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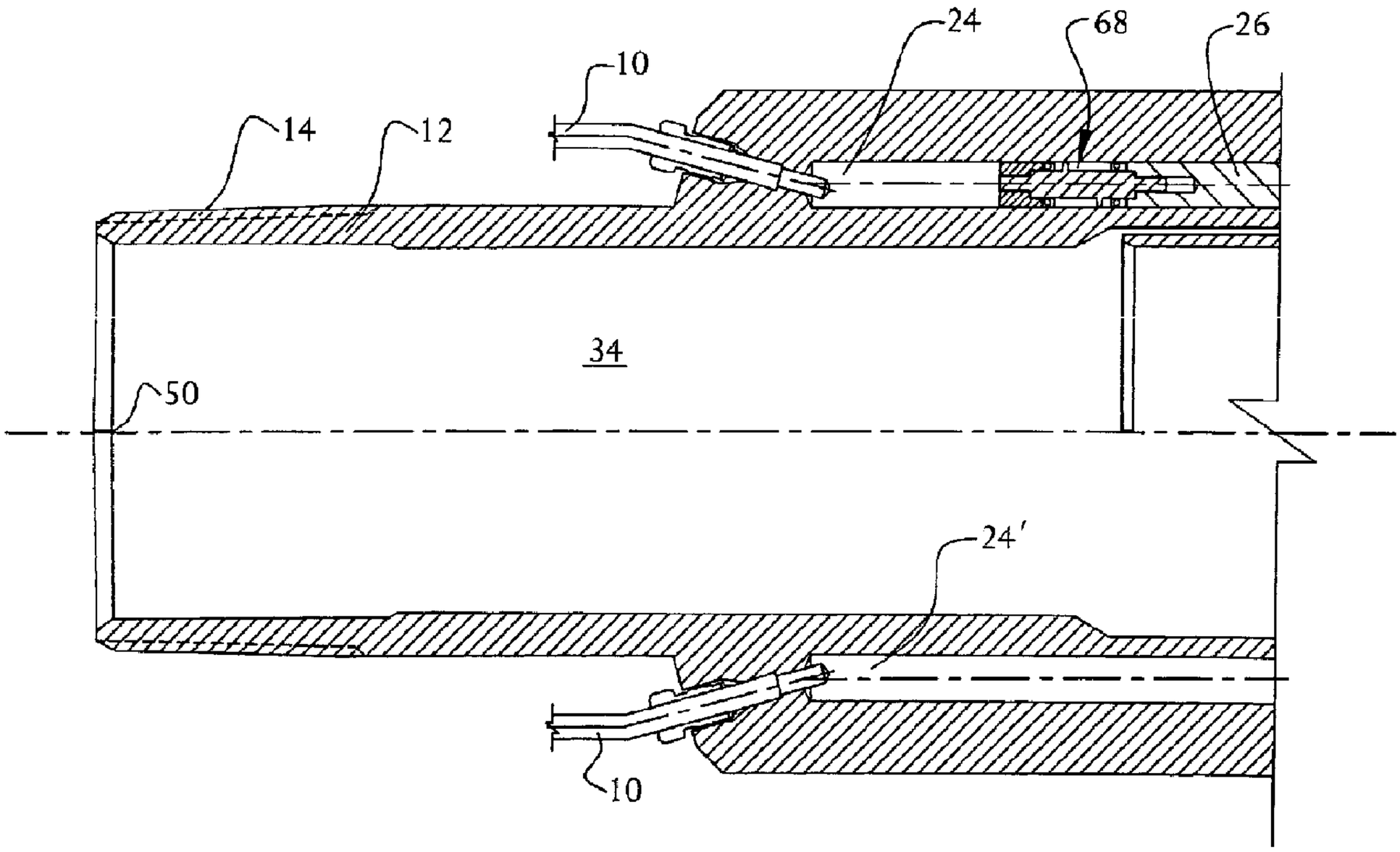
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(54) Titre : SOUPAPE DE FOND REGLABLE
(54) Title: ADJUSTABLE ORIFICE VALVE



(57) Abrégé/Abstract:
The invention relates to valves usable downhole and controlled from the surface hydraulically via control lines or by other techniques. The valve has a minimum flow passage which is preferably oriented along its longitudinal axis and a lateral flow passage which opens upon movement of a valve member via applied control pressure from the surface. Alternatively, the valve comprises a tapered needle movable in a throat. When the valve member shifts, additional flow area is exposed to control the backpressure of a fluid by way of hydraulic pressure control from the surface via the control line. The hydraulic control can be with a single control line acting on a piston attached to the valve member with a return spring opposing such movement, or alternatively, can be carried out with a pair of control lines to actuate reverse movements of the valve member. A pressurized gas chamber can be used to act as the closing force opposing applied pressure from the control line for a return of the valve to its minimum flow or maximum throttle position. Alternatively, an acoustic, electric or other type of surface-directed signal can change the valve position.

ABSTRACT OF THE DISCLOSURE

The invention relates to valves usable downhole and controlled from the surface hydraulically via control lines or by other techniques. The valve has a minimum flow passage which is preferably oriented along its longitudinal axis and a lateral flow passage which opens upon movement of a valve member via applied control pressure from the surface. Alternatively, the valve comprises a tapered needle movable in a throat. When the valve member shifts, additional flow area is exposed to control the backpressure of a fluid by way of hydraulic pressure control from the surface via the control line. The hydraulic control can be with a single control line acting on a piston attached to the valve member with a return spring opposing such movement, or alternatively, can be carried out with a pair of control lines to actuate reverse movements of the valve member. A pressurized gas chamber can be used to act as the closing force opposing applied pressure from the control line for a return of the valve to its minimum flow or maximum throttle position. Alternatively, an acoustic, electric or other type of surface-directed signal can change the valve position.

TITLE: **ADJUSTABLE ORIFICE VALVE**

INVENTOR: JEFFREY J. LEMBCKE and KURT A. HICKEY

FIELD OF THE INVENTION

The field of this invention relates to downhole throttling valves whose position can be adjusted over an operating range from control lines or other signaling techniques from the surface.

BACKGROUND OF THE INVENTION

A subsurface safety valve (SSV) is one commonly used type of down-hole valve which is controlled between a fully open or fully closed position by control lines extending from the valve, usually mounted in a tubing string to the surface.

Other applications require control of the flow as opposed to the on/off capabilities of an SSV. A particular example of this is in the application of a downhole oil/water separator where the valve is used to control the injection rate of the water back into the formation. Since formations change injectivity or resistance to injection of fluid over time, one way to maintain a near-constant backpressure on the separator is to adjust the outlet flow rate of separated water back to the formation. The apparatus of the present invention facilitates this procedure by providing infinite adjustability between a max and minimum flow for a given upstream pressure in the separator.

In the past, auxiliary controlled valves have been used in drillstrings as a signal source for transmitting information from the well to the surface where flushing fluid flows through the string and serves as the transmitting medium. Such a valve is illustrated in U.S. Patent 4,519,574. This valve relies on

downhole differential pressures coupled with an auxiliary power source to operate a solenoid to control an associated hydraulic circuit for positioning the valve member in one of two extreme positions.

It is the object of the present invention to provide a simple valve design which allows throttling with control from the surface via a control line or another signaling technique. Another objective of one embodiment of the present invention is to allow a minimum flow, via a central opening, so that tools can be passed through the valve while it is in its minimum flow or maximum throttling position. Another objective of the present invention is to provide improved control for downhole operations where sensitivity is required to changing conditions which requires regulation of applied pressures in fluids being delivered downhole. Those and other advantages of the invention will become more apparent from a detailed description of the preferred embodiment which appears below.

SUMMARY OF THE INVENTION

The invention relates to valves usable downhole and controlled from the surface hydraulically via control lines or by other techniques. The valve has a minimum flow passage which is preferably oriented along its longitudinal axis and a lateral flow passage which opens upon movement of a valve member via applied control pressure from the surface. Alternatively, the valve comprises a tapered needle movable in a throat. When the valve member shifts, additional flow area is exposed to control the backpressure of a fluid by way of hydraulic pressure control from the surface via the control line. The hydraulic control can be with a single control line acting on a piston attached to the valve member with a return spring opposing such movement, or alter-

natively, can be carried out with a pair of control lines to actuate reverse movements of the valve member. A pressurized gas chamber can be used to act as the closing force opposing applied pressure from the control line for a return of the valve to its minimum flow or maximum throttle position. Alternatively, an acoustic, electric, motion, or light or other type of surface-directed signal can change the valve position.

In accordance with one aspect of the present invention there is provided a throttling valve controllable from the surface of a well for downhole use, comprising:

a body securable to downhole equipment or tubulars;

a valve member strokable between opposed end positions;

said valve member being translatable in an opening in said body for throttling of a fluid passing through said body as said valve member changes the size of said opening when moved between said opposed end positions;

said valve member comprising a housing with a needle extending adjacent an opening in said housing such that flow is through said housing and out through said opening in said housing and past said needle and through said opening in said body,

said housing and said needle translating in tandem in said body; and

a control system mounted at least in part remote from said body at the surface of said well and operatively controlling said valve member;

said control system positioning and maintaining said valve member in at least one position between said opposed end positions.

In accordance with another aspect of the present invention there is provided a throttling valve controllable from the surface of a well for downhole use, comprising:

a body securable to downhole equipment or tubulars;

a valve member strokable between opposed end positions;

said valve member movable in an opening in said body for throttling of a fluid passing through said body as said valve member changes the size of said opening when moved between said opposed end positions;

said valve member comprising a housing with a needle extending adjacent an opening in said housing such that flow is through said housing

and out through said opening in said housing and past said needle and through said opening in said body;

a control system mounted at least in part remote from said body at the surface of said well and operatively controlling said valve member;

said control system positioning and maintaining said valve member in at least one position between said opposed end positions; and

at least one piston in said body operably connected to said needle;

said control system comprising a conduit extending from the surface to said body for selective application of fluid pressure to said piston.

In accordance with yet another aspect of the present invention there is provided a throttling valve for downhole use, comprising:

a body securable to downhole equipment or tubulars;

a valve member strokable between opposed end positions;

said valve member movable in an opening in said body for throttling of a fluid passing through said body as said valve member changes the size of said opening when moved between said opposed end positions;

said valve member comprising a housing with a needle extending adjacent an opening in said housing such that flow is through said housing and out through said opening in said housing and past said needle and through said opening in said body;

a control system mounted at least in part at the surface and operatively controlling said valve member;

said needle movable in said opening of said body;

at least one piston in said body operably connected to said needle;

said control system comprising a conduit extending from the surface to said body for selective application; and

a pair of conduits extending from the surface to opposing sides of said position for movement of said piston into a plurality of positions including said opposed end positions.

In accordance with still yet another aspect of the present invention there is provided a back pressure control system for a subsurface separator, comprising:

a valve body;

a valve member comprising a needle translatable between and including a fully open and fully closed position in a throat formed in said body;

said needle extending adjacent an opening in a housing such that flow is through said housing and out through said opening in said housing and past said needle and through said throat in said body, said housing and said needle translating in tandem in said body; and

a control system operable from the surface of a well to stroke said needle and maintain said needle in at least one position between said fully open and fully closed positions.

In accordance with still yet another aspect of the present invention there is provided a back pressure control system for a subsurface separator, comprising:

a valve body;

a valve member comprising a movable needle between and including a fully open and fully closed position in a throat formed in said body;

said needle extending adjacent an opening in a housing such that flow is through said housing and out through said opening in said housing and past said needle and through said throat in said body; and

a control system operable from the surface of a well to stroke said needle and maintain said needle in at least one position between said fully open and fully closed positions;

said control system further comprising:

a control line from the surface connected to said body;

said body comprising a piston operatively connected to said needle, said control line communicating a pressure to said piston for selective movement of said needle.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will now be described more fully with reference to the accompanying drawings in which:

Figures 1a—1d are a sectional elevational split view of the preferred embodiment of the present invention.

Figure 2 is section view through line 2—2 of Figure 1c.

Figures 3a and 3b are section views for the maximum and minimum positions as line 3-3 of Figure 1c for the valve member.

Figure 4 is split sectional elevational view illustrating an alternative embodiment for the throttling valve of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

As previously stated, downhole throttling valves are useful in a variety applications. In the preferred embodiment, the application is fluid injection into the formation. Since the formation can have variability in its ability to absorb the injected fluid, a throttling valve can be used when a fluid is injected from the surface into the formation to stimulate subsequent production. Alternatively, in wells that are producing with the aid a downhole pump, separation of produced water from the hydrocarbons can be accomplished downhole with the output pressure of the downhole pump driving the produced fluid through a separator where the overhead hydrocarbons continue

to the surface while the water, which is heavier, is reinjected. In order to make such separation equipment effective, the output from a separator, which can be of a cyclonic type, needs to be regulated to effectively separate the water from the hydrocarbon layer. While the overhead hydrocarbon layer can be easily regulated at the surface, the outlet water layer which is reinjected into the formation sees variability in the formation's ability to absorb the outlet water stream. Accordingly, the apparatus **A** of the present invention, in its preferred use, can be installed in the water outlet of a downhole separator to regulate the water flow out of the separator back to the formation. The apparatus **A** is controlled from the surface by a control line or lines **10** which run to the surface. Thus, the assembly as shown in Figures 1a–1d is installed in the water outlet of the separator which is not shown.

Referring to Figures 1a–1d, the apparatus **A** has an upper housing **12** with a thread **14** for connection to the outlet of a separator (not shown). The upper housing **12** is connected to body **16** at thread **18**. The lower housing **20** is connected to body **16** at thread **22**.

While multiple control lines **10** are shown in Figure 1a, those skilled in the art will appreciate that a single control line **10** is sufficient for extension from the surface to adjacent the upper housing **12**. In the preferred embodiment, the branches of the control line **10** are in communication with discrete cavities **24** and **24'**, each of which is in communication with a rod piston **26** and **26'**, respectively. Those skilled in the art can appreciate that any number of individual rod pistons such as **26**, can be used, or alternatively, the cavity **24** and **24'**, instead of being discrete cylindrical bores, can be one common annularly shaped cavity and use an annularly shaped piston **26**. One of the disadvantages of using an annularly shaped piston is that the return spring **28**

must resist a greater hydrostatic force from pressure in control line **10** and, therefore, for a given depth would need to be stiffer than the alternative, which is to use cylindrically shaped cavities, such as **24** and **24'**, in conjunction with rod pistons such as **26** and **26'**. Those skilled in the art will also appreciate that the number of pistons, such as **26**, can be varied, as well as their diameters to suit the particular application.

Mounted inside the body **16** is tubular valve member **30**. Valve member **30** has an upper bore **32** which is aligned with bore **34** of upper housing **12**. Connected to valve member **30** at thread **36** is needle **38**. Needle **38** can have a tapered profile, a parabolic profile, or a straight profile. Referring to Figure 2, the needle **38** has openings **40**, **42**, **44**, and **46**, all of which are in fluid communication with bore **32**. Any number of openings, such as **40**, can be used without departing from the spirit of the invention. Among all the openings and centrally located, as shown in Figure 2, the needle **48** emerges and extends downwardly along longitudinal axis **50** to throat **52** and lower housing **20**. The needle **48** has a taper **54** adjacent its lower end. Thus, when the taper **54** is in the position shown in Figure 1d, the smallest annular opening in throat **52** is created, as shown in Figure 3b. Conversely, when the taper **54** is in its upward position, as shown in Figure 1c, the maximum opening of the throat **52** is available, as shown in Figure 3a. The taper angle and the throat configuration can be varied without departing from the spirit of the invention.

Referring to Figure 1b, the return spring **28** is in an annular cavity **56**. Spring **28** bears on upper ring **58**, one of which is secured to each of the rod pistons such as **26**. Each of the rings **58** has a shoulder **60**, which bears on a shoulder **62** on tubular valve member **30**. Thus, when pressure is increased

in the control line **10**, raising the pressure in cavities **24** and like cavities **24′**, the piston or pistons **26** and/or **26′** urge the ring **58** downwardly. It should be noted that each of the pistons, such as **26** and **26′**, has a groove **64** which accepts a detent **66** to secure the ring **58** collectively to all of the pistons such as **26** and **26′** which are used. Each of the pistons **26** has an upper sealing assembly **68** and a lower guide bushing **70**. The seal assembly **68** isolates the control line pressures in line **10** from the pressure P_1 found upstream of throat **52**. Cavity **56** is not sealed from bores **32** or **34**, as shown in Figure 1c. The lower end of the spring **28** bears on a ring **72**.which rests on and is supported by the lower housing **20**. A bushing **74** guides the movement of the valve member **30** and is itself supported from the lower housing **20**. In the embodiment shown in Figures 1a–1d, the pressure P_1 exists as well in cavity **56**. Those skilled in the art can appreciate alternative ways to actuate the valve member **30**. For example, a pair of control lines can run down to the surface. One control line **10** is already shown, and another shown in dashed lines as **76** can be in communication with chamber **56** with the proper seals between the valve member **30** and the lower housing **20**, as well as between the body **16** and the lower housing **20**. Thus, for example, bushing **74** can alternatively be considered to be a seal which will allow replacement completely of spring **28** and actuation uphole of valve member **30** with control line pressure applied to line **76**. Alternatively, the spring **28** can be replaced without using a second control line **76** if the chamber **56** is sealed with a fluid under sufficient pressure to withstand the hydrostatic forces expected from the control line **10** acting on piston or pistons **26**. In those situations, stroking down of piston **26** will increase the pressure in chamber **56** as its volume is reduced. Withdrawing pressure from the surface in control line **10** will allow

expansion of a compressible fluid in chamber **56** to push the valve member **30** in the uphole direction. Even if a pressurized compressible fluid is charged into chamber **56** to act as an uphole force on pistons **26**, a return spring such as **28** but considerably less stiff can also be used to assist in returning the valve member **30** to the position where maximum opening at throat **52** is experienced.

Referring now to Figure 4, an alternative embodiment is described for accomplishing the same purpose. The drawing of Figure 4 is somewhat schematic and the alternatives to the driving of the valve member **30** described with regard to Figures 1a–1d are equally applicable to the design of Figure 4. In Figure 4, a body is generally shown as **78**. A connection **80** accepts a control line from the surface (not shown). The valve member **82** has a central bore **84** and a peripheral tab **86**, with an O–ring **88** mounted in a groove **90**. O–ring **88** rides on annular surface **92** of body **78** so as to define a variable–volume chamber **94**. Seal **96** mounted in body **78** contacts the valve member **82** to sealingly isolate the variable–volume cavity **94**. A return spring **98** is in a chamber **100**, which is defined between the body **78** and the valve member **82** below variable–volume chamber **94**. Body **78** has a circumferential internal projection **102** which serves as a guide for valve member **82** as well as a support for spring **98**. The other end of spring **98** bears against circumferential tab **86**.

The valve member **82** has a central bore **104** and one or more lateral ports **106**. In the right–hand portion of Figure 4, the ports **106** are in alignment with projection **102** and, hence, effectively sealed off although not necessarily liquid–tight. The opposite end of the movement of the valve member **82** is located on the other portion of Figure 4, indicating that the

lateral ports **106** are now completely below the projection **102**. In that position, arrows **108** and **110** reflect the fact that flow occurs through the ports **106** as well as the central bore **104**. Whereas in the other extreme position, bore **104** represents the available flowpath for flow. Thus, it can be seen that the embodiment seen in Figures 1a–1d, as well as that shown in Figure 4, is not intended to be a throttling valve which closes fluid–tight. It can be configured that way, however, without departing from the spirit of the invention. The additional advantage of the embodiment shown in Figure 4 is that the bore **104** is centrally disposed. Thus, in a particular application where the body **78** is in a tubing string and tools need to be delivered below, the positioning of bore **104** centrally about longitudinal axis **118** allows tools which will fit through bore **104** to be positioned downhole below body **78**.

Those skilled in the art will appreciate that the actuation of the valve member **82** can be done in alternative ways. Thus, if a seal **120** is installed, effectively isolating chamber **100**, the return spring **98** can be replaced with a pressurized compressible fluid as previously described. Alternatively, an auxiliary connection into the chamber **100**, when sealed with seals **88** and **120**, can be used to urge the valve member **82** upwardly toward a position bringing in ports **106** into alignment with projection **102** for maximum throttling.

It should be noted that the advantages of the apparatus **A** of the present invention, as illustrated in the preferred embodiment of Figures 1a–1d and in the alternative embodiment of Figure 4, are that it can be used as a downhole throttling valve with control from the surface, thus allowing a rangeability in the amount of throttling to react to conditions downhole. While various hydraulic actuation mechanisms for valve members **30** or **82** have been shown, those skilled in the art will appreciate that the movement could also be

accomplished by a stepper motor, shown schematically in Figure 4, as **S**. The stepper motor **S**, in combination with power provided from downhole or from the surface, can be used to adjust a position and, hence, the amount of throttling desired. Signals from the surface to the valve member downhole, such as **30** or **82**, can be accomplished in a variety of ways, such as through physical movement, acoustical signals, electrical signals, and/or signals transmitted through fiber optic cable, to name a few. The ability to control a downhole throttle valve in real time can improve the functioning of many downhole operations, particularly those for oil and water separation downhole, which are used in conjunction with a downhole pump. Damage to the formation can be minimized or eliminated. When the injectivity of the formation changes, such a change can be sensed by pressures measured in the system or through other means, and a signal from such measurements is generated to be relayed to the control system for the apparatus **A**. In the preferred embodiment, a single control line **10**, acting on a rod piston **26** with a return spring **28**, is the simple and preferred solution to variability in the size of the throat **52**, which is needed to react to changes in downhole conditions and to control backpressure in the separator. The taper **54** can be altered so as to make the change in open area at throat **52** occur more quickly or more gradually. Needle **54** and throat **52** should be made from erosion resistant materials, such as boronized inconel®, ceramic, tungsten carbide or stellite®. Optionally, the configuration of needle **54** can be such so as to achieve complete shut-off. Seals can also be incorporated into body **20** or taper **54** to facilitate the creation of a bubble-tight shut-off, if necessary.

In a particular example of the apparatus **A** of the present invention, the open area through openings **40–46** can be approximately 8.36 sq. in., with the

maximum flow area at throat **52** being 1.16 sq. in., and the minimum flow area at throat **52** being .374 sq. in. In the embodiment shown in Figures 1a–1d, the throat size is approximately 1¼" and the stroke length is approximately 5". Other configurations of taper angles **54**, throat diameters **52**, and stroke lengths can be used without departing from the spirit of the invention.

The preferred embodiment of Figures 1a–1d provides a simple and economical apparatus **A** that can be built cheaply and can operate reliably for precise throttling control downhole from the surface. The embodiment of Figure 4 adds the advantages of a central bore **104** which can allow tools to pass therethrough for further downhole operations to be conducted through the apparatus **A**.

The foregoing disclosure and description of the invention are illustrative and explanatory thereof, and various changes in the size, shape and materials, as well as in the details of the illustrated construction, may be made without departing from the spirit of the invention.

What is claimed is:

1. A throttling valve controllable from the surface of a well for downhole use, comprising:

a body securable to downhole equipment or tubulars;

a valve member strokable between opposed end positions;

said valve member being translatable in an opening in said body for throttling of a fluid passing through said body as said valve member changes the size of said opening when moved between said opposed end positions;

said valve member comprising a housing with a needle extending adjacent an opening in said housing such that flow is through said housing and out through said opening in said housing and past said needle and through said opening in said body,

said housing and said needle translating in tandem in said body; and

a control system mounted at least in part remote from said body at the surface of said well and operatively controlling said valve member;

said control system positioning and maintaining said valve member in at least one position between said opposed end positions.

2. The valve of claim 1, wherein:

said control system positions said valve member in a plurality of positions between said opposed end positions.

3. The valve of claim 1 or 2, wherein:

said opening in said body comprises a throat.

4. The valve of any one of claims 1 to 3, wherein:

said needle comprises one of a tapered, straight, and parabolic profile adjacent a lower end thereof.

5. The valve of any one of claims 1 to 4, wherein said control system further comprises:

a stepper motor operatively connected to said valve member and actuated by a signal from said control system.

6. The valve of any one of claims 1 to 5, wherein:

said control system operatively controls said valve member by at least one of the following types of signals: acoustic, electric, physical movement, applied stress, and light.

7. A throttling valve controllable from the surface of a well for downhole use, comprising:

a body securable to downhole equipment or tubulars;

a valve member strokable between opposed end positions;

said valve member movable in an opening in said body for throttling of a fluid passing through said body as said valve member changes the size of said opening when moved between said opposed end positions;

said valve member comprising a housing with a needle extending adjacent an opening in said housing such that flow is through said housing and out through said opening in said housing and past said needle and through said opening in said body;

a control system mounted at least in part remote from said body at the surface of said well and operatively controlling said valve member;

said control system positioning and maintaining said valve member in at least one position between said opposed end positions; and

at least one piston in said body operably connected to said needle;

said control system comprising a conduit extending from the surface to said body for selective application of fluid pressure to said piston.

8. The valve of claim 7, further comprising:

a return spring acting on said piston to oppose hydrostatic forces on said piston from said conduit.

9. The valve of claim 7, wherein:

said body defines a chamber on the opposite side of said piston which contains a compressible fluid which is pressurized to put a force on said piston opposing hydrostatic forces from said conduit extending from the surface.

10. A throttling valve for downhole use, comprising:

a body securable to downhole equipment or tubulars;

a valve member strokable between opposed end positions;

said valve member movable in an opening in said body for throttling of a fluid passing through said body as said valve member changes the size of said opening when moved between said opposed end positions;

said valve member comprising a housing with a needle extending adjacent an opening in said housing such that flow is through said housing and out through said opening in said housing and past said needle and through said opening in said body;

a control system mounted at least in part at the surface and operatively controlling said valve member;

said needle movable in said opening of said body;

at least one piston in said body operably connected to said needle;

said control system comprising a conduit extending from the surface to said body for selective application; and

a pair of conduits extending from the surface to opposing sides of said position for movement of said piston into a plurality of positions including said opposed end positions.

11. A back pressure control system for a subsurface separator, comprising:

a valve body;

a valve member comprising a needle translatable between and including a fully open and fully closed position in a throat formed in said body;

said needle extending adjacent an opening in a housing such that flow is through said housing and out through said opening in said housing and past said needle and through said throat in said body, said housing and said needle translating in tandem in said body; and

a control system operable from the surface of a well to stroke said needle and maintain said needle in at least one position between said fully open and fully closed positions.

12. A back pressure control system for a subsurface separator, comprising:

a valve body;

a valve member comprising a movable needle between and including a fully open and fully closed position in a throat formed in said body;

said needle extending adjacent an opening in a housing such that flow is through said housing and out through said opening in said housing and past said needle and through said throat in said body; and

a control system operable from the surface of a well to stroke said needle and maintain said needle in at least one position between said fully open and fully closed positions;

said control system further comprising:

a control line from the surface connected to said body;

said body comprising a piston operatively connected to said needle, said control line communicating a pressure to said piston for selective movement of said needle.

13. The control system of claim 12, wherein:

said piston is biased against forces applied through said control line.

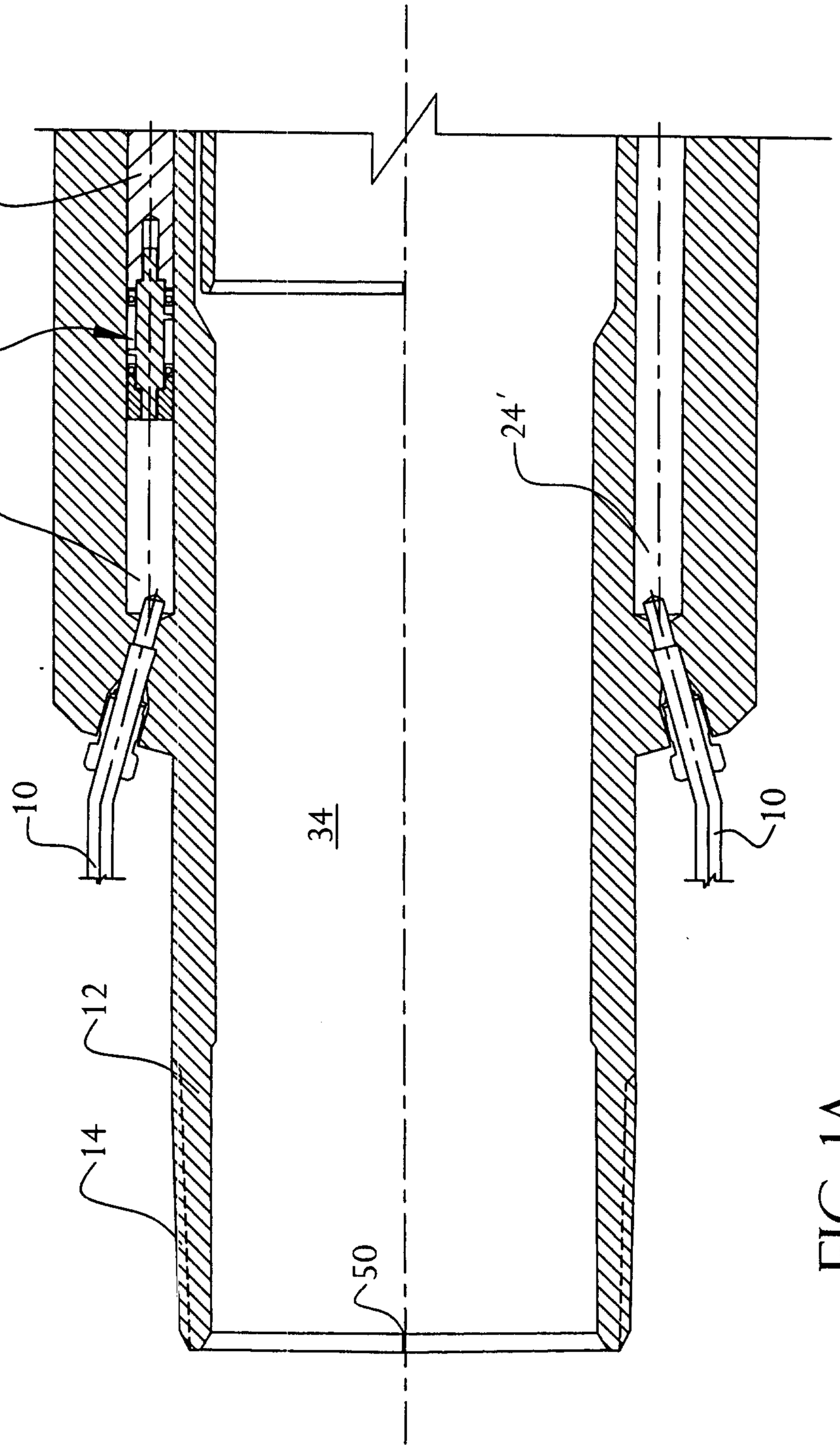


FIG. 1A

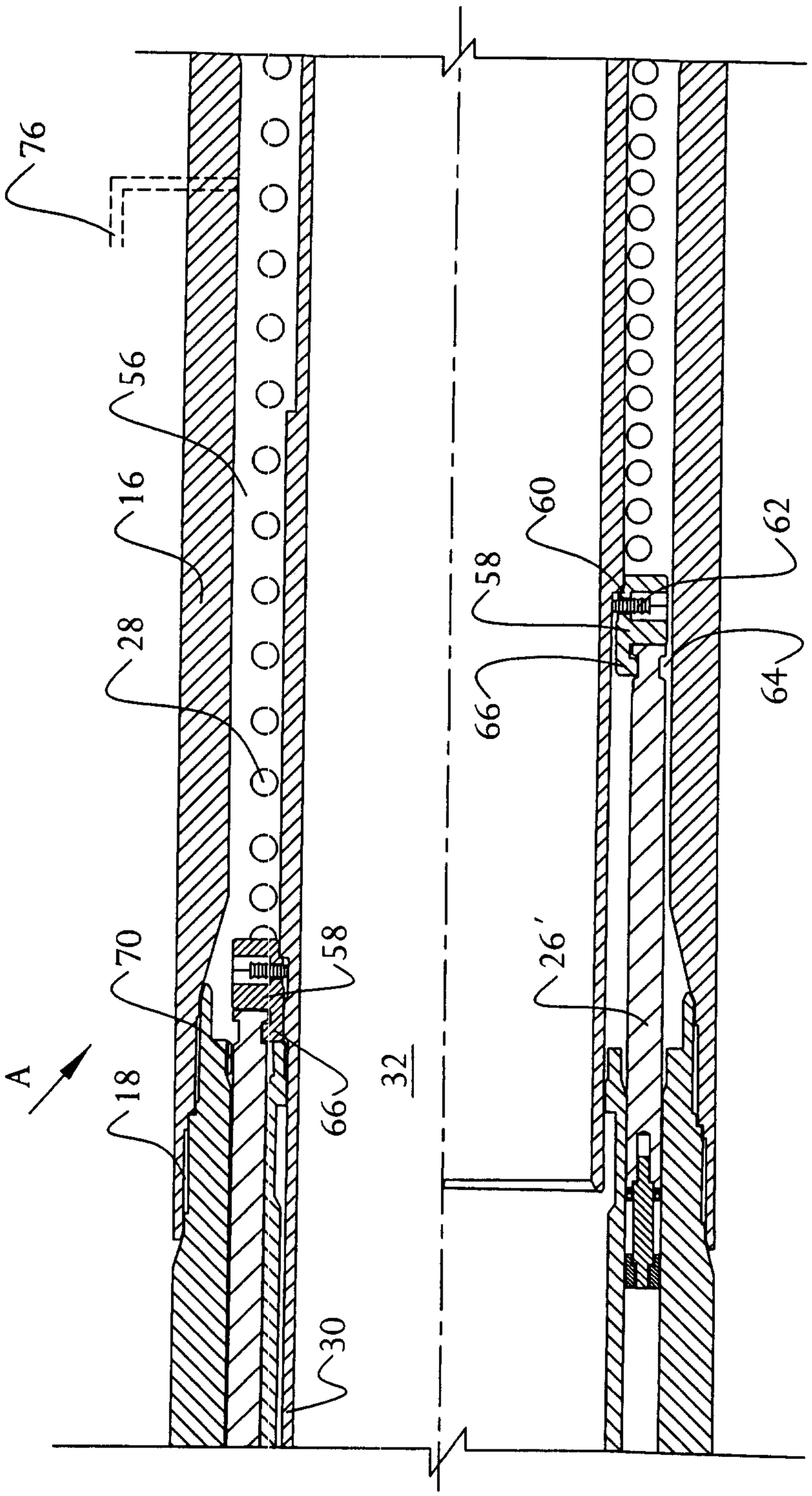


FIG. 1B

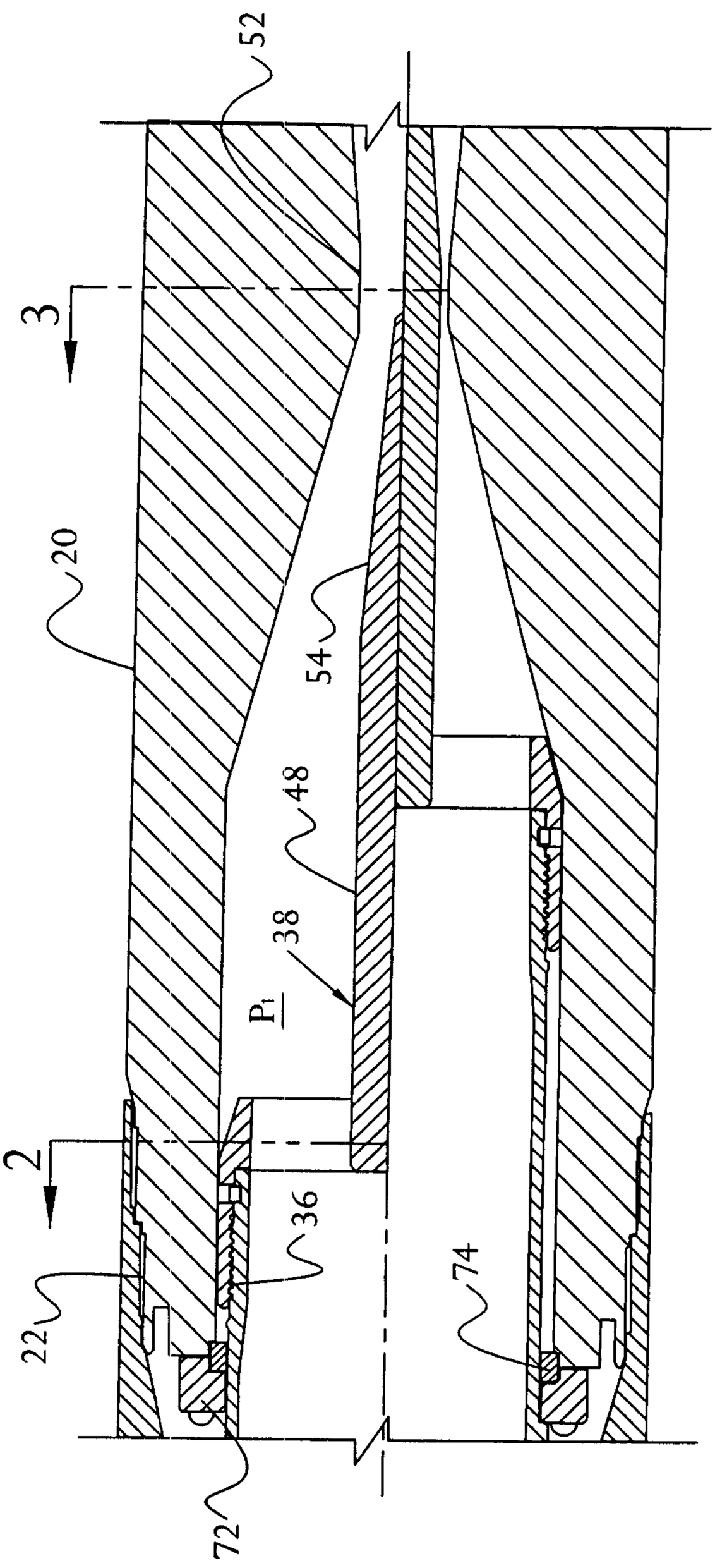


FIG. 1C

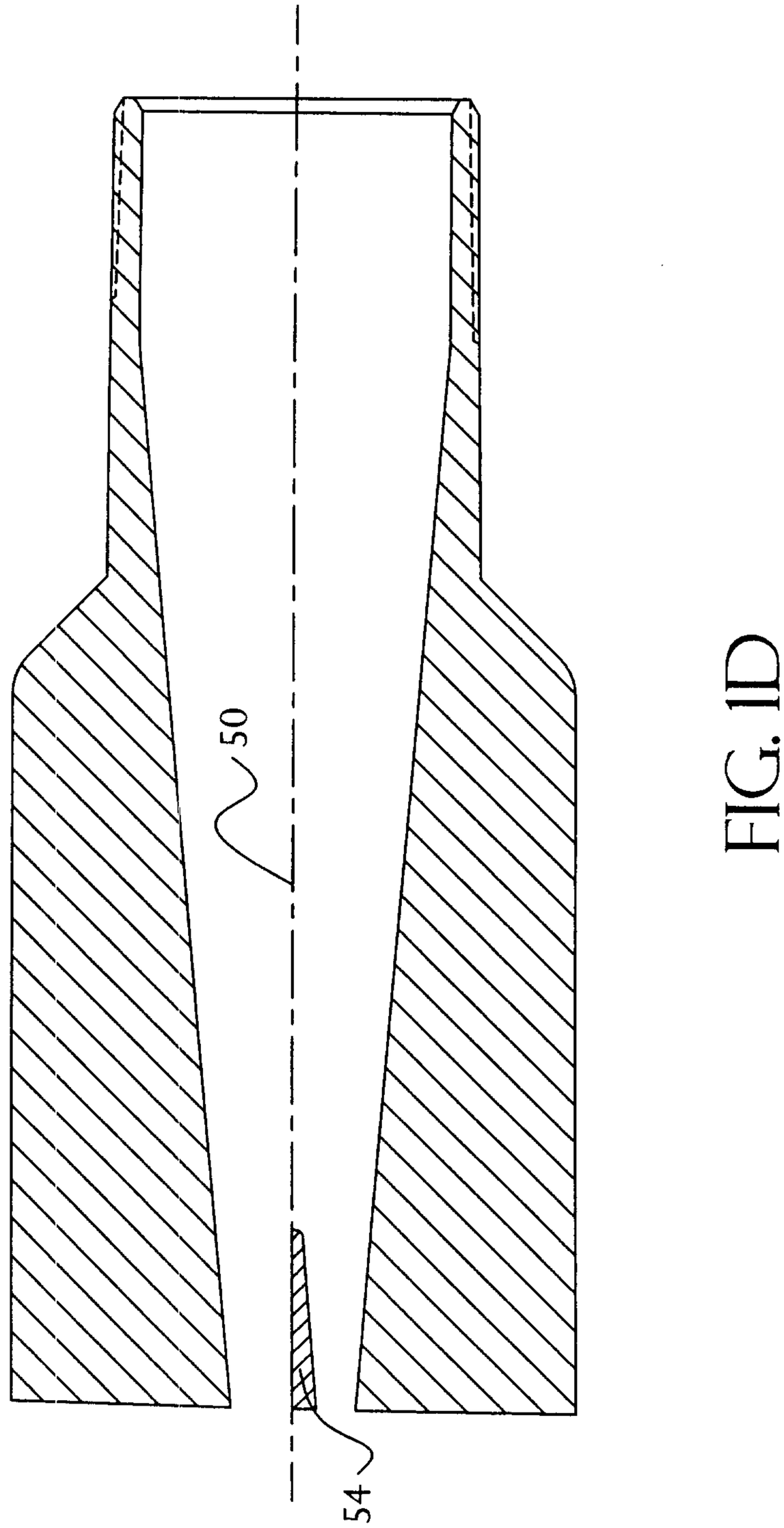


FIG. 1D

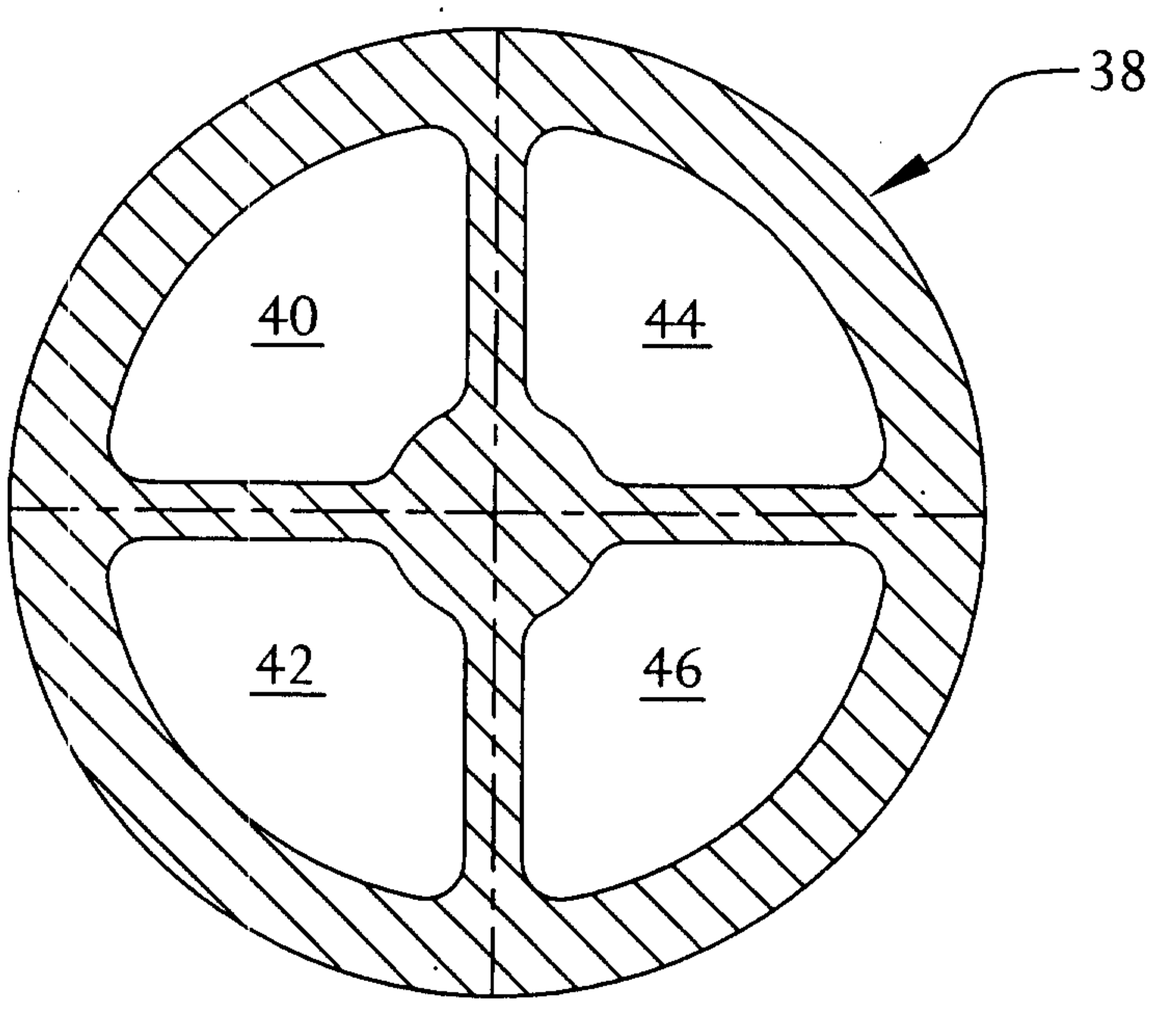


FIG. 2

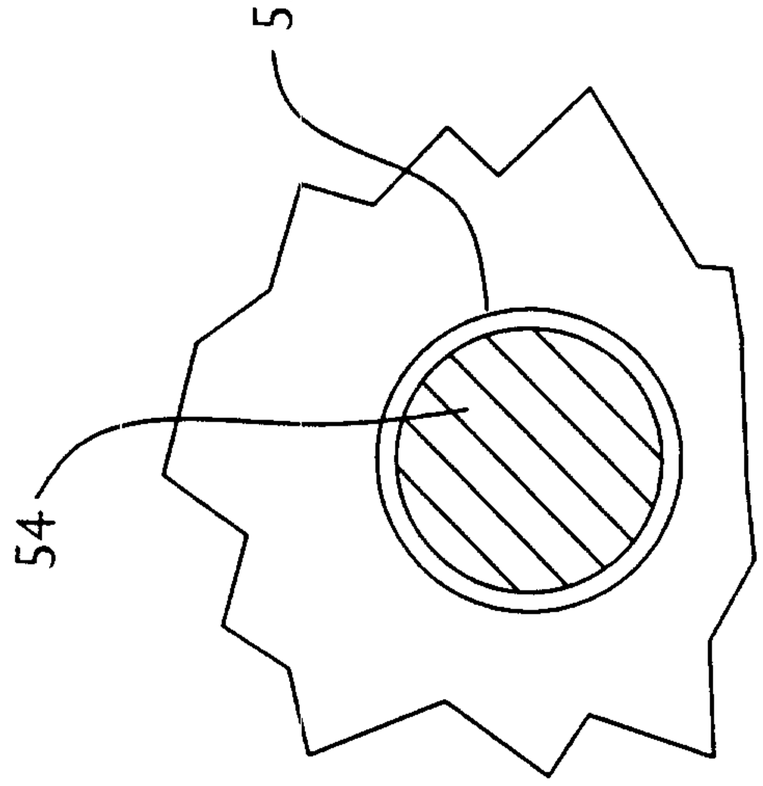


FIG. 3A

FIG. 3B

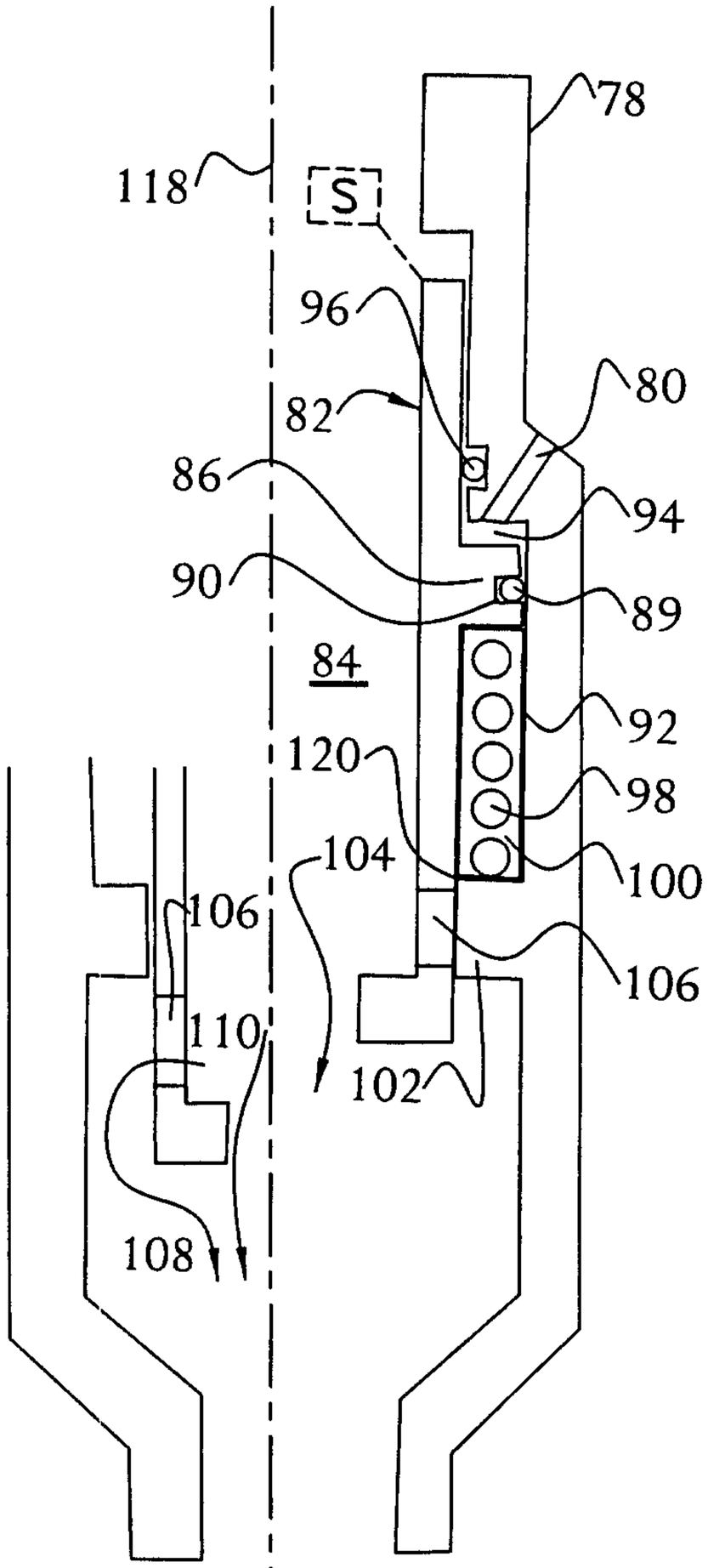
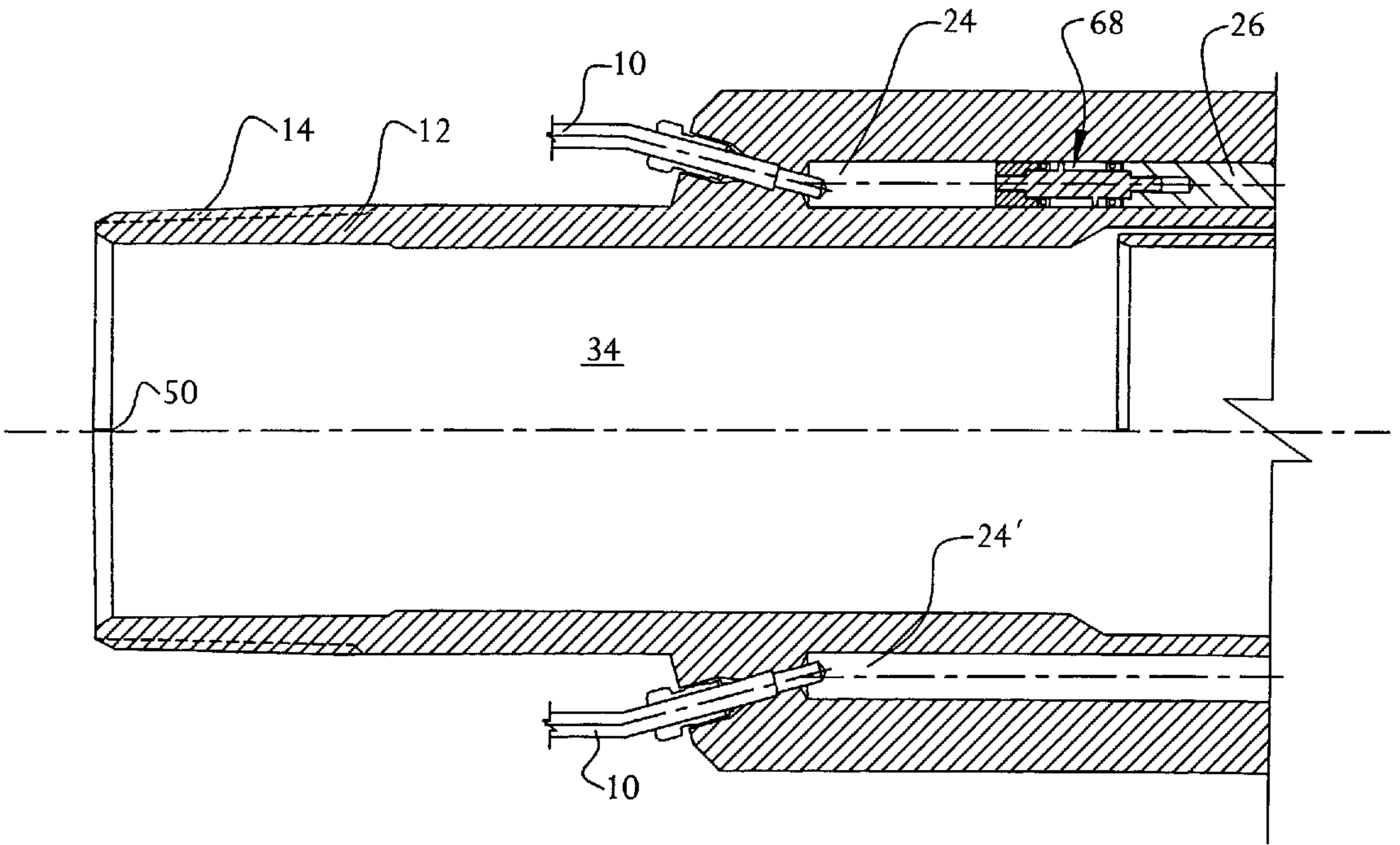

78
118
S
96
80
82
86
94
90
89
84
92
120
98
104
100
106
106
110
102
108

FIG. 4


24
68
26
10
14
12
34
50
24'
10