

**VALVE UNIT FOR INSTALLATIONS WITH PRESSURE EXCHANGERS****DESCRIPTION**

The invention relates to a valve unit, in particular for installations with pressure exchangers with tubular chambers through which flow occurs alternately, a rotatable control element with a plurality of flow paths being arranged within a housing, the housing having a plurality of connections for connection lines, the housing being connected to a first pipework system and, in each case, with an end of at least one tubular chamber, a respective other end of a tubular chamber being connected to a second pipework system with the intermediate connection of further valve units, the control element being provided with a motor-driven drive shaft and the flow paths of the control element being alternately connected to openings arranged in the housing.

Such pressure exchangers consist of two or more tubular chambers, whose ends are provided with valve units. The tubular chambers are alternately subjected to fluids of different energy content by corresponding opening and closing of the valve units. Within the tubular chambers, it is therefore possible to transfer, in an installation or in a technical installation process, a high pressure of a fluid to another fluid which only has low pressure. With the aid of such pressure exchangers, savings in energy costs can therefore be made within installations and pumps for increasing pressure can be made smaller.

A reverse osmosis process is often used for treating water. In this arrangement, a fluid flow to be cleaned is forced at high pressure through a membrane system which, in the case of large fluid quantities, consists of a large number of membrane modules. In such membrane modules, a separation into pure water and an enriched concentrate takes place through a membrane



because, invariably, only a part of the fluid to be cleaned can flow through a membrane. The proportion flowing through emerges as pure water, or also as permeate, on the other side of the membrane as a usable proportion. The part which does not flow through leaves a membrane module as brine - a fluid concentrate enriched with salts and minerals - as an unusable proportion which is at high pressure. This pressure is approximately 2 bar below a module inlet pressure of approximately 65 bar.

From US 5 306 428, a reverse osmosis installation is known in which pressure exchangers in the form of tubular chambers are used for the recovery of energy. With the aid of these tubular chambers, the pressure, which is still high, of the energy-rich brine flowing away from the membrane module is transmitted to a fluid which still has to be cleaned. A lower pump drive power, by the amount of this increase in pressure, is therefore necessary in order to generate the high pressure necessary for the reverse osmosis process in the fluid to be introduced.

In order to control and/or switch over the fluid paths of the brine in and out of the tubular chambers of the pressure exchanger, a valve unit with a rotating control element is used, together with other valve units. With the aid of this control element, the tubular chambers of the pressure exchanger are alternately subjected to the brine emerging from the membrane modules. The rotating control element is configured as a cylinder in which connecting ducts are arranged in the manner of a 3-way valve. During the switch-over procedures, all the flow paths are completely blocked. In order to avoid pressure surges during such switch-over procedures, pressure balance ducts are arranged within the cylinder.

The separation capability of a membrane decreases as a function of the duration of operation of the membrane and a fluid to be cleaned must remain correspondingly longer within a membrane module. For

this reason, the switch-over times of the cylinder are influenced, in the prior art, with the aid of a servomotor. This valve unit, however, is only suitable for small reverse osmosis installations because the  
5 flow cross sections within the valve unit are approximately the same size as the flow cross sections of the ducts to be filled. In the case of large installations, and the fluid columns to be displaced in them and the forces caused by this, a substantial  
10 dimensioning problem arises for the valve unit.

The invention is based on the problem, particularly in the case of large reverse osmosis installations, of producing a switch-over device with the aid of which large fluid flows can be distributed,  
15 simply and without difficulty, between different tubular chambers of the pressure exchanger. In the case of a valve unit of the generic type, the solution of this problem provides, within the housing, for a supply flow to the control element occurring from the axial  
20 and/or radial direction and an outlet flow occurring in the axial direction from the control element. A minimum installation length of the valve unit can be achieved in the case of axial supply and outlet flows. Although, in the case of radial supply flow, on the other hand,  
25 the valve unit is somewhat longer, the axial thrust occurring can be dealt with more easily.

One development provides for the control element being configured as a hollow cylindrical control element and for a separating wall dividing the  
30 hollow cylindrical control element into two spaces of different pressure regions. This permits the formation of additional spaces, in which a flow deflection occurs for a fluid to be exchanged, within the valve unit. In consequence, a simple, thin-walled component, which is  
35 easier to control during the switch-over processes, to be used for the actual control and sealing functions of the valve unit. To this end, a further development provides for additional stiffening features to be arranged in the spaces of different pressure regions.

Such stiffening features are configured as ribs or wall elements subdividing a pressure region through which flow occurs in the flow direction. The additional stiffening features can likewise be configured in the form of annular elements. These can be segments or peripheral parts. They improve the stiffness of the hollow cylindrical control element when it is subjected to different pressure ratios, thus acting against deformation of the component.

Different developments for actuating the hollow cylindrical control element provide for the drive shaft to be connected to the separating wall so as to transmit torque, for the separating wall to be arranged in the central region of the hollow cylindrical control element, for a component, which transmits torque, to be arranged on one end surface of the hollow cylindrical control element, for the separating wall to be solidly connected to the control element or for the separating wall to be solidly connected to the housing. A drive shaft can therefore be connected directly or indirectly to the control element. This depends on the most favorable mode of manufacture. In the case of the arrangement of the separating wall in the central region of the hollow cylindrical control element, the subdivision into two pressure spaces is ensured. The separating wall, which subdivides the control element into two pressure regions, can then be fastened directly on the control element or be connected to the housing.

For this purpose, developments provide for the separating wall to be fastened to the housing with struts in the region of a high-pressure end supply opening. Sealing elements can then be arranged between the separating wall, which is then stationary, and the rotating inner wall surface of the hollow cylindrical control element. The separating wall and/or the separating wall with struts connecting to the housing can also be configured as an exchangeable insert. This facilitates assembly and maintenance operations and the

separating wall fastened to the housing permits an arrangement of the control element which is free from axial thrust.

5 In another development, the control element is configured as a full cylinder and a plurality of groove-shaped flow paths form different pressure regions in its peripheral surface. This different type of manufacture improves the strength properties. To this end, further developments provide for the flow  
10 paths of equal pressure regions to be arranged diametrically opposite to one another on the peripheral surface, thus creating a pressure equilibrium.

Provision is also made for a section of the groove-shaped flow paths connected to a flow opening to  
15 form the control opening of the control element and for a peripheral annular groove in the housing and/or in the peripheral surface of the control element to be arranged in the region of a radial high-pressure end supply opening. This provides better additional radial  
20 connection possibilities. In addition, a closed annular sealing zone is arranged on the control element between ends of the groove-shaped flow paths of the different pressure regions and sealing elements are arranged in the region of the sealing zone on the control element  
25 and/or on the housing. And an axial thrust relief takes place between its end surfaces by means of a pressure-relief duct arranged in the control element. In consequence, it is possible to dispense with additional thrust bearings.

30 The pressure loading on the housing is optimized by control pockets on the outer periphery of the control element. These have a forked and/or stepped configuration and are connected to control openings. In consequence, there is a targeted internal pressure  
35 loading of the housing with high pressure in the region of the control pockets in order to act against external housing loads. In addition, due to the control pockets, there is a further flow path, with the aid of which a brief connection is permitted between the connected

tubular chambers. By this means, a section of the flow-transfer ducts is only briefly displaced into the control element.

5 By means of a fork-shaped configuration of the control pockets, approximately continuous volume flows and pressure ratios are maintained within the valve unit during the switch-over. Protrusion elements located in the actual fork are arranged in the plane of the radial stiffening ribs. This measure likewise  
10 improves the force transfer within the valve unit. In an analogous manner, fork-shaped and/or stepped configurations of flow pockets, which are also connected to flow openings, can be arranged on the inner periphery of the housing inner wall.

15 In a different development of the invention, a plurality of flow-transfer ducts connecting the flow openings are arranged on and/or in the outer wall of the housing. With their aid, an exchange of the fluid out of and into the tubular chambers occurs during the  
20 working strokes of the pressure exchanger, the valve unit ensuring that each connected tubular chamber is always filled from the region of the entering fluid and is emptied into the region of the emerging fluid. For an adaptation of the control periods of the pressure  
25 exchanger, provision is made for the flow openings arranged in the housing to be constituent parts of an adjustable, hollow cylindrical housing inner wall. Such an additional hollow cylindrical housing wall is fashioned as a separate component and can be arranged  
30 so that it is rotated, together with the flow openings arranged within it, relative to the housing. By this means, an overlap time can, if required, be matched to the control openings arranged on the control element. Depending on the development configuration, this can  
35 take place during an operation or when the valve unit is being built into an installation.

In addition, a plurality of access openings are arranged in the outer wall of the housing. In the case of a cast housing, they facilitate the manufacture and

machining processes. They are closed by known means in the form of closing elements, such as plugs, screwed elements and similar components. In order to increase the housing stiffness, a plurality of external stiffening elements are arranged on the outer wall of the housing. These can be arranged peripherally or only as external housing pockets. For weight and manufacturing reasons, the housing pockets are arranged between the flow-transfer ducts.

10 In addition, the tubular chambers of the pressure exchanger can be briefly connected to one another by the flow-transfer ducts during a motion of the control element. If, advantageously, the control openings extend at the high-pressure end over an angular range which is different from that of the associated flow openings, a switch-over with minimum pressure surges occurs. The angle between the openings is dimensioned in such a way that when the opening for the tubular chamber 1 has just closed and has ended the through-flow of the high-pressure flow, the opening for tubular chamber 2 has just opened and it therefore takes over the high-pressure flow. This ensures that a fluid, which still has to be cleaned and is located at the other end of the tubular chambers, is always under high pressure.

25 The flow-transfer ducts can also be configured as external tubular elements, in which case a plurality of connections for the tubular elements are arranged so that, for easier assembly, they are distributed over the outer periphery of the housing. In a different embodiment, the flow-transfer ducts are configured as flow ducts which are integrated into the housing wall. This reduces the number of sealing locations.

30 Another development provides for a fluid exchange between control element and the flow-transfer ducts via, in each case, at least two mutually diametrically opposed flow openings and control openings corresponding to them. A symmetrical arrangement of the openings and the flow ducts

provides, within the housing, support of the control element which is free from radial thrust.

For gentle switching, provision is made for the control openings of the hollow cylindrical control element to be configured as, for example, elongated holes, polygons or in different shape. The position on the control element and the size of the control openings permit a flow switch-over which is free from pressure surge. A closing of a control opening by an adjoining tubular chamber is simultaneously associated with an opening of a previously closed, different control opening by a further tubular chamber and vice versa. In consequence of the increased control openings or due to their position on the control element, an overlap can be achieved by the flow transfer paths with the flow openings solidly arranged in the housing. The overlap then has a favorable effect on the switching and the behavior of the flowing liquid columns influenced by it.

During the operation of the valve unit, different pressure conditions are present at the periphery of the control element in alternating regions. In order to facilitate the switch-over motion of the control element, the control element can be provided with a plurality of pressure-relief ducts on the external periphery. By this means, specific zones of the sliding surface are subjected to a defined back pressure. This type of pressure-relief duct can also be arranged on the outer wall surface of the control element and/or on an opposite valve unit housing surface. Depending on their shape and configuration, a continuous or alternating through-flow takes place in the pressure-relief ducts.

A favorable manufacturing possibility is provided if the control element is rotatably supported on a surface, which extends in meander shape, of the housing or if a housing inner wall configured as a separate component is supported on a surface, which extends in meander shape, of the housing. Between the

arms of the meander, a type of branch ducts which simultaneously act as flow-transfer ducts within the housing, is then formed. By this means, such a housing can be produced with little expenditure because  
5 unfavorable undercuts are avoided by it. The control element can likewise be rotatably supported on a plurality of individual surfaces of the housing.

It is only in the case of the use of a control element with fixed separating wall that a thrust  
10 bearing, on which the control element is supported, is provided within the housing. In the case of a control element in which the high-pressure end is configured between two fixed separating walls, a thrust bearing is, in principle, not required. In the case of the  
15 latter variant, it has been found advantageous for an annular space arranged in the housing to be connected to the high-pressure end. This permits simple sealing in the region of the connections.

Other developments provide for the housing to  
20 be provided with one connection for connection to each tubular chamber and with one connection each for a high-pressure end supply opening and a low-pressure end outlet opening. By this means, the number of sealing locations on the valve unit can be minimized. The  
25 housing can then be provided with an axial and/or radial arrangement of high-pressure end supply opening. An axially arranged supply opening is arranged on an end surface of the housing, the first pipework system being arranged on such a high-pressure end supply  
30 opening. This configuration facilitates the sealing of the valve unit in a simple manner because, in this case, only one static seal is necessary.

In this connection, other developments provide for the high-pressure end supply opening to be fitted  
35 downstream of a flow deflection having support elements and for the flow deflection to surround a bearing arrangement for the control element. This measure likewise serves to reduce the installation length and to improve the stiffness. And because the high-pressure

end supply opening with the flow deflection and the bearing arrangement are arranged in a cap part, there is improved support for the control element with a simultaneously simplified manufacturing possibility.

5           The housing can likewise be provided with an axially and/or radially arranged low-pressure end outlet opening.

          Exemplary embodiments of the invention are shown in the drawings and are described in more detail  
10 below. In the drawings,

Fig. 1           shows an installation according to the prior art,  
Fig. 2           shows a valve unit in cross section with  
15               representations of the section planes for Fig. 3a to 7,  
Fig. 3a & 3b     show two sectional views, offset by 90°, of the valve unit in a first operating condition,  
20   Fig. 4a & 4b   show two sectional views, offset by 90°, of the valve unit in a second operating condition, the control element being respectively rotated by 90° relative to Fig. 3a & 3b,  
25   Fig. 5a & 5b   show two three-dimensional views of the valve unit in partial section,  
Fig. 6           shows a development with drive onto a separating wall,  
Fig. 7           shows a valve unit with additional  
30               control cylinder,  
Fig. 8           shows a valve unit with two separating walls,  
Fig. 9           shows a valve unit with a control element in the form of a full cylinder,  
35   Fig. 10a & 10b show two sectional views, offset by 90°, of a shorter valve unit in a first operating condition,  
Fig. 11           shows a perspective view of the control element of Fig. 10a & 10b, and

Fig. 12 shows a perspective external view of the shorter valve unit.

Fig. 1 shows a mode of operation of a valve unit according to the prior art, using a reverse osmosis installation as an example. A high-pressure pump 1 delivers a fluid which has to be cleaned, generally water in the form of lake water, sea water, brackish water or, indeed, drainage water, to one or a plurality of reverse osmosis modules 2. Because of the high osmotic pressure within this module 2, a separating effect occurs on the membranes arranged within it. Behind the membranes, cleaned water, the so-called permeate, flows away at low pressure, is collected and supplied for further use.

An uncleaned fluid flowing away from the reverse osmosis modules 2, the so-called brine, has a higher concentration density of pollutants, generally salts, after the separation process and is led away to the original source. Because of its high energy content in the form of pressure energy, the brine is led via a valve unit 7 to the energy recovery process in a 2-chamber pressure exchanger. In its tubular chambers 3.1, 3.2 are arranged displaceable separating pistons 4.1, 4.2, which are under the influence of pressure and form a separation between two respective spaces differently subjected to pressure. Installations with tubular chambers without separating pistons are also known but undesirable mixing between the different fluids can occur in them if the system departs from equilibrium or the control periods are no longer correct.

With this arrangement, the high pressure of the brine forces a piston 4.1, which is located in a first tubular chamber 3.1 (the upper tubular chamber in Fig. 1), toward the side located remote from the valve unit 7 and transmits the pressure onto a fluid located in the chamber on the other side of the piston. The high pressure is then transferred to a lower-pressure

fluid, which has to be cleaned and is located to the left of the piston. This fluid then flows out at an already higher pressure on the left-hand side of the upper tubular chamber 3.1 and, through non-return valves 5, to a booster pump 6, which is arranged within a second pipework system. With the aid of the booster pump 6, compensation is then provided for the pressure drop, which is still small, which occurs during the osmotic cleaning process in the modules 2. Because of the energy recovery, the booster pump 6 only has to produce that pressure difference which was lost within the reverse osmosis module. The high-pressure pump 1 can therefore be made substantially smaller, and can therefore be more cost effective, than it is in the case of an installation without energy recovery.

When the piston 4.1 reaches the chamber end within the first tubular chamber 3.1, the valve unit 7 is switched over so that a connection to the atmosphere is now created for the first tubular chamber. The upstream pressure within a suction line leading to the main pump 1 is sufficient to force, by means of a fluid still to be cleaned, the brine, which is now pressure-relieved and is located in the first upper tubular chamber 3.1, toward the right again out of the upper tubular chamber 3.1 so that it flows away to the atmosphere. During the expulsion process of the brine from the first tubular chamber 3.1, the lower second tubular chamber 3.2 is simultaneously subjected to the high pressure of the brine by means of the valve unit 7. The expulsion process of a pressure-relieved brine is shown in the second, lower tubular chamber 3.2.

By appropriate cyclic switching of the valve unit 7, the two tubular chambers 3.1, 3.2 are alternately subjected to pressure, thus providing an efficient recovery of energy. Because of the 3-way function within the valve unit, pressure surges can occur during the switch-over process and this endangers the membranes within the reverse osmosis module 2. Additional special pressure compensation openings are

therefore to be provided in the control element of the valve unit 7 in order to minimize this danger. A further disadvantage arises due to a radial thrust, which occurs during the switch-over motion and for which there is no compensation.

In Fig. 2, a cross section through a valve unit according to the invention, two sectional planes A-A and B-B are arranged offset by  $90^\circ$  to one another and, with the aid of these, the mode of operation of the valve unit is explained in the subsequent figure descriptions. In this figure, a double arrow Z shows the flow direction from and to the tubular chambers - not shown here - of a pressure exchanger; the single arrow Y shows the outlet flow direction of a pressure-relieved brine flowing out of the valve unit.

Fig. 3a and 3b show, in two sections which are respectively arranged offset by  $90^\circ$  to one another, a valve unit according to the invention. The position of the sections A-A and B-B may be taken from Fig. 2 and, in the case of these sectional representations, the position of a hollow cylindrical control element 10 always remains unaltered.

The hollow cylindrical control element 10 is rotatably arranged in the housing 11 of the valve unit. The brine at high pressure, referred to below as high-pressure brine (HPB), flows out of the reverse osmosis modules 2 and enters a high-pressure space 14 of the valve unit through a single high-pressure end supply opening 12 with the aid of an upstream collector - not shown. This example shows a valve unit for connection to a twin-tube pressure exchanger analogous to the representation of Fig. 1. For this reason, the representation of the tubular chambers connected to the valve unit has been omitted.

The housing 11 of this valve unit has two connections 16, 17 on the outer wall 15, to which pipework lines - not shown - are connected for connection to tubular chambers 3.1, 3.2, likewise not shown. The exemplary embodiment of the housing 11 in

this arrangement is provided with integrated flow ducts 18-21 and two annular spaces 26, 27, with the aid of which a connection takes place between the connections 16, 17 and the flow openings 29-36 arranged on the housing inner wall 28. For development reasons, the housing inner wall 28 is here configured as a hollow cylindrical wall element, which is arranged so that it seals in the housing 11. It can also be a fixed constituent of the housing 11 when the latter is, for example, configured as a cast construction. The housing inner wall 28 acts simultaneously as the radial support for the hollow cylindrical control element 10. The wall of the control element 10 is penetrated by a plurality of control openings 37-44.

In the representation of Fig. 3a, a high-pressure brine, which is designated by an arrow HPB, enters the high-pressure space 14 of the housing 11 through the supply opening 12. The high-pressure space 14 is arranged within the control element 10 and is bounded in the axial direction by an end wall 13, which is solid with the housing, and a separating wall 47. In this exemplary embodiment, the separating wall 47 is sealed relative to the control element 10 with the aid of seals 49. And the separating wall 47 is connected, so that it cannot rotate, by struts 48 to the housing 11, in particular to the end wall 13 in this case. By means of this development configuration, the rotatable control element 10 is relieved of axial pressure forces during its switching motions. Solutions known *per se* can be used for the seal 49.

Control openings 37-40 arranged in the region of the high-pressure space 14 in the control element 10 have, in this configuration, a different opening angle from that of the corresponding flow openings 30, 31, 34, 35 in the housing inner wall 28. An appropriate selection of an opening angle achieves the effect that, for a short period during the switch-over by the control element 10, the tubular chambers - not shown here - in effective connection with the valve unit by

means of the connections 16, 17 are simultaneously under high pressure from the supply opening 12. In consequence, the pressure fluctuations endangering the membranes of the reverse osmosis installation are avoided.

The control element 10 is rotatably arranged in the housing 11. Approximately in the central region of the housing is located the separating wall 47, which is rotationally fastened to the housing 11 by means of struts 48. The separating wall 47 effects, within the control element 10, a subdivision into two spaces 14, 45 with different pressure regions. The space 14, in this configuration, is continually connected to the high-pressure region HPB of the membrane modules. In contrast, the other space 45 located to the left of the separating wall 47 in Fig. 3a is connected to a connection 46 for the low-pressure region, designated by the arrow LPB, of the pressure-relieved brine flowing back from the tubular chambers. Because the control element 10 moves relative to the separating wall 47, a seal 49, which is suitable for the pressure ratios to be sealed, is provided.

The control element 10 is driven by a drive shaft 50, one end of which is led to the outside through a housing penetration 52 at the low-pressure end. The rotational motion takes place continually or in steps and the speed is determined as a function of the other system components.

The mode of operation of the switch-over valve unit according to the invention, as represented in Fig. 3a and 3b, is as follows in the case of an unaltered position of the control element 10:

A high-pressure brine HPB flows into the high-pressure space 14 through a single supply opening 12, which is axially arranged in this case. This development reduces the number of connections and the total volume of the valve unit. The supply opening 12 for feeding the high-pressure brine HPB can also, of course, be radially arranged but the valve unit must

then have a longer configuration and the supply must take place in a housing region in which there is no overlap with the control element 10. The low-pressure brine LPB is drained from the valve unit from the connection 46. Fundamentally, the valve unit ensures that, of the tubular chambers connected to the connections 16 and 17, one of them is always filled with high-pressure brine and, from the other, the low-pressure brine, which is then pressure-relieved, can be emptied. It is only for a short period during the switch-over that both tubular chambers receive high pressure simultaneously.

First operating condition (Fig. 3a and 3b):

The high-pressure brine HPB flows from the high-pressure space 14 through mutually opposite control openings 38 and 39 located in the control element 10 and through flow openings 30 and 31, again mutually opposite and located in the housing inner wall 28, into an annular space 27 integrated in the housing 11, see Fig. 3b. Two separating walls 24, 25, which partially bound the annular space 27 in the axial direction, simultaneously form a support for the housing inner wall 28. The high-pressure brine HPB flows out of the annular space 27 to the connection 17 of a first tubular chamber. The other flow openings 34, 35 to the ducts 20 and 21, which form a flow path to the annular space 26 and to the connection 16 within the valve unit, are blocked by the control element 10. By this means, the first tubular chamber located at the connection 17 is filled.

At the same time, the valve unit is in effective connection, via the connection 16, with the other, second tubular chamber. From this, a low-pressure brine LPB, pressure-relieved in the second tubular chamber, flows back to the valve unit and enters, via the connection 16, an annular space 26 and, through mutually opposite flow openings 33 and 36 and via control openings 41 and 44, likewise mutually

opposite and located in the control element 10, the low-pressure space 45. From there, the low-pressure brine LPB flows into a connection 46, so that the tubular chamber is emptied to the atmosphere end. All  
5 the other flow openings 29, 32, which are arranged in the housing inner wall 28 and lead to the ducts 18 and 19, are shut off by the control element 10. Two separating walls 22, 23, which partly bound the annular space 26 in the axial direction, simultaneously form a  
10 further support for the control element 10, see Fig. 3a.

The high-pressure brine, which flows through the connection 17 into the first tubular chamber, transfers its pressure energy to a fluid, which has  
15 still to be cleaned and is located in the first tubular chamber, which fluid is subsequently forced at higher pressure to the reverse osmosis modules. The rotational speed of the drive to the drive shaft 50 (not shown) and the selection of the opening cross section of the  
20 control openings 37-40 ensure that, shortly before the tubular chamber at the connection 17 is completely filled with high-pressure brine, the filling process is terminated. At the same time, the emptying process of the second tubular chamber at the connection 16 is  
25 likewise terminated.

The respective pairs of interacting and mutually opposite openings 38/30 and 39/31 at the high-pressure end, however, remain open somewhat longer than the pair of the openings 41/33 and 44/36 at the low-  
30 pressure end. In consequence, a tubular chamber located at the connection 16 now obtains pressure, which is already high, through the pairs of openings 37/34 and 40/35, the ducts 20 and 21 and the annular space 26, whereas the pairs of openings 38/30 and 39/31 are just  
35 closing. This ensures that the second operating condition with the change of the flow direction to the tubular chambers begins without pressure surge.

Second operating condition (Fig. 4a/4b)

In these figure representations, in contrast to the representations of Fig. 3a and 3b, the control element 10 is shown rotated by 90° within the housing 11 and the flow ratios at the connections 16, 17 to the tubular chambers have reversed. An illustration of intermediate positions during a rotational motion is omitted for reasons of better comprehensibility.

If the pairs of openings 38/30 and 39/31 are in the closed position, the tubular chamber which now has to be filled is further filled at the connection 16. In contrast, the tubular chamber at the connection 17 is emptied through the annular space 27, through the mutually opposite ducts 18 and 19 and the mutually opposite pairs of openings 29/42 and 32/43 and through the low-pressure space 45 and the connection 46. In the second operating condition, the pressure energy of the high-pressure brine HPB is transmitted into the tubular chamber at the connection 16, whereas the tubular chamber at the connection 17 is emptied. Towards the end of the process, in a manner analogous to the first operating condition, the pairs of openings 37/34 and 40/35 and also 38/30 and 39/31 are simultaneously open for a short period so that a transfer into the first operating condition without pressure surge can, once again, take place.

The control element 10 is equipped with a sealing element 49, on its inner and/or outer peripheral surface, in this case in the region of the separating wall 47. This prevents a transfer flow between the high-pressure and low-pressure ends and, in consequence, maintains the efficiency of the overall system. A plurality of such sealing elements 49 on the control element 10 can also be used to suit the dimensioning of such an installation.

A drive shaft 50, with the aid of which the control element 10 is put into rotation, is supported by conventional bearing elements and secured against the emergence of fluid by means of known sealing

elements. The force transfer between drive shaft 50 and control element 10 takes place by means of force transfer means 51 known per se. These can be struts, disk elements or any other means which permit a flow  
5 passage from the low-pressure space 45 to the connection 46. The introduction of force takes place in the example of Fig. 3a to 4b, at the end surface of the control element 10.

Fig. 5a is a three-dimensional view onto a  
10 partially opened housing 11 of the valve unit. Only the housing 11, without the separate housing inner wall 28 used in the exemplary embodiment, is shown. This makes it clear that the total of four ducts 18 to 21 emerging from the annular spaces 26, 27 represent a type of  
15 branch ducts, the wall parts formed between them having a meander-shaped course. As a result, there are surfaces 53, which likewise extend in meander shape and which act as bearing surfaces for supporting the housing inner wall 28. The end surfaces or narrow sides  
20 of the separating walls 22 to 25 simultaneously have, in this case, the functions of bearing surfaces. The housing inner wall 28 can also be designed as an integral constituent of the housing 11. By means of such a configuration of the flow guidance within the  
25 housing 11, respectively mutually opposite flow ducts or flow openings can be created which make possible a motion of the control element 10 which is free from radial forces.

Fig. 5b shows, in a corresponding arrangement  
30 to Fig. 5a, a section through an installed valve unit which is ready for operation. Its connection stubs 16, 17 are directly connected to two tubular chambers 3.2, 3.1. The hollow cylindrical control element 10, which is provided with the control openings 37-44, rotates  
35 within the housing inner wall 28, which is provided with the flow openings 29-36. The drive of the control element 10 takes place at its end surface by means of the sealed drive shaft 50, which acts on a star-shaped force transfer element 51. The flow guidance, which is

here better recognizable due to the sectional representation, corresponds to the representation of Fig. 3a and 3b.

Fig. 6 shows a simplified construction of the valve unit according to the invention. In this case, the separating wall 47 is configured as a fixed constituent of the control element 10. The fastening of the separating wall 47 can take place by conventional means. In the example, the separating wall 47 is configured as an integral constituent of the control element 10, which is possible by means of the cast, welded or other known technical type of connection. This dispenses with the fastening of the separating wall 47 by means of struts to the housing 11, as shown in Figures 3a-4b. The drive of the control element 10 takes place directly to the separating wall 47 by means of the drive shaft 50, which dispenses with further, otherwise necessary connecting means 51 between drive shaft 50 and control element 10. Because the separating wall 47 separates the inside of the valve unit into two regions at different pressures, a resultant axial force on the control element 10 is now to be expected. Such an axial force component acts in the direction of the high-pressure brine HPB flowing into the high-pressure space 14. This acts on the separating wall 47 and generates a force component in the control element. This is taken by a simple additional axial support element 54 and is fed into the housing 11.

An alternative development of the valve unit, with additional control possibilities for variable opening and closing times during the operation, is shown in Fig. 7. An additional control cylinder 55 is located concentrically between the housing inner wall 28 and the control element 10. The control cylinder 55 has the function of an additional hollow cylindrical housing inner wall, is designed as a separate component and can be rotated, with the flow openings arranged in it, relative to the housing. It has, opposite to the control element 10, further flow openings 56-63, whose

extent on the periphery or whose cross section is smaller than or of the same size as the corresponding flow openings 29-36 of the housing inner wall 28. By means of an appropriate selection of the peripheral  
5 extent of these corresponding flow openings 56-63, it is possible to influence the opening and closing time of the valve unit by rotating the control cylinder 55. The adjustment of the control cylinder 55 can take place by means of a hollow shaft 64, which extends  
10 concentrically to the drive shaft 50 and can be adjusted by means of a flange 65. The development is executed in such a way that this can occur during the operation for adaptation to different operating conditions. A different type of adjustment can also be  
15 used. The exemplary embodiment shown is not limited to this type of adjustment.

Fig. 8 shows a solid connection between the control element 10 and the separating wall 47. This achieves greater stiffness of the control element 10 in  
20 the region of the high-pressure and low-pressure ends. In order to deal with an axial thrust then appearing and acting toward the left-hand drawing side in Fig. 8, a further separating wall 66 is arranged which terminates the high-pressure space 14 inside the  
25 control element 10 toward the right. This measure additionally increases the stiffness. The drive takes place directly to the separating wall 47 by means of the drive shaft 50. The high-pressure end supply opening 12 is radially arranged, for which purpose the  
30 control element 10 and the housing inner wall 28 are correspondingly lengthened. The high-pressure brine HPB flows through the radial supply opening 12 into an annular space 67, through two or more flow openings 68, 69 in the housing inner wall 28 and through two or more  
35 openings 70, 71 in the control element 10 into the high-pressure space 14. In this example, the openings 70, 71 in the control element 10 do not exercise any control function but only act, in a manner analogous to

the supply opening 12, to fill the high-pressure space 14.

Fig. 9 shows a control element 10.1 which is configured as a type of full cylinder. This provides a further increase in its stiffness. Respectively mutually and diametrically opposite flow ducts 72-73 and 74-75 are machined into the peripheral surface of the control element 10.1. In consequence, a sufficiently thick wall surface remains between the end regions of the groove-shaped flow ducts 72-75 and their thickness can be adapted in a simple manner to the pressure ratios then existing. The shapes of the groove-shaped flow ducts 72-75 are matched to the materials used in order to prevent notch stresses in the control element 10.1. In a manner analogous to a hollow cylindrical closing piece 10, the flow ducts 72, 73 execute the function of a high-pressure space and the flow ducts 74, 75 execute the function of a low-pressure space. A high-pressure brine HPB is supplied via a radially arranged high-pressure supply opening 12 and enters an annular duct 76, which can either be arranged in the housing or, as shown, in the control element 10.1. In both cases, the annular duct 76 is configured so that it is completely peripheral. With the aid of a relief duct 78, which penetrates the control element 10.1 in axial direction, a pressure exchange takes place between the surfaces on the axial end surfaces. At the same time, a free space is arranged, in this configuration, on the high-pressure end surface of the control element 10.1, this free space being represented in the drawing by the line shown thick on the right-hand side, by which means the appropriate surface for the pressure compensation of an axial thrust relief is created.

In the arrangement represented, the high-pressure brine HPB flows through a flow opening 69 in the housing inner wall 28 into the annular duct 76 of the control element 10.1, from which emerge groove-shaped flow ducts 72, 73, which each extend in the

axial direction. From these high-pressure flow ducts 72, 73, the fluid flows to the flow openings 30, 31, 34 and 35 mentioned in the previous figures. The low-pressure flow ducts 74, 75 in the control element 10.1  
5 accept the low-pressure brine LPB from the flow openings 29, 32, 33 and 36 mentioned in the previous figures and guide the fluid to the connection 46. Here again, a low-pressure brine LPB always emerges in the axial direction from the control element 10.1. Mutually  
10 facing ends of the respective flow duct 72-75 are arranged at a distance from one another and form, between them, a closed annular sealing zone 77. This prevents a flow transfer between the two pressure regions.

15 Fig. 10a and 10b show a valve unit with shorter installation length and sectional representations, which are likewise arranged offset by  $90^\circ$  relative to one another. The position of the sections A-A and B-B is analogous to the representation of Fig. 2 and, here  
20 again, the position of the control element 10 remains unaltered.

The valve unit of Fig. 10a and 10b has a shorter installation length due to a different arrangement of the flow openings. In the housing 11 and  
25 in the control element 10, the position of the flow openings 29-36 and the control openings 37, 40, 42, 43 are respectively referred to the opening planes 79, 80, which are arranged at right angles to the drive shaft 50.2 of the control element 10. In this embodiment,  
30 there is a saving of two opening planes relative to the other embodiments. This embodiment has, in total, only three opening planes, one opening plane 81 being used only for the supply flow to the high-pressure space 14. It is possible to dispense with the opening plane 81 if  
35 there is an axial supply flow to the control element.

In order to achieve the saving of the two opening planes, four flow openings are arranged distributed over the periphery in each of the opening planes 79, 80, of which flow openings, the openings 29,

32, 34, 35 are visible in Fig. 10a. In this embodiment with the two tubular chambers which can be connected, the four flow openings 30, 31, 34, 35 and 29, 32, 33, 36 are respectively arranged offset by 90° relative to one another in the opening planes 79, 80 on the housing inner wall 28. With the aid of control pockets 82 included in the control element 10, a transfer of a high-pressure brine HPB from one opening plane 80 occurs in the axial direction through the control element 10 to the second opening plane 79 of the housing 11. The function of a control pocket 82 is more clearly recognizable from the perspective representation of the control element 10 in Fig. 11.

Arranged in the internal space of the hollow cylindrical control element 10, there are additional stiffening features, which are configured as ribs 83, 89 and penetrate the spaces 14, 45 in the axial direction as a type of radially extending flow splitters. The stiffening ribs 83, 89 shown in section in Fig. 10a extend over the whole diameter of the hollow cylindrical control element 10 and improve its stiffness relative to the external and internal, and continually alternating, pressure loads which act on it. The planes of the stiffening ribs extending in the direction of the drive shaft 50.2 are rotated by 90° relative to one another and, in addition, abut directly on the separating wall 47.

Stiffening features, in the form of annular elements 84 in this case, are arranged in the internal space of the control element 10. These extend radially inward from the inner wall of the control element 10 and protrude into the internal spaces 14, 85 in annular shape. These stiffening annular elements 84 also improve, overall, the stiffness of the control element 10.

The supply opening 12 in this exemplary embodiment is a constituent part of a cap part 85, which is connected to the housing 11 so as to form a seal and transmit forces. The configuration as a cap

part has the advantage that the housing 11 is, *per se*, mainly of cylindrical design and can therefore be manufactured more simply. A flow deflection 86 is arranged within the cap part 85. Within the flow  
5 deflection 86 are arranged a plurality of bearing elements 87, which bound a plurality of flow ducts 88 within the cap part 85. A high-pressure brine HPB from the arcuate flow ducts 88 and entering axially into the cap part 85 is deflected by means of the flow  
10 deflection 86 and, in consequence, flows axially or semi-axially from the outside into the control element 10 through its openings 70, 71 and into the space 14.

The control pockets 82 connected to the control openings 37, 40, and with a forked configuration in  
15 this case, are arranged at the outer periphery of the control element 10 and are located diametrically opposite to one another. In this exemplary embodiment, they extend on both sides of the stiffening rib 83 of the low-pressure space 45 and are only partially  
20 visible in this representation. In addition, a bearing arrangement 90 and seal 91 for the control element 10 are arranged in the cap part 85.

Arranged in the outer wall 15 of the housing 10, there is a plurality of access openings 92, which  
25 are closed by closing elements 93 so as to be pressure-tight and liquid-tight. These access openings 92 are provided for manufacturing technology reasons and substantially simplify housing manufacture. They permit easy access to the hollow spaces, in the form of the  
30 annular spaces 26, 27, within the housing.

Fig. 10b shows a longitudinal section arranged so that it is rotated by 90° relative to Fig. 10a. By this means, it can be recognized that, within the control element 10, the stiffening rib 83 is now at  
35 right angles to the plane of the drawing and is arranged in the manner of a flow part within the low-pressure space 45. On the right-hand side of the separating wall 47, in contrast, the stiffening rib 89 located in the high-pressure space 14 is now located in

the plane of the drawing. In the exemplary embodiment shown here, the stiffening ribs 83, 89 are configured as an integral constituent part of the separating wall 47, the stiffening rib 83 being also, at the same time,  
5 a constituent part of the drive shaft part 50.2 located within the control element 10. This configuration simplifies the manufacture. The stiffening elements can equally well be arranged in the spaces 14, 45 without a direct effective connection to the separating wall 47.

10 From the joint viewing of the two figures 10a, 10b, it may be recognized that, in the region of the space 45, all the control openings and flow openings 41-44 and 29, 32, 33, 36 are combined in one opening plane 79. In the region of the space 14, in a analogous  
15 manner, the control openings and flow openings 37-40 and 30, 31, 34, 35 are combined in the opening plane 80. The opening plane 81 is only used for the radial flow of the HPB into the space 14 and does not take part in the switch-over processes. Overall, in  
20 consequence, there is a substantially shortened embodiment of a substantially improved stiffness of the overall valve unit.

Fig. 11 shows a perspective view onto the hollow cylindrical control element 10, as shown in  
25 Fig. 10a, 10b. It is the view onto the low-pressure end of the control element 10 with the drive shaft part 50.2 protruding out of the space 45. Clearly recognizable is the rib 83, which is arranged within the space 45 and extends in the flow direction or in  
30 the direction of the drive shaft 50.2. Also recognizable is a stiffening annular element 84, which is arranged peripherally in the low-pressure space 45 in the region of its outlet flow end. A plurality of pressure-relief ducts 78 extending in the axial  
35 direction are arranged distributed over the periphery of the wall surface of the control element 10. With the aid of these pressure-relief ducts 78, compensation is provided for an axial thrust load, by which means the bearing arrangement is substantially simplified.

On the outer periphery of the control element 10, fork-shaped and diametrically opposed control pockets 82 are arranged which are in connection with control openings 37, 40 of the space 14 subjected to high-pressure brine HPB. A flow deflection between the two tubular chambers, connected to the valve unit, of a pressure exchanger takes place on the outer periphery of the control element 10 by means of the control pockets. With the aid of this measure, a displacement of all the control openings and flow openings into only one opening plane 79 is possible at the low-pressure brine LPB end.

The configuration of the control pockets 82 in fork shape has the advantage that a protrusion element 96 remains between the fork-shaped flow paths formed by this configuration. This is, in an advantageous manner, arranged in the plane of the stiffening rib 83, by which means the force transfer and the surface pressures between the rotating control element and housing are optimized. In the case of a stepped configuration of the control pockets 82, the arrangement of the protrusion element 96 is dispensed with. Although this increases the space available for a deflection, it leads to somewhat unfavorable flow ratios during the switch-over motion of the control element 10.

A representation of a type of kinematic reversal of the control pockets has been omitted. In an analogous configuration of the control pockets rotating with the control element 10, it is possible to arrange these control pockets in the housing and then in the form of stationary flow pockets. A flow deflection of the brine into the opening plane 79 would then take place in the housing wall and in the stationary flow pockets.

The openings 70, 71 arranged distributed on the periphery can be recognized on the control element 10 in the region of the space 14 subject to high-pressure brine HPB. By this means, a high-pressure brine HPB

flows, after the through-flow, through the flow deflection - not shown here - in the cap part, from radial or semi-axial direction from the outside to the inside in the space 14 of the control element.

5           Fig. 12 shows a perspective view onto a valve unit as shown in Fig. 10-11. Recognizable in the housing outer wall 15 are the access openings 92, which are arranged in the direction of the axial extension plane of the transfer flow ducts located within the  
10 housing. In the exemplary embodiment, simple closure plugs are used as the closing element 93, other constructions, however, being also possible. Additional external reinforcement elements 94 are arranged in the housing 11 between the transfer ducts 18-21 located  
15 within the housing wall 15.

          Additional material accumulations 95, which have the function of support elements and/or suspension elements for the value unit, are arranged on the outer wall 15 of the housing 11. They facilitate an  
20 installation of the valve unit and simplify its handling. In this exemplary embodiment, the connection 46 acting as a drain for the low-pressure brine is a constituent part of a separate cap part. By this means, the outlet flow direction of the low-pressure brine LPB  
25 through the connection 46 can be adapted simply to different local features in the simplest manner and by a correspondingly rotated arrangement of this cap part.

**List of designations**

|    |          |                                |
|----|----------|--------------------------------|
|    | 1        | High-pressure pump             |
|    | 2        | Reverse osmosis module         |
|    | 3.1, 3.2 | Tubular chambers               |
| 5  | 4.1, 4.2 | Separating pistons             |
|    | 5        | Non-return valve               |
|    | 6        | Booster pump                   |
|    | 7        | Valve unit                     |
|    | 8        |                                |
| 10 | 9        |                                |
|    | 10, 10.1 | Control elements               |
|    | 11       | Housing                        |
|    | 12       | Supply opening                 |
|    | 13       | End wall                       |
| 15 | 14       | Space, high-pressure space     |
|    | 15       | Outer wall                     |
|    | 16       | Connection for tubular chamber |
|    | 17       | Connection for tubular chamber |
|    | 18-21    | Flow ducts                     |
| 20 | 22-25    | Separating walls               |
|    | 26-27    | Annular spaces                 |
|    | 28       | Housing inner wall             |
|    | 29-36.1  | Flow openings                  |
|    | 37-44    | Control openings               |
| 25 | 45       | Space, low-pressure space      |
|    | 46       | Connection                     |
|    | 47       | Separating wall                |
|    | 48       | Struts                         |
|    | 49       | Seal                           |
| 30 | 50-50.2  | Drive shaft                    |
|    | 51       | Force transfer means           |
|    | 52       | Housing passage                |
|    | 53       | Surface, bearing surfaces      |
|    | 54       | Thrust bearing                 |
| 35 | 55       | Control cylinder               |
|    | 56-63    | Flow openings                  |
|    | 64       | Hollow shaft                   |
|    | 65       | Flange                         |
|    | 66       | Separating wall                |

|    |       |                             |
|----|-------|-----------------------------|
|    | 67    | Annular space               |
|    | 68-69 | Flow openings               |
|    | 70-71 | Openings                    |
|    | 72-75 | Flow ducts                  |
| 5  | 76    | Annular duct                |
|    | 77    | Sealing zone                |
|    | 78    | Pressure-relief duct        |
|    | 79-81 | Opening planes              |
|    | 82    | Control pocket              |
| 10 | 83    | Stiffening rib              |
|    | 84    | Annular element, stiffening |
|    | 85    | Cap part                    |
|    | 86    | Flow deflection             |
|    | 87    | Guide ribs                  |
| 15 | 88    | Flow ducts                  |
|    | 89    | Stiffening rib              |
|    | 90    | Bearing arrangement         |
|    | 91    | Seal                        |
|    | 92    | Access openings             |
| 20 | 93    | Closing elements            |
|    | 94    | Reinforcement elements      |
|    | 95    | Material accumulations      |
|    | 96    | Protrusion element          |
| 25 | LPB   | Low-pressure brine          |
|    | HPB   | High-pressure brine         |

**Patent claims**

1. A valve unit for switching over fluid paths, in particular for installations with pressure exchangers with tubular chambers (3) through which flow occurs alternately, a rotatable control element (10, 10.1) with a plurality of flow paths being arranged within a housing (11), the housing (11) having a plurality of connections (12, 16, 17, 46) for connection lines, the housing (11) being connected to a first pipework system and to one end, in each case, of at least one pressure exchanger, another end of a pressure exchanger being connected, in each case, to a second pipework system with intermediate connection of further valve units, the control element (10, 10.1) being provided with a motor-driven drive shaft (50) and the flow paths of the control element (10, 10.1) being alternately connected to openings arranged in the housing (11), characterized in that a supply flow takes place from axial and/or radial direction to the control element (10, 10.1) within the housing (11) and an outlet flow takes place in the axial direction from the control element (10, 10.1).

2. The valve unit as claimed in claim 1, characterized in that the control element is configured as a hollow cylindrical control element (10) and in that a separating wall (47) divides the hollow cylindrical control element into two spaces (14, 45) of different pressure regions (HPB, LPB).

3. The valve unit as claimed in claim 2, characterized in that additional stiffening features are arranged in the spaces (14, 45) of different pressure regions (HPB, LPB).

4. The valve unit as claimed in claim 2 or 3, characterized in that the stiffening features are configured as radially extending ribs (83, 89) and/or as annular elements (84).

5. The valve unit as claimed in claims 1, 2, 3 or 4, characterized in that the drive shaft (50) is connected to the separating wall (47) so that it transmits torque.

5 6. The valve unit as claimed in claim 5, characterized in that the separating wall (47) is arranged in the central region of the hollow cylindrical control element (10).

10 7. The valve unit as claimed in one of claims 1 to 6, characterized in that a component (51), which transmits torque, is arranged at one end of the hollow cylindrical control element (10).

15 8. The valve unit as claimed in one of claims 1 to 7, characterized in that the separating wall (47) is solidly connected to the control element (10).

9. The valve unit as claimed in one of claims 1 to 7, characterized in that the separating wall (47) is solidly connected to the housing (11).

20 10. The valve unit as claimed in claim 9, characterized in that the separating wall (47) is fastened to the housing (11) with struts (48) in the region of a high-pressure end supply opening (12).

25 11. The valve unit as claimed in one of claims 1 to 10, characterized in that sealing elements (49) are arranged in a sealing zone between the separating wall (47) and the inner wall surface of the hollow cylindrical control element (10).

30 12. The valve unit as claimed in one of claims 7 to 11, characterized in that the separating wall (47) and/or the struts (48) are a constituent part of an exchangeable insert.

35 13. The valve unit as claimed in claim 1, characterized in that the control element (10.1) is configured as a full cylinder and in that, in its peripheral surface, a plurality of groove-shaped flow paths (72-74) form different pressure regions (HPB, LPB).

14. The valve unit as claimed in claim 13, characterized in that the flow paths (72, 73; 74, 75)

of equal pressure regions are arranged diametrically opposite to one another on the peripheral surface.

15. The valve unit as claimed in claim 13 or 14, characterized in that a section of the groove-shaped  
5 flow paths (72-75) connected to a flow opening (29-31, 33-35) forms the control opening of the control element (10.1).

16. The valve unit as claimed in claim 13, 14 or 15, characterized in that a peripheral annular groove  
10 (76) in the housing (11) and/or in the peripheral surface of the control element (10.1) is arranged in the region of a radial high-pressure end supply opening (69).

17. The valve unit as claimed in one of claims 13  
15 to 16, characterized in that a closed annular sealing zone (77) is arranged on the control element (10.1) between ends of the groove-shaped flow paths (72-75) of the different pressure regions (HPB, LPB).

18. The valve unit as claimed in claim 17,  
20 characterized in that sealing elements are arranged in the region of the sealing zone (77) on the control element (10.1) and/or on the housing (11).

19. The valve unit as claimed in one of claims 1 to 18, characterized in that an axial thrust relief takes  
25 place by means of a pressure-relief duct (78) arranged in the control element (10.1).

20. The valve unit as claimed in one of claims 1 to 19, characterized in that fork-shaped and/or stepped  
30 configurations of control pockets (82), which are connected to control openings (37, 40), are arranged on the outer periphery of the control element (10, 10.1).

21. The valve unit as claimed in claim 20, characterized in that protrusion elements (96) of the  
35 fork-shaped control pockets (82) are arranged in the plane of the radial rib (83).

22. The valve unit as claimed in one of claims 1 to 19, characterized in that fork-shaped and/or stepped configurations of control pockets, which are connected

to flow openings (30, 31, 34, 35), are arranged on the inner periphery of the housing inner wall (28, 55).

23. The valve unit as claimed in one of claims 1 to 22, characterized in that a plurality of flow-transfer  
5 ducts (18-21), which connect the flow openings (29-31, 33-36), are arranged on and/or in the outer wall (15) of the housing (11).

24. The valve unit as claimed in one of claims 19 to 23, characterized in that the flow openings (29-31,  
10 33-36) are a constituent part of an adjustable, hollow cylindrical housing inner wall (55).

25. The valve unit as claimed in one of claims 1 to 24, characterized in that a plurality of access  
15 openings (92) are arranged in the outer wall (15) of the housing (11).

26. The valve unit as claimed in one or more of claims 1 to 25, characterized in that a plurality of outer stiffening elements (94) are arranged in the outer wall (15) of the housing (11).

20 27. The valve unit as claimed in one of claims 1 to 26, characterized in that the tubular chambers (3.1, 3.2) of the pressure exchanger are briefly connected to one another by the flow-transfer ducts (18-21) during a motion of the control element (10, 10.1).

25 28. The valve unit as claimed in one of claims 1 to 27, characterized in that the flow-transfer ducts (18-21) are configured as external tubular elements.

29. The valve unit as claimed in claim 28, characterized in that connections (17, 17) for the  
30 tubular elements are arranged so that they are distributed over the outer periphery of the housing (11).

30. The valve unit as claimed in one of claims 1 to 27, characterized in that the flow-transfer ducts  
35 (18-21) are configured as flow ducts which are integrated into the housing wall.

31. The valve unit as claimed in one of claims 1 to 30, characterized in that a fluid exchange between control element (10, 10.1) and the flow-transfer ducts

(18-21) takes place via, in each case, at least two mutually diametrically opposed flow openings (29, 32; 30, 31; 33, 36; 34, 35) and control openings (37-44) corresponding to them.

5 32. The valve unit as claimed in one of claims 1 to 31, characterized in that position and size of the control openings (37-44) permit a flow switch-over free from pressure surge.

10 33. The valve unit as claimed in claim 32, characterized in that the control openings (37-44) of the hollow cylindrical control element are configured as elongated holes, polygons or in other shape.

15 34. The valve unit as claimed in claim 32 or 33, characterized in that a closing of control openings of a tubular chamber is simultaneously associated with an opening of previously closed control openings of another tubular chamber and vice versa.

20 35. The valve unit as claimed in one of claims 1 to 34, characterized in that a plurality of pressure-relief ducts are arranged on the outer wall surface of the control element (10, 10.1) and/or an opposite housing surface or in a housing inner wall (28, 55).

25 36. The valve unit as claimed in one of claims 1 to 35, characterized in that one or a plurality of pressure-relief ducts (78) are arranged in the control element (10, 10.1).

37. The valve unit as claimed in claim 35 or 36, characterized in that a continuous or alternating through-flow takes place in the pressure-relief ducts.

30 38. The valve unit as claimed in one of claims 1 to 37, characterized in that the control element (10, 10.1) is rotatably supported on a surface (53), which extends in meander shape, of the housing (11).

35 39. The valve unit as claimed in one of claims 1 to 38, characterized in that the control element (10, 10.1) is rotatably supported on a plurality of surfaces (53) of the housing (11).

40. The valve unit as claimed in one of claims 1 to 39, characterized in that a housing inner wall (28),

which is configured as a separate component, is supported on a surface (53), which extends in meander shape, of the housing (11).

41. The valve unit as claimed in one of claims 1 to 5 40, characterized in that the control element (10, 10.1) is arranged with at least one shaft extension in a bearing feature (90).

42. The valve unit as claimed in one of claims 1 to 41, characterized in that the control element (10, 10 10.1) is arranged in such a way that it is free from radial and axial forces.

43. The valve unit as claimed in one of claims 1 to 42, characterized in that a control element (10, 10.1) with a fixed separating wall (47) is in contact with a 15 thrust bearing (54).

44. The valve unit as claimed in one of claims 1 to 43, characterized in that on the control element (10, 10.1), the high-pressure end (HPB) is configured between two fixed separating walls (47, 66).

20 45. The valve unit as claimed in one of claims 42, 43 or 44, characterized in that an annular space (67) arranged in the housing is connected to the high-pressure end (HPB).

46. The valve unit as claimed in one of claims 1 to 25 45, characterized in that the housing (11) is provided with one connection (16, 17) each for connection to a tubular chamber (3) and with one connection each for a high-pressure end supply opening (12) and a low-pressure end outlet opening (46).

30 47. The valve unit as claimed in claim 46, characterized in that the housing (11) is provided with an axially and/or radially arranged high-pressure end supply opening (12).

48. The valve unit as claimed in claim 46 or 47, 35 characterized in that the supply opening (12) is arranged downstream of a flow deflection (86), which has support elements (87), and the flow deflection (86) surrounds a bearing arrangement (90) for the control element (10, 10.1).

49. The valve unit as claimed in claim 46, 47 or 48, characterized in that the supply opening (12) with the flow deflection (86) and the bearing feature (90) are arranged in a cap part (85).

5 50. The valve unit as claimed in one of claims 46 to 49, characterized in that the housing is provided with an axially and/or radially arranged low-pressure end outlet opening (46).

10 51. The valve unit as claimed in one of claims 1 to 50, characterized in that control openings (37-44) of the hollow cylindrical control element are, for example, configured as elongated holes, polygons or in other shape.