operation, so that the entire setup meets the highest sterility requirements possible.

[0032] A butterfly valve **14** is intended for adjustment of pressure in this simple embodiment of the invention (which in addition to the motor control **15**) facilitates adjustment of the fluid flow by operator B.

[0033] The embodiment of the invention shown in FIG. **2** differs from that in FIG. **1** by virtue of the provision of a pressure control valve **35**, which with the aid of a valve membrane **36** can open and close a connecting channel between fluid outlet **7** and fluid inlet **6**. The membrane **36** is operated by an actuator **30** via a push rod **34** and a spring **33**, as well as a dynamometer **31**. The dynamometer **31** supplies a power proportional output signal to a controller **32**, via which an operator B can set a maximum pressure. Instead of a separate dynamometer **31** the operating current of the actuator **30** can also be measured which is also power proportional.

[0034] This arrangement means that the fluid pressure can be accurately adjusted at the applicator **8**. Moreover, pressure fluctuations resulting from piston operation are smoothed out by the control valve **35**. The pressure control valve **35** owing to its construction operates with the membrane pressurised by fluid, in a power-controlled and not a travel-controlled manner. No pressure adjustment error can therefore occur even with dimension tolerances during coupling of the pump unit **20** to the pump actuation device **10**, as it is not the geometric dimensions (travel) which are important, but the power with which the pressure control valve **35** is operated.

[0035] The embodiment shown in FIG. **3** differs from the previously shown embodiments by virtue of the provision of an accumulator **40**, which comprises a cylinder **44** containing a piston **42** sealed by a seal **43**, which is pressurized by a spring **41**. A chamber situated above the piston is connected to the fluid outlet, so that with increasing pressure at the fluid outlet **7** the spring **41** is compressed and with decreasing pressure the spring **41** drives the piston **42**. In this way the pressure directed to the applicator **8** is smoothed out due to its low pass function. This accumulator **40** is arranged in a cylinder head **29** which seals the cylinders **21**, **21'**. It is also possible to combine the variants show here. In particular the pressure control valve **35** can be combined with the accumulator **40**.

[0036] FIG. **4** shows a constructive embodiment of the pump device **20** in an exploded view. In this embodiment the pressure and suction valves **26**/**27** comprise balls **19**, which are pressed onto the valve seats via springs **18** (not visible in the illustration), in an arrangement that is known in principle.

[0037] The cylinder head **29** has two sections to which the cylinders **21**, **21'** are coupled, whereby the valves sit between the cylinders **21**, **21'** and the cylinder head **29**.

[0038] It can further be seen from FIG. **4**, that the piston rods **25**, **25'** have coupling projections **17**, **17'** at their distal ends which serve to create mechanical connections with the coupling systems **13**, **13'**.

[0039] The pistons in this embodiment of the invention are formed by the proximal ends of the piston rods **25**, **25'** fitted with caps **28**, which simultaneously hold seals **23**, **23'** firmly on the piston rods **25**, **25'**.

[0040] The pressure hose **5** is fastened irreversibly to the cylinder head **29** via a connecting piece **37**, a crimping piece **38** and an internal pipe which is inserted into the pressure hose **5**, whereby after assembly of the connecting piece **37** (in a known way) in the cylinder head **29** by means of a catch **45**, the connecting piece is held irreversibly in the cylinder head **29**.

[0041] From FIGS. **5** and **6** details of the layout become clear in particular in relation to the construction of the suction valve **26**, **26'** or the pressure valve **27**, **27'** and especially the layout of the valve seats in the cylinder head **29** on the one hand and the relevant allocated cylinders **21**, **21'** on the other.

[0042] FIGS. **7** and **8** show a section through the pressure control valve **35**, which shows that the membrane **36** can be pressed by the push rod **34** onto a valve seat (FIG. **7** shows the open position and FIG. **8** the closed), so that between fluid outlet **7** and fluid inlet **6**, depending on the position of the membrane **36**, a more or less greater "short circuit" of the pump unit **20** is produced. As the membrane **36** is pressurized by the fluid outlet **7**, a power-controlled valve is present.

[0043] FIG. **4** shows further construction related details of the cylinder head **29** and the valve devices (suction valve, pressure valve and pressure control valve) contained therein. Moreover, FIG. **9** shows the lugs, which are coupled via the pump unit **20** to the pump actuation device **10** or they can be held firmly on the same.

[0044] In an embodiment of the invention not shown here not only is the pressure control valve **35** a membrane valve, but also the two pressure valves **27**, **27'** or suction valves **26**, **26'** are designed as membrane valves instead of the ball valves shown here. This makes the arrangement even more economic. Finally, it is also possible to create the pump in such a

way that not only are all the valves membrane valves but all the membranes are connected in one piece, so that the number of components is decreased still further.

LIST OF REFERENCE NUMERALS

[0045] E Disposable part
[0046] B Operator
[0047] **5** Pressure hose
[0048] **6** Fluid inlet
[0049] **7** Fluid outlet
[0050] **8** Applicator
[0051] **9** Reservoir
[0052] **10** Pump actuation device
[0053] **11**,**11'** Motor
[0054] **12**,**12'** Gearing
[0055] **13**, **13'** Clutch system
[0056] **14** Butterfly valve
[0057] **15** Motor control
[0058] **16**,**16'** Pressure chamber
[0059] **17**,**17'** Coupling projection
[0060] **18** Spring
[0061] **19** Ball
[0062] **20** Pump unit
[0063] **21**, **21'** Cylinder
[0064] **22**, **22'** Piston
[0065] **23**, **23'** Seal
[0066] **24**, **24'** Cup seal
[0067] **25**, **25'** Piston rod
[0068] **26**, **26'** Suction valve
[0069] **27**, **27'** Pressure valve
[0070] **28** Cap
[0071] **29** Cylinder head
[0072] **30** Actuator
[0073] **31** Dynamometer
[0074] **32** Controller
[0075] **33** Spring
[0076] **34** Push rod
[0077] **35** Pressure control valve
[0078] **36** Valve membrane
[0079] **37** Connecting piece
[0080] **38** Crimp tube
[0081] **39** Internal tube
[0082] **40** Accumulator
[0083] **41** Spring
[0084] **42** Piston
[0085] **43** Seal
[0086] **44** Cylinder
[0087] **45** Catch
[0088] **46** Lugs

1. Medical pump, comprising
a pump actuating device;
at least two pistons with pistons rods for displacing the pistons in cylinders defined by said pump and coupling the pistons to said a pump actuation device;
a cylinder head sealing the cylinders;
valve means that respectively connect a pressure chamber in each of the cylinders with a fluid inlets and a fluid outlet; and
an adjustable pressure control valve is provided, in order adapted to limit the fluid pressure in each fluid outlet to a predetermined maximum value.

2. Medical pump according to claim **1**, wherein said pressure control valve is connected to said fluid inlet and said fluid outlet in such a way that, when the fluid pressure exceeds said predetermined maximum value, fluid from said fluid outlet is piped back to said fluid inlet.

3. Medical pump according to claim **1**, wherein at least one of said valve means or said pressure control valve comprises an elastic valve membrane (**36**).

4. Medical pump according to claim **1**, wherein said valve means comprise spring-loaded non-return ball valves

5. Medical pump according to claim **1**, wherein said pressure control valve comprises an actuator and is a power-controlled valve in which said predetermined maximum value is adjustable by a displacement force acting on said actuator.

6. Medical pump according to claim **1**, wherein said pistons and said piston rods are connected to the cylinders in a sealed manner which maintains sterility.

7. Medical pump according to claim **1**, wherein said valve means devices are fitted at least in part in said the cylinder head.

8. Medical pump according to claim **1**, wherein said cylinders are individually connected to said cylinder head.

9. Medical pump according to claim **1**, wherein said fluid outlet has connecting devices irreversibly connecting it to a pressure hose.

10. Medical pump according claim **1** wherein said cylinder head has holding means that holding catches, which are attached to said the pump actuation device.

11. Medical pump according to claim **1**, comprising an accumulator which is connected to the fluid outlet and which smoothes out pressure fluctuations in the fluid at the fluid outlet by means of a low pass function.

12. Medical pump according to claim **11**, wherein said accumulator is located in or is connected to said cylinder head.

13. Medical pump according to claim **1**, wherein said pressure control valve is fitted at least in part in said cylinder head.

* * * * *