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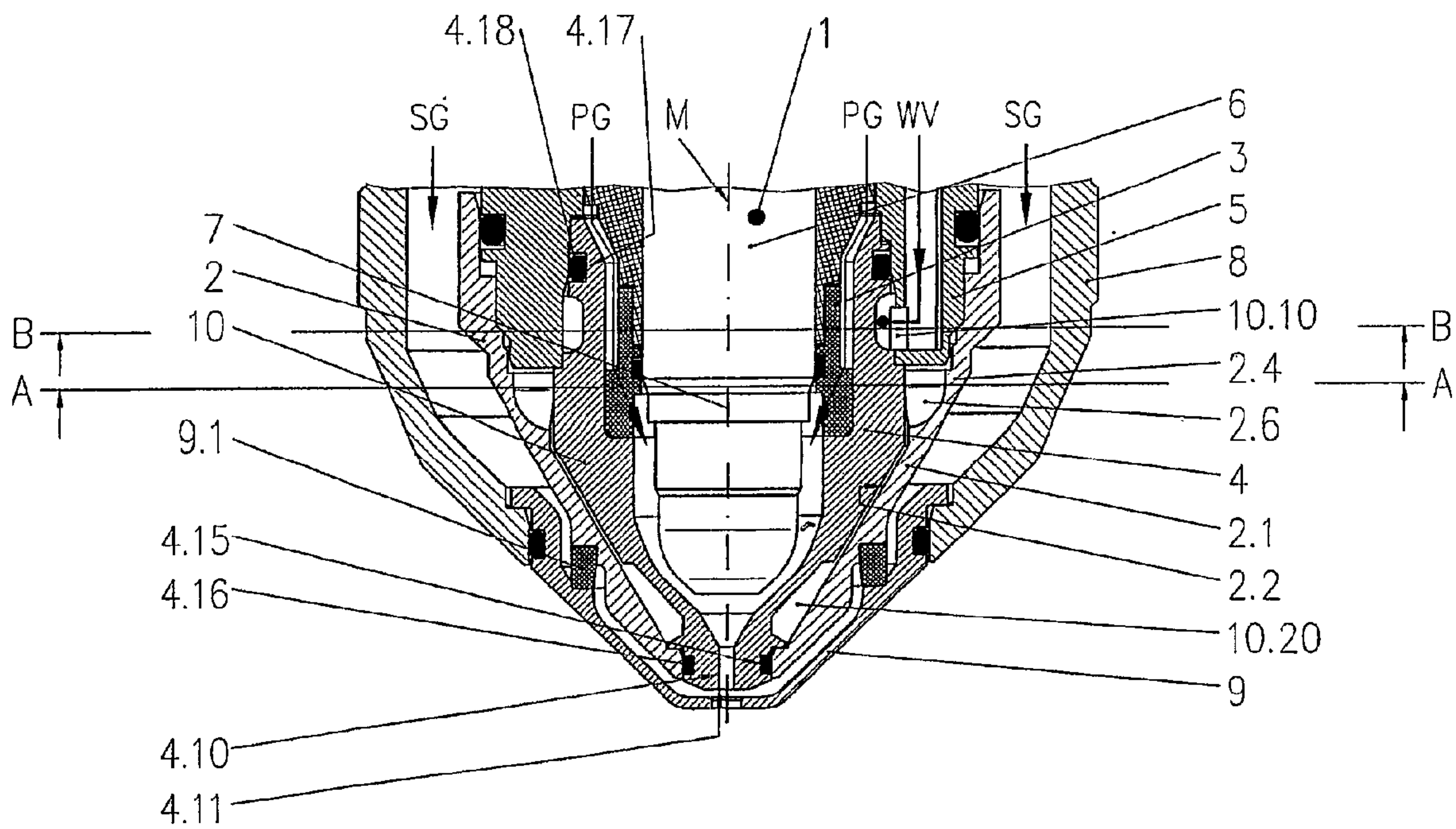



(57) Abrégé/Abstract:
A nozzle for a liquid-cooled plasma torch, comprising a nozzle bore for the exit of a plasma gas jet at a nozzle tip, a first portion, the outer surface of which is substantially cylindrical, and a second portion adjacent thereto towards the nozzle tip, the outer surface of which tapers substantially conically towards the nozzle tip, wherein at least one liquid supply groove and/or at least one liquid return groove is/are provided and extend over the second portion in the outer surface of the nozzle towards the nozzle tip, and wherein the liquid supply groove or at least one of the liquid supply grooves and/or a liquid return groove or at least one of the liquid return grooves also extends/extend over part of the first portion, and there is in the first portion at least one groove which communicates with the liquid supply groove or at least one of the liquid supply grooves or with the liquid return groove or at least one of the liquid return grooves.

## Abstract

A nozzle for a liquid-cooled plasma torch, comprising a nozzle bore for the exit of a plasma gas jet at a nozzle tip, a first portion, the outer surface of which is substantially cylindrical, and a second portion adjacent thereto towards the nozzle tip, the outer surface of which tapers substantially conically towards the nozzle tip, wherein at least one liquid supply groove and/or at least one liquid return groove is/are provided and extend over the second portion in the outer surface of the nozzle towards the nozzle tip, and wherein the liquid supply groove or at least one of the liquid supply grooves and/or a liquid return groove or at least one of the liquid return grooves also extends/extend over part of the first portion, and there is in the first portion at least one groove which communicates with the liquid supply groove or at least one of the liquid supply grooves or with the liquid return groove or at least one of the liquid return grooves.

# NOZZLE FOR A LIQUID-COOLED PLASMA TORCH AND PLASMA TORCH HEAD HAVING THE SAME

## FIELD OF THE INVENTION

The present invention relates to a nozzle for a liquid-cooled plasma torch and a plasma torch head with said plasma torch.

## BACKGROUND OF THE INVENTION

A plasma is the term used for an electrically conductive gas consisting of positive and negative ions, electrons and excited and neutral atoms and molecules, which is heated thermally to a high temperature.

Various gases are used as plasma gases, such as mono-atomic argon and/or the diatomic gases hydrogen, nitrogen, oxygen or air. These gases are ionised and dissociated by the energy of an electric arc. The electric arc is constricted by a nozzle and is then referred to as a plasma jet.

The parameters of the plasma jet can be heavily influenced by the design of the nozzle and the electrode. These parameters of the plasma jet are, for example, the diameter of the jet, the temperature, the energy density and the flow rate of the gas.

In plasma cutting, for example, the plasma is constricted by a nozzle, which can be cooled by gas or water. In this way, energy densities of up to $2x10^6$ $W/cm^2$ can be achieved. Temperatures of up to 30,000° C arise in the plasma jet, which, in combination with the high flow rate of the gas, make it possible to achieve very high cutting speeds on materials.

Plasma torches can be operated directly or indirectly. In the direct operating mode, the current flows from the source of the current, through the electrode of the plasma torch and the plasma jet generated by the electric arc and constricted by the nozzle, directly back to the source of the current via the workpiece. The direct operating mode can be used to cut electrically conductive materials.

In the indirect operating mode, the current flows from the source of the current, through the electrode of the plasma torch, the plasma jet generated by the electric arc and constricted by the nozzle, and through the nozzle back to the source of the current. In the process, the nozzle is subjected to an even greater load than in direct plasma cutting, since it not only constricts the plasma jet, but also establishes the attachment spot for the electric arc. With the indirect operating mode, both electrically conductive and non-conductive materials can be cut.

Because of the high thermal stress on the nozzle, it is usually made from a metallic material, preferably copper, because of its high electrical conductivity and thermal conductivity. The same is true of the electrode holder, though it may also be made of silver. The nozzle is then inserted into a plasma torch, the main elements of which are a plasma torch head, a nozzle cap, a plasma gas conducting member, a nozzle, a nozzle bracket, an electrode quill, an electrode holder with an electrode insert and, in modern plasma torches, a holder for a nozzle protection cap and a nozzle protection cap. The electrode holder fixes a pointed electrode insert made from tungsten, which is suitable when non-oxidising gases are used as the plasma gas, such as a mixture of argon and hydrogen. A flat-tip electrode, the electrode insert of which is made of hafnium for example, is also suitable when oxidising gases are used as the plasma gas, such as air or oxygen. In order to achieve a long service life for the nozzle, it is in this case cooled with a fluid, such as water. The coolant is delivered to the nozzle via a water supply line and removed from the nozzle via a water return line and in the process flows through a coolant chamber, which is delimited by the nozzle and the nozzle cap.

DD 36014 B1 describes a nozzle. It consists of a material with good conductive properties, such as copper, and has a geometrical shape associated with the plasma torch type concerned, such as a conically shaped discharge space with a cylindrical nozzle outlet. The outer shape of the nozzle is designed as a cone, forming an approximately uniform wall thickness, which is dimensioned such that good stability of the nozzle and good conduction of the heat to the coolant is ensured. The nozzle is located in a nozzle bracket. The nozzle bracket consists of a corrosion-resistant material, such as brass, and has on the inside a centring mount for the nozzle and a groove for a rubber gasket, which seals the discharge space against the coolant. In the nozzle bracket, there are in addition bores offest by 180° for the coolant supply and return lines. On the outer diameter of the nozzle bracket there is a groove for an O-ring for sealing the coolant chamber towards the atmosphere and a thread and a centring mount for a nozzle cap. The nozzle cap, likewise made of corrosion-resistant material, such as brass, is shaped with an acute angle and has a wall thickness designed to make it suitable for dissipating radiant heat to the coolant. The smallest internal diameter is provided with an O-ring. For a coolant, it is simplest to use water. This arrangement is intended to facilitate the manufacture of the nozzles, while making sparing use of materials, and to make it possible to replace the nozzles quickly and also to swivel the plasma torch relative to the workpiece thanks to the acute-angled shape, thus enabling slanting cuts.

The published patent application DE 1 565 638 describes a plasma torch, preferably for plasma arc cutting materials and for welding edge preparation. The slender shape of the torch head is achieved by using a particularly acute-angled cutting nozzle, the internal and external angles of which are identical to one another and also identical to the internal and external angles of the nozzle cap. Between the nozzle cap and the cutting nozzle, a space is formed for coolant, in which the nozzle cap is provided with a collar, which establishes a metallic seal with the cutting nozzle, so that in this way a uniform annular gap is formed as the coolant chamber. The coolant, generally water, is supplied and removed via two slots in the nozzle bracket arranged so as to be offset by $180^0$ to one another.

In DE 25 25 939, a plasma arc torch, especially for cutting or welding, is described, in which the electrode holder and the nozzle body form an exchangeable unit. The external coolant supply is formed substantially by a coupling cap surrounding the nozzle body. The coolant flows through channels into an annular space formed by the nozzle body and the coupling cap.

DE 692 33 071 T2 relates to an electric arc plasma cutting apparatus. It describes an embodiment of a nozzle for a plasma arc cutting torch formed from a conductive material and having an outlet opening for a plasma gas jet and a hollow body section designed such that it has a generally conical thin-walled configuration which is slanted towards the outlet opening and has an enlarged head section formed integrally with the body section, the head section being solid, except for a central channel, which is aligned with the outlet opening and has a generally conical outer surface, which is also slanted towards the outlet opening and has a diameter adjacent to that of the neighbouring body section which exceeds the diameter of the body section, in order to form a cut-back recess. The electric arc plasma cutting apparatus possesses a secondary gas cap. In addition, there is a water-cooled cap disposed between the nozzle and the secondary gas cap in order to form a water-cooled chamber for the external surface of the nozzle for a highly efficient cooler. The nozzle is characterised by a large head, which surrounds an outlet opening for the plasma jet, and a sharp undercut or recess to a conical body. This nozzle construction assists cooling of the nozzle.

In the plasma torches described above, the coolant is supplied to the nozzle via a water flow channel and removed from the nozzle via a water return channel. These channels are usually offset from one another by $180^0$, and the coolant is supposed to flow round the nozzle as uniformly as possible on the way from the supply line to the return line. Nevertheless, overheating is repeatedly found in the vicinity of the nozzle channel.

A different coolant flow for a torch, preferably a plasma torch, especially for plasma welding, plasma cutting, plasma fusion and plasma spraying purposes, which can withstand the high thermal loads in the nozzle and the cathode is described in DD 83890 B1. In this case, for cooling the nozzle, a coolant guide ring which can easily be inserted into and removed from the nozzle holding part is provided, which has a peripheral shaped groove to restrict the flow of cooling medium to a thin layer no more than 3 mm thick along the outer nozzle wall. More than one, preferably two to four, coolant lines arranged in a star shape relative to the shaped groove and radially and symmetrically to the nozzle axis and in a star shape relative to the latter are provided at an angle of between 0 and $90^0$ and lead into the shaped groove in such a way that they each have two cooling medium outlets next to them and each cooling medium outlet has two cooling medium inlets next to it.

This arrangement for its part has the disadvantage that greater effort is required for the cooling, because of the use of an additional component, the coolant guide ring. Furthermore, the entire arrangement becomes bigger as a result.

## SUMMARY OF THE INVENTION

The invention is thus based on the problem of avoiding overheating in the vicinity of the nozzle channel or the nozzle bore in a simple manner.

This problem is solved in accordance with the invention by a plasma torch head comprising:

- a nozzle according to the present invention

- a nozzle bracket for holding the nozzle, and

a nozzle cap, the nozzle cap and the nozzle forming a coolant chamber which can be connected via two bores, each offset by $60^0$ to 180°, to a coolant supply line or coolant return line, the nozzle bracket being designed such that the coolant flows into the coolant chamber virtually perpendicularly to the longitudinal axis of the plasma torch head, encountering the nozzle, and/or virtually perpendicularly to the longitudinal axis out of the coolant chamber and into the nozzle bracket.

In addition, the present invention provides a nozzle for a liquid-cooled plasma torch comprising a nozzle bore for the exit of a plasma gas jet at a nozzle tip, a first portion, the outer surface of which is substantially cylindrical, and a second portion adjacent to it towards the nozzle tip, the outer surface of which tapers substantially conically towards the nozzle tip, wherein at least one liquid supply groove and/or at least one liquid return groove is/are provided, extending via the second portion in the outer surface of the nozzle towards the nozzle tip, and wherein the liquid supply groove or at least one of the liquid supply grooves and/or a liquid return groove or at least one of the liquid return grooves also extend(s) via part of the first portion, and in the first portion there is at least one groove, which communicates with the liquid supply groove or at least one of the liquid supply grooves or with the liquid return groove or at least one of the liquid return grooves. "Substantially cylindrical" means that the outer surface is generally cylindrical, at least if the grooves, such as the liquid supply and return grooves, are ignored. In an analogous way, "tapers substantially conically" means that the outer surface tapers generally conically, at least if the grooves, such as the liquid supply and return grooves, are ignored.

According to a particular embodiment of the plasma torch head, the nozzle has at least one liquid supply groove and at least one liquid return groove, and the nozzle cap has on its inner surface at least three recesses, the openings facing the nozzle each extending over a radian (b2), wherein the radian (b4; c4; d4; e4) of the outwardly projecting portions of the nozzle adjacent in the circumferential direction to the liquid supply groove(s) and/or liquid return groove(s), opposite the liquid supply groove(s) and/or liquid return groove(s) is in each case at least as great as the radian (b2). In this way, a shunt from the coolant supply to the coolant return is avoided in a particularly elegant manner.

In addition, it can be contemplated with the plasma torch head that the two bores each extend substantially parallel to the longitudinal axis of the plasma torch head. This makes it possible to connect coolant lines to the plasma torch head in a space-saving manner.

In particular, the bores can be arranged offset by 180°.

The radian of the portion between the recesses in the nozzle cap is advantageously no more than half as big as the minimum radian of the liquid return groove(s) and/or the minimum radian of the liquid supply groove(s) of the nozzle.

In a particular embodiment of the nozzle, at least two liquid supply grooves and/or at least two liquid return grooves are provided.

The centre point of the liquid supply groove or at least one of the liquid supply grooves and the centre point the liquid return groove or at least one of the liquid return grooves are advantageously arranged so as to be offset by $180^0$ relative to one another over the periphery of the nozzle.

The width of the liquid supply groove or at least one of the liquid supply grooves and/or the width the liquid return groove or at least one of the liquid return grooves is/are advantageously in the range from $10^0$ to 270° in the circumferential direction.

According to a particular embodiment, the sum of the widths of the liquid supply and/or return grooves is between 20° and 340°.

It may also be contemplated that the sum of the widths of the liquid supply and/or return grooves is between 60° and 300°.

It may be contemplated that the groove or one of the grooves extends over the entire periphery in the circumferential direction of the first portion of the nozzle.

In particular, it may be contemplated in this context that the groove or one of the grooves extends over an angle Ç1 or Ç2 in the circumferential direction of the first portion of the nozzle.

In particular, it may be contemplated in this context that the groove or at least one of the grooves extends over an angle Ç1 or Ç2 in the range from 90° to 270° in the circumferential direction of the first portion of the nozzle.

In a further embodiment of the nozzle, exactly two liquid supply grooves and exactly two liquid return grooves are provided.

In particular, the two liquid supply grooves may be disposed over the periphery of the nozzle symmetrically to a straight line extending from the centre point of the liquid return grooves at a right angle through the longitudinal axis of the nozzle, and the two liquid return grooves may be disposed over the periphery of the nozzle symmetrically to a straight line extending from the centre point of the liquid supply groove at a right angle through the longitudinal axis of the nozzle.

The centre points of the two liquid supply grooves and/or the centre points of the two liquid return grooves are advantageously arranged so as to be offset relative to one another over the periphery of the nozzle by an angle in the range from $20^0$ to 180°.

In addition, it may be contemplated that the two liquid supply grooves and/or the two return grooves communicate with one another in the first portion of the nozzle.

It is convenient for at least one of the grooves to extend beyond the liquid supply groove or at least one of the liquid supply grooves or beyond the liquid return groove or at least one of the liquid return grooves.

The invention is based on the surprising realisation that by supplying and/or removing the coolant at a right angle to the longitudinal axis of the plasma torch head instead of - as in the state of the art - parallel to the longitudinal axis of the plasma torch head, better cooling of the nozzle is achieved thanks to the distinctly longer contact between the coolant and the nozzle and thanks to the fact that the coolant is guided through grooves in the nozzle in the cylindrical region towards the nozzle bracket.

If more than one liquid supply groove are provided, this means that in the region of the nozzle tip, particularly good turbulence of the coolant can be achieved as a result of the collision of the streams of coolant, which is usually also accompanied by better cooling of the nozzle.

BRIEF DESCRIPTION OF THE DRAWINGS

Further features and advantages of the invention will become clear from the following description, in which a number of embodiments of the invention are illustrated in detail with reference to the schematic drawings. There,

Fig.1 shows a longitudinal section view through a plasma torch head with a plasma and secondary gas supply line with a nozzle in accordance with a particular embodiment of the present invention

Fig. la shows a section view along line A-A in Fig. 1;

Fig. lb shows a section view along line B-B in Fig. 1;

Fig. 2 shows individual illustrations (top left: plan view from the front; top right: longitudinal section view; bottom right: side view) the nozzle from Fig.1;

Fig. 3 shows individual illustrations (top left: plan view from the front; top right: longitudinal section view; bottom right: side view) of a nozzle in accordance with a further particular embodiment of the invention;

Fig. 4 shows individual illustrations (top left: plan view from the front; top right: longitudinal section view; bottom right: side view) of a nozzle in accordance with a further particular embodiment of the invention;

Fig. 5 shows a longitudinal section view through a plasma torch head with a plasma and secondary gas supply line with a nozzle in accordance with a further particular embodiment of the present invention

Fig. 5a shows a section view along line A-A in Fig. 5;

Fig. 5b shows a section view along line B-B in Fig. 5;

Fig. 6 shows individual illustrations (top left: plan view from the front; top right: longitudinal section view; bottom right: side view) of a nozzle in accordance with a further particular embodiment of the invention; and

Fig. 7 shows individual illustrations of the nozzle cap 2 used in Fig. 1, left: longitudinal section view; right: view from the left of the longitudinal section.

DETAILED DESCRIPTION OF THE INVENTION

In the foregoing and also in the following, a groove may also mean a flattened region, for example.

In the following description, embodiments of nozzles are described which have at least one liquid supply groove, here referred to as a coolant supply groove, and at least one liquid return groove, here referred to as a coolant return groove, especially exactly one and exactly two in each case. The invention is not limited to that, however. It is also possible for a larger number of liquid supply and return grooves to be present and/or for the number of liquid supply and return grooves to be different.

The plasma torch head 1 shown in Figure 1 has an electrode holder 6, with which it holds an electrode 7 via a thread (not shown) in the present case. The electrode 7 is designed as a flat-tip electrode. For the plasma torch, it is, for example, possible to use air or oxygen as the plasma gas (PG). A nozzle 4 is held by a substantially cylindrical nozzle bracket 5. A nozzle cap 2, which is attached to the plasma torch head 1 via a thread (not shown), fixes the nozzle 4 and, together with the latter, forms a coolant chamber. The coolant chamber is sealed between the nozzle 4 and the nozzle cap 2 by a seal which takes the form of an O-ring 4.16, and which is located in a groove 4.15 in the nozzle 4, and is sealed between the nozzle 4 and the nozzle bracket 5 by a seal which takes the form of an O-ring 4.18, and which is located in a groove 4.17.

A coolant, e.g. water or water with antifreeze added, flows through the coolant chamber from a bore of the coolant supply line WV to a bore of the coolant return line WR, wherein the bores are arranged so as to be offset by 90° relative to one another (see Fig. 1b).

In prior art plasma torches, it is repeatedly found that the nozzle 4 overheats in the region of the nozzle bore 4.10. Overheating may, however, also occur between a cylindrical portion 4.1 (see Fig. 2) of the nozzle 4 and the nozzle bracket 5. This applies in particular to plasma torches operated with a high pilot current or operated indirectly. This is manifested by a discoloration of the copper after a short period of operation. In this case, even at currents of 40 A, discoloration already occurs after a short time (e.g. 5 minutes). Likewise, the sealing point between the nozzle 4 and the nozzle cap 2 is overloaded, which leads to damage to the O-ring 4.16 and thus to leaks and the escape of coolant. Studies have shown that this effect occurs in particular on the side of the nozzle 4 facing the coolant return line. It is believed that the region subjected to the highest thermal load, the nozzle bore 4.10 of the nozzle 4 is insufficiently cooled, because the coolant flows inadequately through the part 10.20 of the coolant chamber 10 closest to the nozzle bore and/or does not reach it at all, in particular on the side facing the coolant return line.

In the present plasma torch head according to Figure 1, the coolant is fed into the coolant chamber virtually perpendicularly to the longitudinal axis of the plasma torch head 1 from the nozzle bracket 5, encountering the nozzle 4. For this purpose, in a deflection space 10.10 of the coolant chamber, the coolant is deflected from the direction parallel to the longitudinal axis in the bore of the coolant supply line WV of the plasma torch in the direction of the first portion 4.1 (see Fig. 2) virtually perpendicularly to the longitudinal axis of the plasma torch head 1. Then the coolant flows through a groove 4.6 (see Figs. lb and 2), which extends in the circumferential direction of the first portion 4.1 on part of the circumference, i.e. over approx.

$110^0$, into the part 10.11 formed by a coolant supply groove 4.20 (see Figs. la, lb and 2) of the nozzle 4 and the nozzle cap 2 into the part 10.20 of the coolant chamber surrounding the nozzle bore 4.10, and flows round the nozzle 4 there. Then the coolant flows through a space 10.15 formed by a coolant return groove 4.22 of the nozzle 4 and the nozzle cap 2 back to the coolant return line WR, wherein the transition here occurs substantially parallel to the longitudinal axis of the plasma torch head (not shown).

In addition, the plasma torch head 1 is equipped with a nozzle cover guard bracket 8 and a nozzle cover guard 9. It is through this region that a secondary gas SG flows, which surrounds the plasma jet. In the process, the secondary gas SG flows through a secondary gas line 9.1, which can cause it to rotate.

Fig. la shows a section view along the line A-A of the plasma torch from Figure 1. That shows how the part 10.11 formed by the coolant supply groove 4.20 of the nozzle 4 and the nozzle cap 2 prevents a shunt between the coolant supply line and the coolant return line thanks to portions 4.41 and 4.42 of outwardly projecting regions 4.31 and 4.32 of the nozzle 4 in combination with the inner surface 2.5 of the nozzle cap 2. This achieves effective cooling of the nozzle 4 in the region of the nozzle tip and prevents a thermal overload. It is ensured that as much coolant as possible reaches the part 10.20 of the coolant space. During experiments, no discoloration of the nozzle in the region of the nozzle bore 4.10 occurred any longer. Nor did any leaks occur any more between the nozzle 4 and the nozzle cap 2, and the O-ring 4.16 was not overheated.

Figure lb contains a section view along the line B-B of the plasma torch head from Figure 1, showing the plane of the deflection space 10.10 and the connection of the coolant supply line via the groove 4.6 in the nozzle 4 running round approx. $110^0$ and the bores for the coolant supply line WV and the coolant return line WR arranged offset by $90^0$.

Fig. 2 shows the nozzle 4 of the plasma torch head from Figure 1. It has a nozzle bore 4.10 for the exit of a plasma gas jet at a nozzle tip 4.11, a first portion 4.1, the outer surface 4.4 of which is substantially cylindrical, and a second portion 4.2 adjacent thereto towards the nozzle tip 4.11, the outer surface 4.5 of which tapers substantially conically towards the nozzle tip 4.11. The coolant supply groove 4.20 extends over a part of the first portion 4.1 and over the second portion 4.2 in the outer surface 4.5 of the nozzle 4 towards the nozzle tip 4.11 and ends before the cylindrical outer surface 4.3. The coolant return groove 4.22 extends over the second portion 4.2 of the nozzle 4. The centre point of the coolant supply groove 4.20 and the centre point of the coolant return groove 4.22 are arranged so as to be offset by $180^0$ relative to one another over the periphery of the nozzle 4. Between the coolant supply groove 4.20 and the coolant return groove 4.22 are the outwardly projecting regions 4.31 and 4.32 with the associated portions 4.41 and 4.42.

Figure 3 shows a nozzle in accordance with a further special embodiment of the invention, which can also be used in the plasma torch head of Figure 1. The coolant supply groove 4.20 communicates with a groove 4.6, which in this case extends in the circumferential direction over the entire periphery. This has the advantage that the bores for the coolant supply line WV and the coolant return line WR can be arranged in the plasma torch head offset by whatever degree required. Furthermore, this is advantageous for cooling the transition between the nozzle bracket 5 and the nozzle 4. The same can of course also be used in principle for a coolant return groove 4.22.

Figure 4 shows a nozzle in accordance with a further special embodiment of the invention, which can also be used in the plasma torch head of Figure 1. The coolant supply grooves 4.20 and 4.21 extend over a part of the first portion 4.1 and over the second portion 4.2 in the outer surface 4.5 of the nozzle 4 towards the nozzle tip 4.11 and end before the cylindrical outer surface 4.3. The coolant return grooves 4.22 and 4.23 extend over the second portion 4.2 of the nozzle 4. Between the coolant supply grooves 4.20 and 4.21 and the coolant return grooves 4.22 and 4.23 are the outwardly projecting regions 4.31, 4.32, 4.33 and 4.34 with the associated portions 4.41, 4.42, 4.34 and 4.44. The coolant supply grooves 4.20 and 4.21 communicate with one another via a groove 4.6 of the nozzle 4 extending in the circumferential direction of the first portion 4.1 of the nozzle 4 on a part of the circumference between the grooves 4.20 and 4.21, i.e. over approx. 160°.

Figure 5 illustrates a plasma torch head in accordance with a further special embodiment of the invention. Here too, the coolant is fed into a coolant chamber virtually perpendicularly to the longitudinal axis of the plasma torch head 1 from a nozzle bracket 5, encountering the nozzle 4. For this purpose, in the deflection space 10.10 of the coolant chamber, the coolant is deflected from the direction parallel to the longitudinal axis in the bore of the coolant supply line WV of the plasma torch in the direction of the first nozzle portion 4.1 virtually perpendicularly to the longitudinal axis of the plasma torch head 1. After that, the coolant flows through the parts 10.11 and 10.12 (see Fig. 5a) formed by the coolant supply grooves 4.20 and 4.21 of the nozzle 4 and the nozzle cap 2 into the region 10.20 of the coolant chamber surrounding the nozzle bore 4.10 and flows round the nozzle 4 there. After that, the coolant flows through the parts 10.15 and 10.16 formed by the coolant return grooves 4.22 and 4.23 of the nozzle 4 and the nozzle cap 2 back to the coolant return line WR, wherein the transition here occurs virtually perpendicularly to the longitudinal axis of the plasma torch head, through the deflection space 10.9.

Fig. 5a is a section view along the line A-A of the plasma torch from Figure 5, which shows how the parts 10.11 and 10.12 formed by the coolant supply grooves 4.20 and 4.21 of the nozzle 4 and the nozzle cap 2 prevent a shunt between the coolant supply lines and the coolant return lines thanks to portions 4.41 and 4.42 of the outwardly projecting regions 4.31 and 4.32 of the nozzle 4 in combination with the inner surface 2.5 of the nozzle cap 2. At the same time, a shunt between the parts 10.1 1 and 10.12 is prevented by the portion 4.43 of the projecting region 4.33 and between the parts 10.15 and 10.16 by the portion 4.44 of the projecting region 4.43.

Figure 5b is a section view along the line B-B of the plasma torch head from Figure 7, which shows the plane of the deflection spaces 10.9 and 10.10.

Fig. 6 shows the nozzle 4 of the plasma torch head from Figure 5. It has a nozzle bore 4.10 for the exit of a plasma gas jet at a nozzle tip 4.11, a first portion 4.1, the outer surface 4.4 of which is substantially cylindrical, and a second portion 4.2 adjacent thereto towards the nozzle tip 4.11, the outer surface 4.5 of which tapers substantially conically towards the nozzle tip 4.11. The coolant supply grooves 4.20 and 4.21 and the coolant return grooves 4.22 and 4.23 extend over a part of the first portion 4.1 and over the second portion 4.2 in the outer surface 4.5 of the nozzle 4 towards the nozzle tip 4.11 and end before the cylindrical outer surface 4.3. The centre point of the coolant supply groove 4.20 and the centre point of the coolant return groove 4.22 and the centre point of the coolant supply groove 4.21 and the centre point the coolant return groove 4.23 are arranged so as to be offset by $180^0$ relative to one another over the periphery of the nozzle 4 and are equal in size. Between the coolant supply groove 4.20 and the coolant return groove 4.22, there is an outwardly projecting region 4.31 with the associated portion 4.41, and between the coolant supply groove 4.21 and the coolant return groove 4.23, there is an outwardly projecting region 4.32 with the associated portion 4.42. Between the coolant supply grooves 4.20 and 4.21, there is an outwardly projecting region 4.33 with the associated portion 4.43. Between the coolant return grooves 4.22 and 4.23, there is an outwardly projecting region 4.34 with the associated portion 4.44.

Even if it may possibly have been described or illustrated differently above, the (angular) widths of the liquid supply grooves may be different. The same also applies to the (angular) widths of the liquid return grooves.

Figure 7 shows individual illustrations of a nozzle cap 2 inserted in the plasma torch head 1 of Figure 1. The nozzle cap 2 has an inner surface 2.2 which tapers substantially conically, and which in this case has fourteen recesses 2.6 in a radial plane. The recesses 2.6 are arranged equidistantly over the inner circumference and are semicircular in a radial cross-section.

The features of the invention disclosed in the present description, in the drawings and in the claims will be essential to implementing the invention in its various embodiments both individually and in any combinations.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A nozzle for a liquid-cooled plasma torch, comprising a nozzle bore for the exit of a plasma gas jet at a nozzle tip, a first portion, the outer surface of which is substantially cylindrical, and a second portion adjacent thereto towards the nozzle tip, the outer surface of which tapers substantially conically towards the nozzle tip, wherein at least two liquid supply grooves and/or at least two liquid return grooves are provided and extend over the second portion in the outer surface of the nozzle towards the nozzle tip, and wherein the at least two liquid supply grooves and/or the at least two liquid return grooves also extend over part of the first portion, and there is in the first portion at least one groove which communicates with the at least two liquid supply grooves or with the at least two liquid return grooves.

2. The nozzle as claimed in claim 1, wherein the centre point of the at least two liquid supply grooves and the centre point of the at least two liquid return grooves are arranged so as to be offset by 180° relative to one another over the periphery of the nozzle.

3. The nozzle as claimed in claim 1 or 2, wherein the width of the at least two liquid supply grooves and/or the width of the at least two liquid return grooves are in the range from 10° to 270° in the circumferential direction.

4. The nozzle as claimed in any one of claims 1 to 3, wherein the sum of the widths of the at least two liquid supply grooves and/or the at least two return grooves is between 20° and 340°.

5. The nozzle as claimed in any one of claims 1 to 3, wherein the sum of the widths of the at least two liquid supply grooves and/or the at least two return grooves is between $60^0$ and 300°.

6. The nozzle as claimed in any one of claims 1 to 5, wherein the at least one groove extends over the entire periphery in the circumferential direction of the first portion of the nozzle.

7. The nozzle as claimed in any one of claims 1 to 6, wherein the at least one groove extends over an angle $\zeta 1$ or $\zeta 2$ in the range from 60° to 300° in the circumferential direction of the first portion of the nozzle.

8. The nozzle as claimed in claim 7, wherein the at least one groove extends over an angle $\zeta 1$ or $\zeta 2$ in the range from 90° to 270° in the circumferential direction of the first portion of the nozzle.

9. The nozzle as claimed in any one of claims 1 to 8, wherein exactly two liquid supply grooves and exactly two liquid return grooves are provided.

10. The nozzle as claimed in claim 9, wherein the two liquid supply grooves are disposed over the periphery of the nozzle symmetrically to a straight line extending from the centre point of the liquid return grooves at a right angle through the longitudinal axis of the nozzle, and the two liquid return grooves are disposed over the periphery of the nozzle symmetrically to a straight line extending from the centre point of the liquid supply groove at a right angle through the longitudinal axis of the nozzle.

11. The nozzle as claimed in claim 9 or 10, wherein the centre points of the two liquid supply grooves and/or the centre points of the two liquid return grooves are arranged so as to be offset relative to one another over the periphery of the nozzle by an angle in the range from 20° to 180°.

12. The nozzle as claimed in any one of claims 9 to 11, wherein the two liquid supply grooves and/or the two liquid return grooves communicate with one another in the first portion of the nozzle.

13. The nozzle as claimed in any one of claims 1 to 12, wherein the at least one groove extends beyond the at least two liquid supply grooves or beyond the at least two liquid return grooves.

14. A plasma torch head, comprising:

- a nozzle as claimed in any one of claims 1 to 13,

- a nozzle bracket for holding the nozzle, and

- a nozzle cap, the nozzle cap and the nozzle forming a coolant chamber which can be connected via two bores, each offset by 60° to 180°, to a coolant supply line or coolant return line, the nozzle holder being designed such that the coolant flows into the coolant chamber virtually perpendicularly to the longitudinal axis of the plasma torch head, encountering the nozzle, and/or virtually perpendicularly to the longitudinal axis out of the coolant chamber and into the nozzle bracket.

15. The plasma torch head as claimed in claim 14, wherein the nozzle has at least two liquid supply grooves and at least two liquid return grooves, and the nozzle cap has on its inner surface at least three recesses, the openings facing the nozzle each extending over a radian, wherein the radian of the outwardly projecting portions of the nozzle adjacent in the circumferential direction to the at least two liquid supply grooves and/or the at least two liquid return grooves, opposite the at least two liquid supply grooves and/or the at least two liquid return grooves is in each case at least as great as the radian.

16. The plasma torch head as claimed in claims 14 or 15, wherein the two bores each extend substantially parallel to the longitudinal axis of the plasma torch head.

17. The plasma torch head as claimed in any one of claims 14 to 16, wherein the bores are arranged to be offset by 180°.

18. The plasma torch head as claimed in any one of claims 14 to 17, wherein the radian of the portion between the recesses in the nozzle cap is no more than half as big as the minimum radian of the at least two liquid return grooves or the minimum radian of the at least two liquid supply grooves of the nozzle.

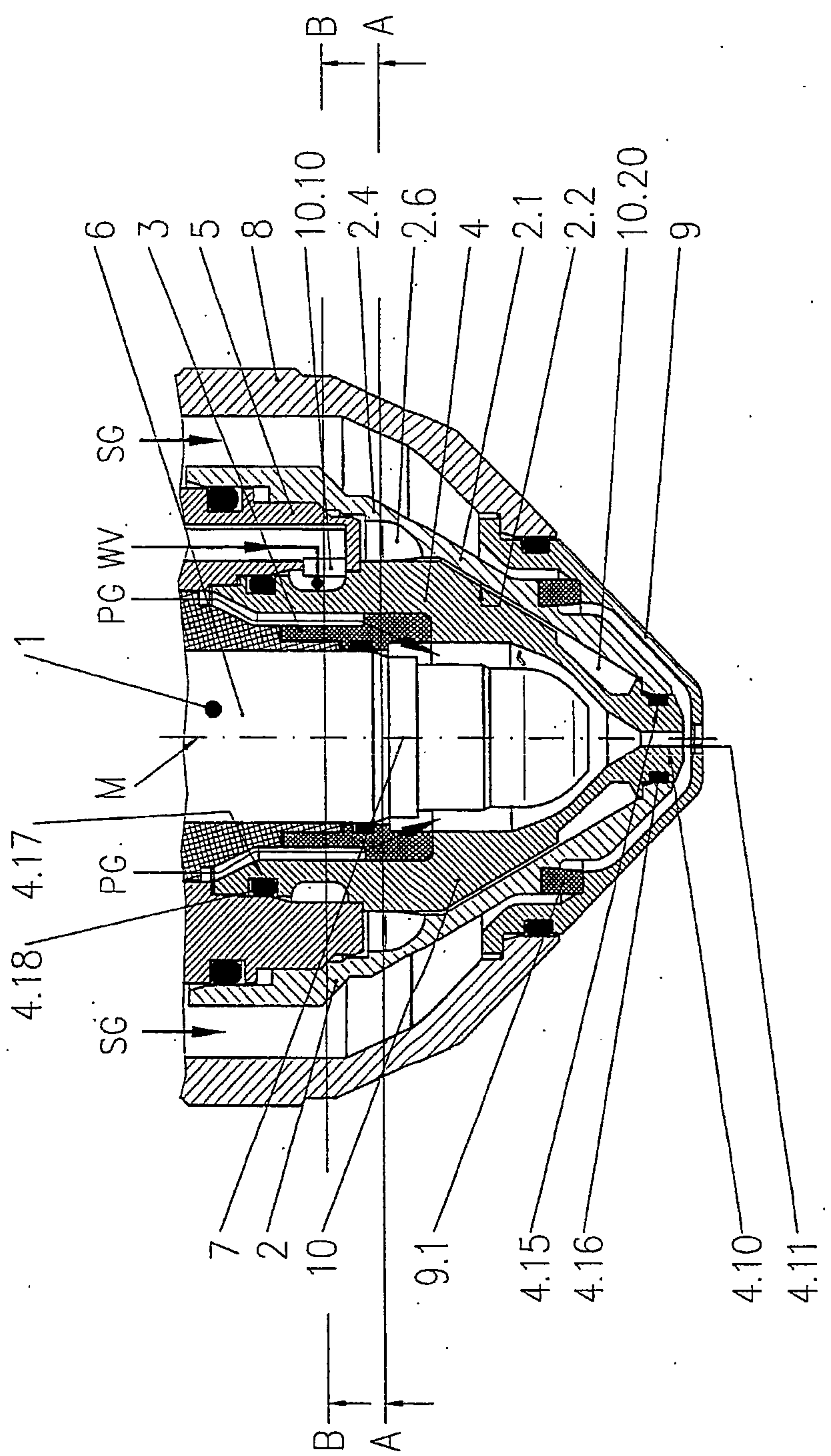

B
A
6
3
5
8
10.10
2.4
2.6
4
2.1
2.2
10.20
9
SG
PG WV
PG
1
M
4.17
4.18
SG
7
2
10
9.1
4.15
4.16
4.10
4.11
B
A

Figure 1

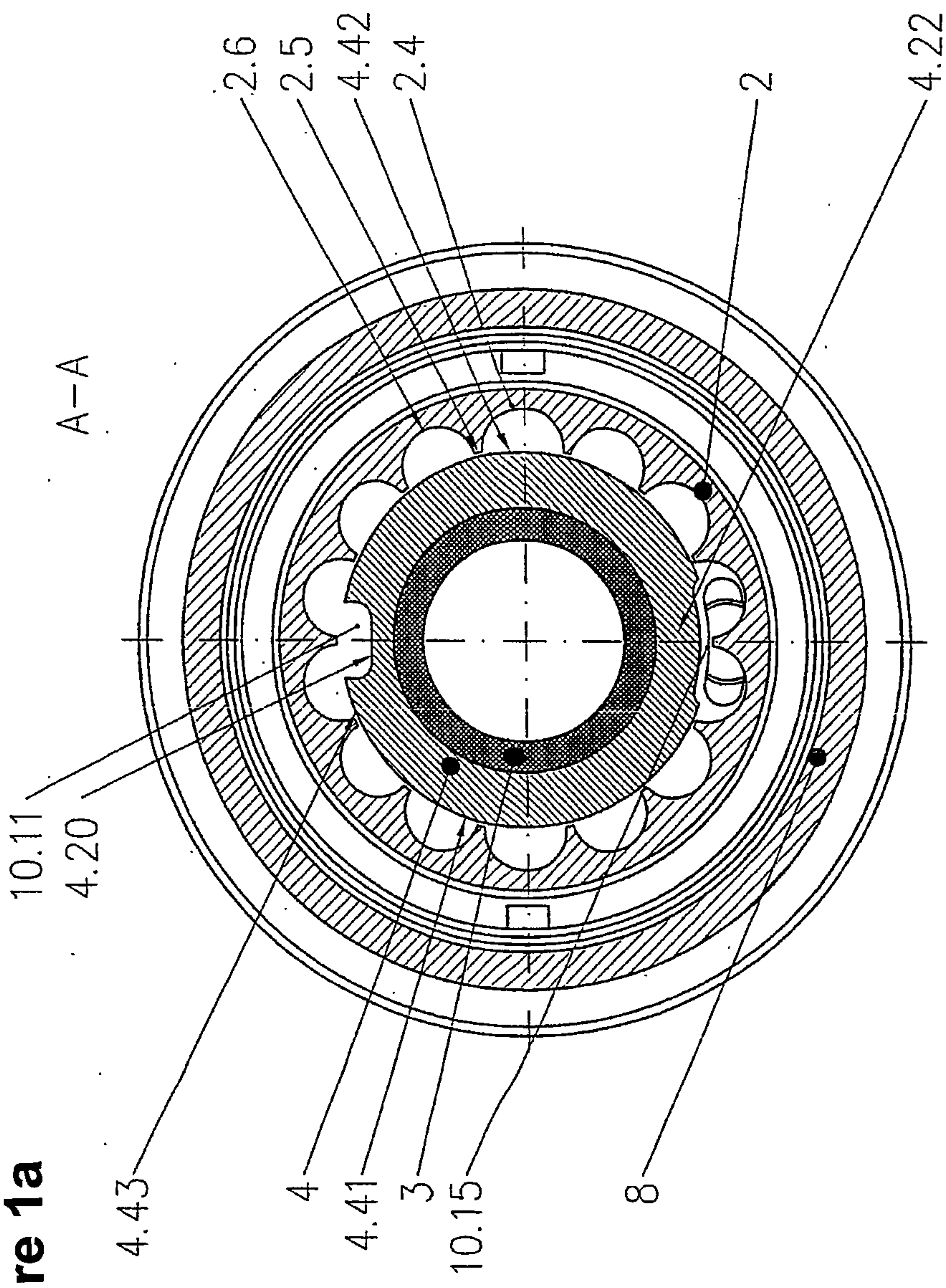



Figure 1a

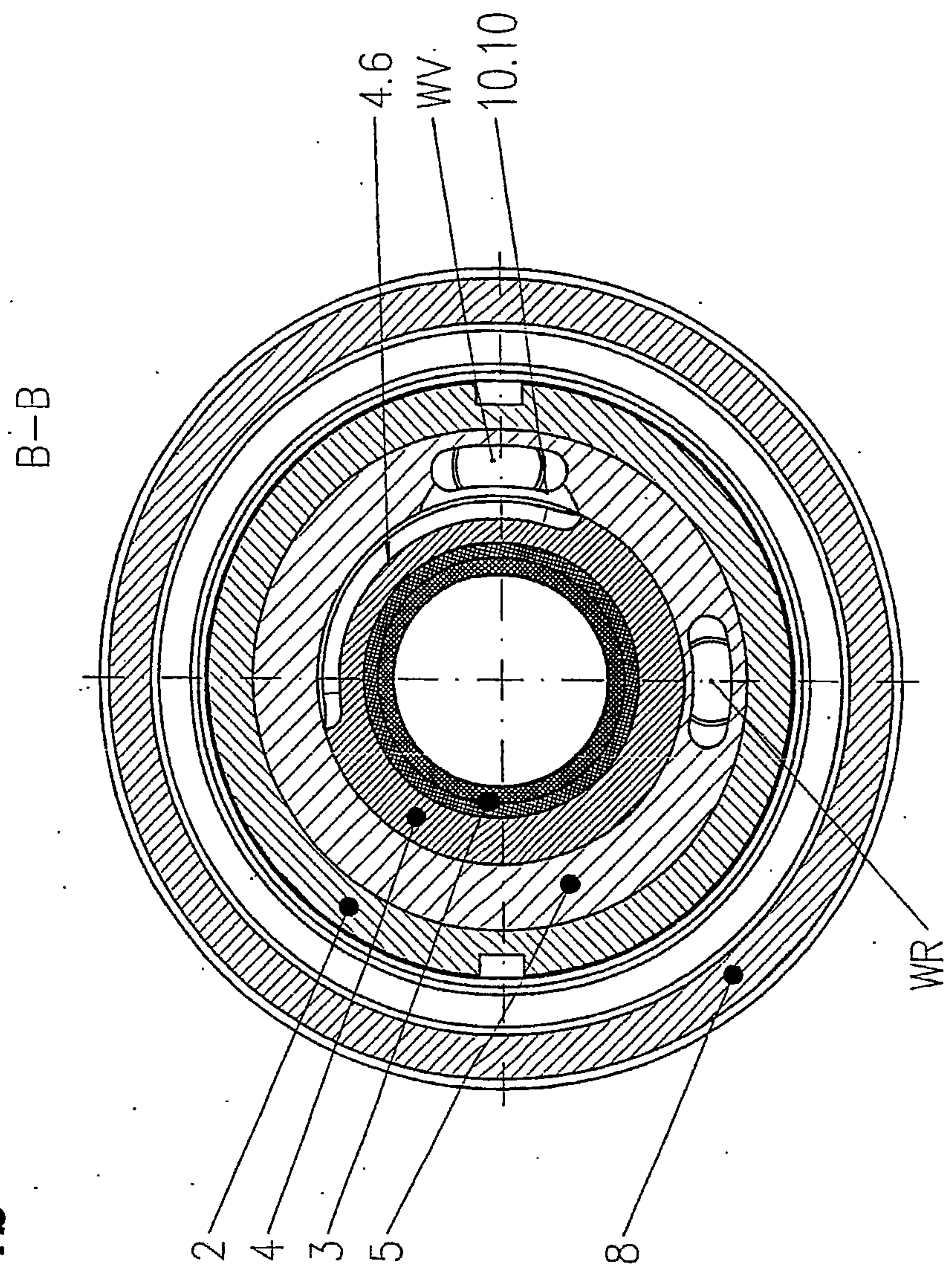



Figure 1b

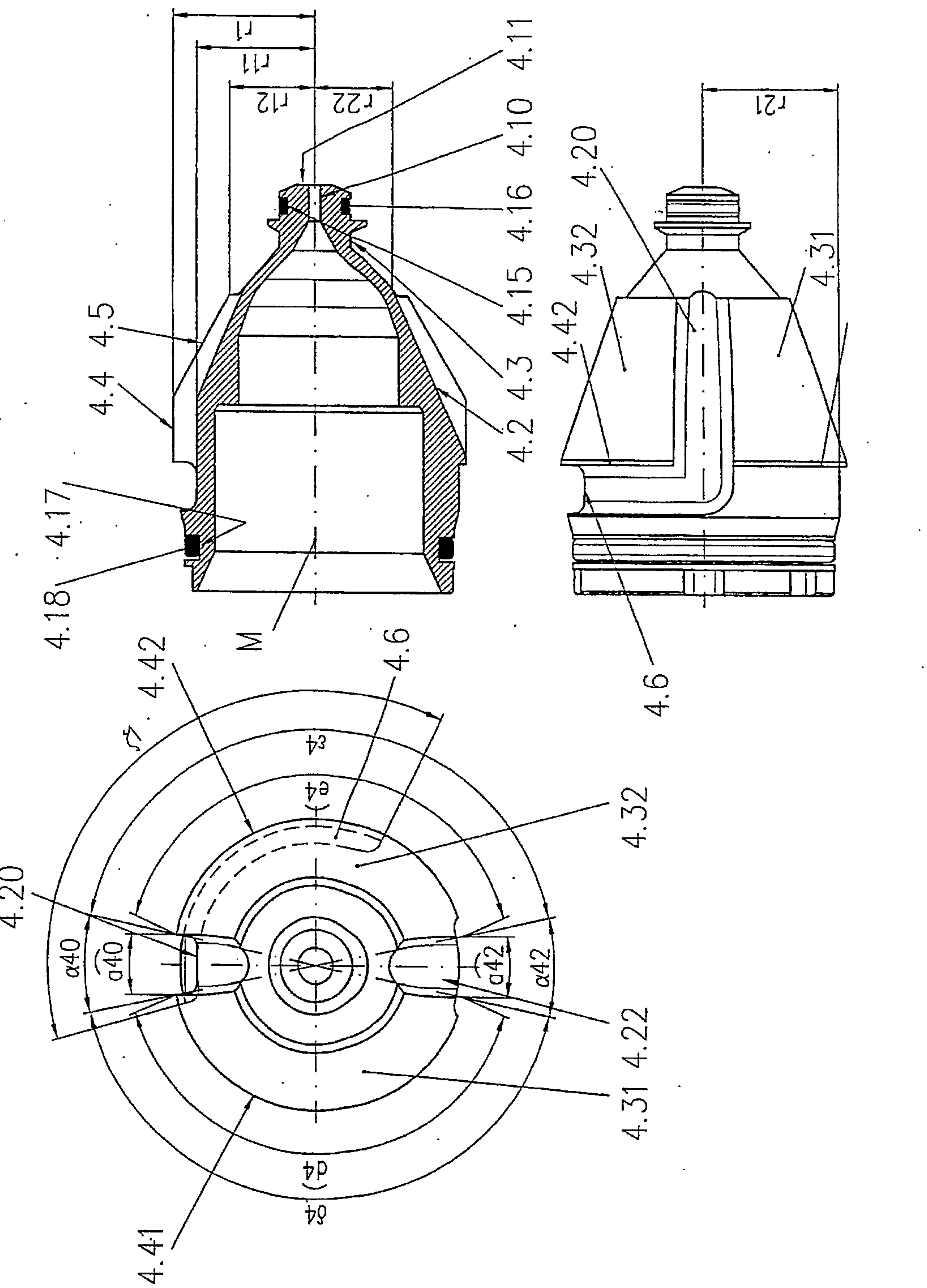

r1
r11
r12
r22
r21
4.11
4.10
4.16
4.15
4.3
4.2
4.4
4.5
4.17
4.18
M
4.20
4.32
4.42
4.31
4.6
4.41
4.22
α40
α42
ε4
δ4

Figure 2

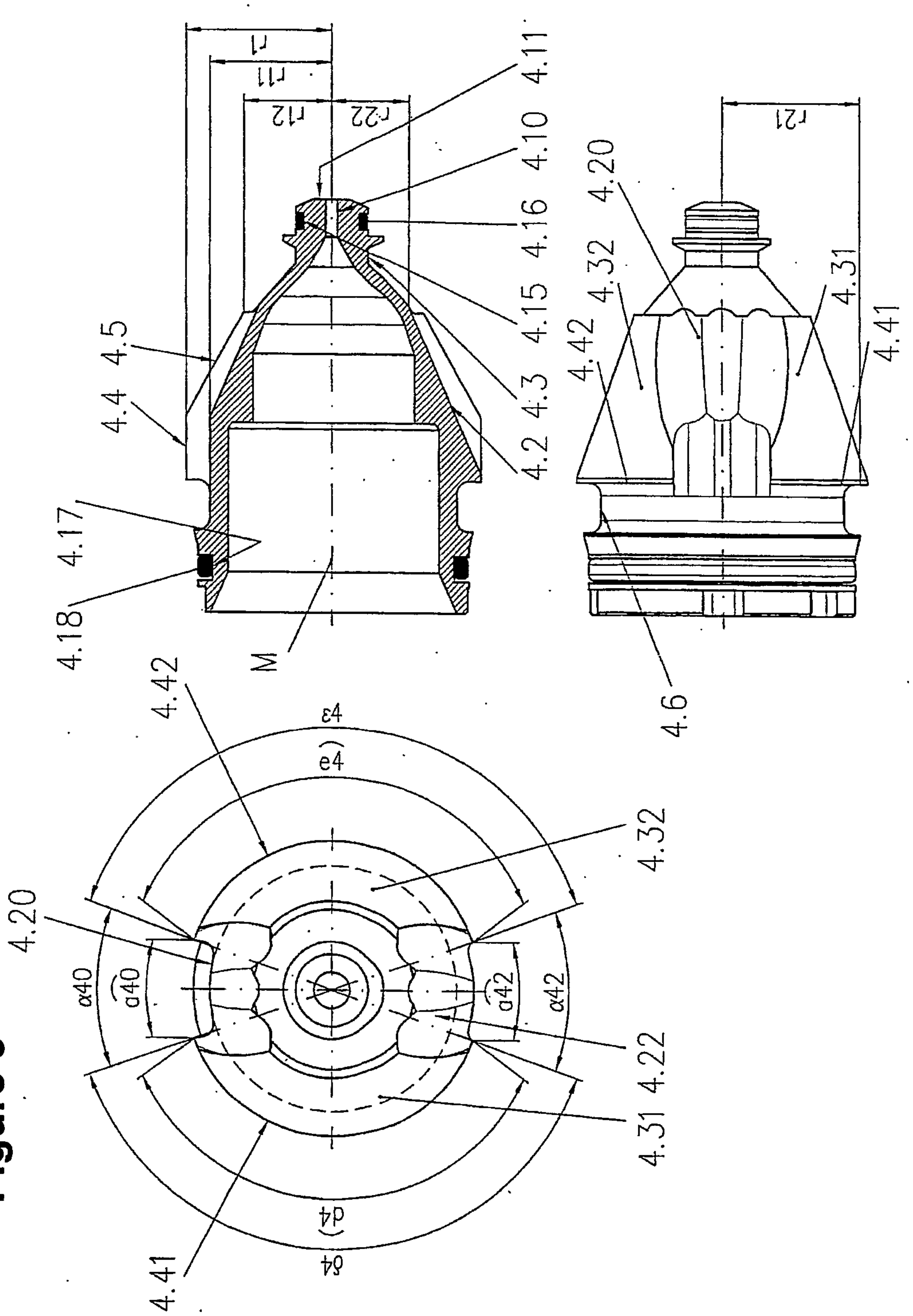
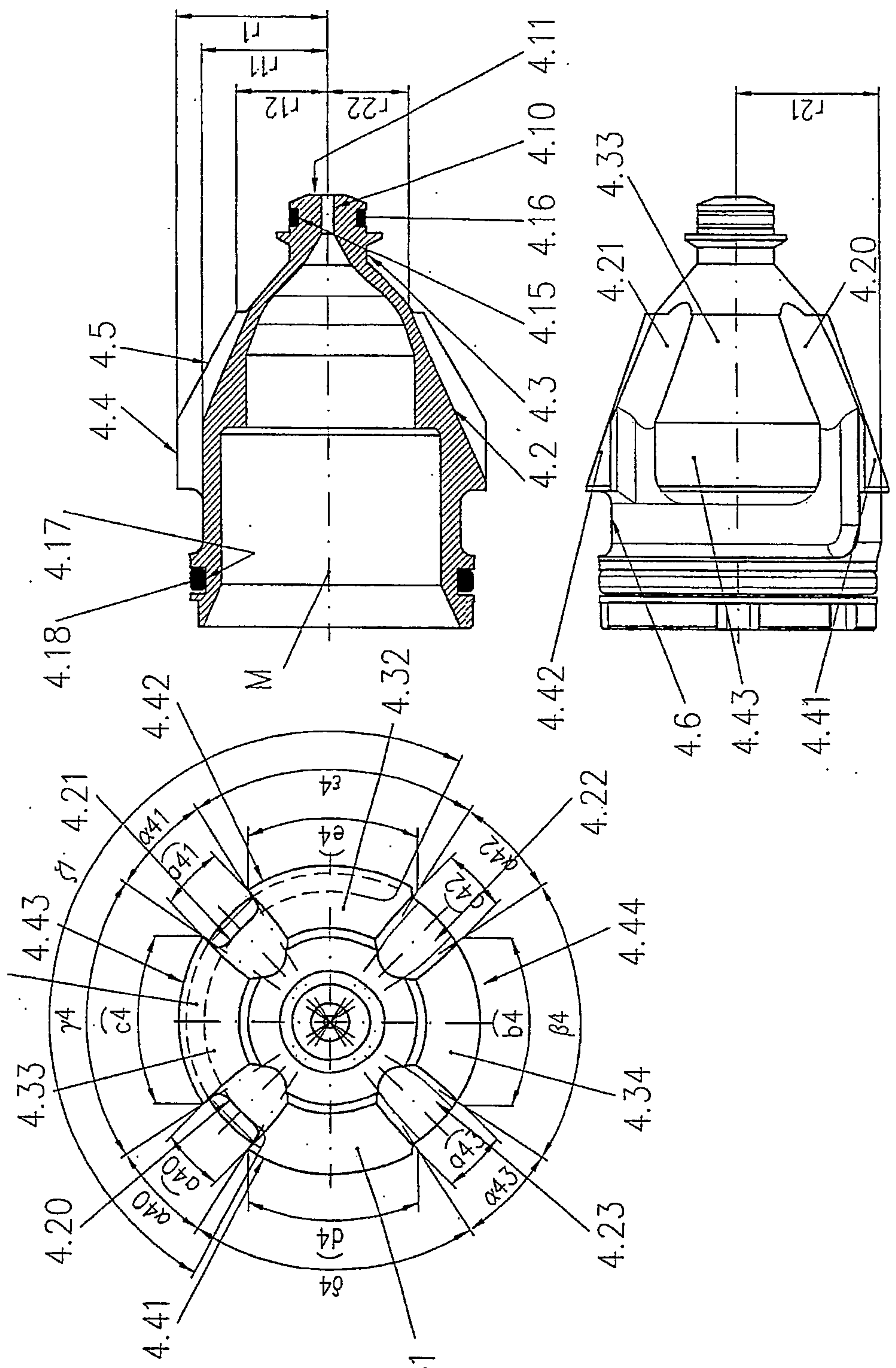
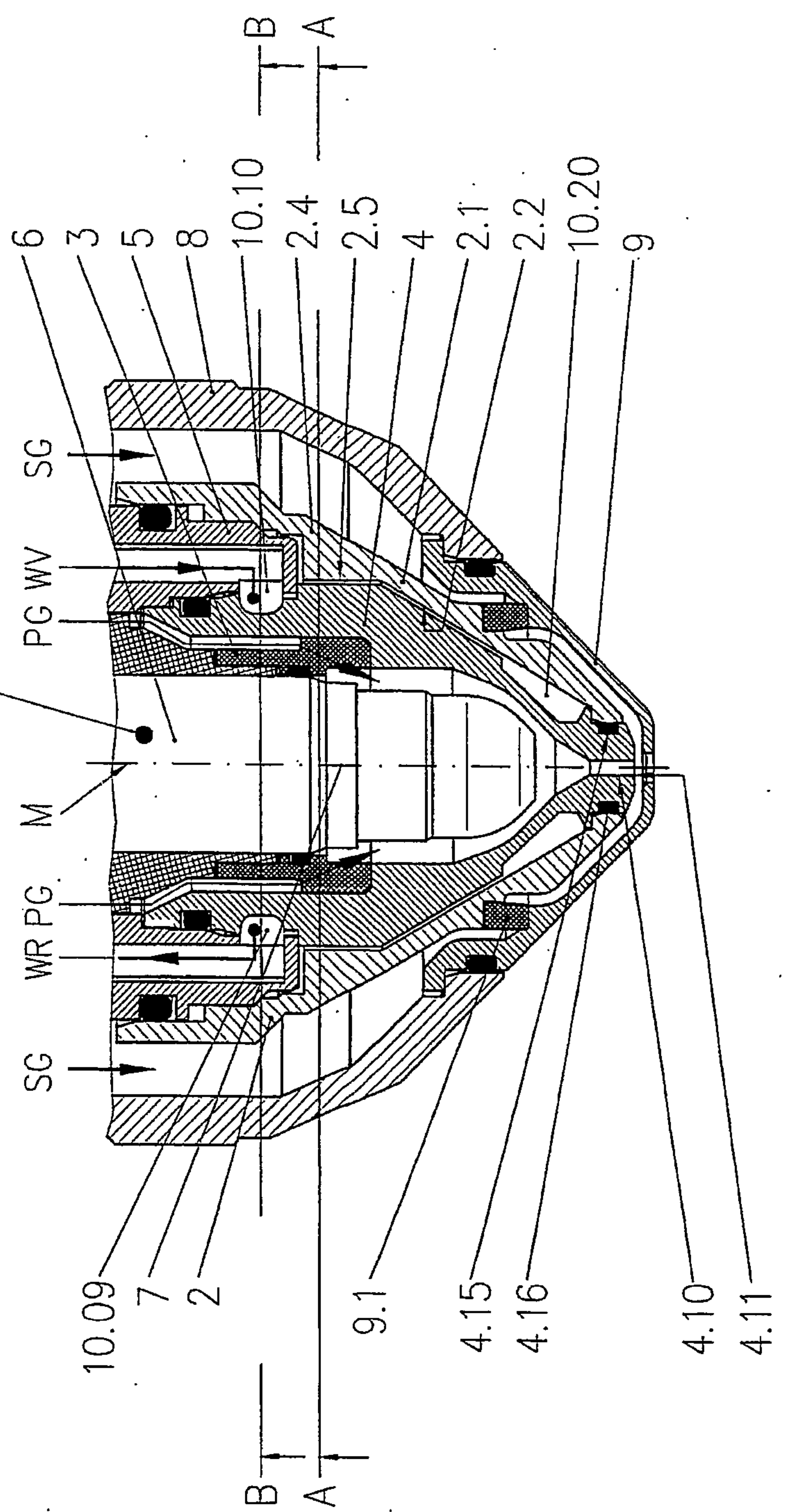

r1
r11
r12
r22
r21
4.11
4.10
4.16
4.15
4.3
4.2
4.4
4.5
4.17
4.18
M
4.20
4.32
4.42
4.31
4.41
4.6
4.22
ε4
e4
δ4
d4
α40
α42

Figure 3



r1
r11
r12
r22
r21
4.11
4.10
4.16
4.15
4.3
4.2
4.4
4.5
4.17
4.18
M
4.33
4.21
4.20
4.42
4.6
4.43
4.41
4.32
4.22
4.44
4.34
4.23
4.31


Figure 4



B
A
6
3
5
8
10.10
2.4
2.5
4
2.1
2.2
10.20
9
SG
PG WV
PG
1
M
WR PG
SG
10.09
7
2
9.1
4.15
4.16
4.10
4.11
B
A


Figure 5

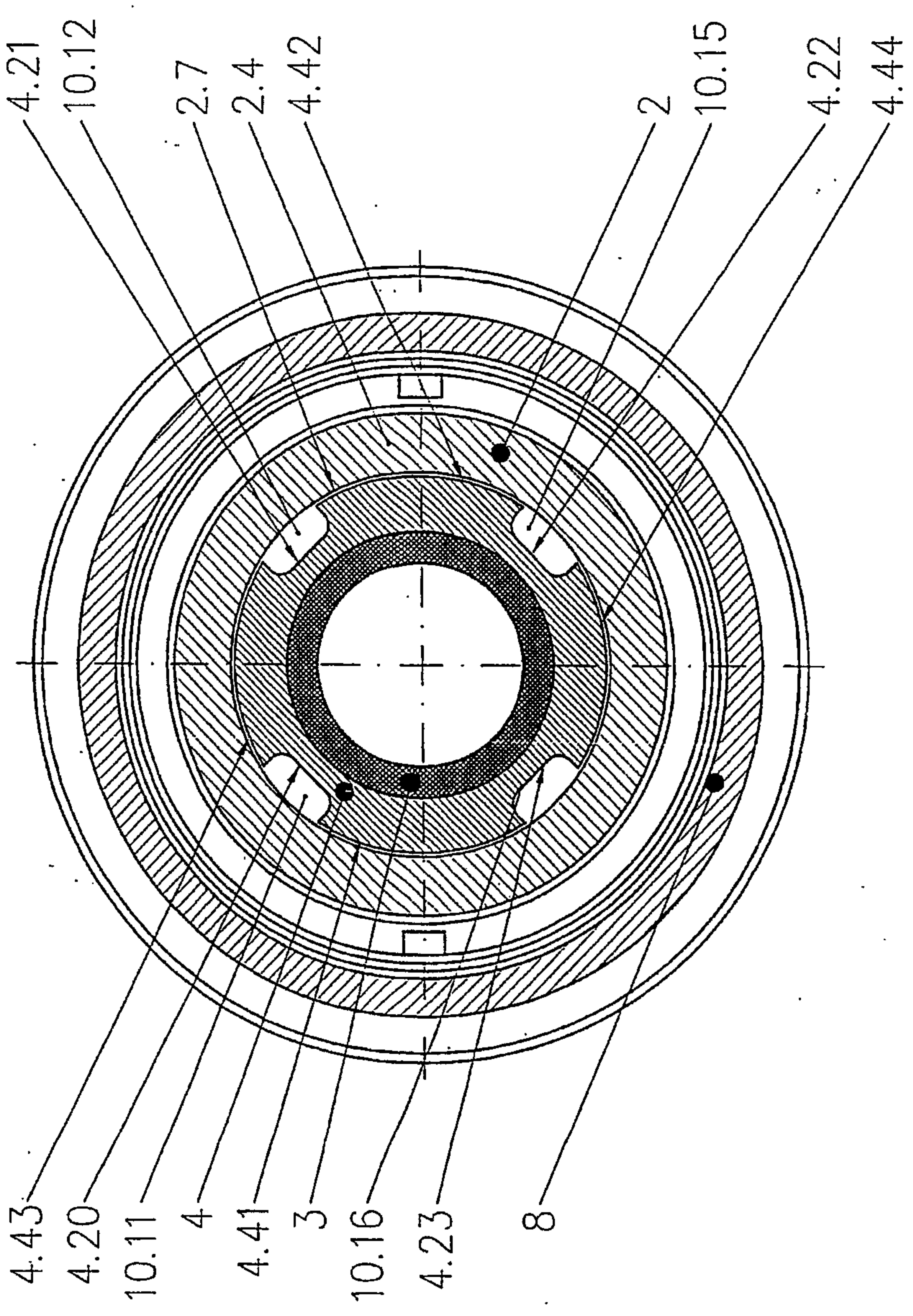

A–A
4.21
10.12
2.7
2.4
4.42
2
10.15
4.22
4.44
4.43
4.20
10.11
4
4.41
3
10.16
4.23
8

Figure 5a

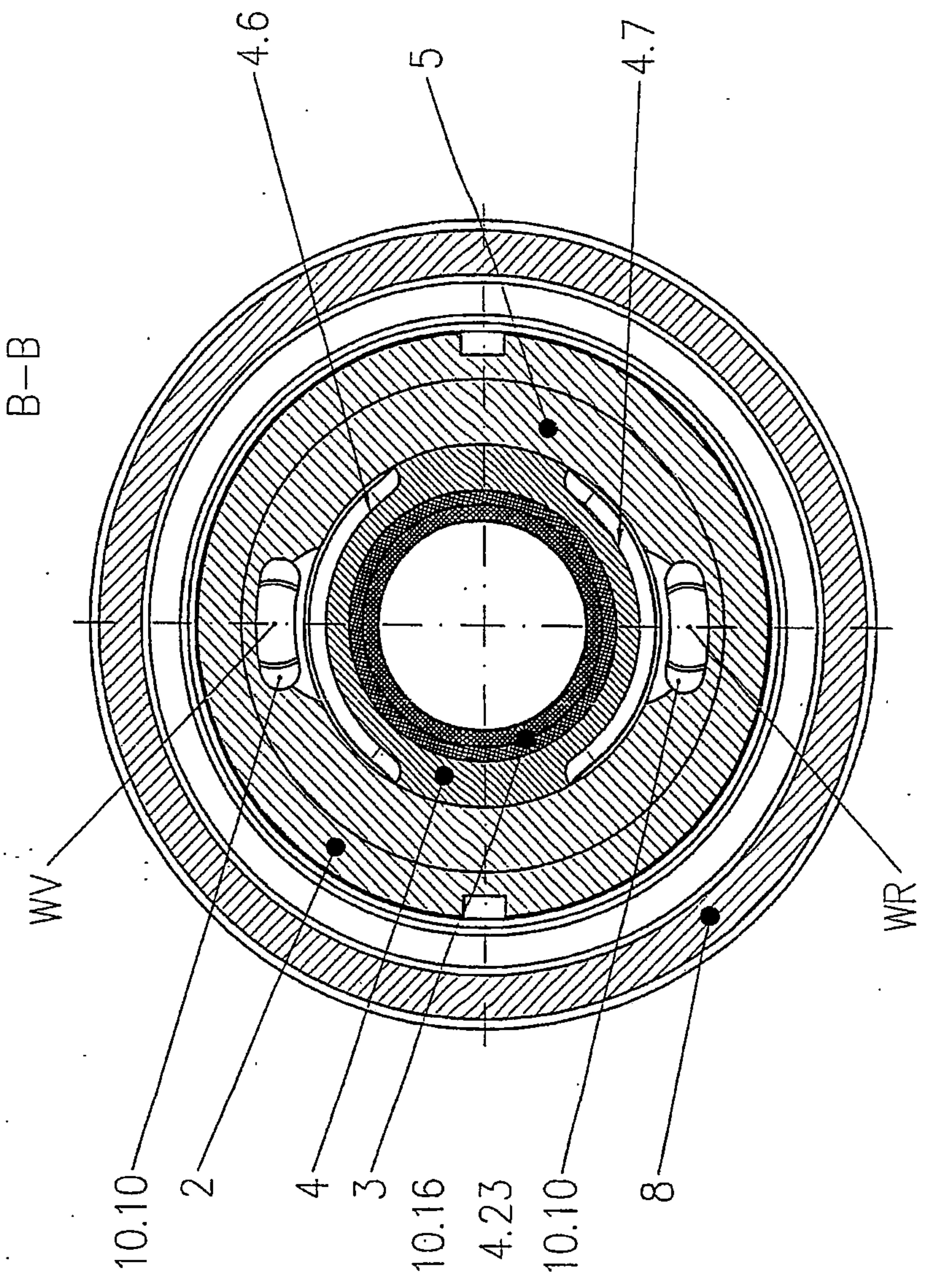



Figure 5b

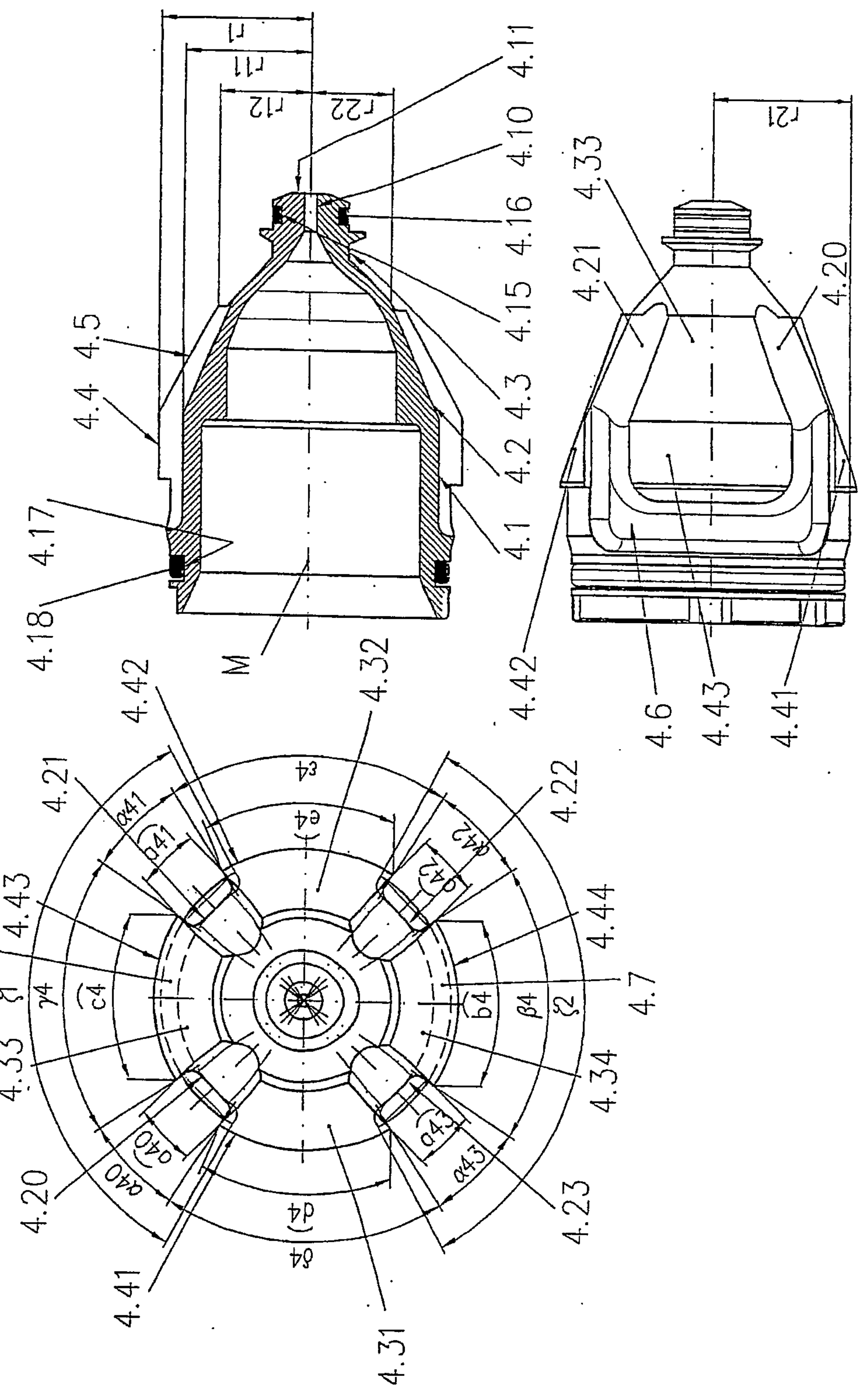

r1
r11
r12
r22
4.11
4.10
4.16
4.15
4.3
4.2
4.1
4.5
4.4
4.17
4.18
M
r21
4.33
4.21
4.20
4.42
4.6
4.43
4.41
4.32
4.22
4.44
4.7
4.34
4.23
4.31
4.20
4.41
4.33
4.6
4.43
4.21
4.42

Figure 6

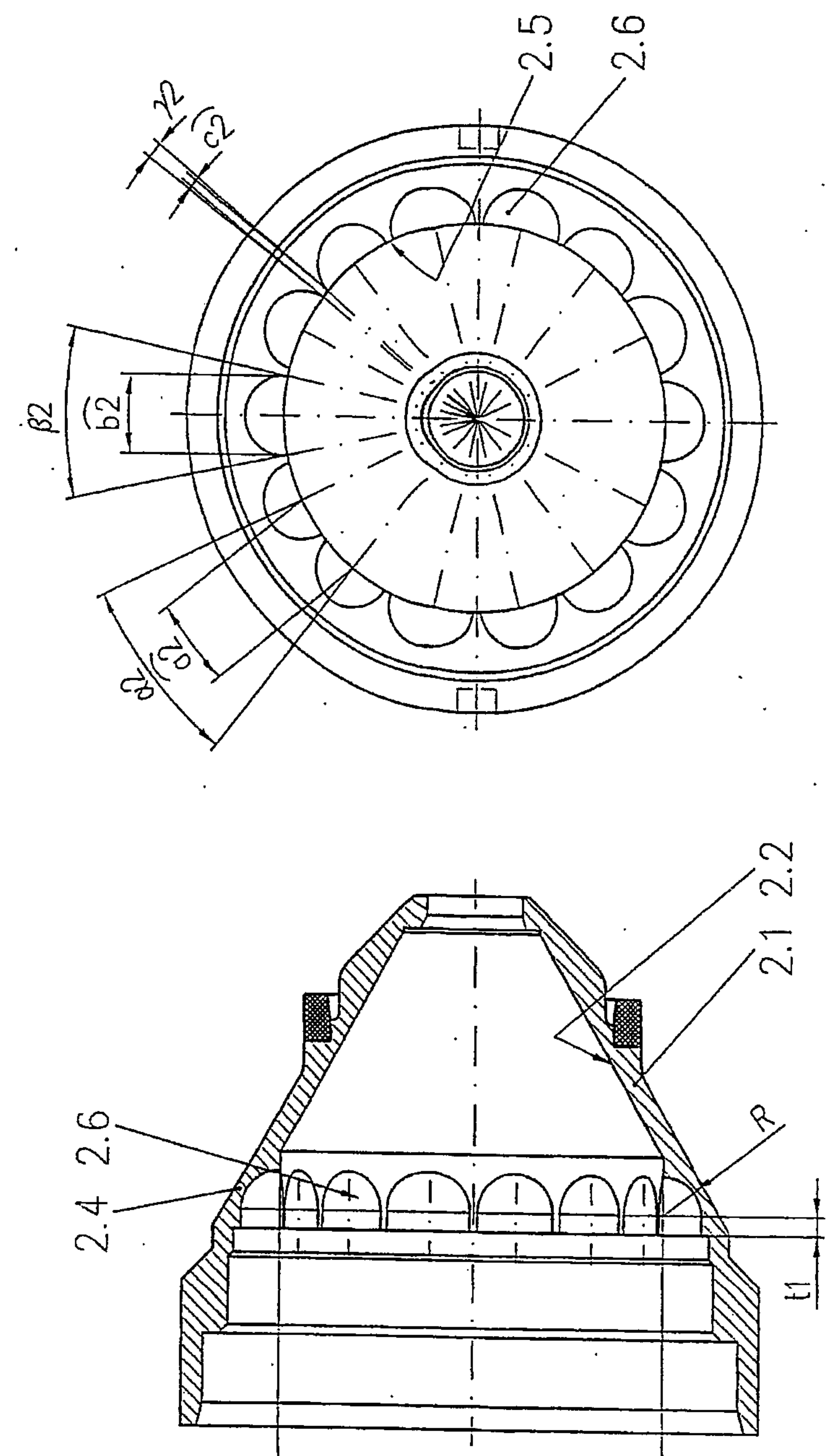
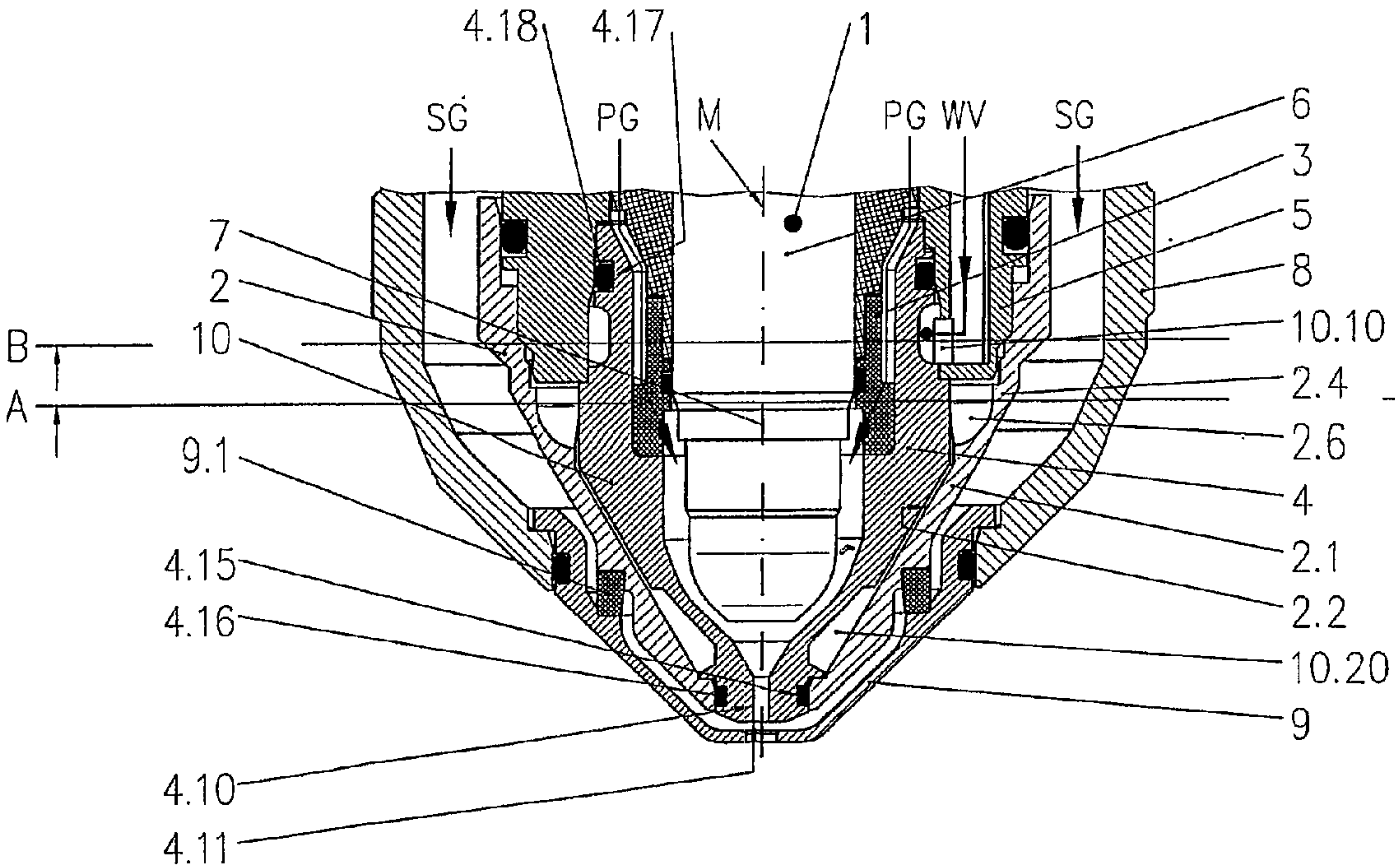



**Figure 7**


4.18
4.17
1
SG
PG
M
PG
WV
SG
6
3
5
8
7
2
10
B
A
10.10
B
2.4
A
2.6
9.1
4
2.1
4.15
2.2
4.16
10.20
9
4.10
4.11