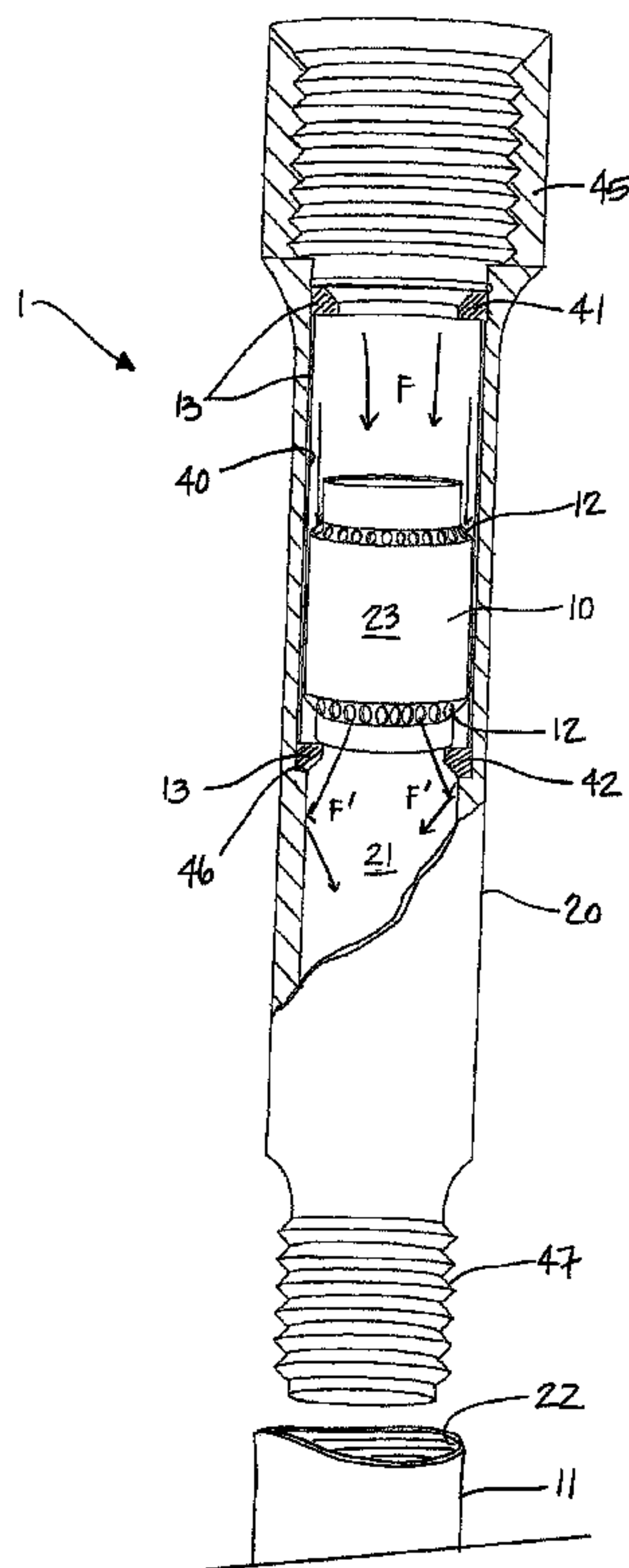




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(54) Titre : DISPOSITIF DE PRODUCTION DE VIBRATIONS DANS UN TRAIN DE TIGES
(54) Title: APPARATUS FOR INDUCING VIBRATION IN A DRILL STRING



(57) Abrégé/Abstract:

An insert having a plurality of ports creating angled passageways through the walls of the insert is positioned in a drill string for altering fluid flow in the drill string and inducing vibration sufficient to speed up directional drilling and to prevent differential sticking in wellbores. Boundary layer flow along the walls of the drill string is drawn into an upstream group of ports to commingle with fluid in the central bore of the drill string and the insert. The flow is separated at a downstream group of ports and angled passageways cause the flow to be directed radially outward inducing vibration into the drill string.

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ABSTRACT

An insert having a plurality of ports creating angled passageways through the walls of the insert is positioned in a drill string for altering fluid flow in the drill string and inducing vibration sufficient to speed up directional drilling and to prevent differential sticking in wellbores. Boundary layer flow along the walls of the drill string is drawn into an upstream group of ports to commingle with fluid in the central bore of the drill string and the insert. The flow is separated at a downstream group of ports and angled passageways cause the flow to be directed radially outward inducing vibration into the drill string.

1 **“APPARATUS FOR INDUCING VIBRATION IN A DRILL STRING”**

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FIELD OF THE INVENTION

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5 Embodiments of the invention relate to apparatus which acts to
6 induce a vibration into a drill string during drilling operations and, more
7 particularly, to aid in advancing the drill string and drill bit, particularly when
8 drilling horizontal wellbores.

8

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BACKGROUND OF THE INVENTION

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11 It is known in drilling wellbores, and particularly, horizontal
12 wellbores that inducing vibration in the drill string during drilling aids in advancing
13 the bit through the formation. In horizontal wellbores, the gravity influence on
14 moving the drill string downhole decreases and the weight lying against the low
15 side of the borehole increases as the inclination angle increases, creating large
16 frictional forces as the drill string is mechanically forced into the wellbore.
17 Vibration acts to reduce friction between the drill string and the borehole
18 permitting the drill string to move more freely therein.

18

19 Further, cleaning of the wellbore becomes more difficult as the
20 inclination angle increase. The cuttings tend to accumulate along the lower side
21 of the wellbore, about the drill string and create a situation wherein the drill string
22 is prone to sticking in the wellbore.

22

23 Further, differential sticking of drill pipe is a common problem found
24 in both vertical and horizontal drilling. Differential sticking is defined as a drill
25 pipe being stuck in a wellbore caused by a differential between the formation
pressure and the hydrostatic pressure in the wellbore. Typically, this situation

1 occurs during overbalanced drilling where a permeable zone exists over which a
2 thick layer of filtercake is deposited and there is contact between the drill pipe or
3 drill collars and the filtercake. Other factors which may contribute to differential
4 sticking are prolonged periods where the drill pipe is stationary, the length of the
5 permeable zone, the filtercake thickness, the drilling mud type and the drilling
6 mud properties. Conventionally differential sticking is resolved by jarring or
7 rotating the drill pipe to attempt to free the drill pipe from the filtercake bond,
8 chemically altering the filtercake properties and introducing nitrogen into the well
9 in an attempt to reduce the hydrostatic pressure.

10 Vibration may be induced into a drill string using mechanical
11 means to provide pulses of mechanical energy to the drill string. US Patent
12 4,384,625 to Roper et al. teaches the use of mechanical vibrators, such as
13 hydraulically driven vibrators, incorporated into a drill string to vibrate the drill
14 string at a suitable frequency and amplitude to reduce friction.

15 US Patent 4,243,112 to Sartor teaches a fluid-,driven rotary orbit
16 jet reaction-type vibrator which is driven by a compressible fluid. The vibrator fits
17 closely between a cover plate and a bearing surface and orbits about in a race
18 so as to exert an orbiting radial vibrator force sequentially in all radial directions.

19 US Patent 6,009,948 to Flanders et al. discloses a resonator
20 hydraulically operated by a fluid circulated from surface or by an electro-
21 mechanical device such as a motor or a solenoid which imparts pulses of
22 mechanical energy to aid in drilling, to free stuck drill string and to aid in
23 cementing operations.

24 One disadvantage of the prior art devices is their complexity and
25 the lack of access to permit passage of a wireline therethrough.

1 moveable therein, the venturi insert having a body fit to the bore and having a
2 central tubular bore formed therethrough for forming an annular wall extending
3 between the drill string and the tubular bore; and a tubular fluid inlet formed in
4 the insert's tubular bore projecting upstream from the annular wall; a tubular fluid
5 outlet formed in the insert's tubular bore projecting downstream from the annular
6 wall; wherein the annular wall comprises: a first angled wall extending
7 downstream between the tubular fluid inlet and the body and radially outwards
8 therefrom; a second angled wall extending downstream between the body and
9 the tubular fluid outlet and radially inwards therefrom; and a plurality of ports
10 formed in the first and second angled walls, the ports forming angled passages
11 being directed radially inwards and downstream and radially outwards and
12 downstream; wherein at least a portion of the fluid flows through the insert's
13 angled passages and at least a portion of the fluid flows through the bore, the
14 turbulence and pattern of the flow created upon exiting the insert inducing
15 vibration in the drill string.

16

17

BRIEF DESCRIPTION OF THE DRAWINGS

18 Figure 1 is a partial section view of a vibration apparatus according
19 to an embodiment of the invention, illustrating a venturi insert fit within a pup joint
20 housing for connection to a drill string;

21 Figure 2 is a perspective view of the venturi insert for the vibration
22 apparatus according to Fig. 1;

23 Figure 3 is a partial longitudinal sectional view of the venturi insert
24 for the vibration apparatus according to Fig.2, detailing the inner pipe, one of a
25 plurality of annular wall ports and the fluid flow therethrough;

1 Figure 4 is a longitudinal section view of the pup joint housing
2 according to Fig.1; and

3 Figures 5a - c are longitudinal sectional views of an internal sleeve
4 of the vibration apparatus and upper and lower sleeve retainer plates fit within
5 the pup joint housing. More particularly,

6 Fig. 5a is a longitudinal sectional view of the internal sleeve and
7 retainer rings in the pup joint housing;

8 Fig. 5b is a sectional view of the upper sleeve retainer ring; and

9 Fig. 5c is a sectional view of the lower sleeve retainer ring; and

10 Figure 6 is a partial section view of a vibration apparatus according
11 to Fig 1 illustrating a wireline passing through the bore of the venturi insert in the
12 pup joint housing.

13

1 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

2 As known to those skilled in the art, flow through a conduit,
3 including flow through a drill string, is typified by a faster flow in a center flow
4 stream and slower flow along the conduit wall; the boundary layer flow. As
5 described in Technical Monograph 41 – Understanding IEC Aerodynamic Noise
6 Prediction for Control Valves by Floyd D. Jury at
7 www.iceweb.com.au/Technical/ValveNoise.htm, noise generated downstream of
8 a valve can come from the dissipation of mechanical energy in the fluid stream at
9 a vena contracta of the valve. The primary noise mechanism is due to turbulence
10 downstream of the vena contracta and is called turbulent shear flow. As flow
11 becomes more intense due to the higher pressure drop across the valve, the
12 normal shock begins to move further downstream and breaks up into several
13 small shock cells. From each of the shock cells, shock waves are formed which
14 travel downstream at some angle from the centerline. The shock waves bounce
15 off the walls of the pipe and are reflected across the pipe to reflect off the
16 opposite wall. As the reflected shock waves “bounce” down the pipe, the waves
17 pass through the area of turbulence creating noise energy and impart vibration
18 into the pipe wall. This is called “shock-turbulence interaction”. While typically
19 this knowledge is used to reduce noise and vibration caused by flow restrictions
20 through valves, in contradistinction, in the case of the present invention, the
21 knowledge is combined with the knowledge of fluid flow through a conduit to
22 create a vibration in a drill string to aid in drilling a wellbore.

23 Having reference to Fig. 1, in embodiments of the present
24 invention, a vibration inducing apparatus 1 comprises at least one venturi insert
25 10 positioned within a drill pipe or drill string 11 to create a turbulence in a flow of

1 fluid F through the drill pipe 11. The insert 10 is positioned in the drill string 11
2 such that venturi flow of fluid F' through a plurality of ports 12 in the venturi insert
3 10 is caused to exit from the insert 10 so as to create shock-turbulence
4 interaction with the drill pipe 11 resulting in a vibration of the drill pipe 11. Means
5 13, used to position the venturi insert 10 in the drill pipe 11, are such that little to
6 no interference is created to the fluid flow F, F'.

7 More particularly, as shown in Figs. 1-5c, and in preferred
8 embodiments, the vibration inducing apparatus 1 comprises a housing 20, such
9 as a tubular pup joint, adapted for positioning within at least a portion of the drill
10 string 11, the tubular pup joint 20 fit having a central tubular bore 21 formed
11 therethrough being substantially coaxial and contiguous with a bore 22 of the drill
12 string 11. The at least one venturi insert 10 is positioned within the central tubular
13 bore 21 and, as shown in Fig. 2, has body 23 having a tubular bore 24 formed
14 therethrough being coaxial with the tubular pup joint's central tubular bore 21,
15 forming an annular wall 25 extending between the venturi insert 10 and the
16 insert's tubular bore 24. The insert's tubular bore 24 further comprises a tubular
17 fluid inlet 26 projecting upstream from the annular wall 25 and a tubular fluid
18 outlet 27 extending downstream. Further, the annular wall 25 has a first outer
19 angled wall 28 which extends downstream and radially outwards from the tubular
20 inlet toward the drill string 11 for connecting the tubular inlet 26 to the body 23
21 and a second angled wall 29 extending downstream and radially inwards for
22 connecting the body 23 to the tubular fluid outlet 27. The first and second angled
23 walls 28,29 have the plurality of ports 12 formed therein, the ports 12 forming
24 passages 30 being directed radially inwards and downstream and radially
25 outwards and upstream respectively for discharging annular fluid flow F into and

1 out of the insert's tubular bore 24, the insert 10 acting as a vena contracta, so
2 that turbulence is created in the fluid flow F', converting fluid stream power into
3 noise for inducing vibration in the drill string 11.

4 In use, wherein the drill string 11 may be stuck in a wellbore or
5 resistant to movement therein due to a high frictional coefficient between the drill
6 string 11 and the wellbore, the vibration induced in the drill string 11 acts to free
7 the drill string 11 or reduce the frictional coefficient, thereby permitting the drill
8 string 11 to advance more rapidly through a formation, particularly during
9 horizontal wellbore drilling. Further, the vibration induced in the drill string 11
10 reduces the likelihood of differential sticking during all types of drilling. Applicant
11 also believes that vibration induced in the drill string 11 above the drill bit may act
12 to absorb undesirable vibrations at the drill bit caused by the impact of the bit in
13 the formation which may cause the drill bit to bounce, reducing drilling efficiency.

14 Having reference to Fig. 3, preferably, the angle of the ports 12
15 through the angled walls 28,29 is in a range of about 24° to about 45° to a
16 perpendicular to the insert's body 23. Most preferably, the angle is in a range of
17 about 24° to about 26° and most preferably the angle is 26°. The number of ports
18 12 is varied with the diameter of the drill string 11, larger diameters having a
19 greater number of ports 12. The ports 12 form the angled passages 30 in the
20 insert 10 which act muchlike a venturi, to cause a slower boundary layer B of
21 fluid flowing adjacent the walls of the tubing string 11 to be accelerated,
22 compressed into faster sound waves S in the flow F at a central portion C of the
23 flow F and then separated again for creating a turbulent flow F' in the fluids
24 exiting and following the insert 10, the turbulence causing the drill string 11 to
25 vibrate.

1 As shown in Figs. 1, 4 and 5a-5c and in one embodiment, the
2 venturi insert 10 is fit within the pup joint's tubular bore 21 using means 13 such
3 as an internal sleeve 40 which is fixed in place by an upper and a lower retainer
4 ring or plate 41,42. A snap ring 43 is fit in a snap ring groove 44 adjacent an
5 upper threaded end 45 of the tubular pup joint 20, for connection with the drill
6 string 11, against which the upper retainer ring 41 is supported. A shoulder 46 is
7 formed in the tubular pup joint 20 against which the lower retainer ring 42 is
8 supported. The venturi insert 10 is axially moveable within the internal sleeve 40,
9 the axial movement of the venturi insert 10 being limited by the retainer rings
10 41,42. As the fluid flow F' exits the ports in the second angled wall 29, the insert
11 10 is lifted from the lower retainer ring 42 to permit flow thereby. Evidence shows
12 that the insert 10, in operation in pup tool 20 in a 3 ½ inch drill pipe, lifted
13 approximately ¾ inch from the lower retainer ring 42. A lower end 47 of the
14 tubular point joint 20 is threaded for engagement with the drill string 11.

15 In one embodiment of the invention, where the lower retainer ring
16 42 is a solid ring, the upper and lower retainer rings 41,42 are spaced sufficient to
17 allow the venturi insert 10 to be lifted off the lower retainer ring 42 by the fluid
18 flow F' exiting the ports 12 and thus permit the fluid to flow from the venturi insert
19 10 with minimal interference in the pattern of fluid flow F'. As shown in Figs. 1
20 and 3, the venturi insert 10 is fit into the internal sleeve 40 having a very small
21 radial tolerance which substantially eliminates any lateral movement restricting
22 movement to axial movement. Fluid flow F through the venturi insert 10 may
23 cause the venturi insert 10 to spin within the sleeve 40.

24 As shown In Fig. 6, most preferably, the venturi insert's tubular
25 bore 24 is sized sufficiently to permit passage of a wireline 50 therethrough to

1 permit ongoing operations during rotating and sliding portions of a horizontal
2 drilling process, for providing measurements and orientation information while
3 drilling and to free stuck floats or set plugs or packers and the like, located
4 downhole from the vibration apparatus. Most preferably, the tubular bore is sized
5 to accommodate 1 $\frac{3}{4}$ " wireline.

6 In particular drilling situations, it may be advantageous to position a
7 plurality of said vibration inducing apparatus 1 within the drill string 11 at intervals
8 along a length of the drill string 11 for creating vibration, particularly during sliding
9 operations when drilling horizontal wellbores. A plurality of vibration inducing
10 apparatus 1, as previously described are most easily inserted into the drill string
11 11 in individual housings or pup joints 20, the pup joints 20 being inserted into the
12 drill string 11 at intervals such as at tubular joints (not shown).

13 The dimensions of the vibration apparatus 1 are dependant upon
14 the diameter of the drill pipe 11 in which it is to be connected. The following is
15 illustrative of one example only.

16 In one embodiment of the invention sized for use in a 3 $\frac{1}{2}$ inch drill
17 pipe, as shown in Fig. 4, the pup joint 20 is approximately 3 feet in length L_o .
18 The snap ring groove 44 is sized to house a 3 inch snap ring 43. The internal
19 diameter ID_u of the pup joint 20, above the shoulder 46 and below the upper
20 threaded end 45 is between 3.100 inches and 3.105 inches, the wall thickness
21 W_u being about 0.31 inches. A length L_u between the shoulder 46 and the upper
22 threaded end 45 is 11 inches for housing the internal sleeve 40 and retainer rings
23 41,42 therein. The remainder of the wall of the pup joint below the shoulder has
24 an inner diameter ID_s of 2.75 inches and a wall thickness W_s of 0.43 inches. An
25 outer diameter OD_p of the pup joint 20 below the upper threaded end 45 is 3.62

1 inches. The upper threaded end 45 has an outer diameter ODt of 4.75 inches and
2 a length Lt of about 9 inches.

3 As shown in Figs. 5a-c, the inner sleeve 40 has an OD of 3.10
4 inches and an ID of 2.97 inches and a length L of 9.75 inches. The retainer rings
5 or plates 41, 42 have an OD of 3.1 inches and have an angled face 48, preferably
6 angled about 40° to 45° from a perpendicular to the insert body 23, on an
7 upstream and downstream face 49,51 respectively.

8 An insert 10 suitable for the 3½ inch pup joint having the above-
9 listed dimensions is about 6 inches in length and has an outer diameter of 2.87
10 inches and an inner diameter of 2.67 at the body portion 23. The inlet and outlet
11 26,27 extend approximately 1 inch from the angled walls 28, 29 which are angled
12 at 45 degrees and are approximately 0.25 inches in length. The body portion is
13 approximately 3.43 inches in length. The inlet and outlet 26, 27 have an outer
14 diameter of 2.5 inches and an inner diameter of 2.3 inches. Any number of ports
15 12 between eighteen to forty two ports 12, all having a diameter ranging from
16 0.1875 to 0.210 inches, are formed in each of the angled walls 28, 19.

17

18 Examples

19 In a horizontal wellbore to be drilled in northern British Columbia,
20 Canada, surface pipe was first set with a directional shoe in place. A vibration
21 apparatus 1 according to an embodiment of the invention was positioned in a
22 conventional directional drilling drill string 11 approximately 250 metres (833
23 feet) away from a drill bit. Drilling was commenced to drill out the directional
24 shoe which incorporates a rubber wiper plug and a steel shoe. Surprisingly, the
25 operation which typically takes 2-3 hours was accomplished in about ½ hour. So

1 unusual was the rapidity of the drilling time, an on-site consultant on site halted
2 the drilling so that the actual length of drill pipe 11 could be re-tallied. Further,
3 drilling cuttings were examined for evidence that the rubber plug and steel shoe
4 were actually drilled through. Evidentiary bits of rubber and steel were found in
5 the cuttings.

6 In another example, generally directional drilling is accomplished
7 with an alternating combination of repeated orientation of the drill bit by rotation
8 of the drill string and drilling using a mud motor to rotate the drill bit.

9 More specifically, during the orientation operation, the drill string 11
10 is slowly rotated to orient a bent housing in the bottom hole assembly in the
11 desired direction. A mud motor is then energized so as to rotate the drill bit
12 along a curved path in the oriented direction. The non-rotating drill string 11
13 slides along the borehole as the mud motor drills the curved path. Repeated
14 orientation is necessary for adjusting or setting the direction of the borehole.
15 Each time the borehole inclination must be adjusted, drilling is stopped, the drill
16 string is rotated to reorient the drill bit and then drilling using the mud motor is
17 recommenced.

18 Applied in this second example, typically a 1.5 metre slide in the
19 formation being drilled, took 2-3 hours and possibly up to 5 hours to accomplish.
20 Numerous slides were performed during drilling using the novel vibration
21 apparatus, the result being a significant savings in time. A particular example
22 was one 7 metre slide which took only 1 hour, 15 minutes to complete. Rig time
23 was estimated to cost about \$4000 CDN per hour. Thus, the savings realized
24 using the novel vibration apparatus were significant. An approximate saving of

1 \$10,000 CDN was made in drilling out the directional shoe and an additional
2 saving of about \$19,000 CDN for the 7 metre slide alone.

3 Other advantages arose. Additionally, soap and nitrogen used to
4 create foam to lift drilling cuttings, typically has a tendency to lose foam integrity,
5 the soap and nitrogen separating from one another. Advantageously, the
6 turbulence in the drilling fluids created by the vibration apparatus 1 acts to
7 effectively remix the soap and nitrogen improving the integrity of the foam and
8 thus providing better cleaning of cuttings from the wellbore.

9 The result of the improved cuttings removal has further advantages
10 in the drilling process, particularly related to directional surveys performed to
11 determine the direction of the drill bit after each connection is made to the drill
12 string 11. As the wellbore is much cleaner than when conventional vibration
13 apparatus are used, the directional survey is typically completed the first time it is
14 attempted. With conventional drilling techniques where much debris and cuttings
15 may remain in the wellbore, it may take 2-3 times to successfully survey the bit
16 orientation.

17

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

4
5 1. A vibration inducing apparatus for controlling fluid flow within
6 a bore of a drill string for creating vibration within said drill string comprising:

7 a venturi insert fit to the drill string's bore and being axially
8 moveable therein, the venturi insert having a body fit to the bore and having a
9 central tubular bore formed therethrough for forming an annular wall extending
10 between the drill string and the tubular bore; and

11 a tubular fluid inlet formed in the insert's tubular bore projecting
12 upstream from the annular wall;

13 a tubular fluid outlet formed in the insert's tubular bore projecting
14 downstream from the annular wall; wherein

15 the annular wall comprising:

16 a first angled wall extending downstream between the
17 tubular fluid inlet and the body and radially outwards therefrom;

18 a second angled wall extending downstream between the
19 body and the tubular fluid outlet and radially inwards therefrom; and

20 a plurality of ports formed in the first and second angled
21 walls, the ports forming angled passages being directed radially inwards
22 and downstream and radially outwards and downstream;

23 wherein at least a portion of the fluid flows through the insert's
24 angled passages and at least a portion of the fluid flows through the bore, the
25 turbulence and pattern of the flow created upon exiting the insert inducing
26 vibration in the drill string.

27

1 2. The vibration inducing apparatus as described in claim 1
2 further comprising a housing for positioning the venturi insert within the at least a
3 portion of the drill string, further comprising:

4 means for securing the venturi insert within a bore of the housing
5 for axial movement therein.

6

7 3. The vibration inducing apparatus as described in claim 2
8 wherein the means for securing the venturi insert in the housing further
9 comprises:

10 an internal sleeve fit within the bore of the housing for housing the
11 venturi insert and receiving the fluid flow, the insert being axially moveable
12 therein; and

13 upper and lower retaining rings for retaining the internal sleeve in
14 the housing's bore and for limiting the axial movement of the venturi insert
15 therebetween.

16

17 4. The vibration inducing apparatus as described in claim 3
18 further comprising:

19 a shoulder formed in the housing against which the lower retainer
20 ring is supported;

21 a snap ring against which the upper retainer ring is supported; and

22 a snap ring groove formed in the housing for accepting the snap
23 ring for retaining the internal sleeve and retaining rings in the housing bore.

24

1 5. The vibration inducing apparatus as described in claim 2
2 wherein the housing is a pup joint threaded at an upper and lower end for
3 connection to the drill string.

4

5 6. The vibration inducing apparatus as described in claim 1
6 wherein the plurality of ports are angled from about 24° to about 28°.

7

8 7. The vibration inducing apparatus as described in claim 6
9 wherein the plurality of ports are angled 26°.

10

11 8. The vibration inducing apparatus as described in claim 1
12 wherein the insert's bore is sized sufficient to permit passage of a wireline
13 therethrough.

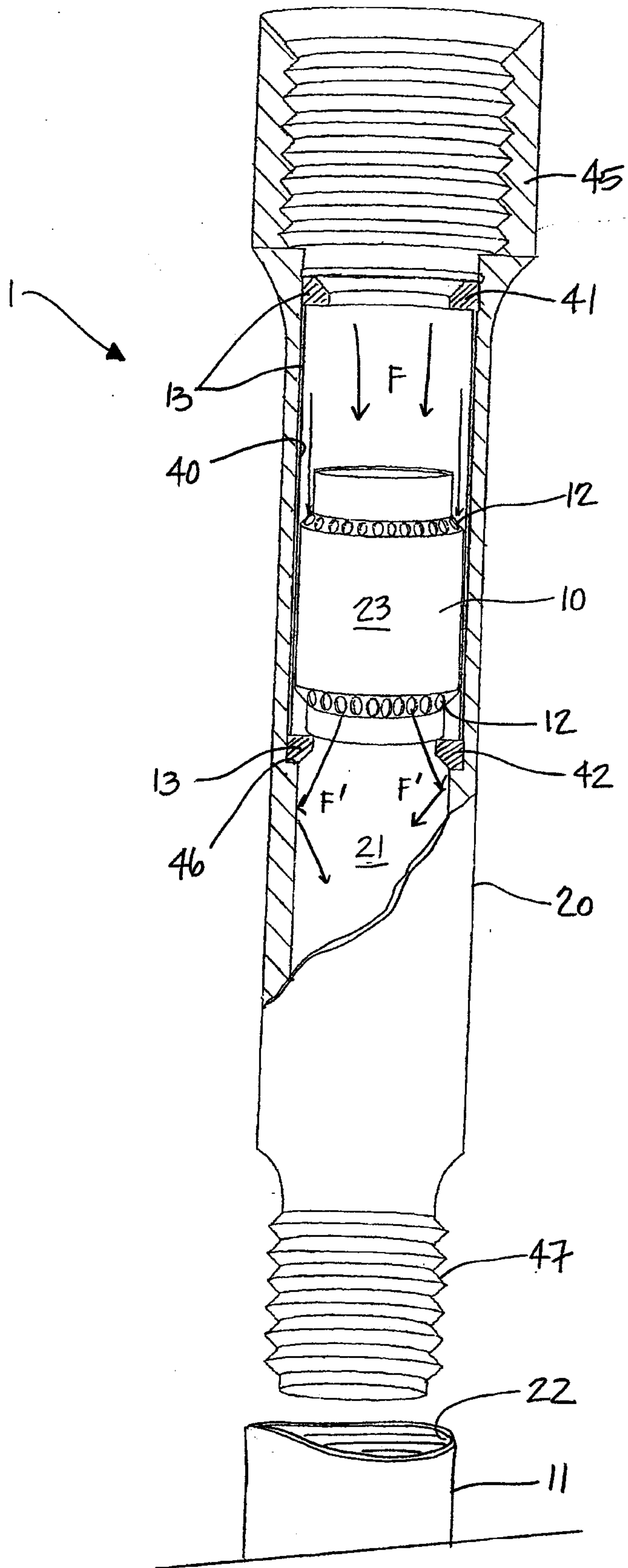
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15 9. The vibration inducing apparatus as described in claim 1
16 wherein a number of the ports varies depending upon a diameter of the venturi
17 insert.

18

19 10. The vibration inducing apparatus as described in claim 5
20 wherein a plurality of pup joints are threadedly engaged within a drill string at
21 selected intervals for inducing vibration therealong.

Fig. 1



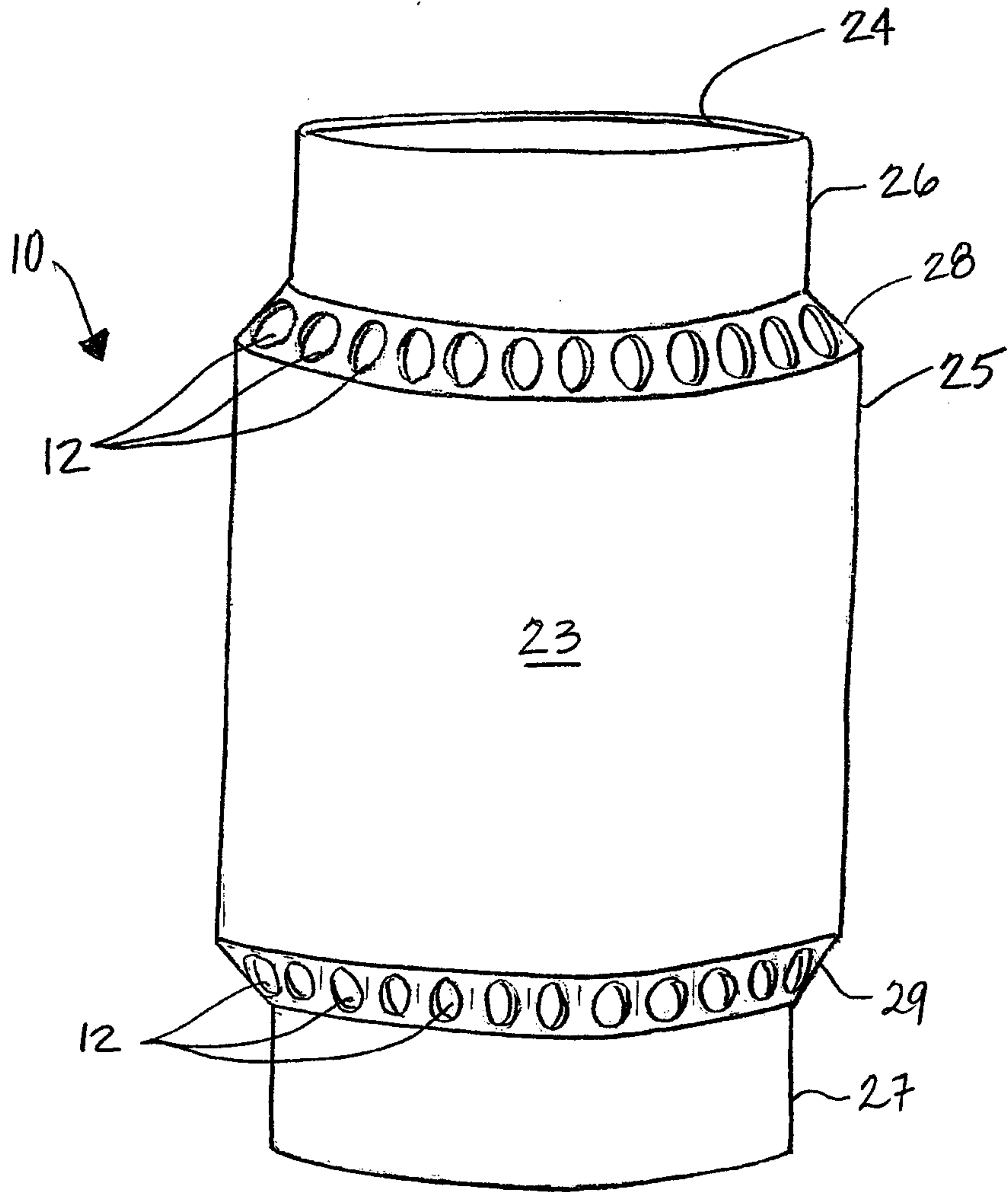


Fig. 2

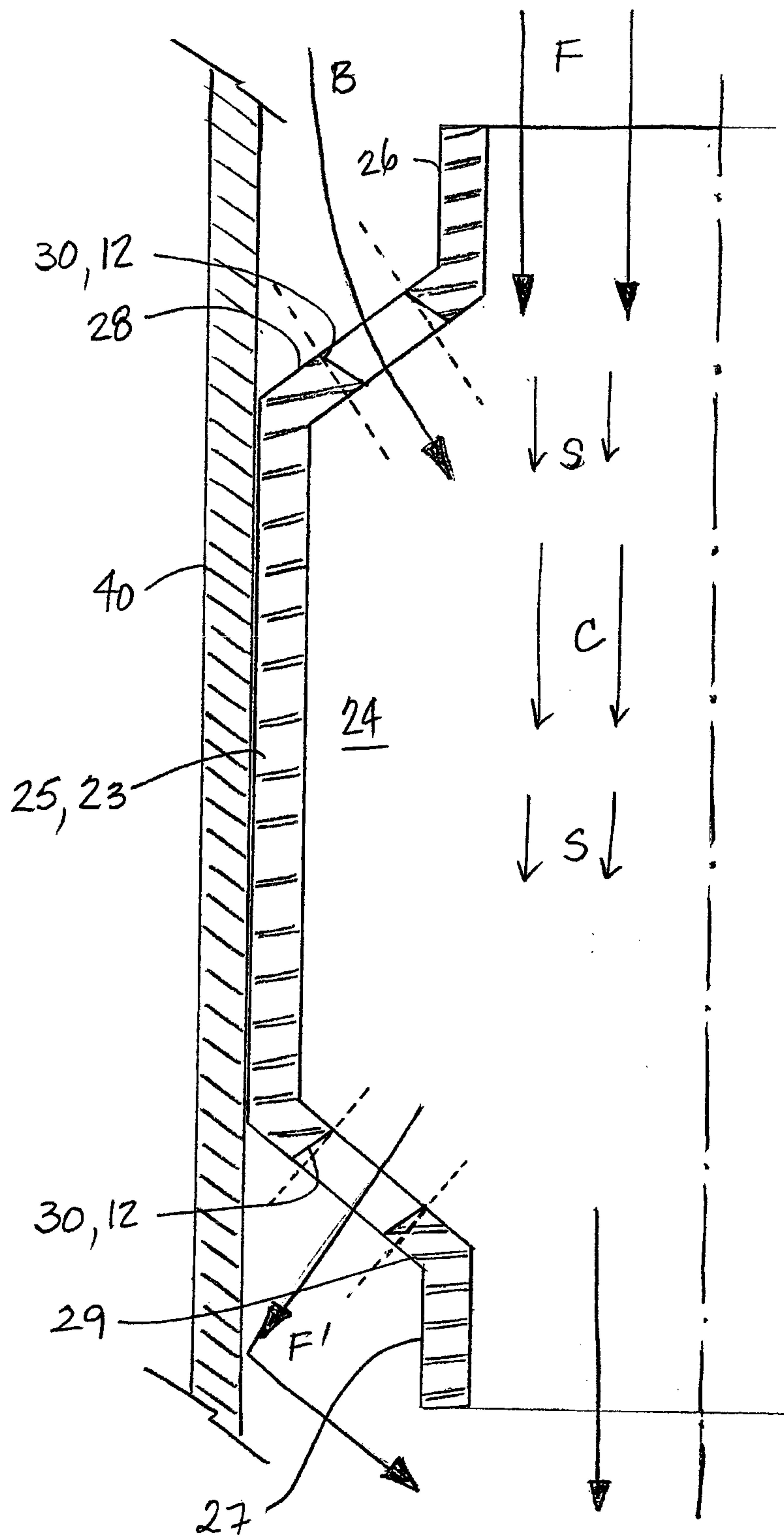


Fig. 3

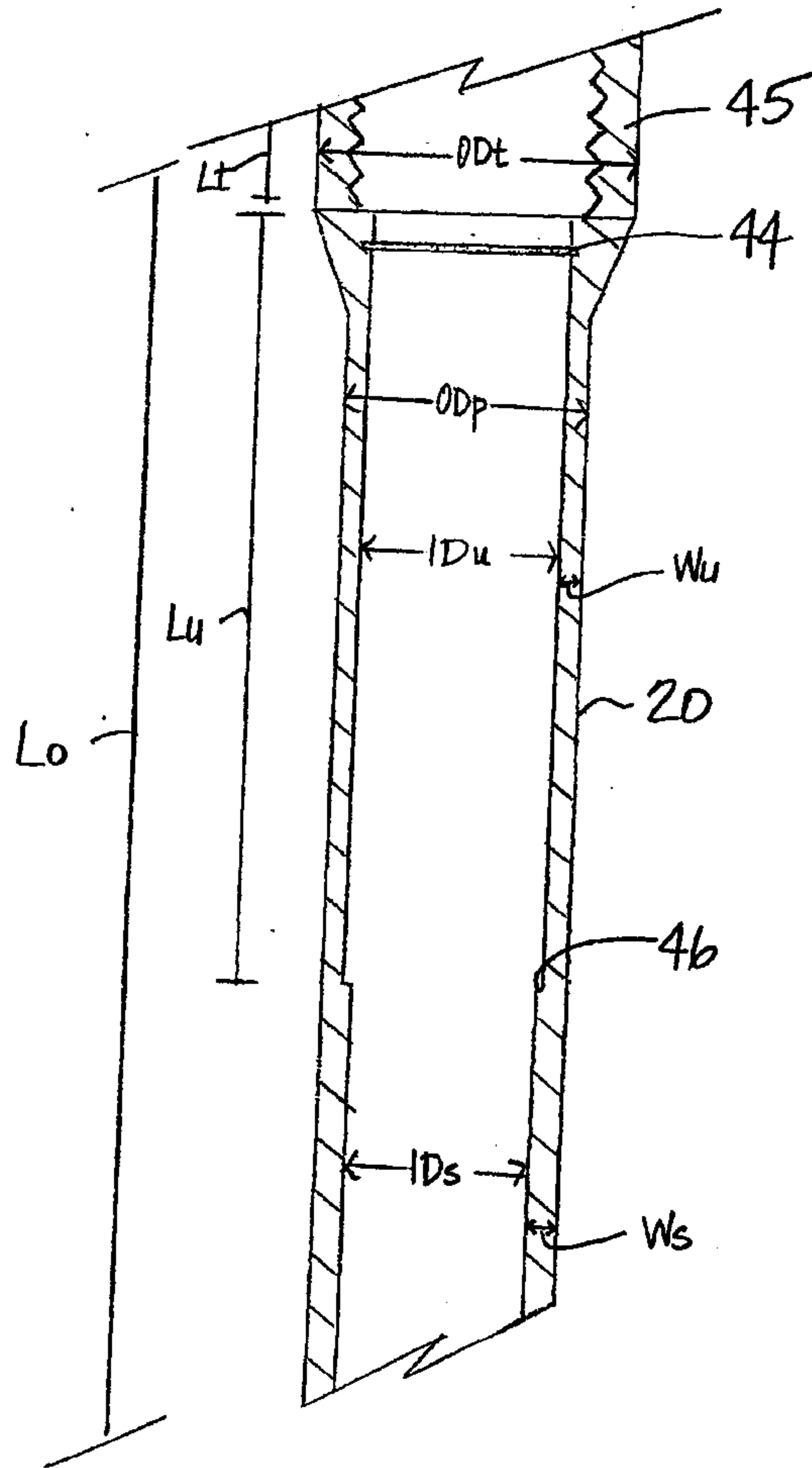


Fig. 4

Fig. 5a

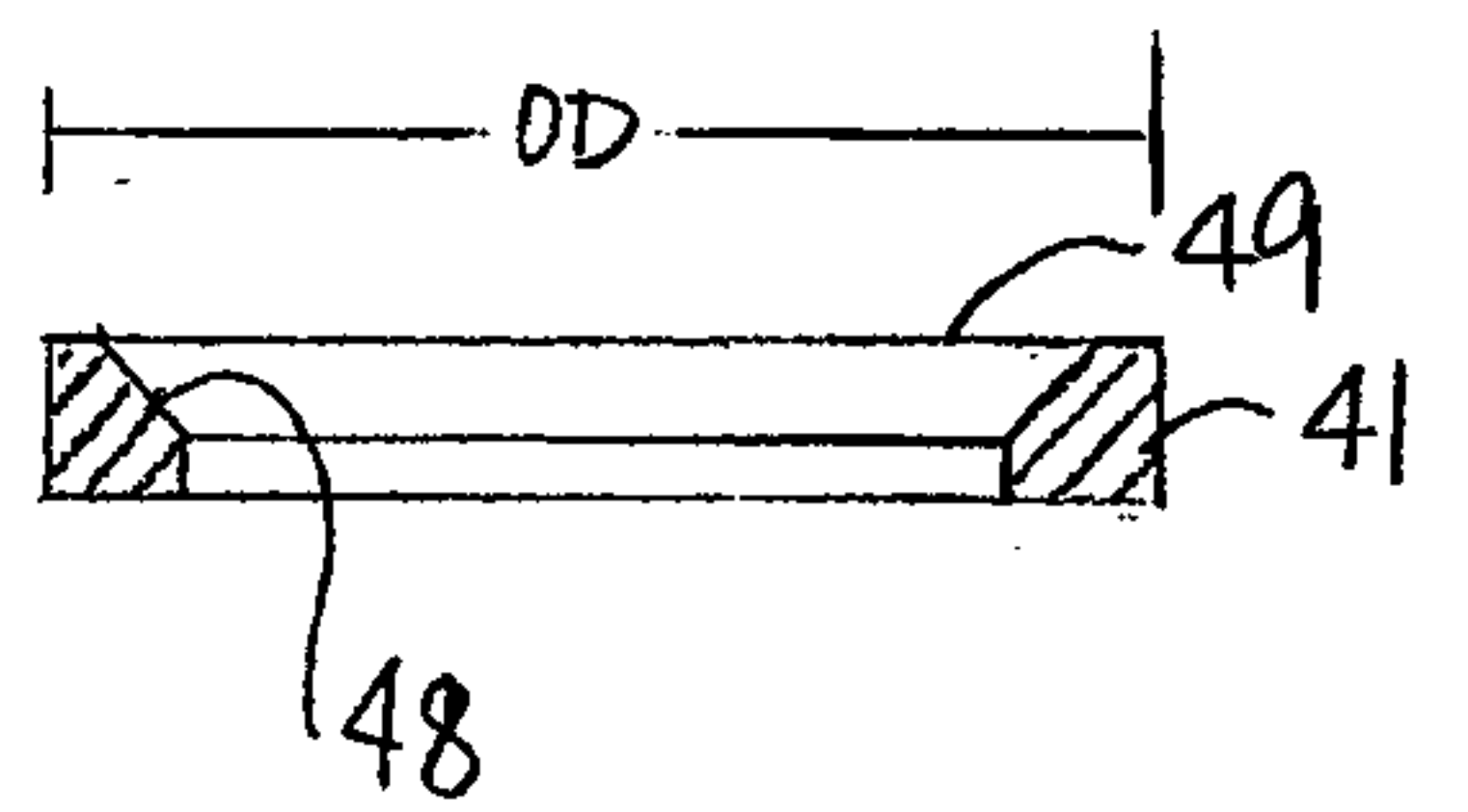
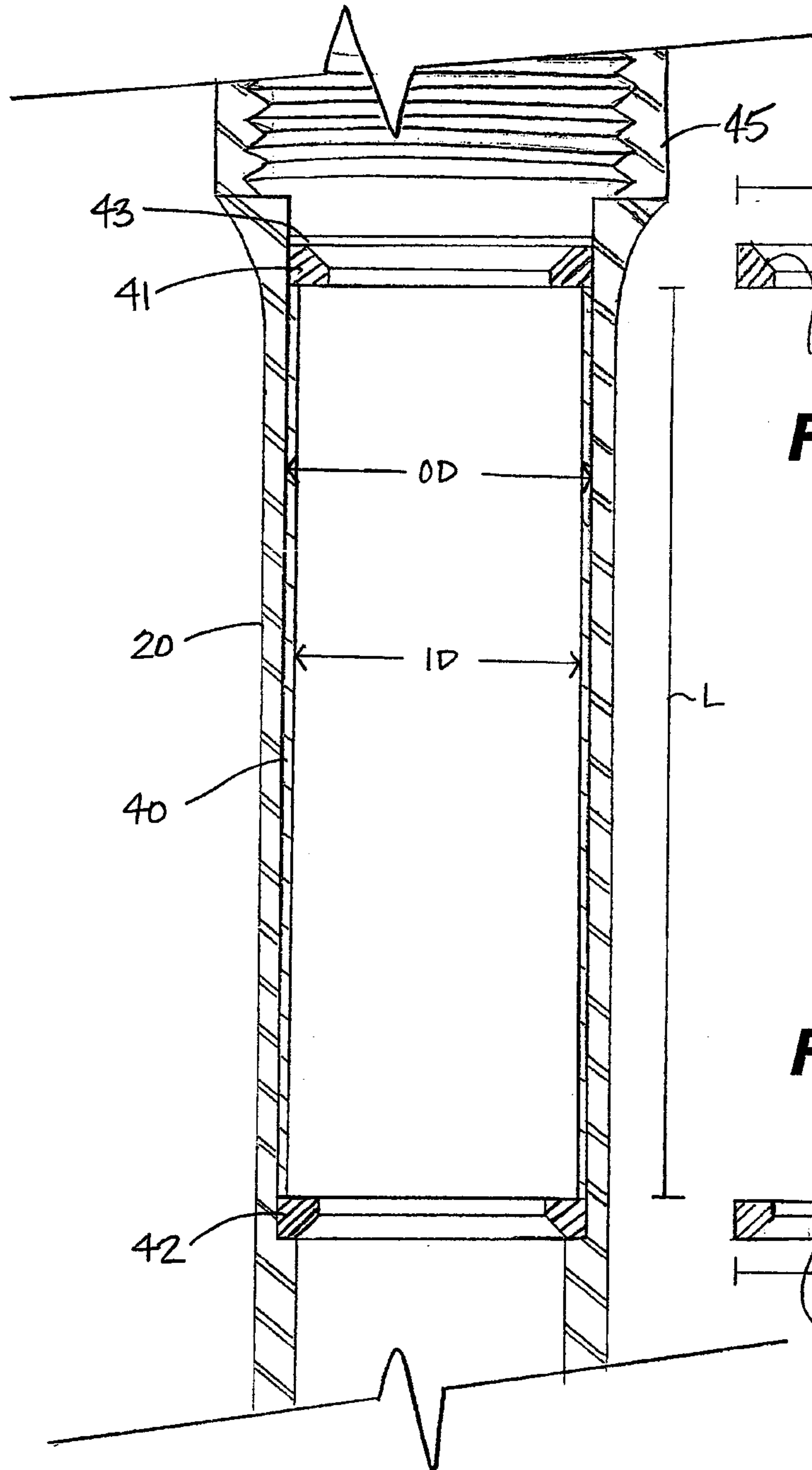
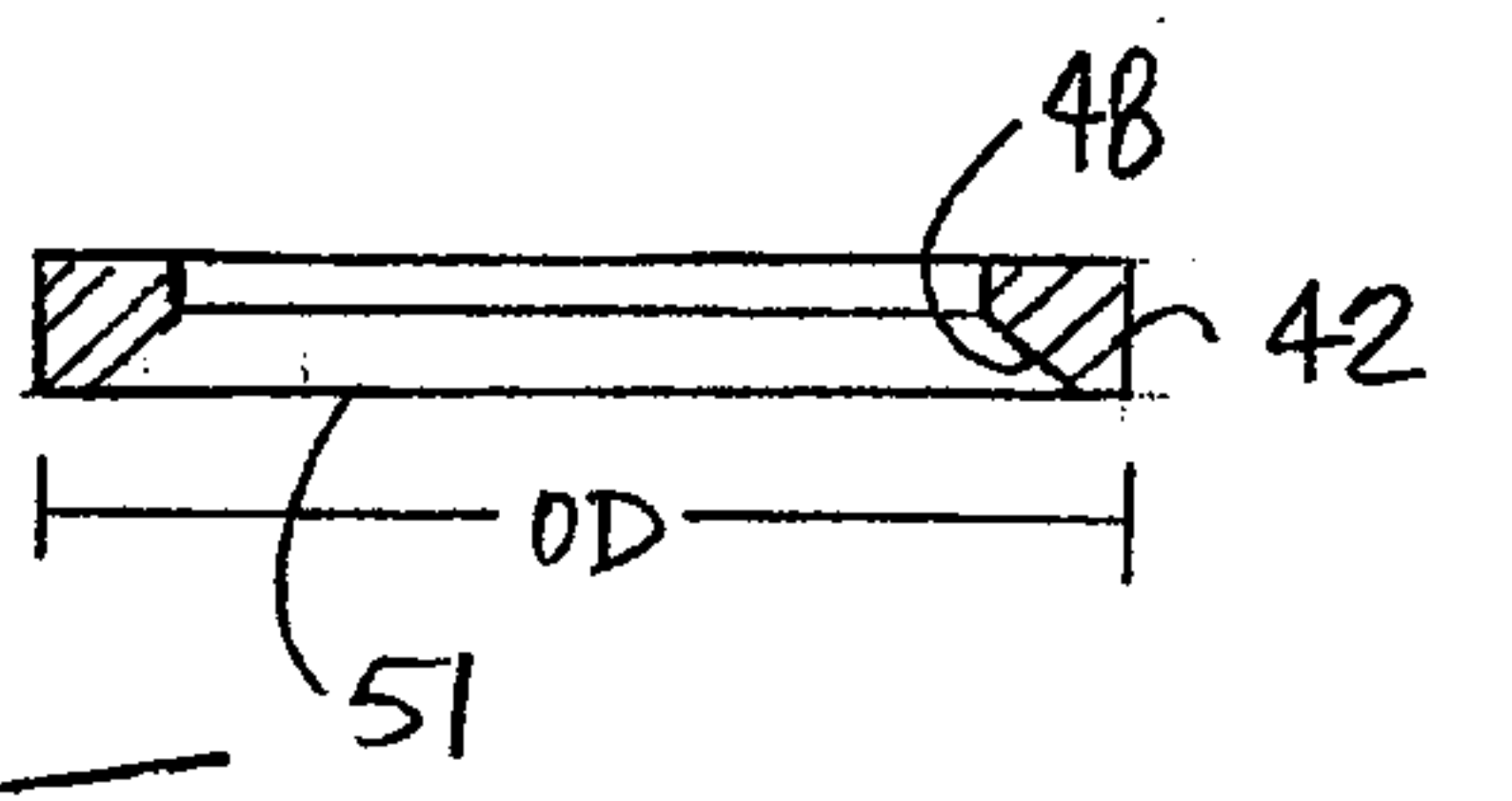


Fig. 5b

Fig. 5c



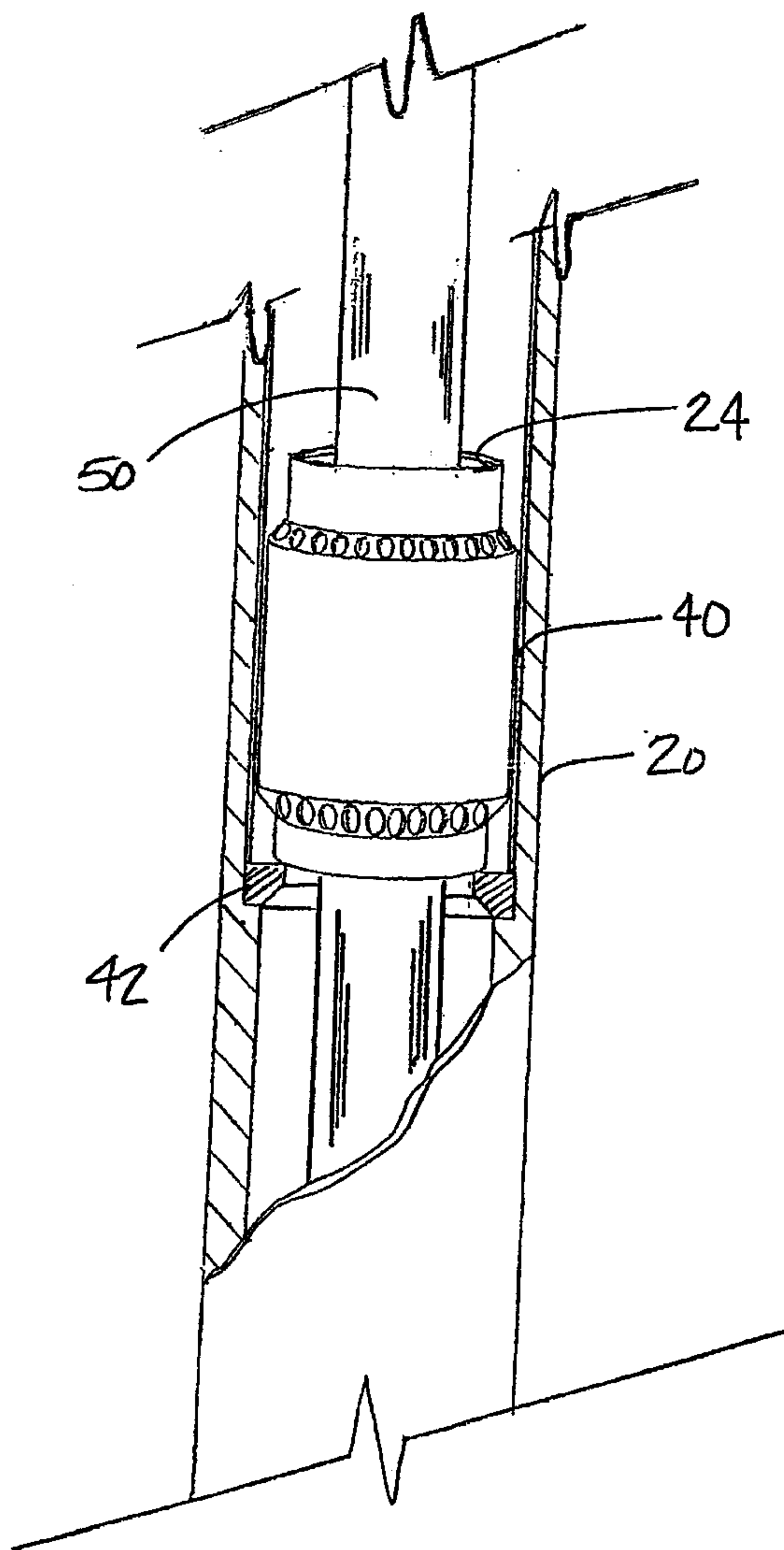


Fig. 6

