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Method for modifying the swirl motion of a liquid in a swirl chamber of a nozzle and swirl generator for nozzles

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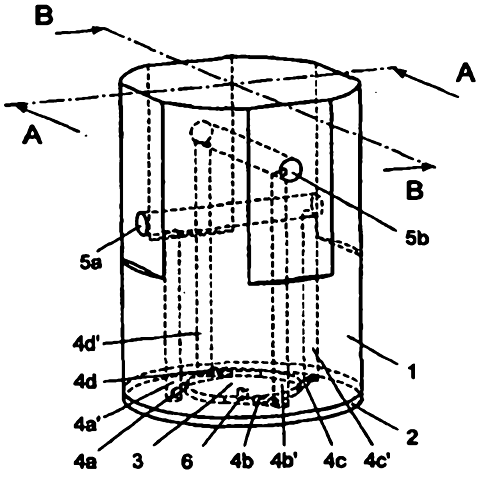
(54) Title: METHOD FOR MODIFYING THE SWIRL MOTION OF A LIQUID IN A SWIRL CHAMBER OF A NOZZLE AND SWIRL GENERATOR FOR NOZZLES

(54) Bezeichnung: VERFAHREN ZUM VERÄNDERN DER DRALLBEWEGUNG EINES FLUIDS IN DER DRALLKAMMER EINER DÜSE UND DRALLERZEUGER FÜR DÜSEN

(57) Abstract

The invention relates to a method for modifying the swirl motion of a liquid in the swirl chamber of a nozzle and swirl generator for nozzles. Such nozzles are used especially in industrial burners, oil burners and installations for cleaning flue gas and spray–drying food. Owing to the disadvantages of state–of–the–art technology, the invention aims to provide a method and a corresponding nozzle which make it possible to adjust the mean droplet diameter at a constant volume flow rate or to maintain the droplet spectrum constant in case of adjustment of the volume flow rate. To this end the invention provides for the partial flows (T_1, T_2) to be distributed across supply channels (4a, 4b, 4c, 4d) which differ in terms of their cross–sections at their point of connection with the swirl chamber (3). When the partial flows (T_1, T_2) are divided across more than two tangential supply channels (4a, 4b, 4c, 4d) the cross–sections are constituted by the sum of cross–sections of the supply channels (4a, 4c or 4b, 4d) branching off the corresponding partial flow (T_1, T_2). As a result the sums of the cross–sections at the point of connection (S_1, S_2) of the partial flows (T_1, T_2) with the swirl chamber (3) are different.



(57) Zusammenfassung

Die Erfindung betrifft ein Verfahren zum Verändern der Drallbewegung eines Fluids in der Drallkammer einer Düse und Drallerzeuger für Düsen. Derartige Düsen werden insbesondere in Industriebrennern, Ölbrennern und Anlagen zur Rauchgaswäsche und zur Sprühtrocknung von Lebensmitteln eingesetzt. Ausgehend von den Nachteilen des bekannten Standes der Technik sollen ein Verfahren und die dazugehörige Düse geschaffen werden, mit denen es möglich ist, den mittleren Tropfendurchmesser bei konstantem Volumenstrom regeln zu können oder bei Regelung des Volumenstromes das Tropfenspektrum konstant zu halten. Hierzu wird vorgeschlagen, daß die Teilströme (T_1, T_2) auf Zuführungskanäle (4a, 4b, 4c, 4d) aufgeteilt werden, die sich in ihren Querschnittsflächen an der Verbindungsstelle zur Drallkammer (3) unterscheiden, wobei bei einer Aufteilung der Teilströme (T_1, T_2) auf mehr als zwei tangentiale Zuführungskanäle (4a, 4b, 4c, 4d) die Querschnittsflächen aus der Summe der Querschnittsflächen der Zuführungskanäle (4a, 4c oder 4b, 4d), die von dem jeweiligen Teilstrom (T_1, T_2) abzweigen, gebildet werden, und sich demzufolge die Summen der Querschnittsflächen an der Verbindungsstelle (S_1, S_2) zur Drallkammer (3) der jeweiligen Teilströme (T_1, T_2) unterscheiden.

Description

Method for varying the swirling movement of a fluid in the swirl chamber of a nozzle, and a nozzle system

The invention relates to a method for varying the swirling movement of a fluid in the swirl chamber of a nozzle, and to a nozzle system for carrying out the method.
Such nozzles are used, in particular, in industrial burners, oil burners and systems for washing flue gas and for the spray-drying of foodstuffs.

It is frequently desired to be able to vary the atomization characteristic when atomizing liquids with the aid of swirl nozzles. It is possible to influence the drop size of the spray produced by varying the circumferential speed (swirling movement or swirl component) of the fluid in the swirl chamber. It is important here that the circumferential speed can be varied independently of the liquid throughput, and also that there is no need to undertake mechanical variation at the nozzle.
So-called spill-return nozzles (bypass nozzles) constitute a variant. With these nozzles, the liquid is directed tangentially into the swirl chamber and drained off both from the nozzle outlet opening and through a return-flow opening on the middle of the axis. This portion of the liquid throughput is led back again into the liquid reservoir. By varying the return rate, the liquid throughput which is atomized can be kept constant, although the inlet speed of the liquid into the swirl chamber can be varied and thereby adjusted to the swirl intensity and, consequently, to the drop quality. The disadvantage of this solution consists in the necessity of conducting liquid in a circuit. The control range of the spill-return nozzles

is bounded below. There is a substantial variation in the jet angle over the desired control range.

Also known are so-called "duplex nozzles" (DE-C 893 133 and US-A 2,628,867), which are used for atomizing fuels. The nozzles have a swirl chamber into which the fuel is introduced via a plurality of tangential feed channels, and is set rotating about an axis. The nozzles can have different cross-sectional surfaces at the connecting point to the swirl chamber, and the tangential feed channels are connected to separate feed conduits. Incorporated into one of the feed conduits inside the nozzle is a valve which is opened as a function of the pilot pressure present in the other feed conduit, and permits the feed of a larger fuel quantity. The disadvantage of the "duplex nozzles" resides chiefly in the fact that they can implement only a limited possibility of regulation and control which is a function of the pilot pressure present or throughput. US-A 4,796,815 describes a shower head for a hand-held shower in the case of which the incoming water flow is introduced via two tangential and two radial channels into a swirl chamber, in which a rotatable ball is also located, as well. The water feed in the nozzle head may be varied by means of an adjusting element which can be actuated by hand; either the water inlet into the tangential channels or into the radial channels is covered, or the radial and tangential channels are only partially covered. Different spray patterns are obtained by means of these possible adjustments. The disadvantage of this spray head consists in that for the purpose of generating different spray patterns the adjusting element is arranged inside the swirl chamber, and this varies the inlet surfaces of the tangential and radial channels. This shower head is essentially limited in its application to the sanitary field.

DE 39 36 080 C2 has disclosed a method for varying the circumferential speed component of the swirl flow of a fluid at the outlet from a swirl nozzle having a swirl space with a plurality of tangential feed lines. The entire material flow of the fluid is subdivided into at least two subflows, it being possible to vary the size of at least one subflow. The subflows are fed into the tangential feed conduits of the swirl space. It is disadvantageous that the achievable control range depends on the number of the feed conduits, the result being a rise in the outlay of production for the nozzles with a wide control range. Although rotational symmetry of the flow is achieved, the control range remains narrow. The known nozzles for industrial burners have the disadvantage that the burner output must be kept constant, because otherwise undesired pollutant emissions occur, in particular when the throughput is varied. Remedy is frequently found with a plurality of nozzles, it being possible to achieve optimum conditions only for one operating case.

With the known nozzle systems used in spray-drying, a system start-up time of 2 to 3 hours is required when switching products. The powder produced during the start-up time cannot be reused, and must be recycled with considerable outlay. Moreover, it is not possible to influence variations in the product quality and product specification during the operation of production with the aid of the known nozzle systems. The reason for these disadvantages in the known swirl nozzles is their limited and/or inadequate control range.

It was the object of the invention to create an improved method for varying the swirling movement of a fluid in the swirl chamber of a nozzle which renders it possible to be able to operate a nozzle with a wide control range and, in the process, to achieve as far as possible a comparable drop quality (mean drop diameter and drop distribution), that is to say to create possibilities of being able to control the mean drop diameter in conjunction with a constant volumetric flow, or to keep the drop spectrum constant in conjunction with controlling the volumetric flow. The aim is also to create a suitable nozzle system for the purpose of carrying out the method.

According to the invention, the object is achieved by means of the features specified in Claims 1 and 18. Corresponding variant refinements of the proposed method are specified in Claims 2 to 17. Advantageous refinements of the nozzle system are the subject matter of Claims 19 to 32.

The proposed method for subdividing the subflows over tangential feed conduits which differ in their cross-sectional surfaces at the connecting point to the swirl chamber, it being the case that upon subdivision of the subflows over more than two tangential feed conduits, the cross-sectional surfaces are formed from the sum of the cross-sectional surfaces of the feed conduits which branch off from the respective subflow, and the sums of the cross-sectional surfaces at the connecting point to the swirl chamber of the respective subflows therefore differ, leads to

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different cross-sectional surfaces. It is the cross-sectional surfaces at the inlet of the liquid into the swirl chamber (connecting point of the feed conduit and swirl chamber) which are decisive, since the circumferential speed at the periphery of the swirl chamber is fixed at this point. If the aim is a high swirl intensity for a fine drop spectrum, it is necessary to enlarge the subflow applied to the feed conduits which have the smallest cross section, and vice versa. Intermediate values can be set continuously. The simplest way of influencing the throughput of a subflow is to use a valve. The other object for which the method may be applied is to maintain a specific swirl intensity at the outlet from the swirl chamber. In this case, the ratio of the sum of the cross-sectional surfaces of the feed conduits which are affected in the full load case, and the sum of the cross-sectional surfaces of the feed conduits which are affected in the part load case is to be selected to be at least as high as the desired ratio of the volumetric flows in the cases of full load and part load.

The principle of swirl control according to the invention can be applied during atomization of liquids in single-component and double-component nozzles in which either the liquid or the gas or both are provided with a circumferential speed in the nozzle. The application is performed in such a way that the method is applied both [sic] to the liquid or the gas or to both. It is therefore possible to influence the drop quality in the case of double-component nozzles without changing the liquid throughput/gas throughput ratio. The purpose for which the liquid is atomized is not important here. The atomization can be performed, for example, for subsequent drying of a suspension in the dry tower. However, it is also possible to atomize oil which, as customary with burners, is burnt at the nozzle outlet. However, the fluid can also be a gas. This case is possible with multiple-component nozzles, where the gas is provided with a swirl component in order to atomize liquid. However, the gas can also be provided with a swirl component without the presence of liquid, as in the case of gas burners which operate with recirculation in the vicinity of the nozzle outlet. Finally, it is possible to combine the principle according to the invention with the spill-return method, in order to permit a further widening of the control range. With most spray-drying systems, the use of return flow nozzles is precluded for quite different reasons. In the case of these systems, it has previously been necessary to operate with a prescribed nozzle geometry. The frequent changes in the product therefore necessitated a new selection of the nozzle system and, because of the change of nozzle required, the system had to be run up and run down. The new system renders it possible to adapt during operation, and it is even possible to carry out control owing to continuous measurement of the product parameters. Variations in the product parameters which result from wear of the nozzle can be leveled out over a certain time, and the service life of the spray tower can be prolonged thereby. In the case of using the invention in the field of oil combustion, success is achieved in operating with a wide load range without the return line and without varying the jet angle in conjunction with a virtually unchanged drop size. This influences the effectiveness of the entire heating system and the service life of the boiler, since in the case of fluctuating heat requirements there is no need to implement frequent running up and running down of the burner.

The method according to the invention can also be successfully applied in the case of gas burners and coal dust burners, chiefly in order to influence the shape of the burner flame.

In the case of the application of the invention to fuel atomization in turbines, a reaction to different operating requirements is rendered possible. It is necessary to adapt the fuel atomization in aircraft turbines because of different load requirements (launch period, normal flight) or because of different combustion conditions (the density and composition of air vary as a function of altitude). This is now possible when applying the method according to the invention. Further detailed discussions on the method and the design of the nozzles emerge within the framework of the following exemplary embodiments.

In the associated drawing:

Figure 1 shows a nozzle according to the invention in a three-dimensional diagrammatic representation,

Figure 2 shows a longitudinal section in accordance with the line A-A in Figure 1,

Figure 3 shows a longitudinal section in accordance with the line B-B in Figure 1,

Figure 4 shows a bottom view of the nozzle in accordance with Figure 1, without cover plate,

Figure 5 shows a circuit diagram for subdividing the fluid flow for the nozzle represented in Figure 1,

Figure 6 shows a further variant embodiment of a nozzle, in an exploded representation of two different views,

Figure 7 shows the swirl member of the nozzle in accordance with Figure 6,

Figure 8 shows a further swirl member for a nozzle in accordance with Figure 6,

Figure 9 shows the top view of a swirl member in an enlarged representation,

Figure 10 shows a section in accordance with the line A-A in Figure 9, rotated by 90°,

Figure 11 shows a circuit diagram for a nozzle having two tangential feed conduits,

Figure 12 shows a circuit diagram for a nozzle having four tangential feed conduits, and

Figure 13 shows a circuit diagram for a further variant embodiment for a nozzle having four tangential feed conduits.

The nozzle represented in Figure 1 comprises the nozzle body 1 and the cover plate or nozzle plate 2 arranged at the outlet end of the nozzle. Arranged in the nozzle body 1 above the swirl chamber 3 are two feed lines 5a and 5b which are mutually spaced in the axial direction and whose inlet openings are offset by 90°. The feed lines 5a and 5b run horizontally at a spacing from the nozzle plate 2. The openings of the feed lines 5a and 5b are connected via separate lines 8, 9 to a central line 10 for feeding the total fluid flow F_G (Figure 5). A feed pump 11 is incorporated into the line 10. A valve 7 is incorporated as a control member in the line 8 which branches off from the line 10 and is connected to the feed line 5b. Representation of details of the fastening of the lines and the connection of the nozzle body 1 and cover plate 2 was dispensed with in the present drawing, since these are connecting techniques with which the person skilled in the art is conversant.

Provided in the cover plate 2 is the nozzle outlet opening 6, which lies on the central axis of the nozzle and is connected to the swirl chamber 3 located above the cover plate 2 (Figures 2 and 3). The swirl chamber 3 has a constant height and a diameter which is five times the diameter of the nozzle outlet opening 6 in the cover plate 2. Opening into the swirl chamber 3 are four tangential feed conduits 4a, 4b, 4c and 4d, which have the same height in each case at the connecting point to the swirl chamber 3. The respectively opposite conduits 4a and 4c or 4b and 4d are connected to the feed lines 5a and 5b, respectively, via vertically arranged conduits 4a′, 4b′, 4c′ and 4d′. The feed conduits 4a and 4c, which have the same cross section at the connecting point to the swirl chamber, are connected to the feed line 5a via the vertical conduits 4a′ and 4c′. The definition of "cross-sectional surfaces" will be examined in further detail below. The feed line 5b is connected via the vertical conduits 4b' and 4d' to the tangential feed conduits 4b and 4d, which likewise have the same cross section at the connecting point to the swirl chamber 3. The feed conduits 4a or 4c and 4b or 4d differ in cross section at the connecting point to the swirl chamber 3; the feed conduits 4a and 4c are not as wide as the feed conduits 4b and 4d. The offset radial arrangement of the individual feed conduits, referred to their central axis, by 90° in each case were selected thus to maintain the symmetry of the flow of the fluid into the swirl chamber 3. The method and device are explained jointly with reference to achieving the control range. The first step is to consider the case in which the drop quality is to remain largely uniform in conjunction with a variable overall throughput. This is a requirement, for example, with oil burners.

In the case of full load, the overall liquid throughput F_G is subdivided over all the tangential feed conduits 4a, 4b, 4c and 4d by forming the tangential subflows T_{t1}, T_{t2}, T_{t3} and T_{t4}. This is achieved by subdividing the total fluid flow F_G into two subflows T_1 and T_2 which are respectively applied to the feed lines 5a and 5b. The subflow T_2 which is applied to the tangential feed conduits 4b and 4d, that is to say the tangential subflows T_{t2} and T_{t4} (Figure 5) can be influenced by controlling the valve 7, that is to say the throughput of the tangential subflows T_{t2} and T_{t4} can be controlled thereby. The liquid flow T_2 is subdivided over the tangential feed conduits T_{t2} and T_{t3}. The overall throughput drops in the case of part load. As a countermeasure, the subflow T_2 in the branch line 8, which supplies the tangential feed conduits 4b and 4d via the feed line 5b, is choked by means of the valve 7. A larger throughput T_{t1} and T_{t3} thereby passes into the tangential feed conduits 4a and 4c. The inlet speed in these feed conduits rises there despite a falling overall throughput, and therefore leads to a constant swirling movement at the outlet opening 6 of the nozzle. The lowermost limit of constant drop quality is reached when the overall throughput is still just directed through the feed conduits 4a and 4c, and the feed conduits 4b and 4d are no longer affected. If the overall throughput drops even more strongly, an increase in the mean drop diameter can be expected.

The second case which can be treated using the method according to the invention is the control of the drop size in conjunction with a throughput which remains constant. The subflows are subdivided in a way similar to the first case. If the drop size is to be reduced in conjunction with the same throughput, it is necessary to increase the subflow which supplies the feed line 5a. The overall throughput is to be kept constant by means of an appropriate circuit. The opposite procedure is to be adopted if a larger drop size is desired. A further variant embodiment of a nozzle is shown in an exploded representation in Figure 6 and has three tangential feed conduits. To ease comprehension, the nozzle is shown in two views - the view a as a vertical arrangement of the nozzle, and the view b as an arrangement inclined about the central axis. The nozzle comprises the base body or nozzle body 1, the swirl member 12, the cover plate or nozzle plate 2 and the cap 13, which is screwed onto the nozzle body 1. By comparison with the nozzle represented in Figures 1 to 4, the feed lines 5a and 5b are arranged not horizontally but vertically in the nozzle body 1. The subdivision of the feed lines 5a and 5b over the vertical conduits 4a', 4b' and 4d' as well as the tangential feed conduits 4a, 4b and 4d, which open into the swirl chamber 3, is performed in the swirl member 12, which is designed as an interchangeable insert. Arranged on the underside of the swirl member is a corresponding cutout for the nozzle plate 2, in which the nozzle outlet opening 6 is located. The line branches 8 and 9, which are connected to the feed lines 5a and 5b, as well as the line 10 for the total fluid flow with the pump 11, and the arrangement of the control valve 7, which is incorporated into the line 8, which is connected to the line 5b, are not represented again in this figure.

The feed line 5a merges in the swirl member 12 into the vertical conduit 4a', which opens into the tangential feed conduit 4a. The feed line 5b merges in the swirl member 12 into two vertical conduits 4b' and 4d', which are respectively connected to a tangential feed conduit 4b or 4d (Figure 7). Two different varied embodiments of the swirl member 12 are represented in Figures 7 and 8, as a top view a or bottom view b, respectively.

The swirl member 12 in accordance with Figure 7 is identical to the swirl member shown in Figure 6. Unlike the latter, the swirl member 12 in accordance with Figure 8 is equipped only with two tangential feed conduits 4a, 4b. The view a shows the top view, and the view b the bottom view, respectively. In the variant shown in Figure 7, the fluid subflow T_1 flowing through the feed line 5b is subdivided into two tangential subflows T_{t2} and T_{t4}, and the other subflow T_2 passes into the tangential feed conduit 4a without further subdivision.

In the variant shown in Figure 8, the subflows T_1 and T_2 are not further subdivided and are fed to the swirl chamber 3 via the respective associated tangential feed conduit 4a or 4b.

The advantage of the nozzle shown in Figure 6 consists chiefly in that different variant methods can be realized by exchanging the swirl member without the need to replace the entire nozzle. The details of the respective nozzle can be configured differently in design terms. This also dependent, in particular, on the respective case of use or application of the nozzles. The top view of a swirl chamber 3 is represented in an enlarged fashion in Figure 9, two tangential feed conduits 4a and 4b opening into the said chamber. The two feed conduits 4a and 4b have different cross-sectional surfaces at the connecting point to the swirl chamber 3. The tangential feed conduits of a nozzle have the same height at the connecting point to the swirl chamber 3, and can differ in width, if required, as illustrated in Figure 9 by the width dimensions B_1 and B_2. The respective width dimension is the distance between two points of intersection S_1 and S_2 lying on a line parallel to the central axis M, the point of intersection S_1 being the point of intersection between the lateral surface of the swirl chamber and the wall, adjacent thereto, of the tangential feed conduit, and the point of intersection S_2 is the point of intersection of the parallel line with the opposite wall of the tangential feed conduit. The connecting point of the tangential feed conduits to the swirl chamber can also be designed as a circular cross section, in which case different cross-sectional surfaces are then achieved in a similar way by means of different diameters of the respective bores at this point. It also emerges clearly from Figure 9 that the tangential feed conduits 4a and 4b can be of different design outside the connecting point to the swirl chamber, for example they can have a constant conduit cross section, or the conduit cross section can taper in the direction toward the swirl chamber. In the case of two tangential feed conduits of a nozzle, as represented in Figures 9 and 10, it is mandatory for these conduits to have different cross-sectional surfaces at the connecting points to the swirl chamber. In the case of more than two tangential feed conduits, the latter can have the same cross-sectional surface at the connecting point to the swirl chamber, it then being essential only that the sums of the relevant cross-sectional surfaces which are assigned to the respective subflows T_1 and T_2 or the associated conduits differ.

A further important design feature is the ratio of the diameter D_1 of the nozzle outlet opening to the diameter D_2 of the swirl chamber, the aim being that the ratio $D_2:D_1$ should be in a range from 2 to 12. In the case of a design of a nozzle with a plurality of tangential feed conduits, it is expedient if the latter are distributed uniformly over the circumference of the inner lateral surface of the swirl chamber. It has proved to be advantageous for the swirl chamber and the cross sections of the tangential feed conduits at the connecting point to the swirl chamber to be dimensioned in accordance with a specified ratio, and specifically as follows:

$$\frac{2B}{D_2 - D_1} < 0.5$$

B signifying either the width or the diameter of the conduit at the connecting point to the swirl chamber, and D_1 and D_2 being the diameters of the outlet nozzle and the swirl chamber, respectively, as explained above. In a way known per se, the height of the swirl chamber is a lesser dimension than the diameter. The larger the ratio of the swirl chamber diameter to the nozzle outlet diameter (D_2:D_1), the more effectively a potential vortex can form and a high circumferential speed, which is a precondition for good atomization of the fluid, can be set up at the nozzle outlet. In the case of a large swirl chamber diameter, the speeds at the inner lateral surface of the swirl chamber can also be lower than in the case of smaller swirl chamber diameters, since, because of the larger radial distance to the nozzle outlet opening higher circumferential speeds are formed. Consequently, in the case of larger swirl chamber diameters the cross-sectional surfaces of the feed conduits can be of larger design. The production of the tangential feed conduits is thereby rendered simpler, and the risk of blockage drops. In the case of an excessively large ratio of the swirl chamber diameter to the nozzle outlet diameter, however, there is a decrease in the circumferential speed because of the wall friction.

Various circuit arrangements for different variant embodiments of nozzles are represented in Figures 11 to 13. It holds for all the circuit variants shown, including that in accordance with Figure 5, that the control intervention in the throughput of the fluid flow is undertaken outside the nozzle either via a valve or separate pumps. Controllers or control members are understood to be all possibilities of intervention which act on the throughput of the fluid flow such as, for example, throttling by means of valves, influencing the characteristic of a pump by changing the speed of the latter, or the like. The further subdivision of the total fluid flow F_G into further subflows T_1, T_2 etc. can be anticipated either inside or outside the nozzle. The subflows T_{t1} to T_{t4} are always fed into the swirl chamber tangentially.

In the case of the embodiment shown in Figure 10, the total fluid flow F_G fed by a pump 11 is subdivided into two subflows T_1 and T_2, and fed to the swirl chamber via one tangential feed conduit T_{t1} and T_{t2} each, which have different cross-sectional surfaces at the connecting point to the swirl chamber 3 of the nozzle 14. A valve 7 is incorporated into the line for the subflow T_2, which is connected to the tangential feed conduit with the larger cross-sectional surface at the connecting point to the swirl chamber. An appropriate throttling of the subflow T_2 simultaneously varies the tangential subflow T_{t2} and thus influences the circumferential speed of the fluid in the swirl chamber, and thereby the drop spectrum when the fluid emerges from the nozzle.

This basic variant entails the lowest outlay on production. The case with a constant liquid throughput will be discussed. The liquid is fed via a line, and two subflows are formed by a bifurcation. The size of one subflow can be limited by a valve. Downstream of the valve, the subflow is fed to the feed conduit with the larger cross-sectional surface. The two limiting cases are given, namely when the valve is fully open or fully closed. In the case of a fully opened valve, the liquid throughput is distributed over both feed conduits. The circumferential speed has its lowest value at the inner lateral surface of the swirl chamber, and the circumferential speed is thereby also lowest at the nozzle outlet. The highest value is assumed by the circumferential speed at the nozzle outlet when the valve is closed. The ratio of the smallest cross-sectional surface of the two feed conduits determines the ratio of part load to full load which can be achieved, and in the case of which the atomization properties do not essentially change. The circuit variant shown in Figure 11 corresponds to the nozzle, shown in Figure 6, having a swirl member 12 in accordance with Figure 8.

The circuit variant represented in Figure 12 differs from the circuit variant shown in Figure 11 only in that the subflow T_2 is not subdivided into one tangential subflow, but over three tangential subflows T_{t2}, T_{t3} and T_{t4} whose sum of the cross-sectional surfaces of the tangential feed conduits at the connecting point is larger than the analogous cross-sectional surface for the tangential subflow T_{t1}.

If the larger cross-sectional surface is designed in the case of a circuit variant in accordance with Figure 11 to be very large in relation to the smaller cross-sectional surface, there is the risk that asymmetries can occur in the flow of the fluid in the swirl chamber. The variant represented in Figure 12 is proposed in order to avoid this disadvantage. The same variant renders it possible to arrive at feed conduits which are arranged over the inner lateral surface of the swirl chamber and therefore lead to a symmetrical flow. The sum of the cross-sectional surfaces of these tangential feed conduits is larger at the connecting point than that of the remaining feed conduit which is fed by the subflow which is not influenced directly via the valve.

In the case of the circuit variant shown in Figure 13, the design of the nozzle is similar to the case of the design in accordance with Figure 12. The difference consists in that there is no branching of a total fluid flow, but two separate subflows T_1 and T_2 are influenced independently of one another via eccentric worm screw pumps 11, 11' incorporated into the lines, and specifically by a change in the speed of the pumps. In the case of the conveyance of suspensions, it is sometimes necessary to avoid blockage through line cross sections, as in the case of valves or cocks, since obstructions can otherwise occur. It is therefore necessary to use a variant in which subflows can be influenced in another way. This can be performed by positive displacement pumps whose discharge characteristic is varied. In accordance with this variant, use is made in each subflow of eccentric worm screw pumps 11, 11' whose throughput is adapted via a change in speed. The present invention can also be applied in such cases where it is necessary in conjunction with different throughputs to keep the jet angle of the fluid emerging from the nozzle constant, that is to say to influence the control of the jet angle. In the case of conventional swirl nozzles, a larger jet angle is achieved with increasing throughput.

An increase in the jet angle with increasing overall throughput is likewise to be noted in the case of the method according to the invention in conjunction with a constant ratio of subflows. The following situation results in the case of the use of the circuit variant in accordance with Figure 11. For a given outlet pressure, the overall throughput can be increased by opening the valve. The jet angle is thereby slightly increased. Thus, if the outlet pressure is lowered when the valve is closed, a constant jet angle is achieved.

Patent Claims

1. A method for varying the swirling movement of a fluid in the swirl chamber (3) of a nozzle, the swirling movement not being coupled to the overall throughput of the fluid flow, and the total fluid flow (F_G) being subdivided into a plurality of subflows (T_1, T_2) which are led to the swirl chamber (3) via tangential feed conduits (4a, 4b, 4c, 4d) of the swirl chamber (3), characterized in that the subflows (T_1, T_2) are subdivided over feed conduits (4a, 4b, 4c, 4d) which differ in their cross-sectional surfaces at the connecting point to the swirl chamber (3), it being the case that upon subdivision of the subflows (T_1, T_2) over more than two tangential feed conduits (4a, 4b, 4c, 4d), the cross-sectional surfaces are formed from the sum of the cross-sectional surfaces of the feed conduits (4a, 4c or 4b, 4d) which branch off from the respective subflow (T_1, T_2), and the sums of the cross-sectional surfaces at the connecting point (S_1, S_2) to the swirl chamber (3) of the respective subflows (T_1, T_2) therefore differ, and the subdivision of the individual tangential subflows (T_{t1}, T_{t2}, T_{t3}, T_{t4}) passing into the swirl chamber (3) is undertaken for the purpose of implementing different control possibilities during the operating state independently of throughput.

2. The method as claimed in claim 1, characterized in that in the case of more than two feed conduits (4a, 4b, 4c, 4d) the tangential subflows (T_{t1}, T_{t2}, T_{t3}, T_{t4}) are introduced into the swirl chamber (3) through cross-sectional surfaces at the connecting point to the swirl chamber (3) which are identical and/or different in size.

3. The method as claimed in either of claims 1 or 2, characterized in that the subdivision of the subflows (T_1, T_2) over the tangential feed conduits (4a, 4b, 4c, 4d) is undertaken in such a way that in the case of a required higher swirl intensity at the outlet from the swirl chamber (3) the larger subflow (T_2) or the total fluid flow (F_G) is applied to the tangential feed conduits with the smaller cross-sectional surface or sum of the cross-sectional surfaces at the connecting point (S_1, S_2) to the swirl chamber (3), and vice versa.

4. The method as claimed in one of claims 1 to 3, characterized in that in the case of a change in the total fluid flow (F_G) in the sense of a full load/part load operating mode and with the aim of maintaining the swirl intensity at the outlet from the swirl chamber (3) for a desired ratio of full load/part load of the fluid flow, the subdivision of the tangential subflows (T_{t1}, T_{t2}, T_{t3}, T_{t4}) is undertaken in such a way that the ratio of the sum of the cross-sectional surfaces of the affected feed conduits at full load to the sum of the cross-sectional surfaces of the affected tangential feed conduits at part load corresponds at least to the volumetric flow ratio of full load to part load.

5. The method as claimed in one of claims 1 to 4, characterized in that the total fluid flow (F_G) is subdivided into two subflows (T_1, T_2) which are introduced tangentially into the swirl chamber (3) via one feed conduit (4a, 4b) each, the subflow which is connected to the larger cross-sectional surface at the connecting point (S_1, S_2) to the swirl chamber (3) being controlled by a control member (7).

6. The method as claimed in one of claims 1 to 4, characterized in that the total fluid flow (F_G) is subdivided into more than two subflows (T_{t1}, T_{t2}, T_{t3}, T_{t4}) introduced tangentially into the swirl chamber (3), at least two tangential subflows (T_{t2}, T_{t3}, T_{t4}) being branched off from one subflow (T_2), and the subflow (T_2) whose tangential feed conduits (4b, 4c, 4d) at the connecting point (S_1, S_2) to the swirl chamber (3) yield the highest value in the sum of the cross-sectional surfaces is controlled by means of a control member (7, 11, 11').

7. The method as claimed in one of claims 1 to 6, characterized in that a pump (11, 11') and/or a valve (7) are used as control members.

8. The method as claimed in one of claims 1 to 7, characterized in that the subflows (T_1, T_2) are controlled independently of one another by changing the delivery rate of the respective pump (11, 11').

9. The method as claimed in one of claims 1 to 8, characterized in that two separate subflows (T_1, T_2) form the total fluid flow (F_G), each of these subflows (T_1, T_2) being controlled by a pump (11, 11'), and at least one subflow (T_2) being subdivided over a plurality of tangential feed conduits (4b, 4c, 4d) to form the corresponding subflows (T_{t2}, T_{t3}, T_{t4}).

10. The method as claimed in one of claims 1 to 9, characterized in that influence is exercised in a stepless fashion on the division ratio of the subflows (T_1, T_2) by the different control of at least one of the subflows (T_1, T_2) and the subdivision of the subflows (T_1, T_2) over the

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tangential feed conduits (4a, 4b, 4c, 4d) in such a way that the swirling movement in the swirl chamber (3) is controlled, and thereby the drop size of the fluid emerging from the nozzle outlet opening (6) is increased or decreased, or is held constant in the case of variations in the material parameters of the fluid.

11. The method as claimed in one of claims 1 to 10, characterized in that the tangential subflows (T_{t1}, T_{t2}, T_{t3}, T_{t4}) are fed to the swirl chamber (3) so that they lie on the same axial coordinate.

12. The method as claimed in one of claims 1 to 11, characterized in that the tangential subflows (T_{t1}, T_{t2}, T_{t3}, T_{t4}) are introduced into the swirl chamber (3) so that they are distributed uniformly over the interior lateral surface thereof.

13. The method as claimed in one of claims 1 to 12, characterized in that the influence on the throughput of the subflows (T_1, T_2) is undertaken outside the nozzle (14).

14. The method as claimed in one of claims 1 to 13, characterized in that the subdivision of the subflows (T_1 T_2) for forming the tangential subflows (T_{t1}, T_{t2}, T_{t3}, T_{t4}) is undertaken inside or outside the nozzle (14).

15. The method as claimed in one of claims 1 to 14, characterized in that in the case of an increasing overall throughput the jet angle of the atomized fluid is maintained by virtue of the fact that the total fluid pressure is reduced and the subflow (T_2) it [sic] is subdivided over the tangential feed conduits (4a, 4b, 4c, 4d) with the largest cross-sectional surface or sum of the

cross-sectional surfaces at the connecting point (S_1, S_2) to the swirl chamber (3) is increased with respect to the other subflow (T_1).

16. The method as claimed in one of claims 1 to 15, characterized in that in the case of a constant overall throughput the jet angle of the atomized fluid is increased by virtue of the fact that the total fluid pressure is increased and the subflow (T_2) which is subdivided over the tangential feed conduits (4a, 4b, 4c, 4d) with the largest cross-sectional surface or sum of the cross-sectional surfaces at the connecting point (S_1, S_2) to the swirl chamber (3) is reduced with respect to the other subflow (T_1).

17. The method as claimed in one of claims 1 to 16, characterized in that said method is used to atomize liquids with the aid of gases, the liquid or the gas or both, either individually or as a mixture, being subjected to a variable swirling movement before emerging from the nozzle.

18. A nozzle system for carrying out the method as claimed in at least one of the preceding claims, having a swirl generator in which fluids are set rotating about an axis, the swirl generator comprising a swirl chamber (3) with a plurality of tangential feed conduits (4a, 4b, 4c, 4d) on the periphery of the swirl chamber (3) as well as an outlet opening (6), characterized in that

a) in the case of an arrangement of two feed conduits (4a, 4c) the latter have a different cross-sectional surface at the connecting point (S_1, S_2) to the swirl chamber (3), and
b) in the case of an arrangement of more than two tangential feed conduits (4a, 4b, 4c, 4d) the latter have different and/or the same cross-

sectional surfaces at the connecting point (S_1, S_2) to the swirl chamber (3), and individual tangential feed conduits (4a, 4c, 4b, 4d) are connected to separate feed lines (8, 9), the sum of the cross-sectional surfaces of the tangential feed conduits (4a, 4b, 4c, 4d) at the connecting point (S_1, S_2) to the swirl chamber (3), which are connected to different feed lines (8 or 9), being different, and

c) a control member (7, 11, 11') operating independently of throughput is incorporated into at least one of the feed conduits (4a', 4b', 4c', 4d', 5a, 5b, 8, 9, 10) outside the swirl generator.

19. The nozzle system as claimed in claim 18, characterized in that the tangential feed conduits (4a, 4b, 4c, 4d) at the connecting point (S_1, S_2) to the swirl chamber (3) have the same height and the same or a different width (B_1, B_2).

20. The nozzle system as claimed in either of claims 18 or 19, characterized in that the different cross-sectional surfaces or the formed sums of the cross-sectional surfaces differ by more than a factor of 4.

21. The nozzle system as claimed in one of claims 18 to 20, characterized in that the tangential feed conduits (4a, 4b, 4c, 4d) with the same cross-sectional surfaces at the connecting point (S_1, S_2) to the swirl chamber (3) are connected to a common feed line (8 or 9).

22. The nozzle system as claimed in one of claims 18 to 21, characterized in that a steplessly settable control member (7, 11, 11′) is incorporated into at least one of the feed lines (8 or 9).

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23. The nozzle system as claimed in claim 22, characterized in that the control member is a pump (11, 11') or a valve (7).

24. The nozzle system as claimed in one of claims 18 to 23, characterized in that the valve (7) is incorporated into the feed line (8 or 9) which is connected to the tangential feed conduits (4a, 4b, 4c, 4d) with the largest cross-sectional surface or sum of the cross-sectional surfaces at the connecting point (S_1, S_2) to the swirl chamber (3).

25. The nozzle system as claimed in one of claims 18 to 24, characterized in that the central axes of the cross-sectional surfaces of the tangential feed conduits (4a, 4b, 4c, 4d) at the connecting point to the swirl chamber (3) lie in a plane, and the cross-sectional surfaces are arranged distributed uniformly.

26. The nozzle system as claimed in one of claims 18 to 25, characterized in that the tangential feed conduits (4a, 4b, 4c, 4d) are arranged lying on the same axial coordinate.

27. The nozzle system as claimed in one of claims 18 to 26, characterized in that a pump (11) is incorporated into the feed line (10) for the total fluid flow (F_G) and the feed line (10) is subdivided into two subflow lines (8, 9) which are connected to separate conduits (5a, 5b, 4a', 4b', 4c', 4d'), located in the nozzle (14), which are connected to one tangential feed conduit (4a, 4b, 4c, 4d) each which have different cross-sectional surfaces at the connecting point (S_1, S_2) to the swirl chamber (3), and the valve (7) is incorporated into the feed line (8) which is

connected to the tangential feed conduit (4a) with the larger cross-sectional surface at the connecting point (S_1, S_2) to the swirl chamber (3).

28. The nozzle system as claimed in one of claims 18 to 26, characterized in that a pump (7) [sic] is incorporated into the feed line (10) for the total fluid flow (F_G) and the feed line (10) is subdivided into two subflow lines (8, 9) which are connected to separate conduits (5a, 5b, 4a', 4b', 4c', 4d'), located in the nozzle (14), one conduit (5a) being connected to one tangential feed conduit (4a), and the other conduit (5b) being connected to a plurality of tangential feed conduits (4b, 4c, 4d), and the valve being incorporated into the subflow line (8) which is connected to a plurality of tangential feed conduits.

29. The nozzle system as claimed in one of claims 18 to 26, characterized in that the nozzle (14) is connected to two separate feed lines (8, 9) into which in each case one pump (11, 11') is incorporated, one feed line (9) being connected to one tangential feed duct (4a), and the other feed line (8) being connected to a plurality of tangential feed conduits (4b, 4c, 4d).

30. The nozzle system as claimed in one of claims 18 to 29, characterized in that the quotient of the diameter (D_2) of the swirl chamber (3) and the diameter (D_1) of the nozzle outlet opening (6) of the swirl chamber (3) is in a range from 2 to 12.

31. The nozzle system as claimed in one of claims 18 to 31, characterized in that the ratio of double the width or double the diameter of the inlet opening of the respective tangential feed conduit

(4a, 4b, 4c, 4d) at the connecting point (S_1, S_2) to the swirl chamber (3) divided by the difference between the swirl chamber diameter (D_2) and the nozzle outlet diameter (D_1) is smaller than 0.5.

32. The nozzle system as claimed in one of claims 18 to 31, characterized in that the feed lines (8, 9, 5a, 5b) have different connecting cross sections in such a way that the feed lines which are connected to the tangential feed conduits whose cross-sectional surface or sum of the cross-sectional surfaces at the connecting point (S_1, S_2) to the swirl chamber (3) is largest have the larger connecting cross section.

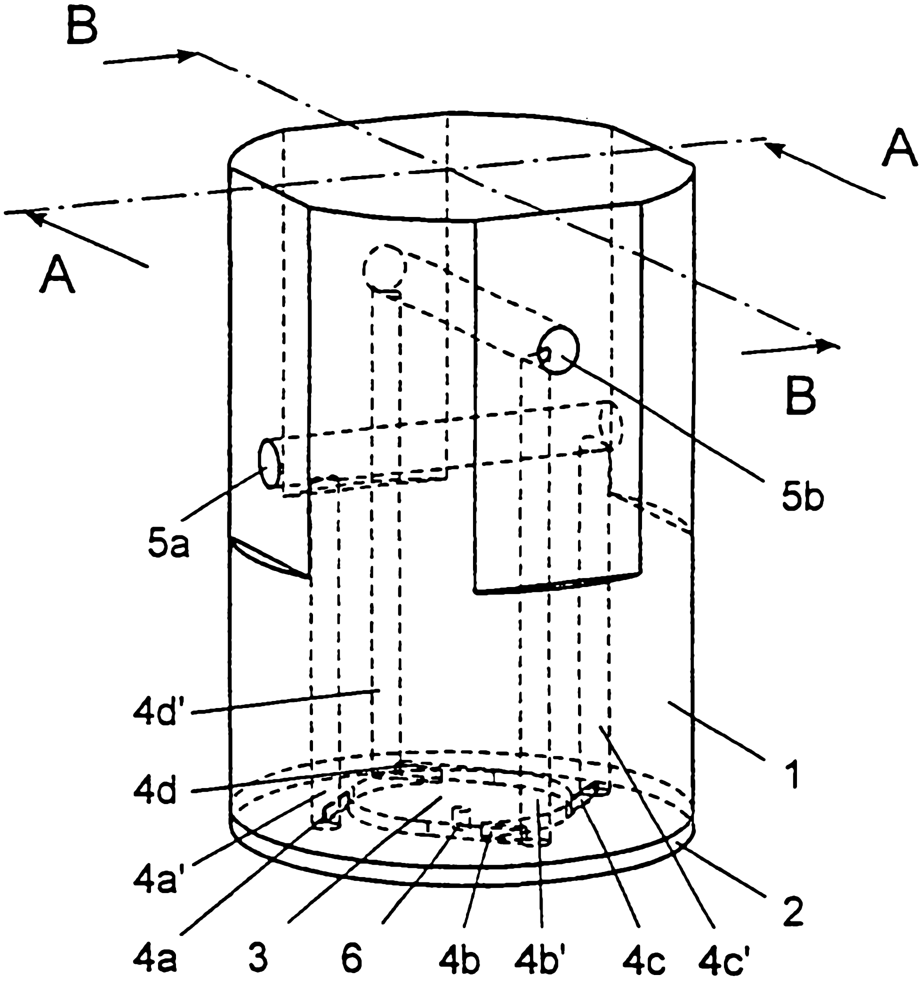


Figure 1

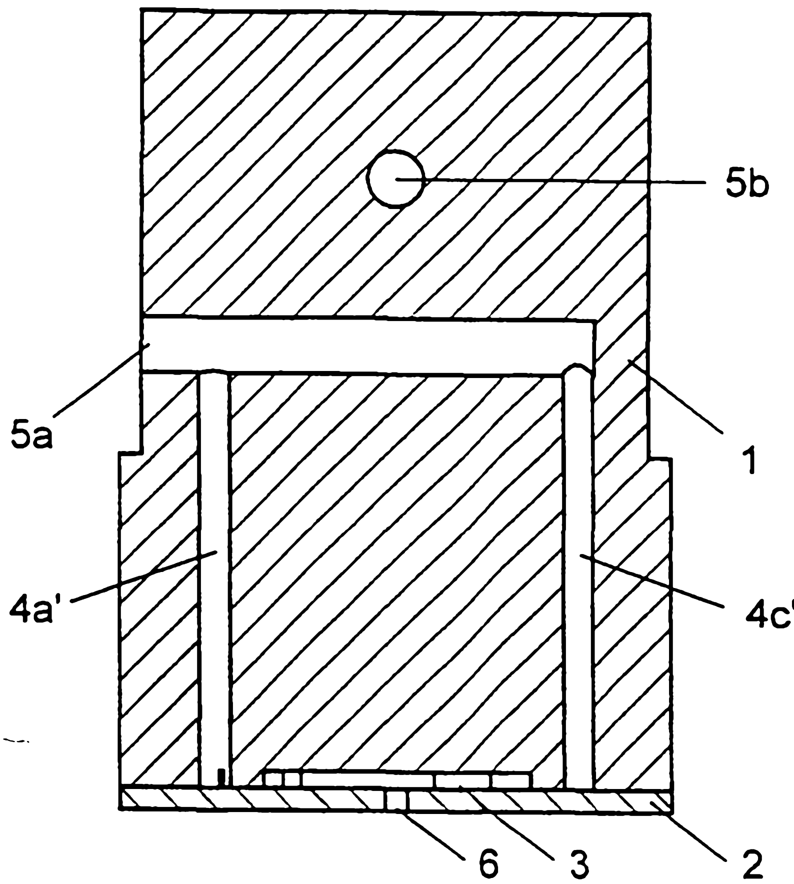


Figure 2

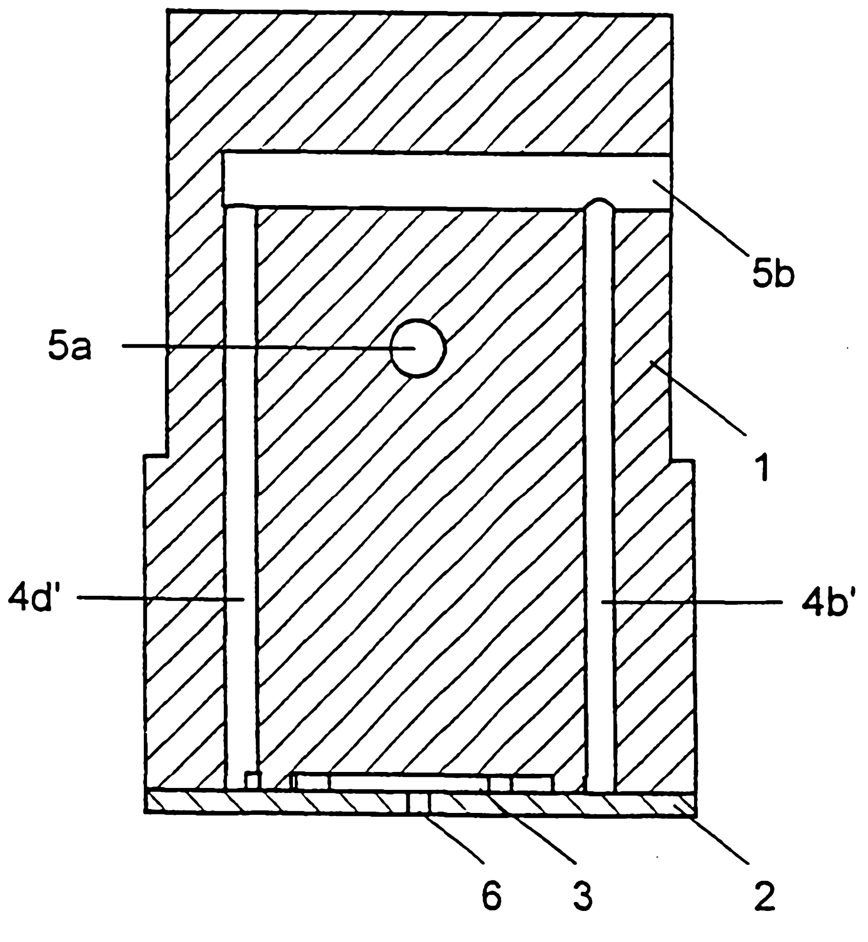


Figure 3

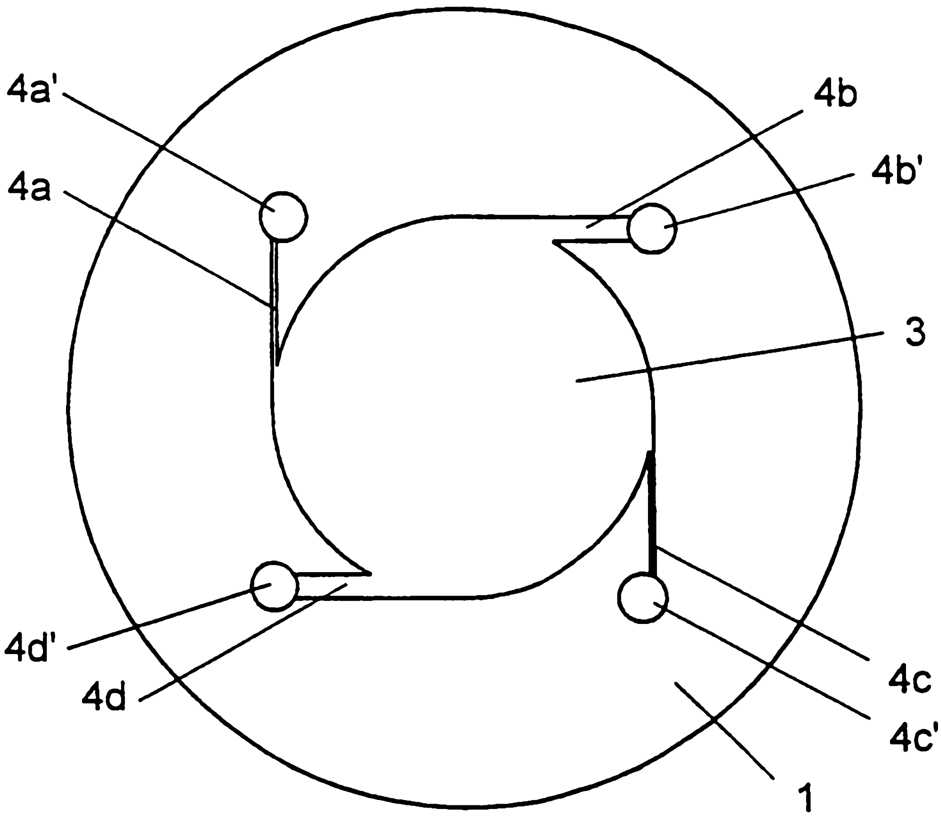


Figure 4

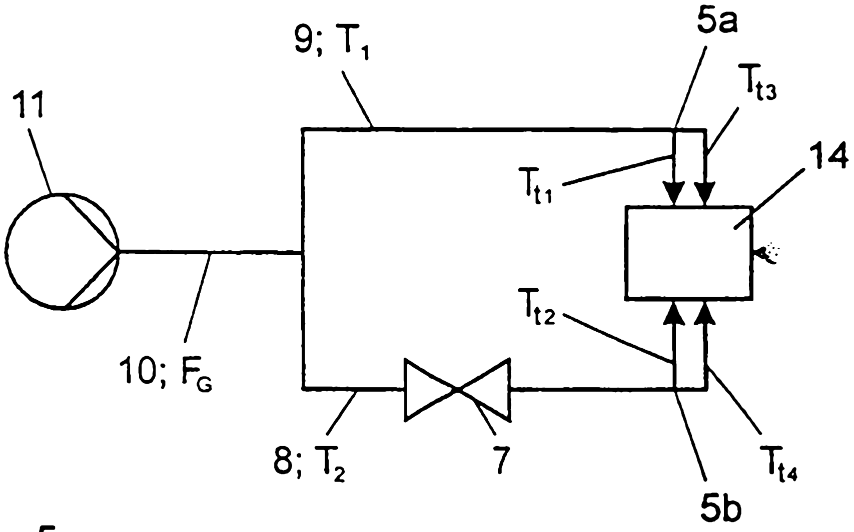


Figure 5

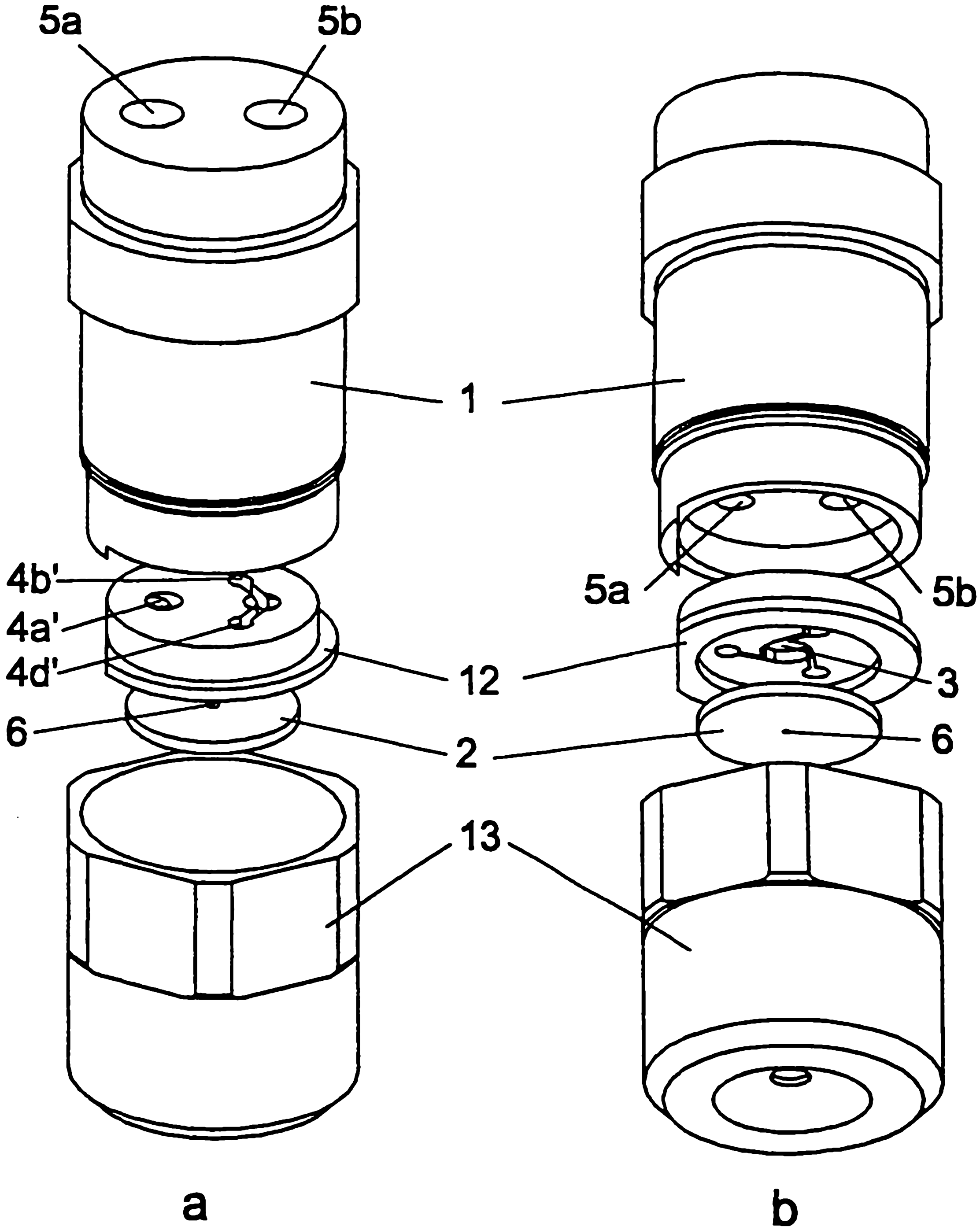


Figure 6

Figure 7

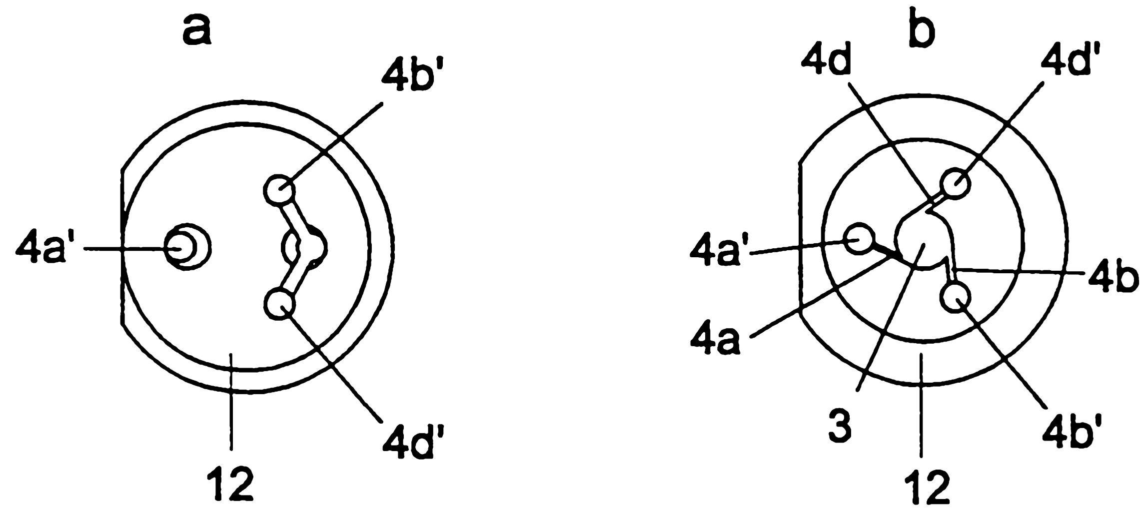
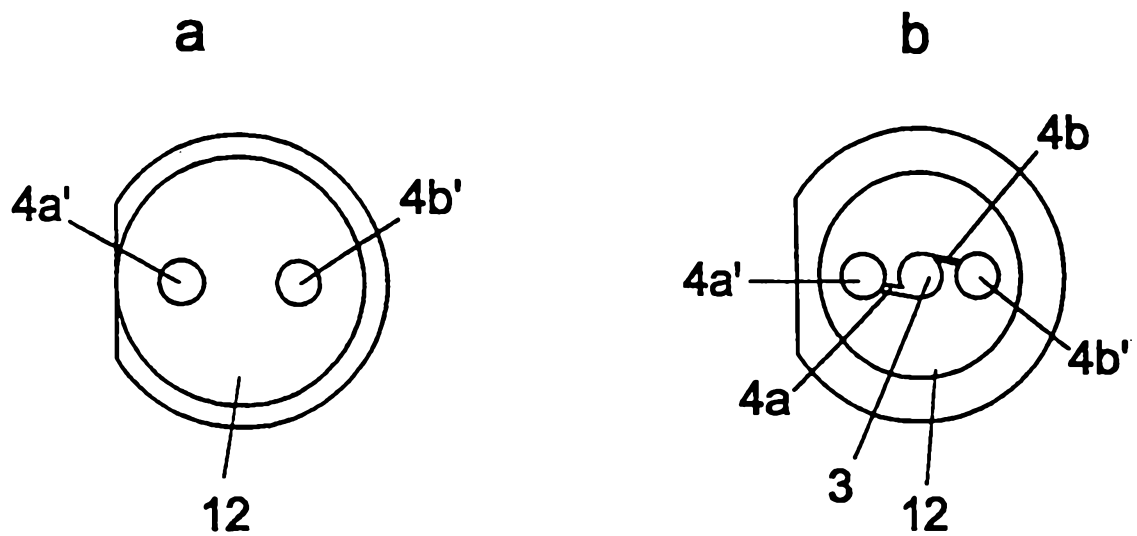


Figure 8



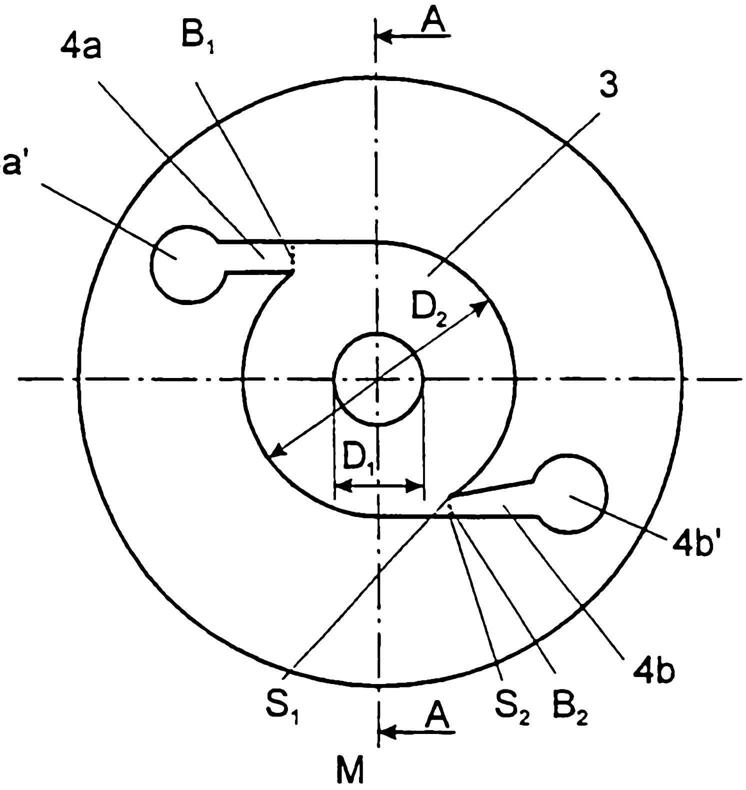


Figure 9

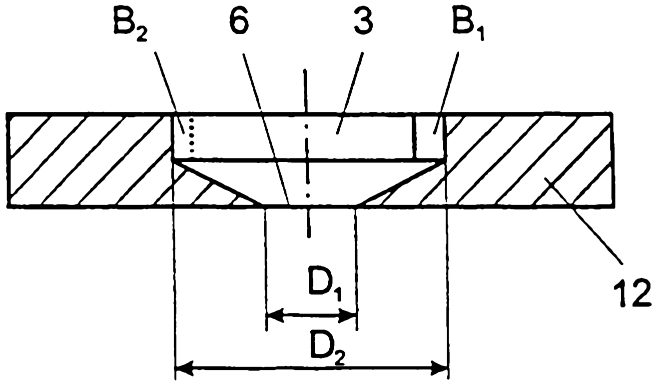


Figure 10

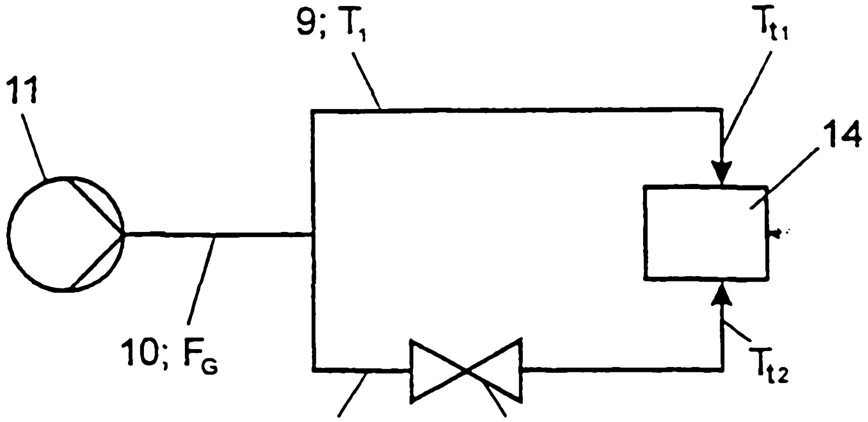


Figure 11

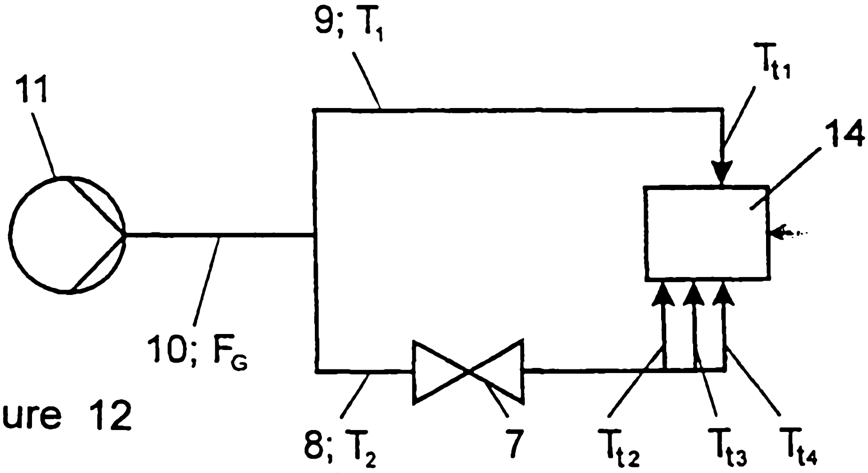


Figure 12

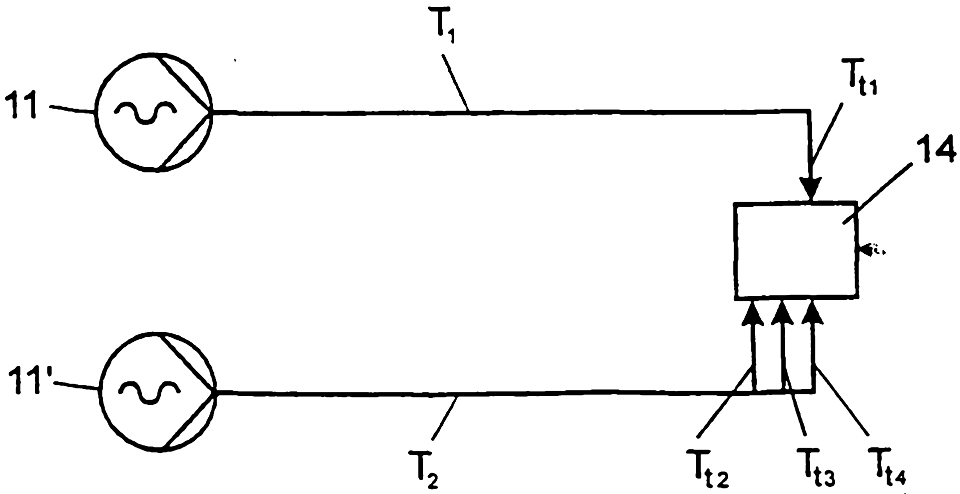


Figure 13