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(54) MODULAR FLUID DISTRIBUTOR DEVICE AND RESPECTIVE REMOTE ELECTRONIC CONTROL AND COMMUNICATION SYSTEM

(57) A fluid distributor device (10) comprising a fluidic portion (12) in which the fluids to be treated flow, provided with one or more fluid inlet ducts (18) and one or more fluid outlet ducts (20) arranged in communication with a single chamber (30) closed by at least one fluid flow adjustment element (32) that determines the opening and closing of the fluid outlet ducts (20), and an actuator portion (14) separated from the fluidic portion through the fluid flow adjustment element (32) and comprising at least one actuator element (16) operatively connected to such a fluid flow adjustment element (32) to carry out the selective opening and closing of the fluid inlet and outlet ducts. The actuator element is configured to activate the fluid flow adjustment element and place the fluid inlet ducts in communication with the fluid outlet ducts.

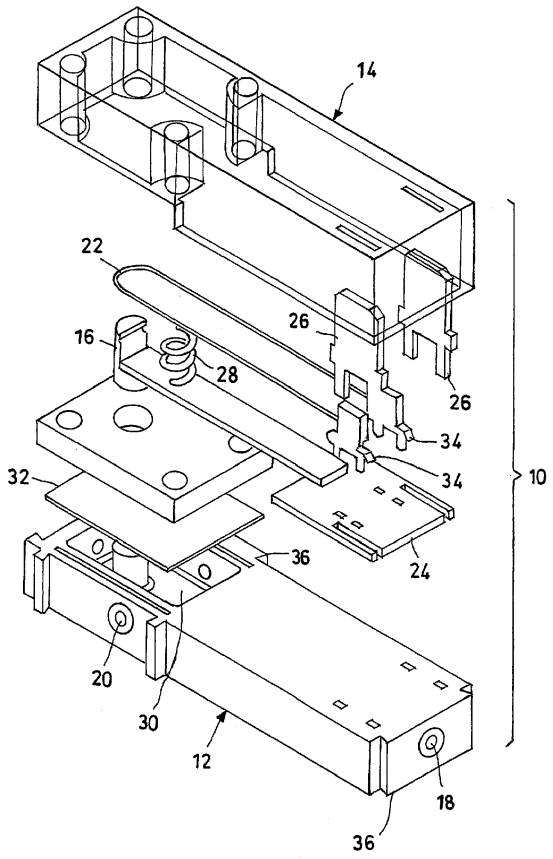

Fig.4

EP 3 059 205 A1

Description

[0001] The present invention refers to an electronic control and communication system applied to a modular fluid distribution platform. In particular, the electronic control and communication system is configured for applications in the field of beverages, medicine and in any case in all fields where a fluid can be classified as "*hazardous*".

[0002] In recent years, also thanks to the spread of both wired and wireless information connection networks, there has been an increasing need to be able to recover and process "field" information of any technological process in order to optimise the performance and efficiency thereof.

[0003] With reference to the field of beverages, for example, an essential requirement for a professional drinks distribution apparatus for commercial enterprises is the possibility of simultaneously dispensing beverages of different types, fizzy or not. Normally, these processes take place without the possibility of recovering any information from the devices involved in the management of the various fluids in these apparatuses. Simply, in order to obtain the final beverage a concentrated syrup component is mixed with water, which may or may not be fizzy, in different ratios according to the final beverage that is wished to be made. In order to obtain the mixing, typically, inside the hydraulic system of these apparatuses there are some components or valve systems assigned to distributing, for example, the fizzy water in the different points where the mixing with the single syrups takes place, or to distributing the different syrups over independent ducts, which will then make the beverage with the water.

[0004] A typical example of such components or valve systems is illustrated in figure 1 and is represented by a distributor system with five inlets and a single outlet. In this distributor system, controlled electronically, there is the possibility of sending five different beverages over a single outlet, with the additional inlet for the water component.

[0005] It is therefore clear how such a distributor system is rather bulky and heavy, since it is equipped with the different magnetic cores for the solenoid valves. Moreover, the system is rigid, in the sense that it is not possible to vary the number of inlets or outlets in a simple manner because this, in fact, would mean the total redesigning of the hydraulic manifold of the valves. In order to obtain a certain modularity in the distributor systems, different independent modules have thus been used.

[0006] In general, fluid distributor systems are equipped, as an option, with a mechanical flow control device capable of calibrating the flow rate with which the beverage is dispensed and/or made up. However, these distributor systems, as already specified, do not have the possibility of processing, managing and communicating any information relative to the fluids that they are treating. On the other hand, it is increasingly important to have some parameters available relative to the technological treatment process of the fluids, like for example pressure, flow rate, temperature, etc.

[0007] Fluid distributor systems have thus been made in which the control of the flow of fluid takes place through electronic devices, like for example the one described in document US 2014/263418 A1. Document US 2014/263418 A1 refers in particular to a beverage distribution system, designed mainly for automatically preparing and serving cocktails or similar beverages. The system is made up of a dosing valve able to adapt directly to the bottles of the various base beverages, which communicates remotely with automatic ordering and payment systems in order to facilitate and automate the beverages serving operations.

[0008] Document US 2014/263418 A1 focuses on the methods of communication that takes place inside the distribution system. This distribution system does not, however, allow modulated and proportional control of the fluid, so that in the distribution system according to document US 2014/263418 A1 the dosing of the beverages is managed by time.

[0009] The purpose of the present invention is therefore to make an electronic control and communication system applied to a modular fluid distribution platform that is able to solve the aforementioned drawbacks of the prior art in an extremely simple, cost-effective and particularly functional manner.

[0010] In detail, a purpose of the present invention is to make a remote electronic control and communication system, suitably developed for a modular fluid distribution platform, which is able to send and receive, with a bi-directional communication mode, information concerning the characteristic physical parameters of the fluid, and to make available such information remotely, and furthermore to proportionally modulate the flow rate of the fluid.

[0011] Another purpose of the present invention is to make a remote electronic control and communication system applied to a modular fluid distribution platform that is completely modular and thus easy to configure.

[0012] A further purpose of the present invention is to make a remote electronic control and communication system applied to a modular fluid distribution platform that is of extremely small size and weight.

[0013] These purposes according to the present invention are accomplished by making an electronic control and communication system applied to a modular fluid distribution platform as outlined in claim 1.

[0014] Further characteristics of the invention are highlighted by the dependent claims, which are an integral part of the present description.

[0015] In general, since the modular fluid distribution platform according to the present invention has a component manufactured from a shape memory alloy as actuator element for managing the fluid, the remote electronic control and communication system will be configured to manage the current necessary to move such a component manufactured from a shape memory alloy (typically consisting of a wire). The control can also be

of the proportional type, thus having the possibility to linearly modulate the flow of fluid to be managed. The same remote electronic control and communication system of the fluid distributor device can process, indirectly and thanks to the presence of suitable sensor means, preferably consisting of the same actuator element manufactured from a shape memory alloy, some intrinsic parameters of the fluid like for example the pressure, flow rate and temperature.

[0016] Indeed, thanks to the fact that by reading the electrical resistance of the wire made of shape memory alloy it is possible to obtain the length of the wire itself, and therefore the actual open position of the valve of the device, by reading the energy injected it is possible to understand the force with which the wire is acting, and thus indirectly the pressure of the system. Moreover, considering that the total amount of energy necessary to reach the transition of the shape memory alloy is also a function of the temperature of the system, it will also be simple to provide these parameters without a further introduction into the system of specific sensors.

[0017] The electronic control and communication system is provided with an electronic board that integrates a wireless remote communication module configured to make available the "field" parameters of the fluid quoted earlier. Such a remote communication module can interface, and therefore can communicate wirelessly, with portable devices such as smartphones, tablets or similar, or can interface with the network and therefore communicate with remote terminals via the web.

[0018] The possibility of having available and processing the data concerning the fluid brings numerous advantages in terms of remote control of the apparatuses. Indeed, it is for example possible, based on the flow rate and pressure information, to intervene remotely on the mixing ratios of the two syrup and water components, or to intervene on the final flow rate of the beverage, as well as to monitor the correct operation of the devices, with an advantage on the efficiency and preciseness of the maintenance interventions of the apparatuses. In general, the parameters of use and consumption can also be available, like for example the number of beverages dispensed, the amount of syrup used, etc.

[0019] The remote electronic control and communication system can also be advantageously applied in the field of medicine, where necessarily the possibility of monitoring the different process parameters is of even greater value. For example, in a specific field like that of apparatuses for dialysis and, in particular, in the management of the flows of dialysis liquids obtained as reconstitution of osmotic water with concentrated saline solutions, it is advantageous to know in real time, remotely, the main parameters of the dialysis liquid itself and monitor the correct operation, in terms of pressure and flow rate in various points of the hydraulic circuit (in general very complex), of the apparatuses. These controls can be carried out without the introduction of further sensors, but rather carried out intrinsically through the fluid distributor device.

[0020] The characteristics and advantages of an electronic control and communication system applied to a modular fluid distribution platform according to the present invention will become clearer from the following description, given as an example and not for limiting purposes, referring to the attached schematic drawings, in which:

figure 1 is a perspective view of a known fluid distributor system, provided with five inlets and a single outlet;
figure 2 is a transparent view of a single fluid distributor device that integrates an electronic control and communication system according to the present invention;
figure 3 is a section view of the single fluid distributor device of figure 2;
figure 4 is an exploded view of the single fluid distributor device of figure 2;
figure 5 is a perspective view illustrating three distinct fluid distributor devices connected together;
figure 6 is a graph showing the trend of the fluid flow rate as a function of the degree of opening of a single fluid distributor device;
figure 7 is a schematic view of the control circuit of the actuator of a single fluid distributor device;
figure 8 is a graph showing an average duty cycle of a single fluid distributor device;
figure 9 is a graph showing the trend of the pressure of the fluid as a function both of the average duty cycle, and of the degree of opening of a single fluid distributor device;
figure 10 is a graph showing the variation of the average value of the duty cycle as a function of the variation in pressure of the fluid; and
figure 11 is a graph showing a possible pressure compensation procedure able to be actuated through the electronic control and communication system according to the present invention.

[0021] With reference to figures 2 to 5, a single fluid distributor device that integrates an electronic control and communication system according to the present invention is shown. The fluid distributor device, or modular fluid distributor, is wholly indicated with reference numeral 10.

[0022] The fluid distributor device 10 substantially consists of a fluidic portion 12, in which the fluids to be treated flow, and an actuator portion 14. The fluidic portion 12 is equipped with a plurality of interface and quick connection means 36 for putting two or more analogous fluid distributor devices 10 in fluid connection with each other and/or with an apparatus for treating fluids in which such fluid distributor devices 10 can be inserted. The fluidic portion 12 is also equipped with at least one adjustment element 32 of the flow of fluid, which will be illustrated in detail herein after.

[0023] The actuator portion 14 comprises at least one

actuator element 16 that carries out the selective opening and closing of the fluid inlet 18 and outlet 20 ducts. Advantageously, the actuator element 16 consists of a mechanical rod that operates by elastic deformation under the action of at least one wire 22 manufactured from a shape memory alloy. The wire 22 is capable of applying a force, preferably a traction force, on the actuator element 16 due to the temperature variation (heating) determined by the Joule effect by the passage of an electric current through the wire 22 itself.

[0024] The fluid distributor device 10 is thus provided with an electronic control and communication system comprising a control board 24 in turn provided with power supply connections 26. The control board 24 is also provided with operational connection means 34, for example consisting of one or more mechanical and electrical crimps, with the wire 22 manufactured from a shape memory alloy. The control board 24 is further provided with a communication and control module capable of indirectly obtaining certain physical parameters of the fluid through the characteristics of the wire 22 manufactured from a shape memory alloy. Alternatively, the electronic control and communication system can be provided with sensor means (not shown) capable of directly obtaining the aforementioned physical parameters of the fluid.

[0025] The actuator portion 14 can also be equipped with at least one contrast element 28, like for example a spring, configured for increasing the mechanical sealing load of the actuator element 16. The fluidic portion 12, as shown in detail in figure 3, is equipped with one or more fluid inlet ducts 18 and one or more fluid outlet ducts 20. The fluid inlet 18 and outlet 20 ducts all communicate with a single distribution chamber 30 closed by an adjustment element 32 of the flow of fluid, advantageously consisting of a separation membrane. The separation membrane 32, as well as separating the fluidic portion 12 from the actuator portion 14, also determines the opening and closing of the fluid outlet ducts 20.

[0026] The wire 22 manufactured from a shape memory alloy, by Joule effect determined by the passage of a current controlled by the control board 24, deforms applying a traction force on the actuator element 16. Consequently, the actuator element 16 flexes elastically, lifting the separation membrane 32 and placing the fluid inlet ducts 18 in communication with the fluid outlet ducts 20.

[0027] The control board 24 is configured for deforming in a modular and controllable manner the wire 22 manufactured from a shape memory alloy, so as to determine a corresponding modular and controllable traction force on the actuator element 16. Consequently, the very precise control of the movement of the actuator element 16 is obtained. This, in fact, allows a proportional control of the passage equivalent section of the fluids in the fluidic portion 12 and, therefore, of the flow rate of the fluid exiting the respective one or more outlet ducts 20. The modulable and proportional actuation modes of the wire 22 manufactured from a shape memory alloy and of the actuator element 16 can also be varied remotely thanks to the communication and control module integrated in the control board 24.

[0028] In particular, the separation membrane 32 is an essential element for ensuring the transmission of the physical parameters of the fluid, notably the pressure $\boldsymbol{p}$, to the actuator element 16 comprising the wire 22 manufactured from a shape memory alloy, so that such an actuator 16 can be used as a sensor without the wire 22 itself coming into contact with the fluid. In other words, by using the separation membrane 32, the actuator element 16 can simultaneously operate as actuator, and as sensor.

[0029] With reference to figure 3, it can be seen that the fluid, entering into the distribution chamber 30 while the actuator element 16 is in closed position, generates a pressure increase $\boldsymbol{p}$ inside the distribution chamber 30 itself. The separation membrane 32, which has the ability to deform under the effect of the pressure $\boldsymbol{p}$, would tend to lift. However, in the condition in which the fluid distributor device 10 is deactivated, the separation membrane 32 is kept in closed position by the contrast element 28 or bias spring.

[0030] From the aforementioned operative condition, the force necessary to move (lift) the actuator element 16, and therefore the force that the wire 22 manufactured from a shape memory alloy must exert, will be lower as the pressure $\boldsymbol{p}$ inside the distribution chamber 30 increases. It is possible, at this point, to put the force exerted by the wire 22 manufactured from a shape memory alloy in relation with the pressure $\boldsymbol{p}$ to which the separation membrane 32 and, therefore, the fluid, is subjected. The force exerted by the wire 22 manufactured from a shape memory alloy is in turn linked to the energy supplied to the wire 22 itself to heat it, in order to make it carry out a certain movement. Basically, by measuring the instantaneous electric current supplied to the wire 22 to carry out a certain movement with the communication and control module, also measurable by reading the electrical resistance, it is possible to identify the pressure value $\boldsymbol{p}$ present inside the distribution chamber 30, moment by moment, in dynamic conditions.

[0031] In greater detail, in static conditions, given a certain pressure condition $\boldsymbol{p}$ inside the distribution chamber 30, which determines a certain deformation of the separation membrane 32 and therefore a certain force on the wire 22 in order to have a desired flow rate $\dot{\boldsymbol{q}}$ (corresponding to a certain opening $\hat{\boldsymbol{a}}$ of the distribution module 10 - see figure 6), the average energy supplied to the wire 22 to keep the desired flow rate $\dot{\boldsymbol{q}}$ constant is in turn constant. A measurement of such energy can be obtained, for example, by calculating the average value $\overline{d}$ of the *"duty cycle"* of the PWM *("pulse-width modulation"*) with which the wire 22 is controlled (see the control circuit of figure 7, in which the wire 22 is represented by the electrical resistance RSMA).

[0032] In dynamic conditions, an analysis of the response transients to a flow rate step shows, for the av-

erage *"duty cycle"* $\bar{d}$, a time constant **r** equal to about 0.5 seconds. After about 2.5 seconds all of the transient phenomena can be considered exhausted (see figure 8). Hypothesising, therefore, that the transients are negligible and by analysing the behaviour of the system in normal conditions, it is possible to obtain the pressure value ***p*** from the measurement of the average *"duty cycle"* $\bar{d}$ and from the opening ***â*** of the distribution module 10 (see figure 9). By subjecting the system to pressure variations Δp, corresponding variations of the average value $\bar{d}$ of the *"duty cycle"* are observed: if the pressure ***p*** of the system increases, the average *"duty cycle"* $\bar{d}$ decreases and vice-versa (see figure 10).

[0033] Moreover, starting from an indirect measurement of the pressure ***p*** and knowing the opening/flow rate curve of the distribution module 10 (curve of figure 6) it is possible to implement a compensation procedure to keep the flow rate $\dot{q}$ constant even after pressure variations Δp of the system. Given a certain opening ***â*** of the distribution module 10, pressure increases ***p*** cause an increase in the flow rate $\dot{q}$. Vice-versa, pressure decreases ***p*** cause a decrease in the flow rate $\dot{q}$. If the distribution module 10 is in a normal operating condition and variations of the average value $\bar{d}$ of the *"duty cycle"* are detected, it is possible to compensate pressure increases ***p*** by reducing the opening of the valve and pressure decreases ***p*** by increasing the opening ***â*** of the distribution module 10, in this way keeping the desired flow rate $\dot{q}$ constant. A basic compensation procedure, carried out with software installed in the electronic control and communication system and tested experimentally, is represented in figure 11.

[0034] With reference to figure 5, it is highlighted how the fluid distributor device 10 according to the present invention is particularly compact and is equipped with a parallelepiped configuration that facilitates the installation thereof in the most common apparatuses for treating fluids. As stated earlier, each fluid distributor device 10 is provided with interface and quick connection means 36, typically provided in the fluidic portion 12, configured to carry out the coupling of many distribution modules 10 and thus form manifolds of variable shape and size. The whole thing is able to be made with maximum flexibility and simplicity.

[0035] Figure 5 shows an example of modularity in which it is highlighted how the interface and quick connection means 36 of the single distribution modules 10 have been studied specifically to allow easy connection between the distribution modules 10 themselves. Of course, all or part of the interface and quick connection means 36 of each single distribution module 10 can be kept closed, through corresponding suitably configured plugs, in the operating condition in which such a distribution module 10 is not connected to any contiguous distribution module. Another possibility is that the various fluid inlet 18 and outlet 20 ducts are normally closed by a wall in the interface point. Such a wall can be opened under mechanical thrust at the moment in which it is wished to place the distribution module 10 in communication with other modules.

[0036] It has thus been seen that the electronic control and communication system applied to a modular fluid distribution platform according to the present invention achieves the purposes outlined earlier, in particular obtaining the following advantages:

- the remote electronic control and communication system exploits the ability of the shape memory wire to operate simultaneously both as actuator, and as sensor, obtaining some characteristic parameters of the fluid and making them available remotely. The communication is of the bi-directional type, which makes it possible both to import "field" information from the module, and also to intervene remotely on the operating characteristics of the distributor device;
- the distributor device is completely modular, thus easy to configure, since it consists of a plurality of valve elements able to be coupled together so as to define the desired distribution system in terms of inlets/outlets for the fluid, being able to create both a single duct with different outlets, and different independent ducts;
- the distributor device is easily modulable thanks to the fact that each single valve element is of extremely small size and weight and is provided with quick interface connections;
- the size and weight are particularly small also thanks to the use of an actuator consisting of a wire made of shape memory alloy;
- each single valve element can also be designed with total separation, with the fluidic portion completely independent and separated, through a suitable membrane, from the actuator portion;
- the actuator with wire made of shape memory alloy can vary in a controlled and modular manner the flow of fluid. There is thus proportional electronic control of the desired flow rate of the fluid, as well as the normal ON/OFF opening and closing function;
- the use of the actuator manufactured from a shape memory alloy finally makes it possible to obtain a completely silent valve system.

[0037] The electronic control and communication system applied to a modular fluid distribution platform of the present invention thus conceived can in any case undergo numerous modifications and variants, all of which are covered by the same inventive concept; moreover, all of the details can be replaced by technically equivalent elements. In practice, the materials used, as well as the shapes and sizes, can be whatever according to the technical requirements.

[0038] The scope of protection of the invention is therefore defined by the attached claims.

Claims

1. Fluid distributor device (10) comprising:

   - a fluidic portion (12) in which the fluids to be treated flow, said fluidic portion (12) being provided with one or more fluid inlet ducts (18) and one or more fluid outlet ducts (20), said fluid inlet (18) and outlet (20) ducts being placed in communication with a single distribution chamber (30) closed by at least one fluid flow adjustment element (32) which determines the opening and closing of the fluid outlet ducts (20); and
   - an actuator portion (14), separated from the fluidic portion (12) by means of said at least one fluid flow adjustment element (32) and comprising at least one actuator element (16) operatively connected to said at least one fluid flow adjustment element (32) to carry out the selective opening and closing of said fluid inlet (18) and outlet (20) ducts,

   wherein said at least one actuator element (16) is configured to activate said at least one fluid flow adjustment element (32) and to put in communication the fluid inlet ducts (18) with the fluid outlet ducts (20), the fluid distributor device (10) comprising an electronic control and communication system in turn comprising one or more sensor means capable of acquiring certain physical parameters of the fluid, as well as a control board (24) provided with operational connection means (34) with said one or more sensor means, said control board (24) integrating a wireless remote communication module, interfaceable via the web with remote terminals and/or with portable devices and configured to make available said physical parameters of the fluid on said remote terminals and/or said portable devices, the fluid distributor device (10) being **characterised in that** said at least one actuator element (16) is configured for operating under the action of at least one wire (22) manufactured from a shape memory alloy, said at least one wire (22) manufactured from a shape memory alloy being capable of imparting a force onto said at least one actuator element (16) due to the temperature variation determined by the Joule effect by the passage of an electric current through said wire (22) manufactured from a shape memory alloy.

2. Fluid distributor device (10) according to claim 1, **characterised in that** said at least one adjustment element (32) is made of a separation membrane configured for rising as a result of the action of said at least one actuator element (16), thus putting in communication the fluid inlet ducts (18) with the fluid outlet ducts (20).

3. Fluid distributor device (10) according to claim 2, **characterised in that** said control board (24) is provided with a communication and control module capable of indirectly obtaining said physical parameters of the fluid through the characteristics of said wire (22) manufactured from a shape memory alloy, said communication and control module measuring the instantaneous electric current supplied to said wire (22) manufactured from a shape memory alloy to identify the pressure value ***(p)*** present inside said distribution chamber (30) based on the relationship between the force exerted by said wire (22) manufactured from a shape memory alloy and the pressure ***(p)*** to which said separation membrane (32) is subjected.

4. Fluid distributor device (10) according to claim 3, **characterised in that** said control board (24) is configured for deforming in a modular and controllable manner said wire (22) manufactured from a shape memory alloy, so as to determine a corresponding modular and controllable force on said at least one actuator element (16) and for allowing a proportional control of the passage equivalent section of the fluids in the fluidic portion (12) and, therefore, of the flow rate ($\dot{q}$) of the fluid exiting from the respective outlet ducts (20).

5. Fluid distributor device (10) according to any claims 1 to 4, **characterised in that** said physical parameters of the fluid are selected from the group consisting of pressure ***(p)***, flow rate **($\dot{q}$)** and temperature.

6. Fluid distributor device (10) according to any claims 1 to 5, **characterised in that** it comprises a plurality of interface and quick connection means (36) configured for carrying out the coupling and connection of fluid between two or more contiguous fluid distributor devices (10).

7. Fluid distributor device (10) according to claim 6, **characterised in that** said interface and quick connection means (36) are obtained on the fluidic portion (12).

8. Fluid distributor device (10) according to claim 6 or 7, **characterised in that** at least one part of said interface and quick connection means (36) is provided with respective plugs configured for maintaining closed said interface and quick connection means (36) in the operating condition in which the corresponding fluid distributor device (10) is not connected to any contiguous fluid distributor device (10).

9. Fluid distributor device (10) according to claim 6 or 7, **characterised in that** at least one part of said interface and quick connection means (36) is provided with respective walls configured for maintaining closed said interface and quick connection means

(36) in the operating condition in which the corresponding fluid distributor device (10) is not connected to any contiguous fluid distributor device (10), said walls being openable under mechanical thrust when it is desired to put in communication the corresponding fluid distributor device (10) with one or more contiguous fluid distributor devices (10).

10. Fluid distributor device (10) according to any preceding claims, **characterised in that** said control board (24) is provided with power supply connections (26) and **in that** said operational connection means (34) are made of one or more mechanical and electrical crimps.

11. Fluid distributor device (10) according to any preceding claims, **characterised in that** the actuator portion (14) is provided with at least one contrast element (28) configured for increasing the mechanical sealing load of said at least one actuator element (16).

12. Fluid distributor device (10) according to claim 11, **characterised in that** said at least one contrast element (28) is a spring.

13. Fluid distributor device (10) according to any preceding claims, **characterised in that** said at least one actuator element (16) consists of a mechanical rod configured for operating by elastic deformation under the action of said wire (22) manufactured from a shape memory alloy.

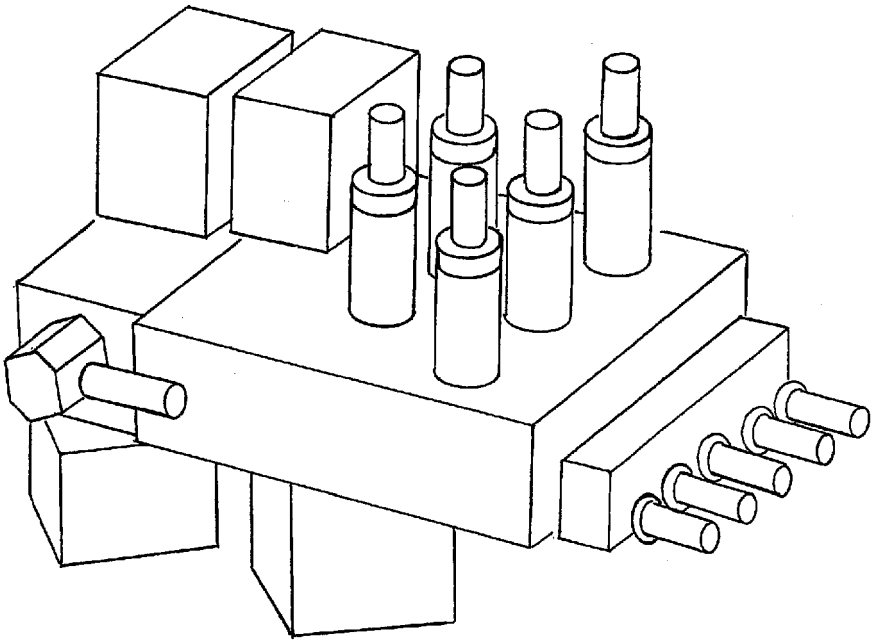

Fig.1

PRIOR ART

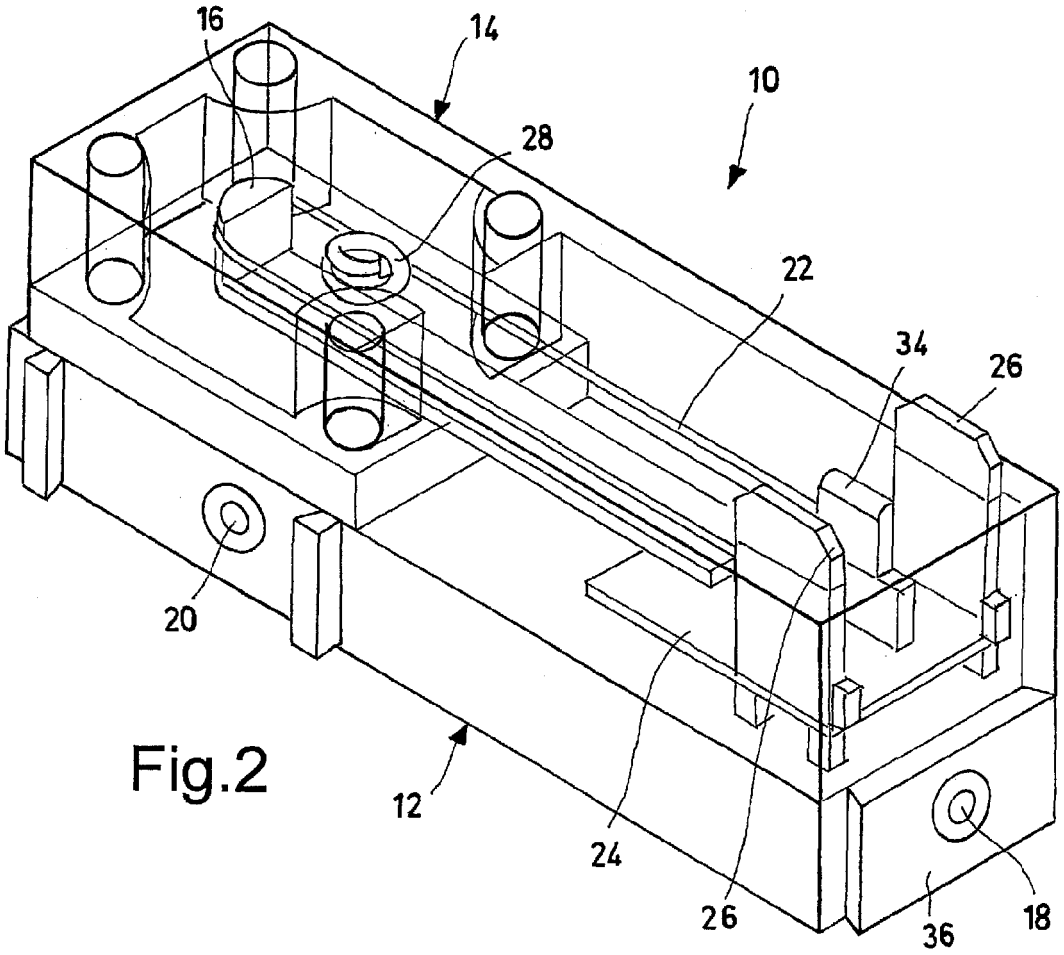
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Fig.2

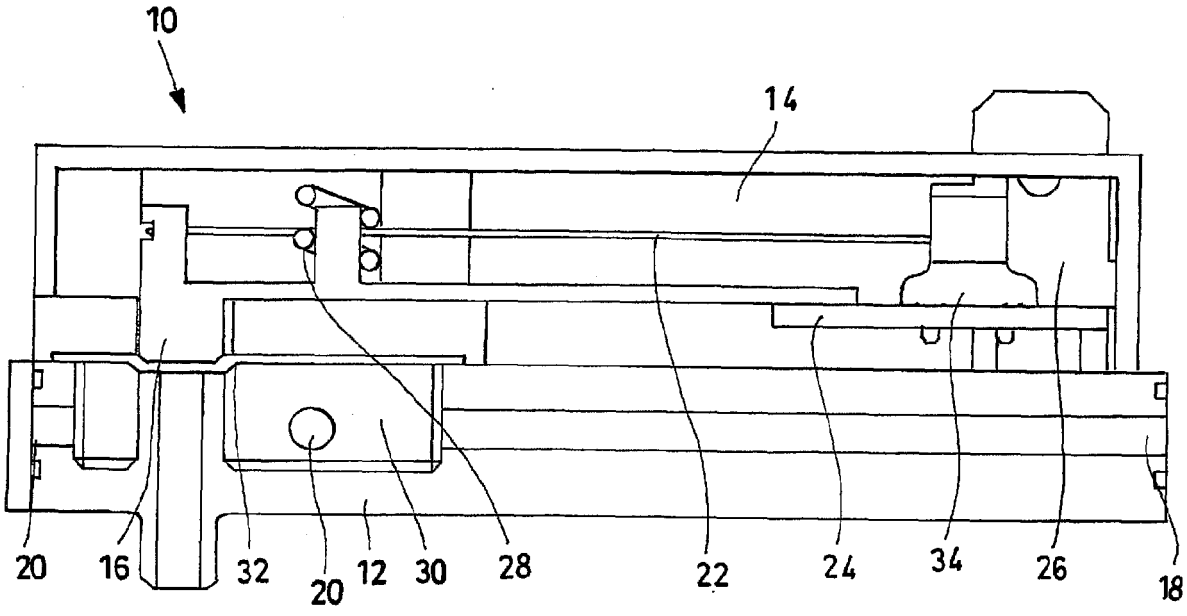
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Fig.3

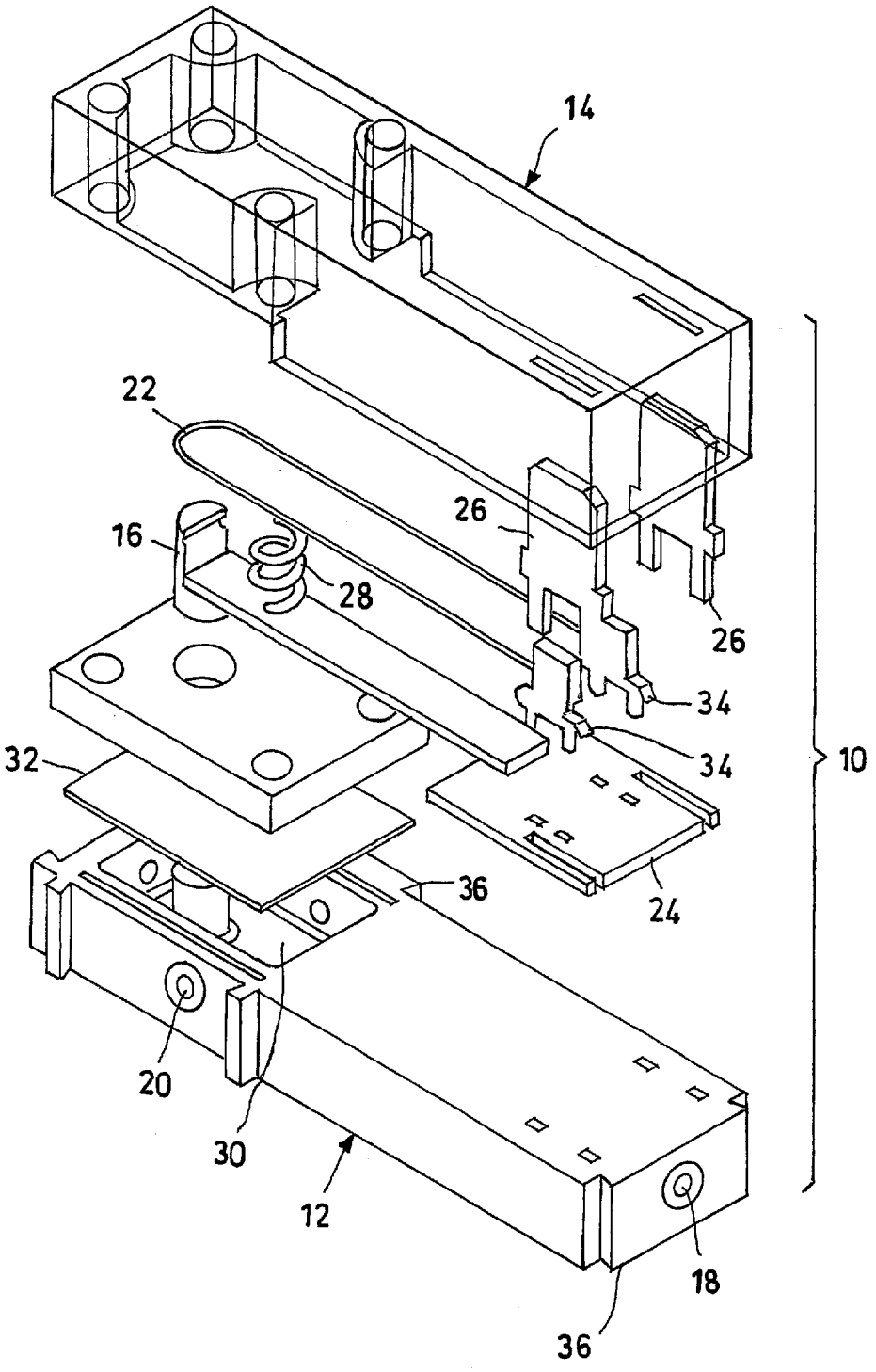

Fig.4

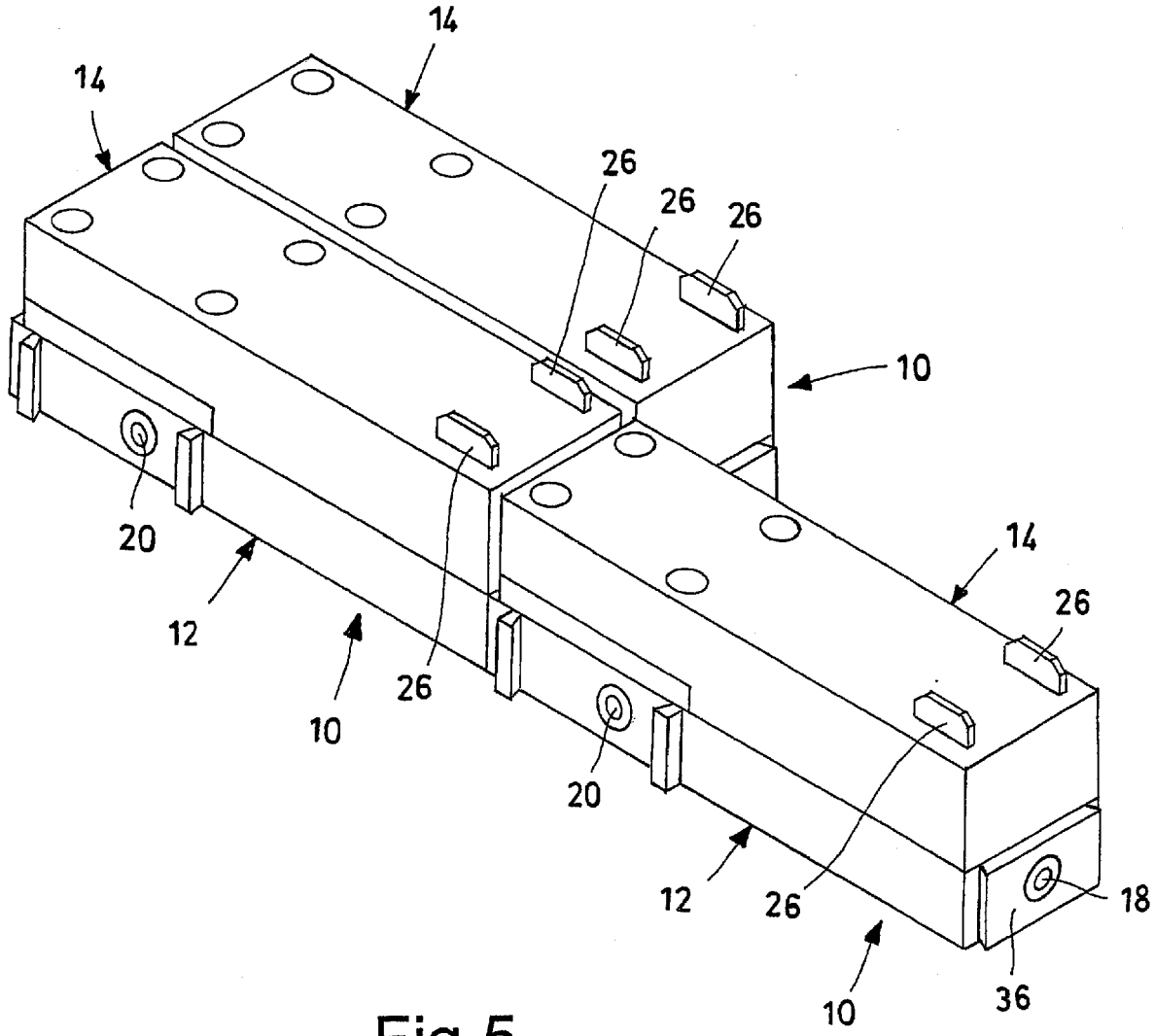

Fig.5

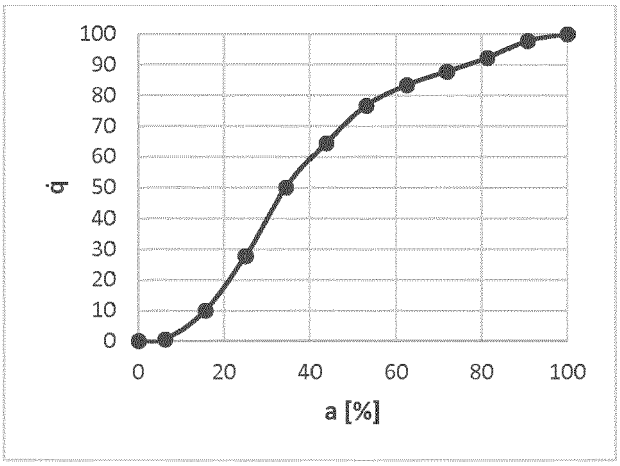

Fig. 6

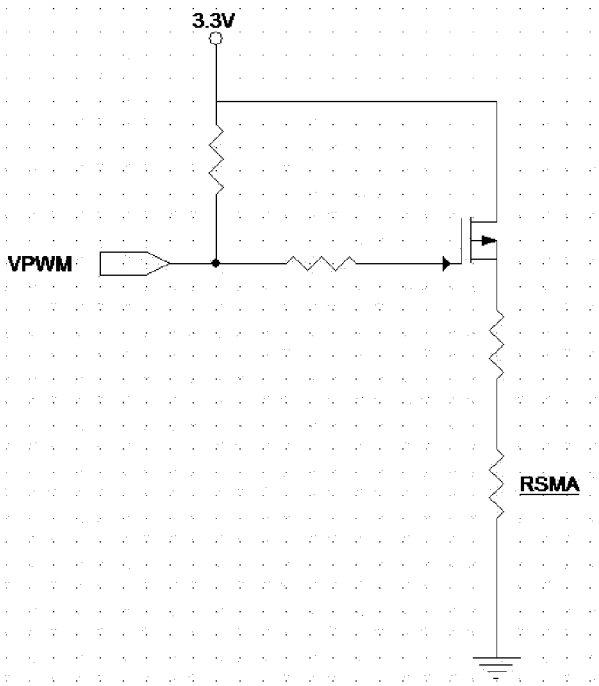

Fig. 7

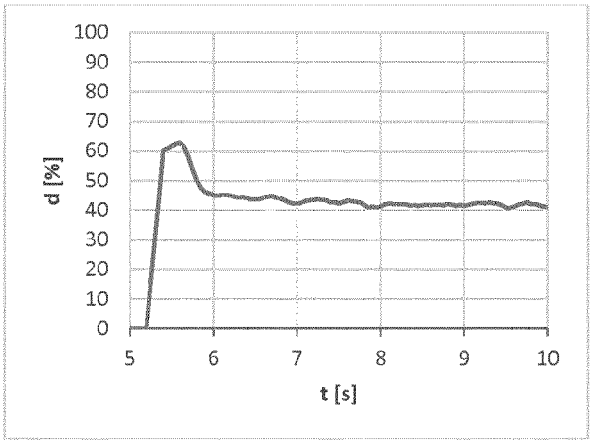

Fig. 8

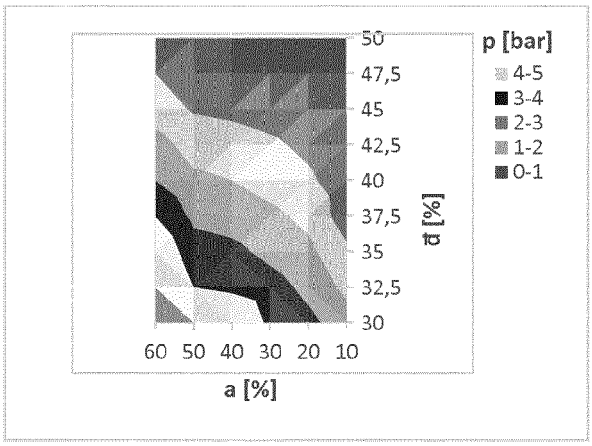

Fig. 9

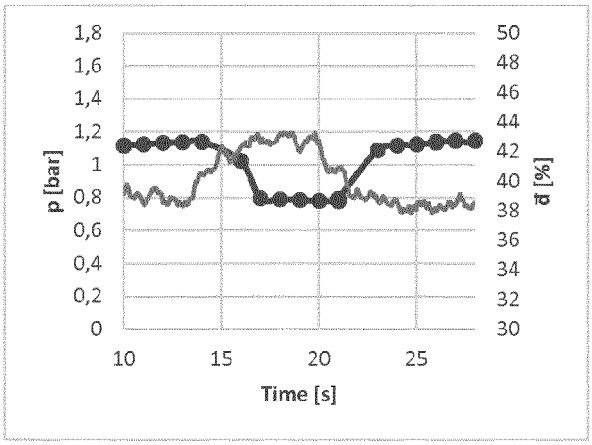

Fig. 10

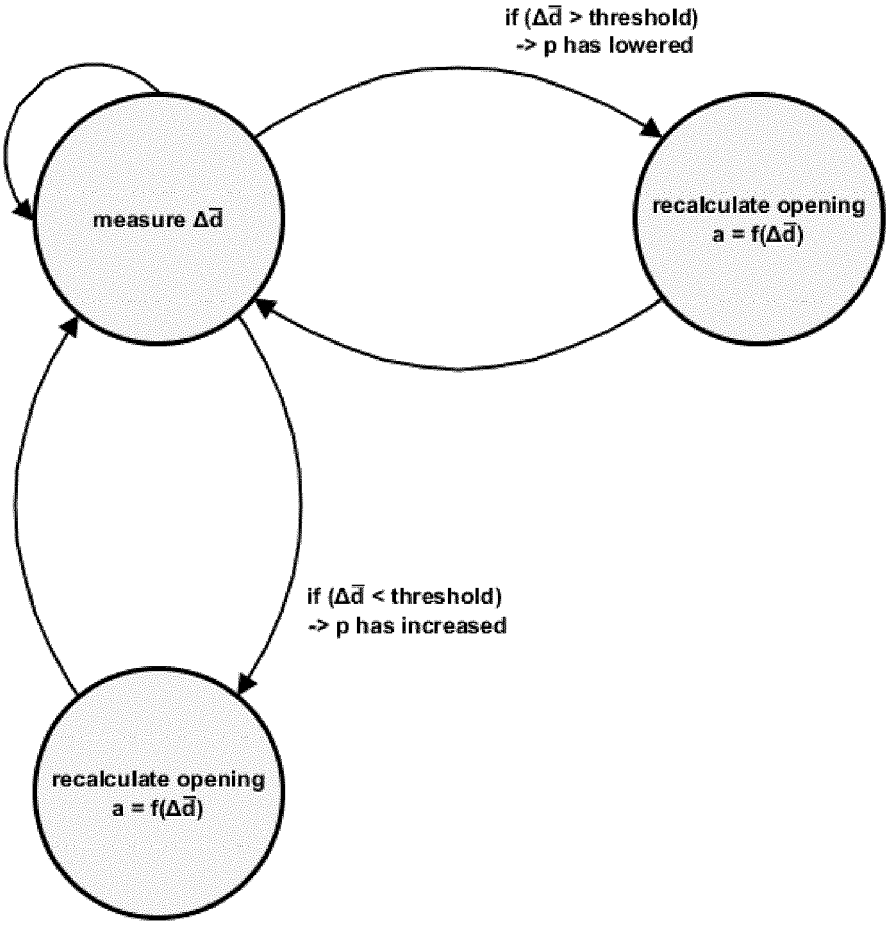
if ($\Delta\bar{d}$ > threshold)
-> p has lowered
measure $\Delta\bar{d}$
recalculate opening
a = f($\Delta\bar{d}$)
if ($\Delta\bar{d}$ < threshold)
-> p has increased
recalculate opening
a = f($\Delta\bar{d}$)

Fig. 11

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EUROPEAN SEARCH REPORT

Application Number
EP 16 15 6086

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Place of search	Date of completion of the search	Examiner
Munich	19 July 2016	Schultz, Tom

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