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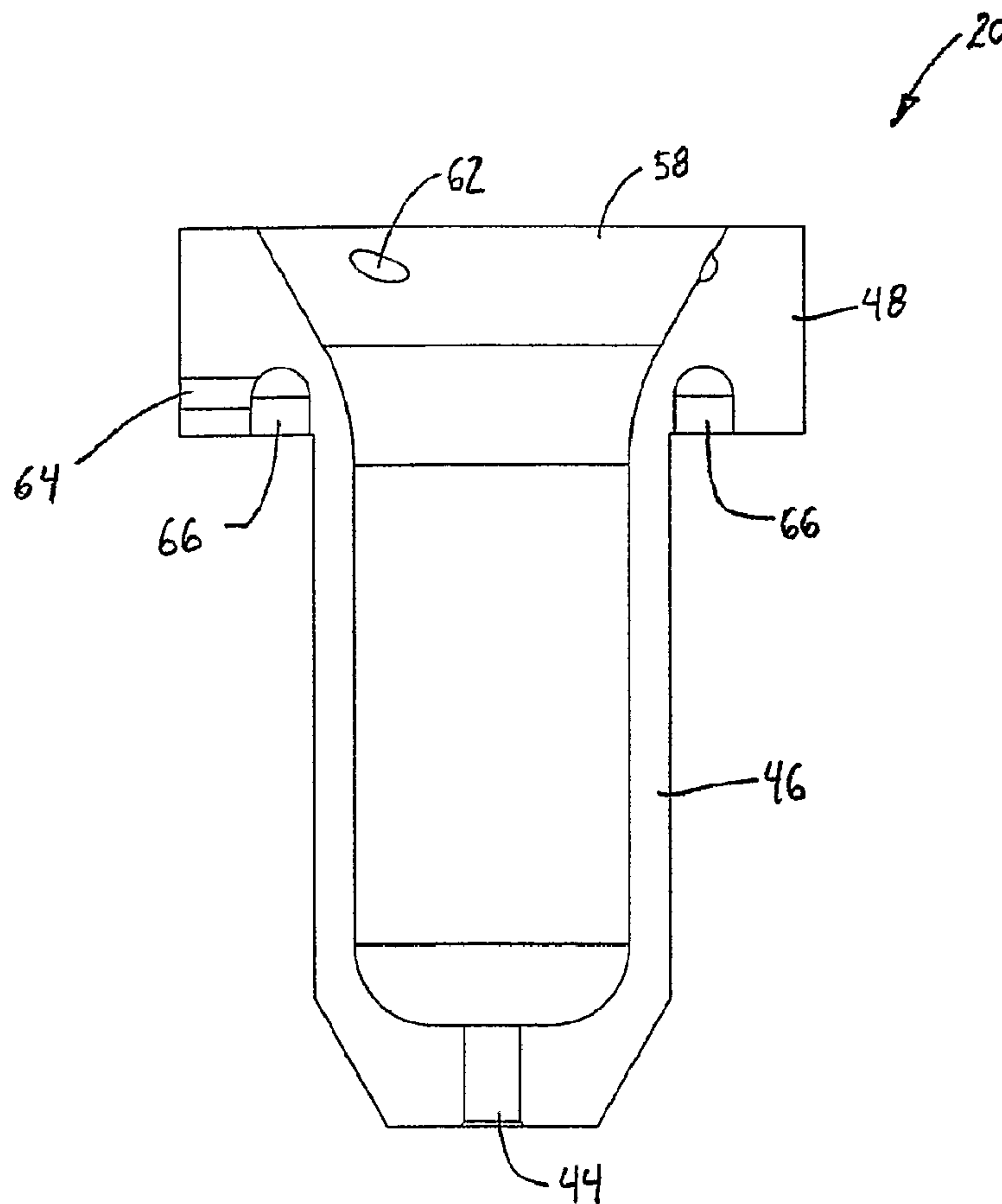
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(57) Abrégé/Abstract:

A tip gas distributor is provided that preferably comprises a plurality of swirl holes and a plurality of secondary gas holes, wherein the swirl holes direct a plasma gas to generate a plasma stream, and the secondary gas holes direct a secondary gas to stabilize

(57) **Abrégé(suite)/Abstract(continued):**

the plasma stream. Additionally, a tip gas distributor is provided that comprises swirl passages and secondary gas passages formed between the tip gas distributor and an adjacent component to generate and stabilize the plasma stream. Further, methods of generating and stabilizing the plasma stream are provided through the use of the swirl holes and passages, along with the secondary gas holes and passages.

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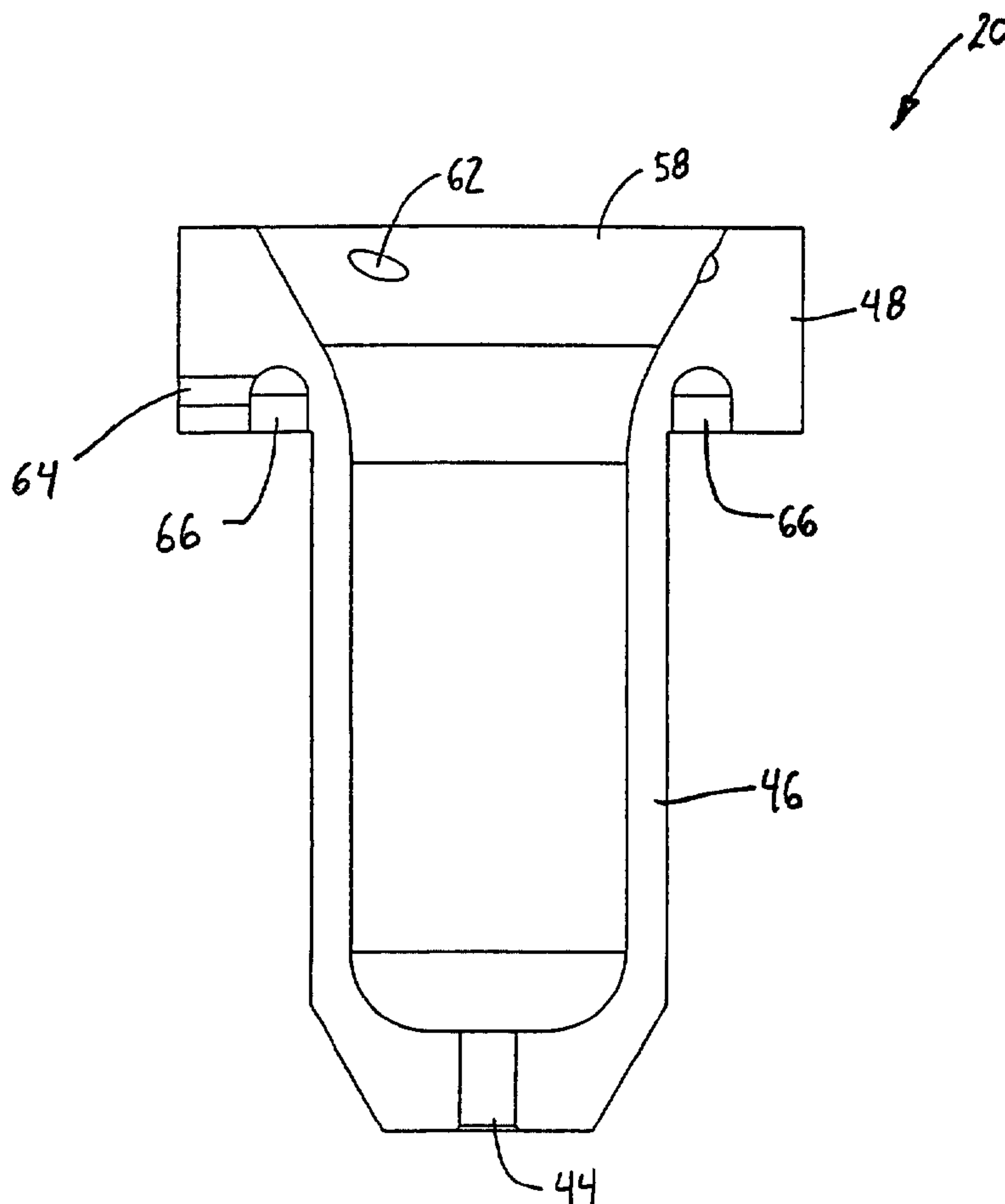
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[Continued on next page]

(54) Title: TIP GAS DISTRIBUTOR



(57) Abstract: A tip gas distributor is provided that preferably comprises a plurality of swirl holes and a plurality of secondary gas holes, wherein the swirl holes direct a plasma gas to generate a plasma stream, and the secondary gas holes direct a secondary gas to stabilize the plasma stream. Additionally, a tip gas distributor is provided that comprises swirl passages and secondary gas passages formed between the tip gas distributor and an adjacent component to generate and stabilize the plasma stream. Further, methods of generating and stabilizing the plasma stream are provided through the use of the swirl holes and passages, along with the secondary gas holes and passages.



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TIP GAS DISTRIBUTOR

FIELD OF THE INVENTION

[0002] The present invention relates generally to plasma arc torches and more particularly to devices and methods for generating and stabilizing a plasma stream.

BACKGROUND OF THE INVENTION

[0003] Plasma arc torches, also known as electric arc torches, are commonly used for cutting, marking, gouging, and welding metal workpieces by directing a high energy plasma stream consisting of ionized gas particles toward the workpiece. In a typical plasma arc torch, the gas to be ionized is supplied to a distal end of the torch and flows past an electrode before exiting through an orifice in a tip, or nozzle, of the plasma arc torch. The electrode (which is one among several consumable parts in a plasma arc torch), has a relatively negative potential and operates as a cathode. Conversely, the torch tip constitutes a relatively positive potential and operates as an anode. Further, the electrode is in a spaced relationship with the tip, thereby creating a gap, at the distal end of the torch. In

operation, a pilot arc is created in the gap between the electrode and the tip, which heats and subsequently ionizes the gas. Further, the ionized gas is blown out of the torch and appears as a plasma stream that extends distally off the tip. As the distal end of the torch is moved to a position close to the workpiece, the arc jumps or transfers from the torch tip to the workpiece because the impedance of the workpiece to ground is lower than the impedance of the torch tip to ground. Accordingly, the workpiece serves as the anode, and the plasma arc torch is operated in a "transferred arc" mode.

[0004] One of two methods is typically used for initiating the pilot arc between the electrode and the tip. In the first method, commonly referred to as a "high frequency" or "high voltage" start, a high potential is applied across the electrode and the tip sufficient to create an arc in the gap between the electrode and the tip. Accordingly, the first method is also referred to as a "non-contact" start, since the electrode and the tip do not make physical contact to generate the pilot arc. In the second method, commonly referred to as a "contact start," the electrode and the tip are brought into contact and are gradually separated, thereby drawing an arc between the electrode and the tip. The contact start method thus allows an arc to be initiated at much lower potentials since the distance between the electrode and the tip is much smaller.

[0005] With either start method, distribution and regulation of the plasma gas utilized for forming the plasma stream is typically provided by a separate element commonly referred to as a gas distributor or a swirl ring. Additionally, a secondary gas for stabilizing the plasma stream is often provided through another

separate element or a combination of elements within the plasma arc torch such as passageways through a shield cup or between a shield cup and another consumable component such as a tip. By way of example, a gas distributor such as that described in U.S. Patent No. 6,163,008, is primarily responsible for regulating the plasma gas in a gas passage leading to a central exit orifice of the tip. The secondary gas is generally circulated through passages formed between a shield cup insert and the tip, and travels along the tip exterior to stabilize the plasma stream exiting the central exit orifice. Accordingly, several torch elements (i.e., gas distributor, shield cup, and tip) are required to distribute and regulate the plasma gas and the secondary gas.

[0006] Many of the consumable components, including the gas distributor, the tip, and the electrode, are often interchanged as a function of an operating current level in order to improve gas flow and form a stable plasma stream. For example, if a power supply is being used that operates at 40 amps, one set of consumable components are installed within the plasma arc torch to optimize cutting performance. On the other hand, if a power supply is being used that operates at 80 amps, another set of consumable components are typically installed to optimize cutting performance for the increased current level. Unfortunately, changing consumable components can be time consuming and cumbersome, and if an operator uses different operating current levels on a regular basis, an increased number of consumable components must be maintained in inventory to facilitate the different current levels.

[0007] Accordingly, a need remains in the art for a device and method to simplify operation of a plasma arc torch that operates at different current levels. Further, the device and method should simplify and reduce the amount of time required to change consumable components when operating at different current levels.

SUMMARY OF THE INVENTION

[0008] In one preferred form, the present invention provides a tip gas distributor comprising at least one swirl passage and at least one secondary gas passage, wherein the swirl passage directs a plasma gas to generate a plasma stream, and the secondary gas passage directs a secondary gas to stabilize the plasma stream. Accordingly, regulation of the plasma gas and secondary gas is controlled by a single torch component, which further provides a function as a tip, having positive, or anode, potential, in addition to metering the plasma stream during operation.

[0009] In another form, a tip gas distributor is provided that comprises a plurality of swirl holes, without any secondary gas holes, to direct a plasma gas to generate a plasma stream. Further, a tip gas distributor is provided that comprises a plurality of secondary gas holes, without any swirl holes, to stabilize the plasma stream. Additionally, tip gas distributors are provided that comprise at least one swirl hole and/or at least one secondary gas hole.

[0010] In other forms of the present invention, tip gas distributors are provided that comprise swirl passages and/or secondary gas passages formed between the tip gas distributor and an adjacent component rather than holes formed within the tip gas distributor. Similarly, the swirl passages direct a plasma gas to generate a plasma stream and the secondary gas passages direct a secondary gas to stabilize the plasma stream.

[0011] Additionally, methods of directing a plasma gas to generate a plasma stream and directing a secondary gas to stabilize the plasma stream are provided, wherein a source of gas is provided that is distributed through a plasma arc apparatus to generate a plasma gas and a secondary gas. The plasma gas is then directed through at least one swirl hole formed in a tip gas distributor of the plasma arc apparatus and the secondary gas is directed through at least one secondary gas hole formed in the tip gas distributor. Accordingly, the swirl hole directs the plasma gas to generate a plasma stream

and the secondary gas hole directs the secondary gas to stabilize the plasma stream that exits the tip gas distributor. Moreover, methods of generating a plasma stream and stabilizing the plasma stream are provided that utilize at least one swirl passage and at least one secondary gas passage.

[0011a] In yet another form of the present invention there is provided, in a plasma arc apparatus, a method of directing a plasma gas to generate a plasma stream and directing a secondary gas to stabilize the plasma stream, the method comprising the steps of:

providing a source of gas;

distributing the gas through the plasma arc apparatus to generate the plasma gas and the secondary gas;

directing the plasma gas through at least one swirl passage formed in a tip gas distributor of the plasma arc apparatus; and

directing the secondary gas through at least one secondary gas passage formed in the tip gas distributor, wherein the swirl passage directs the plasma gas to generate the plasma stream and the secondary gas passage directs the secondary gas to stabilize the plasma stream exiting the tip gas distributor.

[0012] Further areas of applicability of the present invention will become apparent from the detailed description provided hereinafter, It should be understood that the detailed description and specific examples, while indicating the preferred embodiment of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The present invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

[0014] Figure 1 is a perspective view of a manually operated plasma arc apparatus in accordance with the principles of the present invention;

[0015] Figure 2 is a cross-sectional view taken through an exemplary torch head illustrating a tip gas distributor in accordance with the principles of the present invention;

[0016] Figure 3 is an exploded perspective view illustrating a tip gas distributor with other consumable components that are secured to a plasma arc torch head;

[0017] Figure 4a is an upper perspective view of a tip gas distributor constructed in accordance with the principles of the present invention;

[0018] Figure 4b is a lower perspective view of a tip gas distributor constructed in accordance with the principles of the present invention;

[0019] Figure 5 is a cross-sectional view taken through a tip gas distributor constructed in accordance with the principles of the present invention;

[0020] Figure 6 is a top view of a tip gas distributor illustrating off center swirl holes and constructed in accordance with the principles of the present invention;

[0021] Figure 7 is a bottom view of a tip gas distributor illustrating secondary gas holes and constructed in accordance with the principles of the present invention;

[0022] Figure 8 is a perspective view of a second embodiment of a tip gas distributor constructed in accordance with the principles of the present invention;

[0023] Figure 9 is a bottom view of the second embodiment of the tip gas distributor, illustrating the size and number of secondary gas holes, in accordance with the principles of the present invention;

[0024] Figure 10a is a cross-sectional view through a third embodiment of a tip gas distributor within a plasma arc torch, illustrating swirl passages and secondary gas passages, and constructed in accordance with the principles of the present invention;

[0025] Figure 10b is a side view of the third embodiment of the tip gas distributor in accordance with the principles of the present invention;

[0026] Figure 11 is a side view of a fourth embodiment of a tip gas distributor illustrating swirl holes and constructed in accordance with the principles of the present invention;

[0027] Figure 12 is a side view of a fifth embodiment of a tip gas distributor illustrating a swirl passage and constructed in accordance with the principles of the present invention;

[0028] Figure 13 is a side view of a sixth embodiment of a tip gas distributor illustrating a secondary gas hole and constructed in accordance with the principles of the present invention; and

[0029] Figure 14 is a side view of a seventh embodiment of a tip gas distributor illustrating a secondary gas passage and constructed in accordance with the principles of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0030] The following description of the preferred embodiments is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses.

[0031] Referring to the drawings, a tip gas distributor according to the present invention is generally operable with a manually operated plasma arc apparatus as indicated by reference numeral 10 in Figure 1. Typically, the manually operated plasma arc apparatus 10 comprises a plasma arc torch 12 connected to a power supply 14 through a torch lead 16, which may be available in a variety of lengths according to a specific application. Further, the power supply 14 provides both gas and electric power, which flow through the torch lead 16, for operation of the plasma arc torch 12 as described in greater detail below.

[0032] As used herein, a plasma arc apparatus, whether operated manually or automated, should be construed by those skilled in the art to be an apparatus that generates or uses plasma for cutting, welding, spraying, gouging, or marking operations, among others. Accordingly, the specific reference to plasma arc cutting torches, plasma arc torches, or manually operated plasma arc torches herein should not be construed as limiting the scope of the present invention. Furthermore, the specific reference to providing gas to a plasma arc torch should not be construed as limiting the scope of the present invention, such that other fluids, e.g. liquids, may also be provided to the plasma arc torch in accordance with the teachings of the present invention.

[0033] Referring now to Figures 2 and 3, a tip gas distributor according to the present invention is illustrated and generally indicated by reference numeral 20 within a torch head 22 of the plasma arc torch 12. The tip gas distributor 20 is one of several consumable components that operate with and that are secured to the torch head 22 during operation of the plasma arc torch 12. As shown, the torch head 22 defines a distal end 24, to which the consumable components are secured, wherein the consumable components further comprise, by way of example, an electrode 26, a start cartridge 28, (which is used to draw a pilot arc as shown and described in co-pending application titled "Contact Start Plasma Arc Torch," filed on February 26, 2002, and commonly assigned with the present application, the contents of which are incorporated herein by reference), and a shield cup 30 that secures the consumable components to the distal end 24 of the torch head 22 and further insulates the consumable components from the surrounding area during operation of the torch. The shield cup 30 also positions and orients the consumable components, e.g., the start cartridge 28 and the tip gas distributor 20, relative to one another for proper operation of the torch when the shield cup 30 is fully engaged with the torch head 22. As used herein, the terms proximal or proximal direction should be construed as meaning towards or in the direction of the power supply 14 (not shown), and the terms distal or distal direction should be construed as meaning towards or in the direction of the tip gas distributor 20.

[0034] As further shown, the torch head 22 comprises a housing 32 in which fixed components are disposed. More specifically, the fixed components comprise a cathode 34 that has relatively negative potential, an anode 36 that has

relatively positive potential, and an insulating body 38 that insulates the cathode 34 from the anode 36, each of which provides certain gas distribution functions. In operation, the electrode 26 is in electrical contact with the cathode 34 to form the negative side of the power supply, and the tip gas distributor 20 is in electrical contact with the anode 36, more specifically through a shield cup insert 40, to form the positive side of the power supply. Accordingly, the tip gas distributor 20 is a conductive member and is preferably formed of a copper or copper alloy material.

[0035] The tip gas distributor 20 is mounted over a distal portion of the electrode 26 and is in a radially and longitudinally spaced relationship with the electrode 26 to form a primary gas passage 42, which is also referred to as an arc chamber or plasma chamber. A central exit orifice 44 of the tip gas distributor 20 communicates with the primary gas passage 42 for exhausting ionized gas in the form of a plasma stream from tip gas distributor 20 and directing the plasma stream down against a workpiece. The tip gas distributor 20 further comprises a hollow, generally cylindrical distal portion 46 and an annular flange 48 at a proximal end. The annular flange 48 defines a generally flat, proximal face 50 that seats against and seals with a tip seat 52 of the start cartridge 28, and a distal face 54 adapted to seat within and make electrical contact with the conductive insert 40 disposed within the shield cup 30. The conductive insert 40 is further adapted for connection with the anode 36, such as through a threaded connection, such that electrical continuity between the positive side of the power supply is maintained.

[0036] Additionally, the tip gas distributor 20 preferably defines a conical interior surface 58, which makes electrical contact with a portion of the start

cartridge 32 in one form of the present invention. In operation, a working gas is supplied to the tip gas distributor 20 through a primary gas chamber 60 that extends distally from the torch head 22, wherein the working gas is subsequently divided into a plasma gas to generate a plasma stream and a secondary gas to stabilize the plasma stream by the tip gas distributor 20 as set forth in the following.

[0037] Referring now to Figures 4 through 7, the tip gas distributor 20 further defines a plurality of swirl holes 62 around and through the annular flange 48 and a plurality of secondary gas holes 64 extending radially through the annular flange 48 and into an annular recess 66 on the distal face 54. Preferably, the swirl holes 62 are offset from a center of the tip gas distributor 20 as shown in Figure 6, such that the plasma gas is introduced into the primary gas passage 44 in a swirling motion, which generates a more robust plasma stream and further cools the electrode 26 (not shown) during operation. Additionally, the secondary gas holes 64 are preferably formed approximately normal through the annular flange 48 as shown more clearly in Figure 7, such that the secondary gas flows directly into the annular recess 66 and distally along the cylindrical distal portion 46 to stabilize the plasma stream that exits through the central exit orifice 44.

[0038] In operation, the working gas flows to the tip gas distributor 20 and is split or divided into the plasma gas and the secondary gas by the swirl holes 62 and the secondary gas holes 64, respectively. The plasma gas flows through the swirl holes 62 and is swirled proximate the conical interior surface 58 to generate the plasma stream. The secondary gas flows through the secondary gas holes 64, into the annular recess 66, and along the cylindrical distal portion 46 to stabilize the

plasma stream as the stream exits the central exit orifice 44. Accordingly, the tip gas distributor 20 regulates the plasma gas and the secondary gas, while metering the plasma stream and maintaining the positive, or anode, side of the power supply.

[0039] As illustrated, the tip gas distributor 20 in one form comprises three (3) swirl holes 62 and three (3) secondary gas holes 64 spaced evenly around the annular flange 48, which is a preferred configuration for an operating current of approximately 40 amps. However, with different operating currents, a ratio of a flow rate of the plasma stream through the central exit orifice 44 to a flow rate of the secondary gas through the secondary gas holes 64 is preferably adjusted to produce an optimum plasma stream. Accordingly, with a different current level, the size of the central exit orifice 44 and/or the size and number of secondary gas holes 64 are adjusted for the optimum plasma stream, while the swirl holes 62 may be adjusted or may remain constant according to specific flow requirements. Therefore, a different tip gas distributor 20 is preferred for different operating current levels. In operation, therefore, only the tip gas distributor 20 need be changed with different current levels, rather than a plurality of consumable components to achieve the proper flow ratio for an optimum plasma stream.

[0040] For example, at an operating current level of approximately 80 amps, the tip gas distributor 20 preferably defines six (6) swirl holes 62 and six (6) secondary gas holes 64 to optimize the plasma stream as shown in Figures 8 and 9. Further, the diameter of the central exit orifice 46 is preferably 0.055 in. (0.140 cm.), which results in a ratio of 1:2 of the plasma stream rate flowing through the central exit orifice 44 to the secondary gas rate flowing through the secondary gas holes 64.

Accordingly, preferable tip gas distributor configurations for different operating current levels are listed below in Table I, wherein the preferred number and diameter of secondary gas holes 64 are shown, along with the corresponding central exit orifice 44 diameters, and the corresponding ratio of flow rate through the central exit orifice 46 to the flow rate through the secondary gas holes 64.

[0041]

Table I

Operating Current	Plasma Orifice Diameter (in.)	Swirl Holes (number)	Secondary Gas Holes (number x dia)	Flow Ratio Plasma:Secondary
40	0.033	3	3 x 0.028	1:2
60	0.049	3	4 x 0.033	1:2
80	0.055	6	6 x 0.033	1:2

[0042]

As used herein, the term "hole" may also be construed as being an aperture or opening through the tip gas distributor 20 that allows for the passage of gas flow, such as a slot or other polygonal configuration, or an ellipse, among others. Accordingly, the illustrations of the swirl holes 62 and the secondary gas holes 64 as being circular in shape should not be construed as limiting the scope of the present invention. In addition, the tip gas distributor 20 may comprise at least one swirl hole 62 and/or at least one secondary gas hole 64, among the various forms of the present invention.

[0043]

Referring now to Figures 10a and 10b, swirl passages 70 and secondary gas passages 72 are formed between a tip gas distributor 80 and an

adjacent component rather than exclusively through the tip gas distributor 20 as previously described. In one form as shown, the swirl passages 70 are formed between the tip gas distributor 80 and the tip seat 52 of the start cartridge 28, while the secondary gas passages 72 are formed between the tip gas distributor 80 and the conductive insert 40 of the shield cup 30. As shown, the swirl passages 70 are preferably formed on the proximal face 50 of the tip gas distributor 80, while the secondary gas passages 72 are preferably formed on the distal face 54 of the tip gas distributor 80. Additionally, the tip gas distributor 80 may comprise at least one swirl passage 70 and/or at least one secondary gas passage 72, among the various forms of the present invention.

[0044] Alternately, the swirl holes 62 (shown in phantom) as previously described may be formed through the annular flange 48 of the tip gas distributor 80 while the secondary gas passages 72 are formed between the tip gas distributor 80 and an adjacent component such as the conductive insert 40. Conversely, the swirl passages 70 may be formed between the tip gas distributor 80 and an adjacent component, such as the tip seat 52, while the secondary gas holes 64 (shown in phantom) as previously described are formed through the annular flange 48 of the tip gas distributor 80. Accordingly, a combination of holes and passages may be employed in the tip gas distributor 80 in accordance with the teachings of the present invention.

[0045] Referring now to Figures 11 and 12, additional embodiments of the present invention are illustrated, wherein tip gas distributors 21 and 81 comprise swirl holes 62 and swirl passages 70, respectively, without the secondary gas holes

64 or secondary gas passages 72 as previously described. Accordingly, the tip gas distributors 21 and 81 regulate the flow of plasma gas for generation of a plasma stream as previously described. Alternately, as shown in Figures 13 and 14, tip gas distributors 23 and 83 comprise secondary gas holes 64 and secondary gas passages 72, respectively, without the swirl holes 62 or swirl passages 70 as previously described. Similarly, the tip gas distributors 23 and 83 regulate the flow of secondary gas to stabilize the plasma stream. Accordingly, the tip gas distributors 21, 23, 81, and 83 serve additional functions beyond that of a conventional tip, (e.g., regulating the plasma stream exiting the tip and maintaining the positive, or anode, side of the power supply), by providing gas distribution functions not heretofore observed in plasma arc torches of the art.

[0046] In yet other forms of the present invention, methods of directing a plasma gas to generate a plasma stream and directing a secondary gas to stabilize the plasma stream are provided, which generally comprise the steps of providing a source of gas, distributing the gas through a plasma arc apparatus to generate the plasma gas and the secondary gas, directing the plasma gas through at least one, and preferably a plurality of, swirl hole(s) formed in a tip gas distributor of the plasma arc apparatus, and directing the secondary gas through at least one, and preferably a plurality of, secondary gas hole(s) formed in the tip gas distributor. Additional methods of generating a plasma stream and directing a secondary gas to stabilize the plasma stream are provided that direct the plasma gas through at least one, and preferably a plurality of, swirl passage(s) and further direct the secondary gas through at least one, and preferably a plurality of, secondary gas passage(s).

Accordingly, the swirl holes or passages regulate the plasma gas to generate the plasma stream, while the secondary gas holes or passages regulate the secondary gas to stabilize the plasma stream exiting the tip gas distributor.

[0047] In summary, the tip gas distributors as described herein regulate either or both a plasma gas that is used to generate a plasma stream and a secondary gas that is used to stabilize the plasma stream. Accordingly, a single component serves multiple functions as opposed to numerous torch components that perform the same functions (i.e., generating a plasma stream, stabilizing the plasma stream, and tip functions) as required in plasma arc torches in the art. As a result, operation of the plasma arc torch is simplified and the number of consumable parts required to operate at different current levels is significantly reduced, along with a significant reduction in the amount of inventory required to support operation of a single plasma arc torch at different current levels.

[0048] The description of the invention is merely exemplary in nature and, thus, variations that do not depart from the substance of the invention are intended to be within the scope of the invention. Such variations are not to be regarded as a departure from the spirit and scope of the invention.

What is claimed is:

1. A tip gas distributor comprising:
at least one swirl passage; and
at least one secondary gas passage, wherein the swirl passage directs a plasma gas to generate a plasma stream, and the secondary gas passage directs a secondary gas to stabilize the plasma stream.
2. The tip gas distributor according to claim 1, wherein the at least one swirl passage comprises:
a plurality of swirl holes; and
the at least one secondary gas passage comprises a plurality of secondary gas holes, wherein the swirl holes direct the plasma gas to generate the plasma stream, and the secondary gas holes direct the secondary gas to stabilize the plasma stream.
3. The tip gas distributor according to claim 2 further comprising:
an annular flange formed at a proximal end of the tip gas distributor;
a generally cylindrical distal portion formed at a distal end of the tip gas distributor;
a primary gas passage formed within the generally cylindrical distal portion; and
a central exit orifice, wherein the swirl holes and the secondary gas holes are formed through the annular flange such that the swirl holes direct the primary gas to generate the plasma stream that flows through the primary gas passage and the central exit orifice, and the secondary gas holes direct the

secondary gas along the generally cylindrical distal portion to stabilize the plasma stream exiting the central exit orifice.

4. The tip gas distributor according to claim 3, wherein the swirl holes are offset from a center of the tip gas distributor.

5. The tip gas distributor according to claim 3, wherein the secondary gas holes are oriented approximately normal through the annular flange.

6. The tip gas distributor according to claim 3, wherein the annular flange further defines a distal face, and the tip gas distributor further comprises an annular recess formed on the distal face such that the secondary gas holes formed through the annular flange are in fluid communication with the annular recess.

7. The tip gas distributor according to claim 3 further comprising a conical interior surface formed at the proximal end of the tip gas distributor, the swirl holes being formed through the conical interior surface and the annular flange.

8. The tip gas distributor according to claim 1, defining a proximal end and a distal end, the tip gas distributor further comprising:

an annular flange formed at the proximal end;

a generally cylindrical distal portion formed at the distal end;

a primary gas passage formed within the generally cylindrical distal portion;

a central exit orifice;

the at least one swirl passage comprising a plurality of swirl holes formed through the annular flange; and

the at least one secondary gas passage comprising a plurality of secondary gas holes formed through the annular flange, wherein the swirl holes direct the primary gas to generate the plasma stream that flows through the primary gas passage and the central exit orifice, and the secondary gas holes direct the secondary gas along the generally cylindrical distal portion to stabilize the plasma stream exiting the central exit orifice.

9. The tip gas distributor according to claim 8, wherein the swirl holes are offset from a center of the tip gas distributor.

10. The tip gas distributor according to claim 8, wherein the secondary gas holes are oriented approximately normal through the annular flange.

11. The tip gas distributor according to claim 8, wherein the annular flange further defines a distal face, and the tip gas distributor further comprises an annular recess formed on the distal face such that the secondary gas holes formed through the annular flange are in fluid communication with the annular recess.

12. The tip gas distributor according to claim 8 further comprising a conical interior surface formed at the proximal end of the tip gas distributor, the swirl holes being formed through the conical interior surface and the annular flange.

13. The tip gas distributor according to claim 1, defining a proximal end and a distal end, the tip gas distributor further comprising:

an annular flange formed at the proximal end, the annular flange defining a distal face;

an annular recess formed on the distal face;

a generally cylindrical distal portion formed at the distal end;

a primary gas passage formed through the generally cylindrical distal portion;

a central exit orifice;

the at least one swirl passage comprising a plurality of swirl holes formed through the annular flange and in fluid communication with the primary gas passage and the central exit orifice; and

the at least one secondary gas passage comprising a plurality of secondary gas holes formed through the annular flange and in fluid communication with the annular recess, wherein the swirl holes direct the primary gas to generate the plasma stream that flows through the primary gas passage and the central exit orifice, and the secondary gas holes direct the secondary gas along the generally cylindrical distal portion to stabilize the plasma stream exiting the central exit orifice.

14. The tip gas distributor according to claim 13, wherein the swirl holes are oriented at an angle through the annular flange.

15. The tip gas distributor according to claim 13, wherein the secondary gas holes are oriented approximately normal through the annular flange.

16. The tip gas distributor according to claim 13 further comprising a conical interior surface formed at the proximal end of the tip gas distributor, the swirl holes being formed through the conical interior surface and the annular flange.

17. The tip gas distributor according to claim 1 further comprising:
an annular flange; and
a proximal face formed on the annular flange, wherein the swirl passage is formed on the proximal face of the annular flange.
18. The tip gas distributor according to claim 1 further comprising a distal face, wherein the secondary gas passage is formed on the distal face of an annular flange.
19. The tip gas distributor according to claim 1, wherein the at least one swirl passage comprises:
at least one swirl hole; and
the at least one secondary gas passage comprising at least one secondary gas hole, wherein the at least one swirl hole directs the plasma gas to generate the plasma stream, and the at least one secondary gas hole directs the secondary gas to stabilize the plasma stream.
20. The tip gas distributor according to claim 19 further comprising:
an annular flange formed at a proximal end of the tip gas distributor;
a generally cylindrical distal portion formed at a distal end of the tip gas distributor;
a primary gas passage formed within the generally cylindrical distal portion; and
a central exit orifice, wherein the swirl hole and the secondary gas hole are formed through the annular flange such that the swirl hole directs the

primary gas to generate the plasma stream that flows through the primary gas passage, an interior portion and the central exit orifice, and the secondary gas hole directs the secondary gas along the generally cylindrical distal portion to stabilize the plasma stream exiting the central exit orifice.

21. The tip gas distributor according to claim 20, wherein the swirl hole is offset from a center of the tip gas distributor.

22. The tip gas distributor according to claim 20, wherein the secondary gas hole is oriented approximately normal through the annular flange.

23. The tip gas distributor according to claim 20, wherein the annular flange further defines a distal face, and the tip gas distributor further comprises an annular recess formed on the distal face such that the secondary gas hole formed through the annular flange is in fluid communication with the annular recess.

24. The tip gas distributor according to claim 20 further comprising a conical interior surface formed at a proximal end of the tip gas distributor, the swirl hole being formed through the conical interior surface and the annular flange.

25. The tip gas distributor according to claim 19 further comprising three swirl holes and three secondary gas holes.

26. In a plasma arc apparatus, a method of directing a plasma gas to generate a plasma stream and directing a secondary gas to stabilize the plasma stream, the method comprising the steps of:

providing a source of gas;

distributing the gas through the plasma arc apparatus to generate the plasma gas and the secondary gas;

directing the plasma gas through at least one swirl passage formed in a tip gas distributor of the plasma arc apparatus; and

directing the secondary gas through at least one secondary gas passage formed in the tip gas distributor, wherein the swirl passage directs the plasma gas to generate the plasma stream and the secondary gas passage directs the secondary gas to stabilize the plasma stream exiting the tip gas distributor.

27. The method according to claim 26, wherein the at least one swirl passage is a plurality of swirl holes, the step of directing the plasma gas through the at least one swirl passage comprising directing the plasma gas through the plurality of swirl holes and wherein the at least one secondary gas passage is a plurality of secondary gas passages, and the step of directing the secondary gas through the at least one secondary gas passage comprising directing the secondary gas through the plurality of secondary gas holes, wherein the swirl holes direct the plasma gas to generate the plasma stream and the secondary gas holes direct the secondary gas to stabilize the plasma stream exiting the tip gas distributor.

28. The method according to claim 27 further comprising the steps of:
directing the secondary gas through the secondary gas holes and into an annular recess; and
directing the secondary gas along a generally cylindrical portion of the tip gas distributor.

29. The method according to claim 27 further comprising the step of metering a flow rate through a central exit orifice and the secondary gas holes for an operating current level.

30. The method according to claim 27 further comprising the step of changing a number and size of the secondary gas holes and a size of a central exit orifice for an operating current level.

31. The method according to claim 26, wherein the at least one swirl passage has at least one swirl hole, the step of directing the plasma gas through the at least one swirl passage comprising directing the plasma gas through the at least one swirl hole and wherein the at least one secondary gas passage has at least one secondary gas hole, the step of directing the secondary gas through the at least one secondary gas passage comprising directing the secondary gas through the at least one secondary gas hole, wherein the swirl hole directs the plasma gas to generate the plasma stream and the secondary gas hole directs the secondary gas to stabilize the plasma stream exiting the tip gas distributor.

32. The method according to claim 31 further comprising the steps of:
directing the secondary gas through the secondary gas hole and into an annular recess; and
directing the secondary gas from the annular recess along a generally cylindrical portion of the tip gas distributor.

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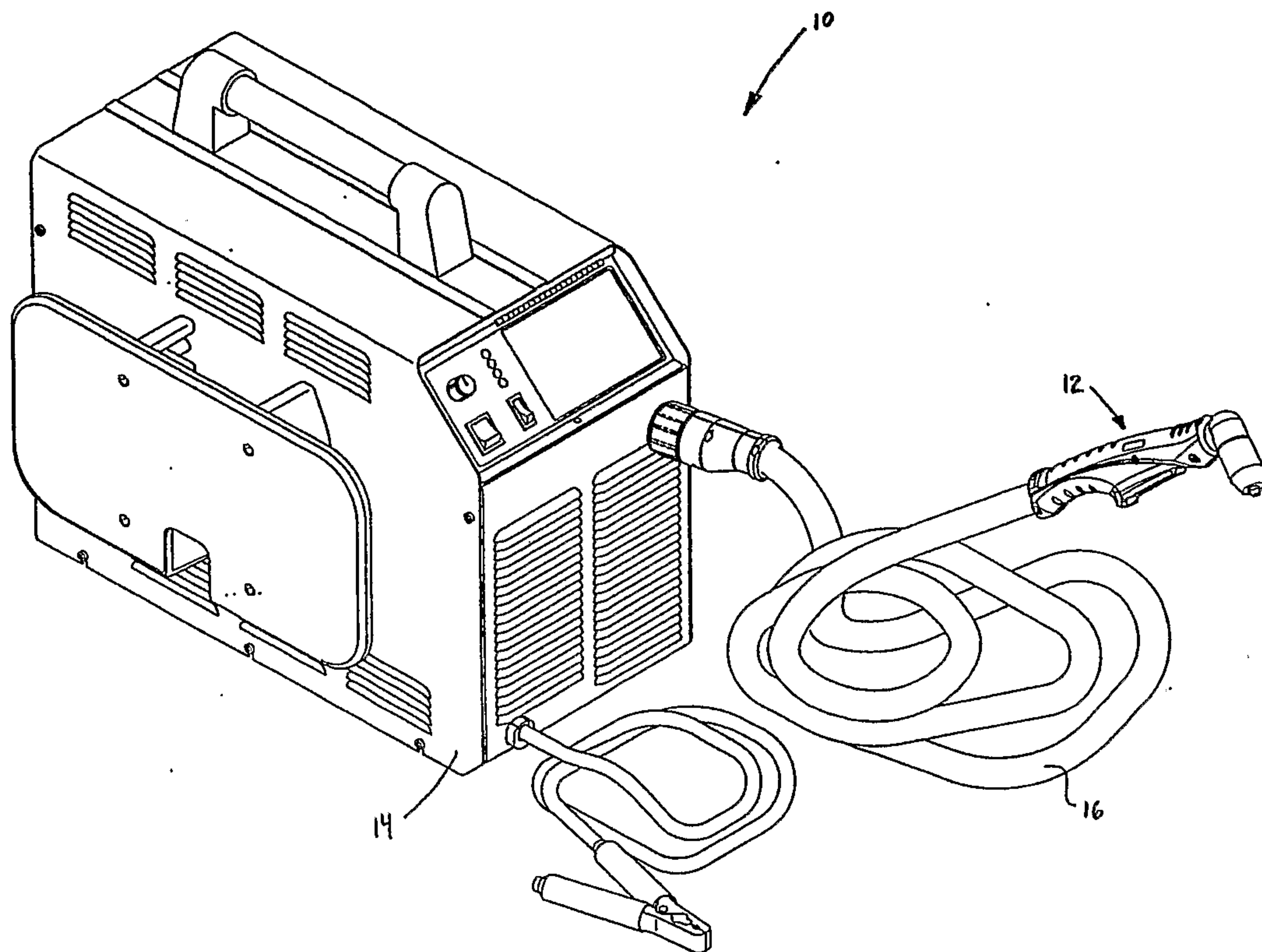


FIGURE 1

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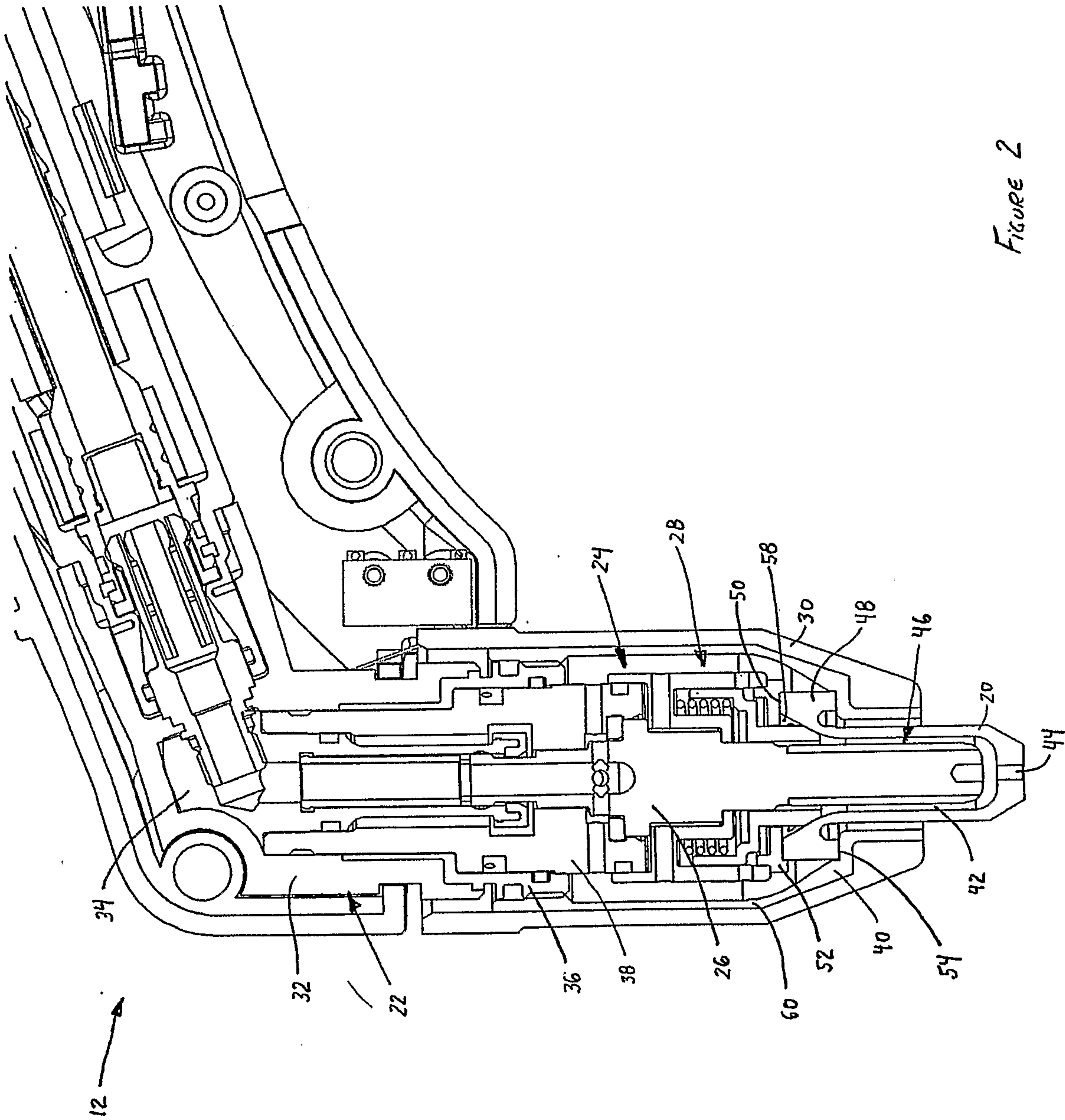


Figure 2

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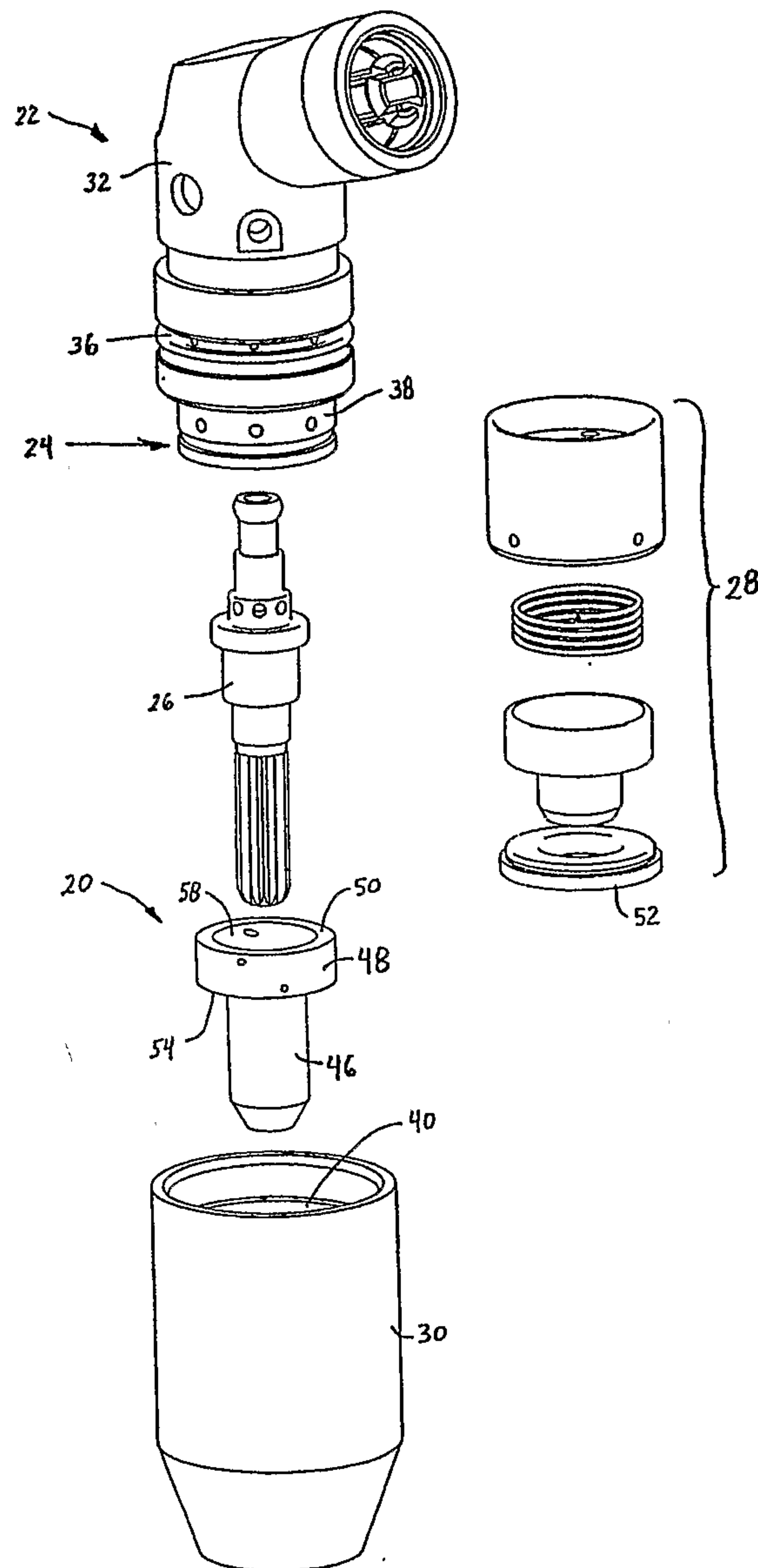


FIGURE 3

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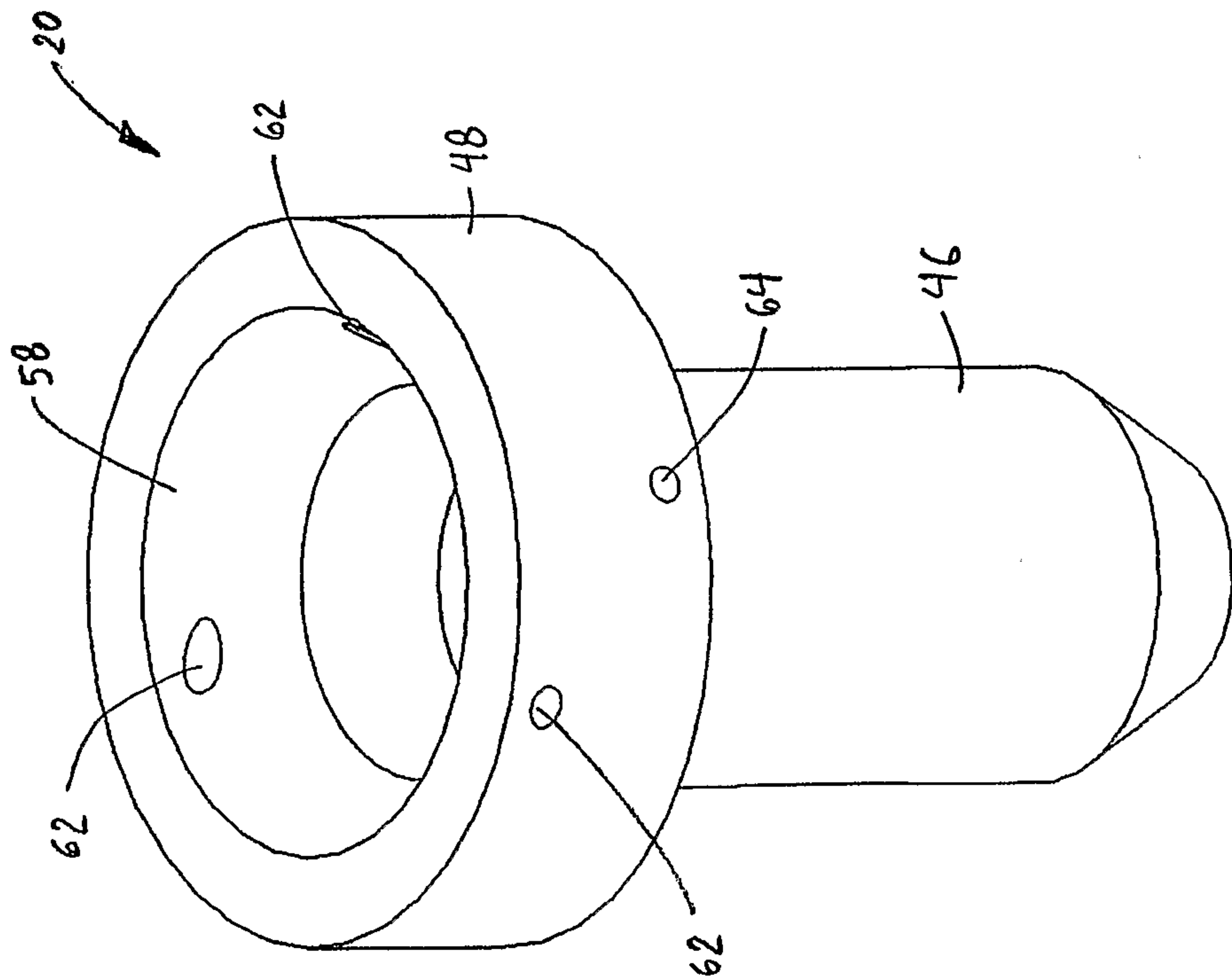


FIGURE 4a

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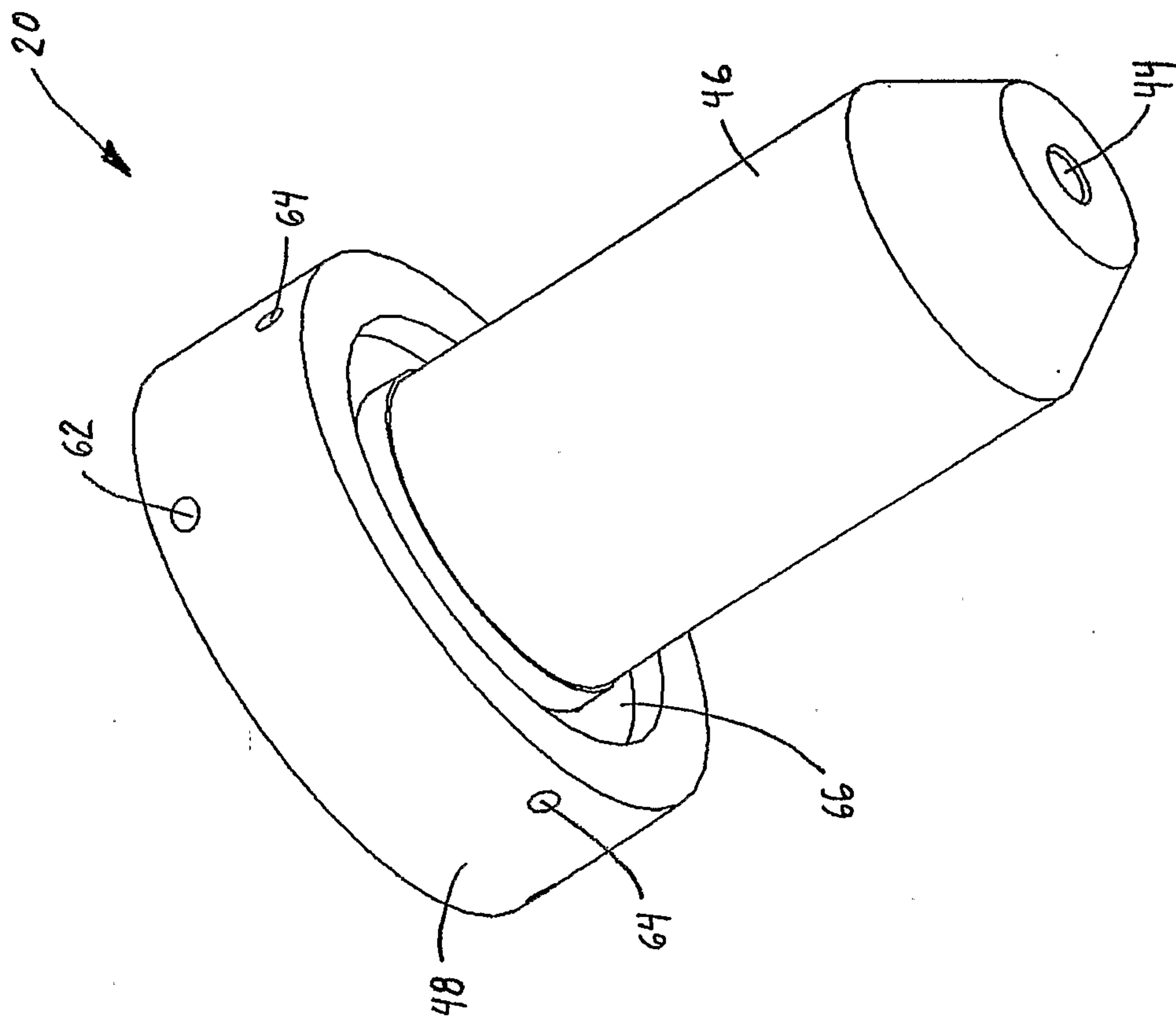


FIGURE 4b

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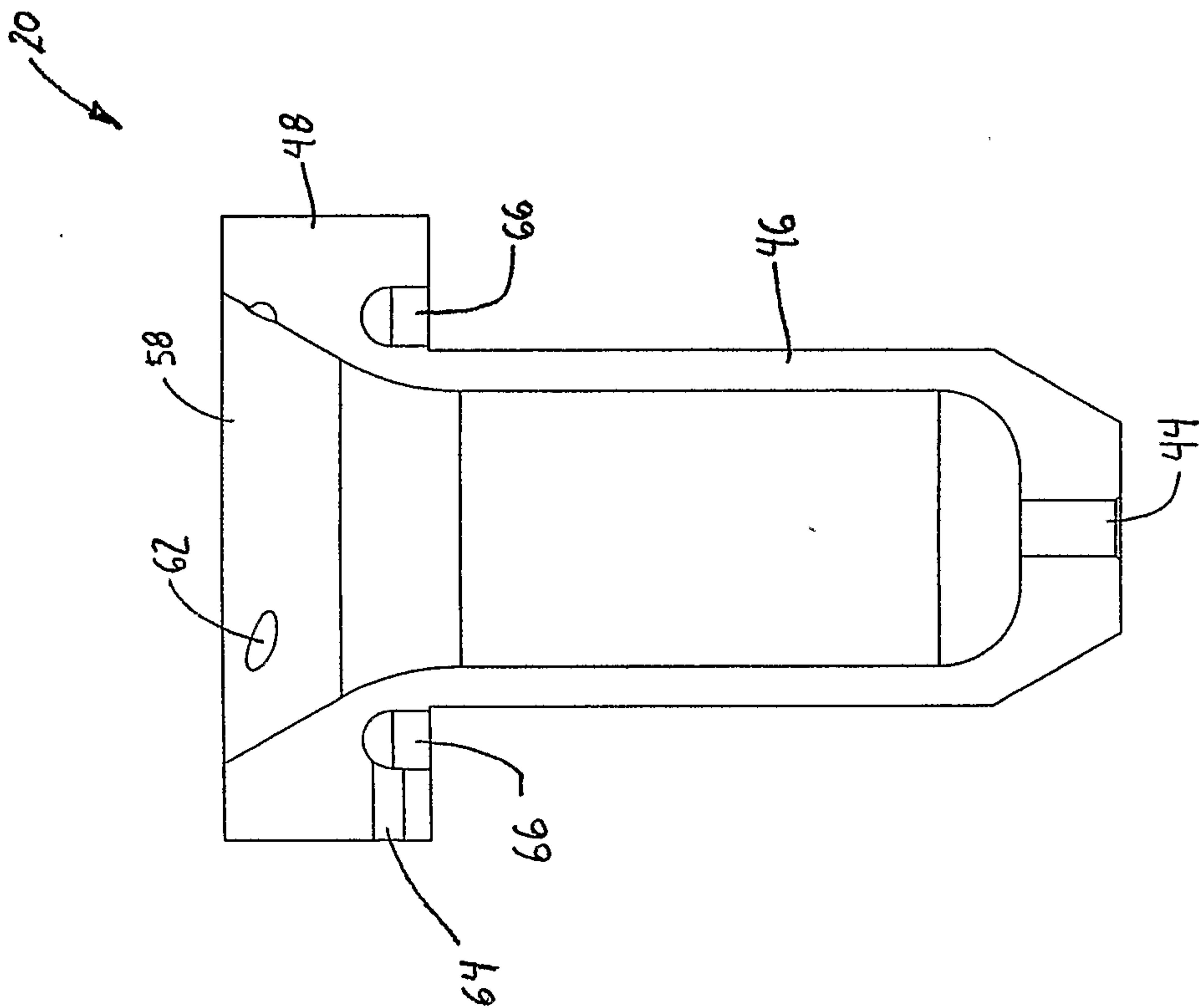


FIGURE 5

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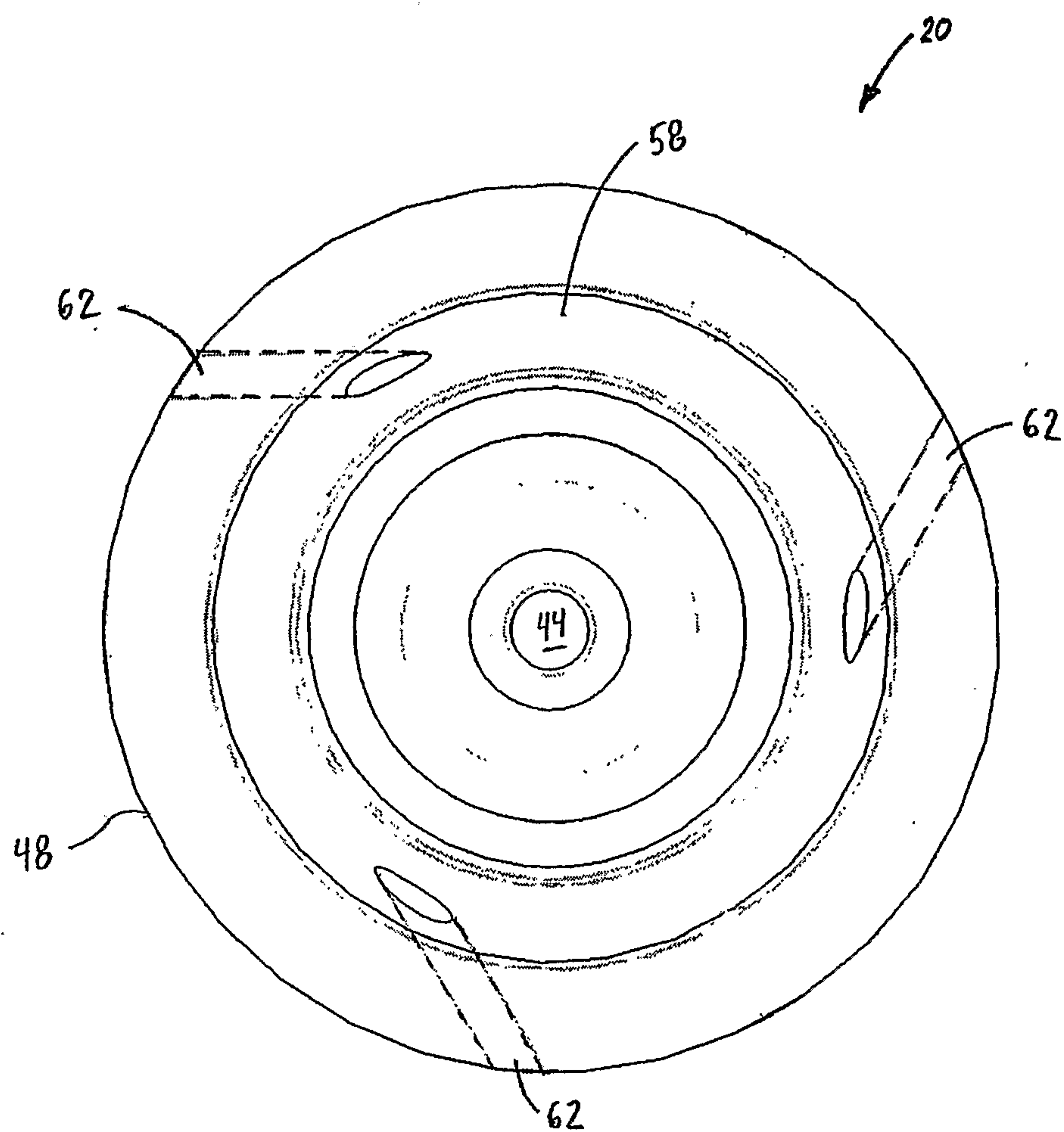


FIGURE 6

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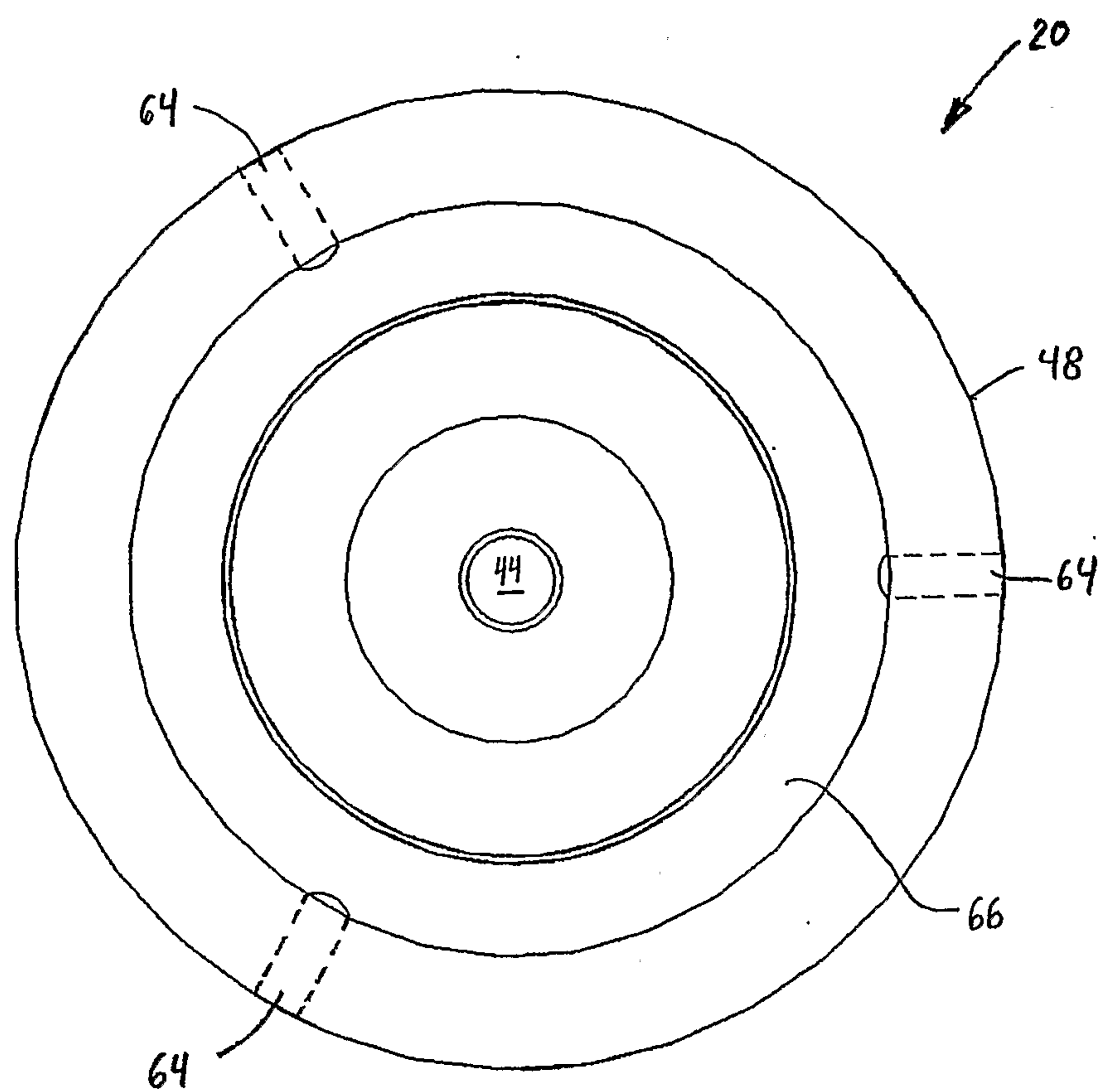


FIGURE 7

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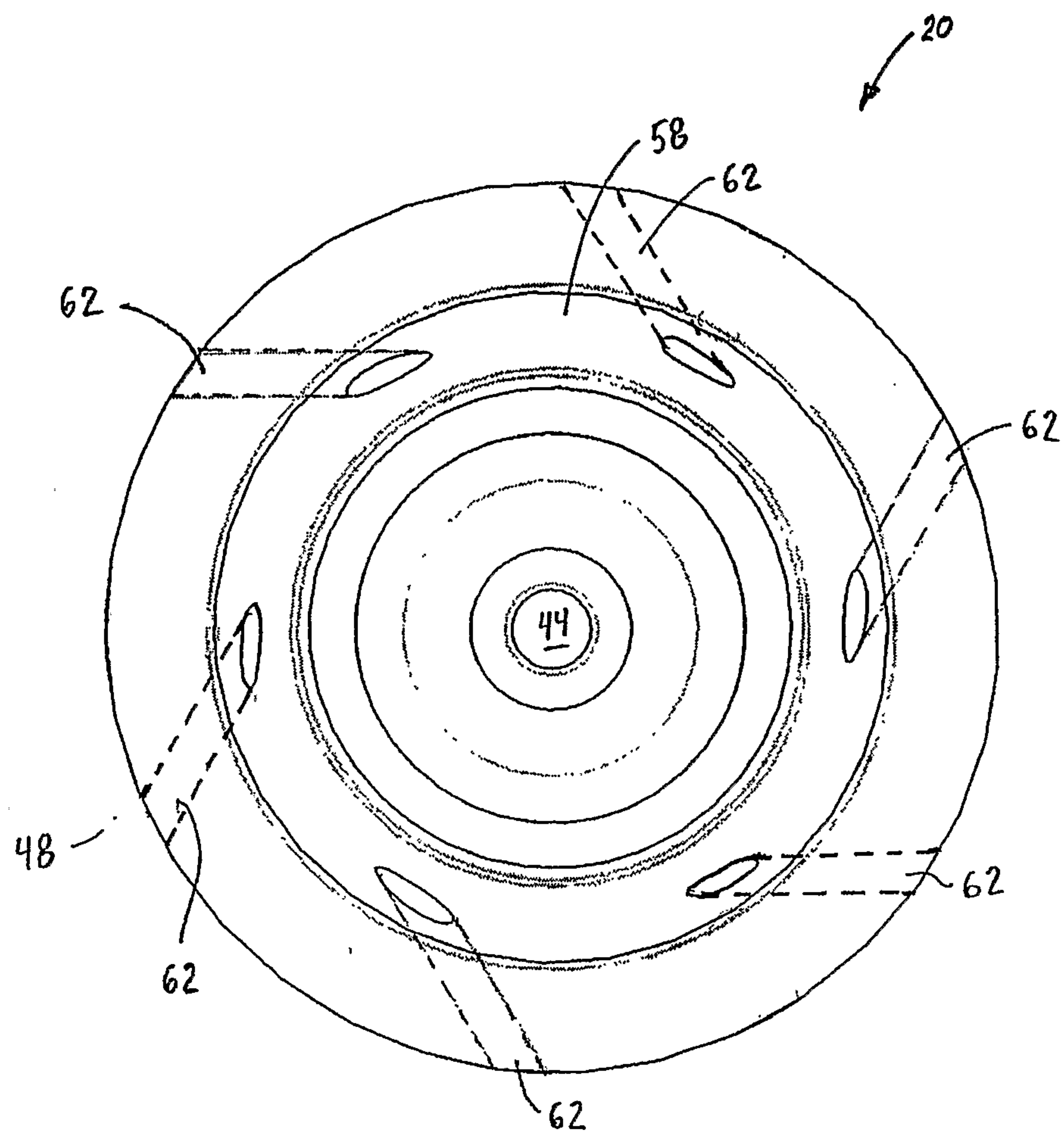


FIGURE 8

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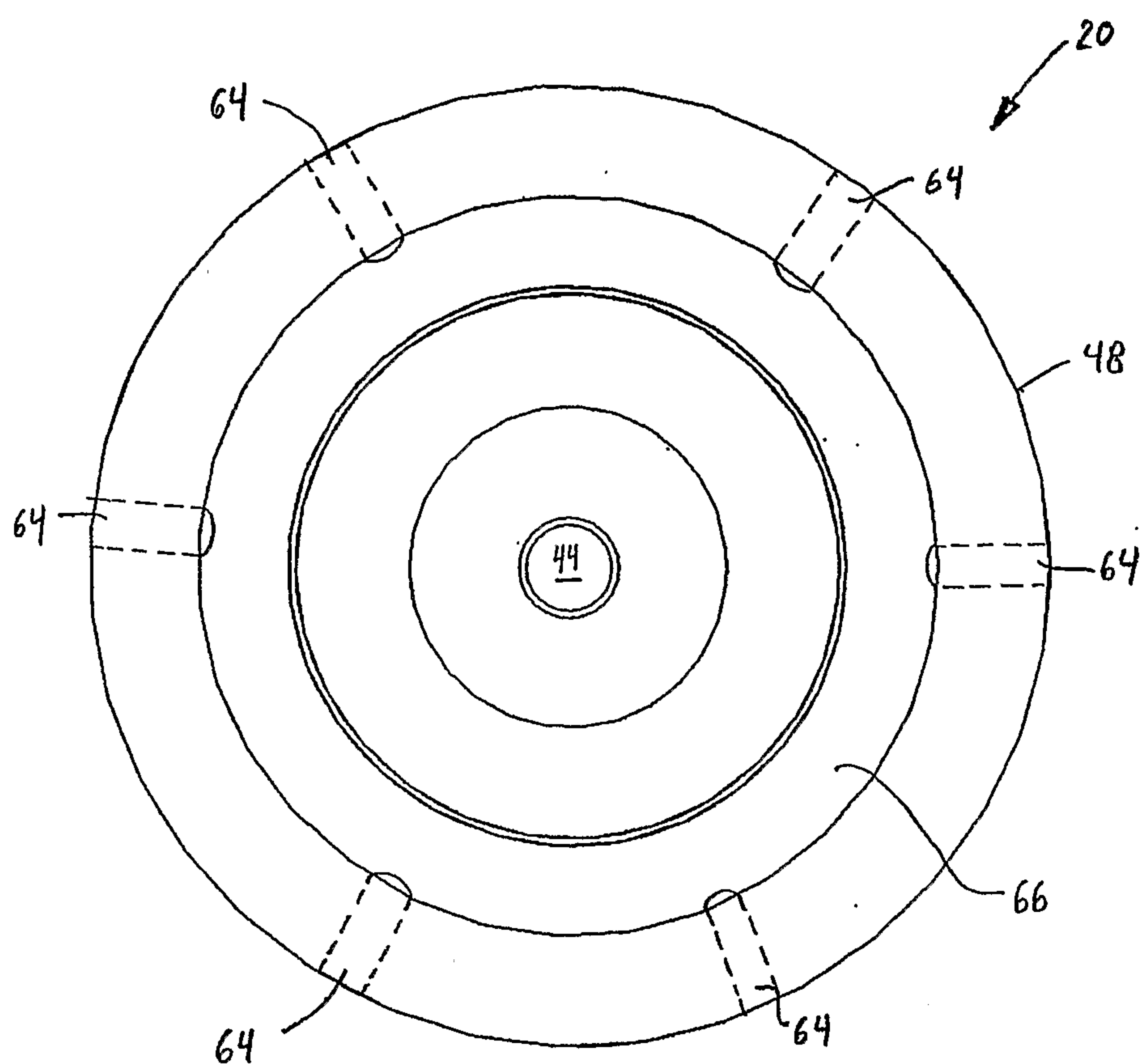


FIGURE 9

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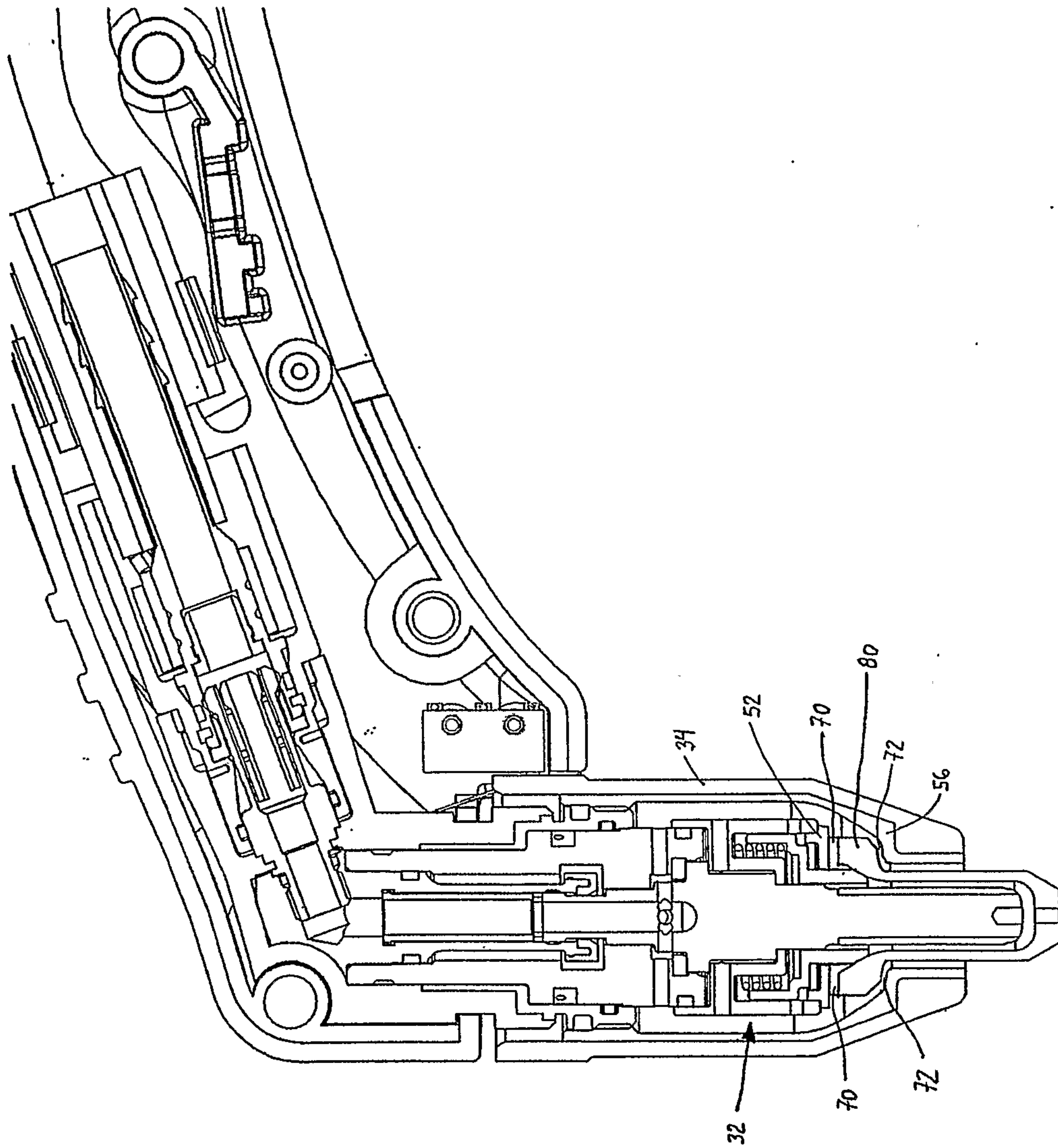


Figure 10a

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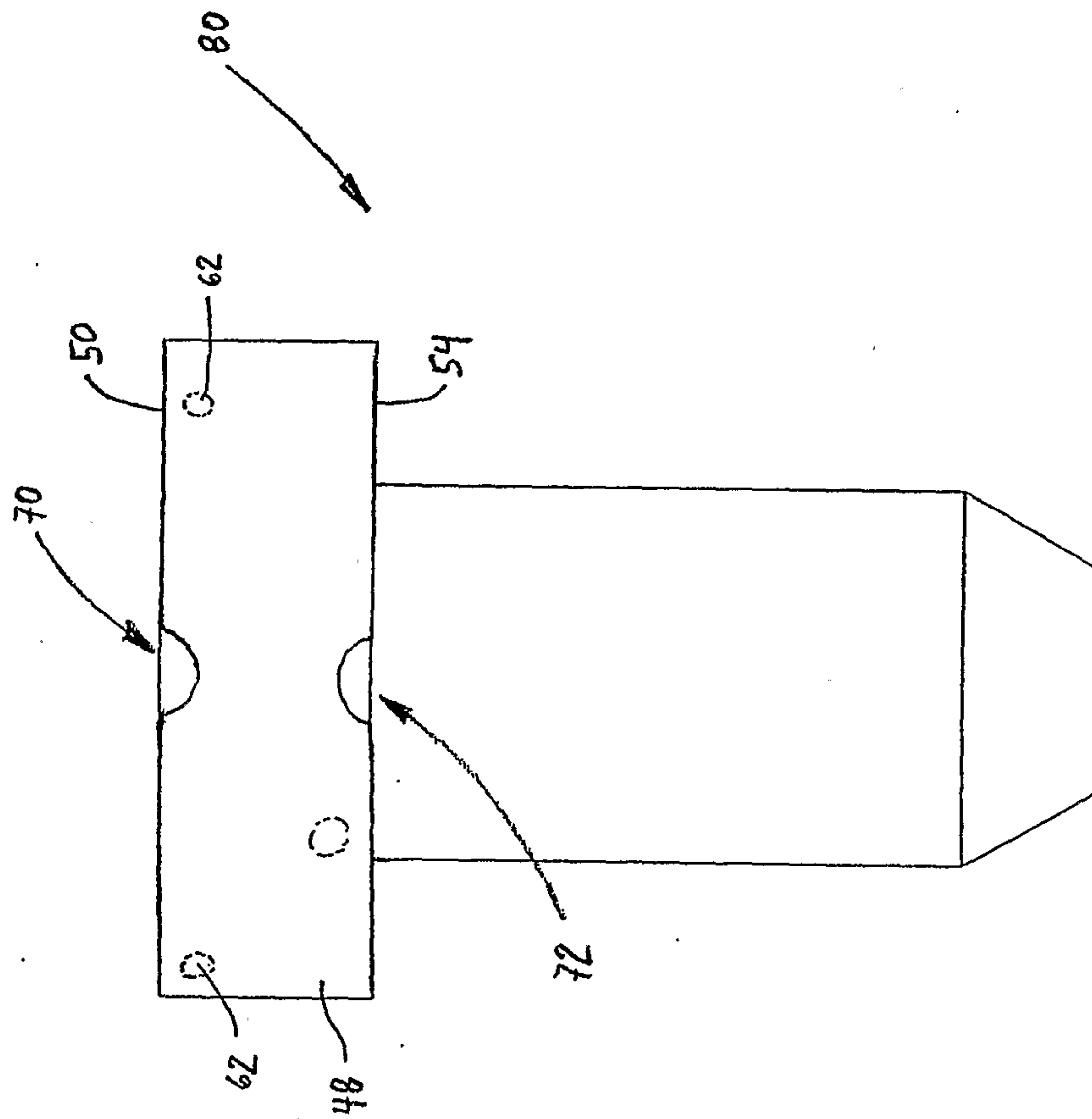


FIGURE 10b

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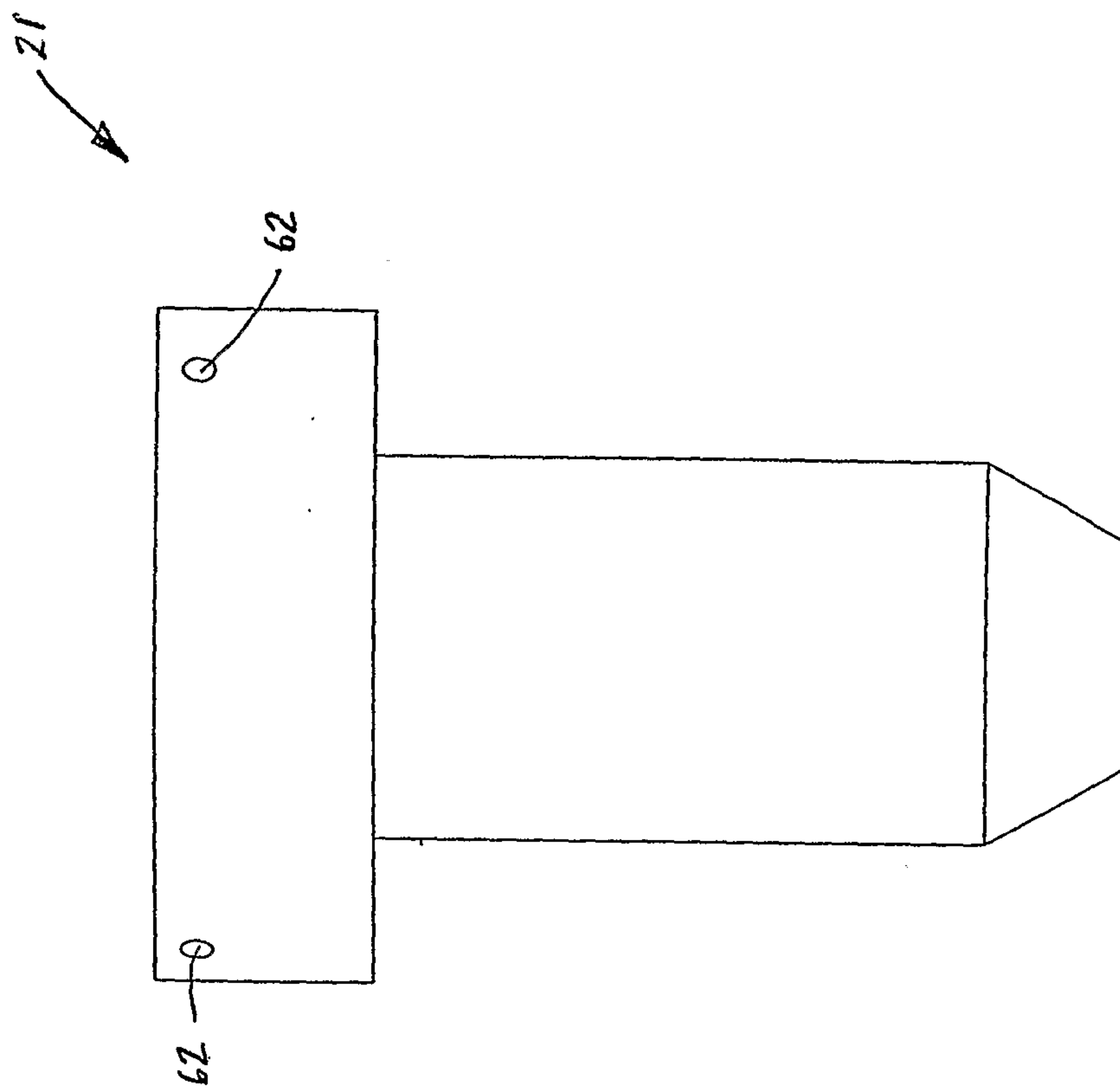


Figure 11

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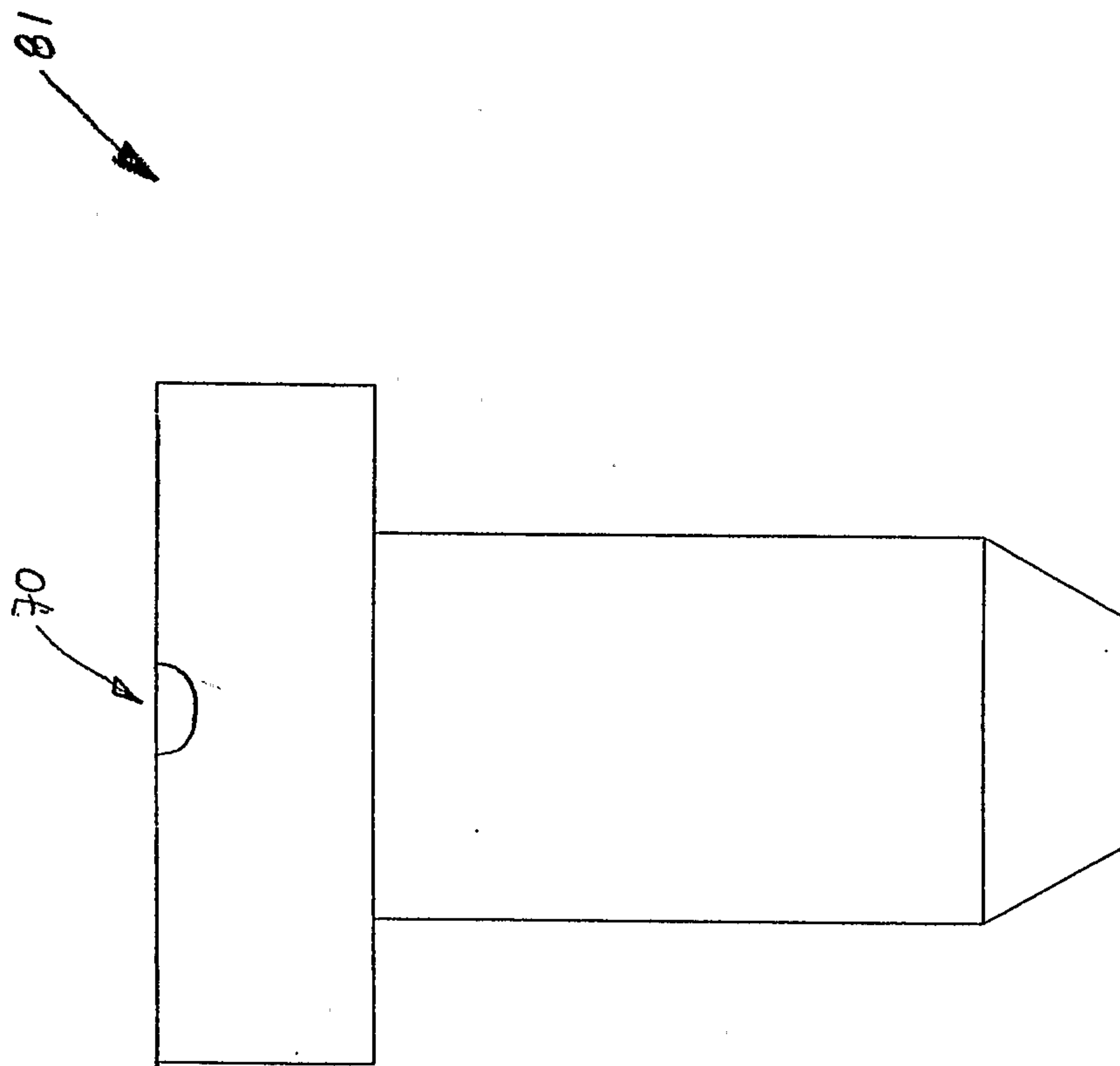


FIGURE 12

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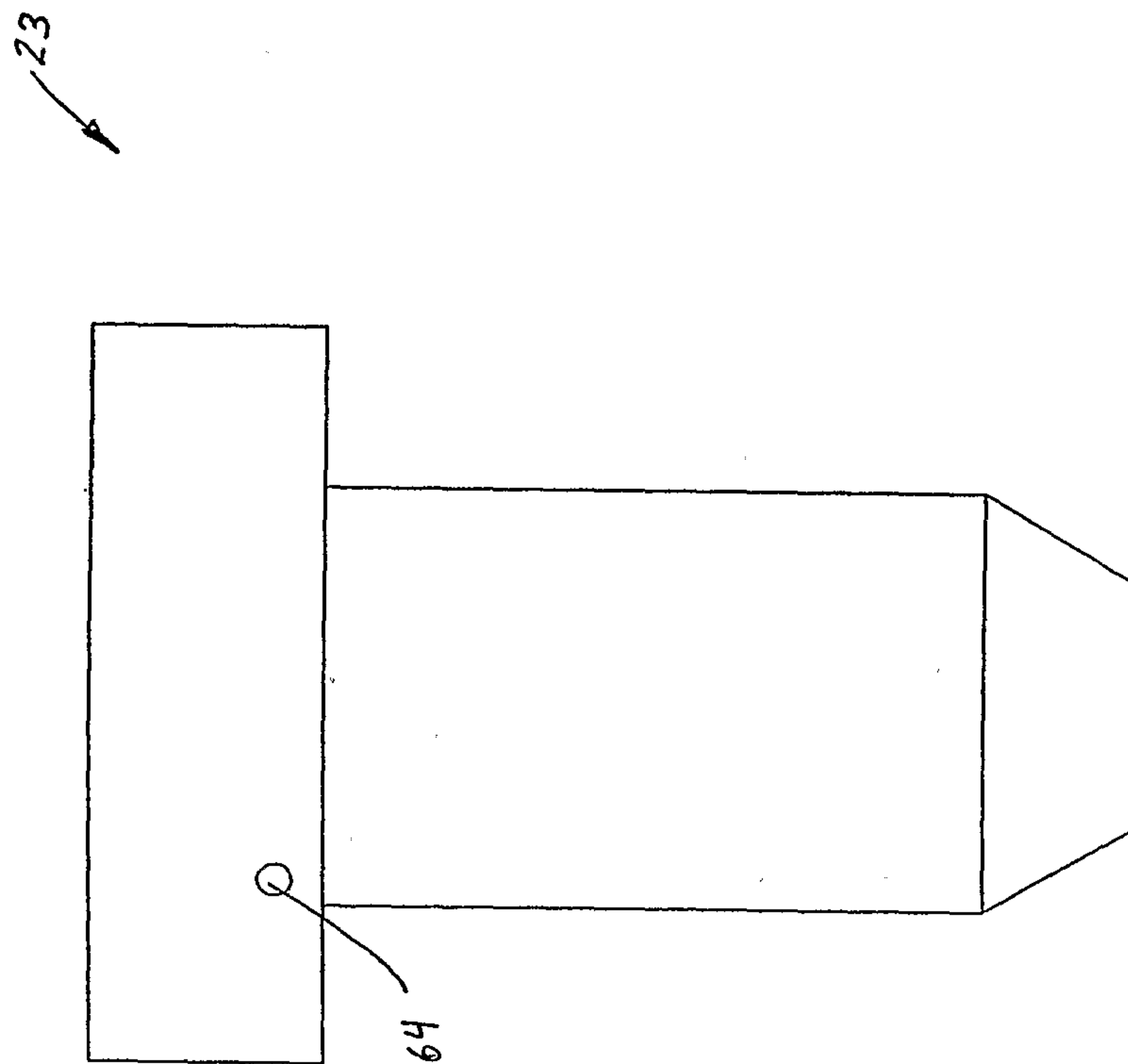


FIGURE 13

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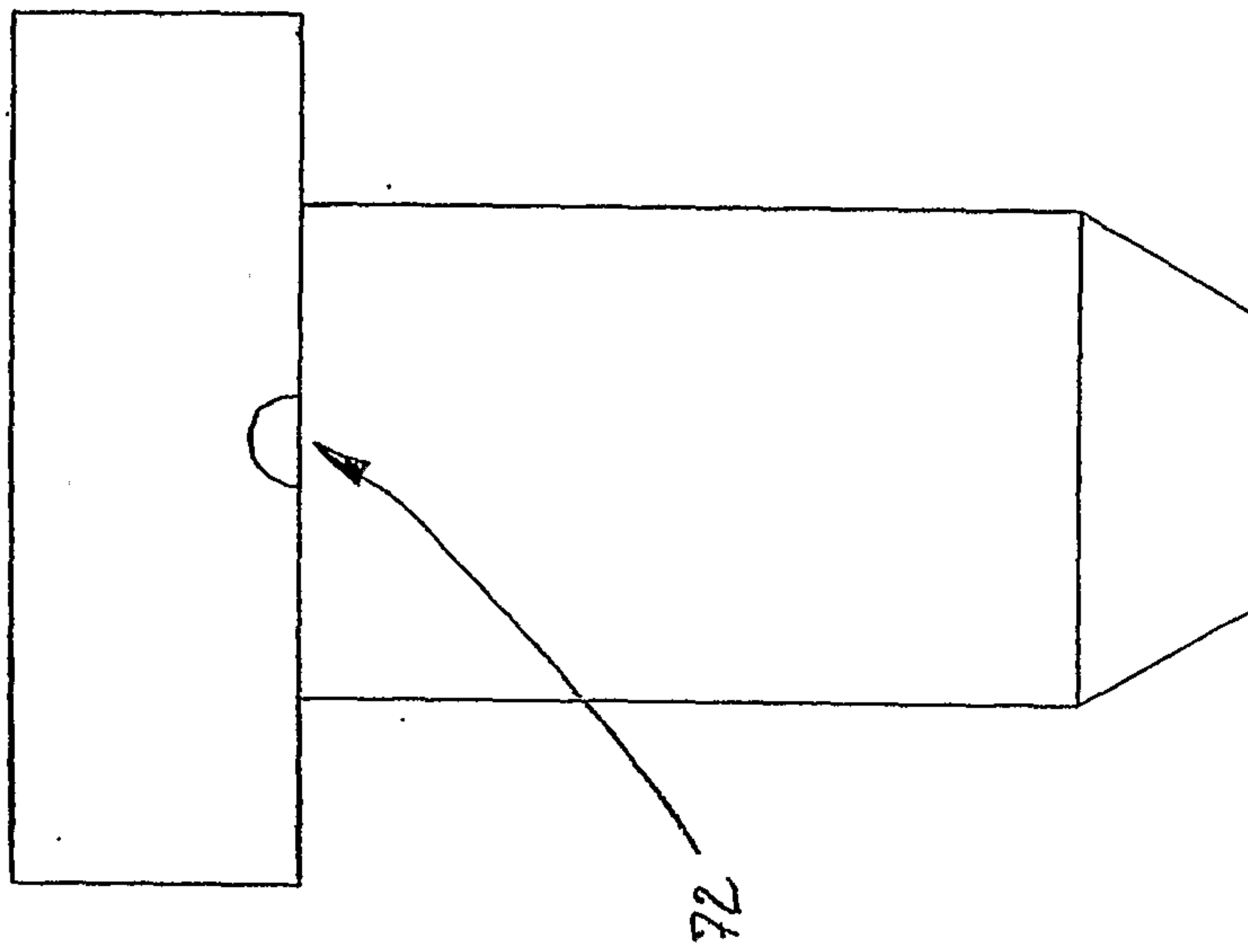


FIGURE 14

