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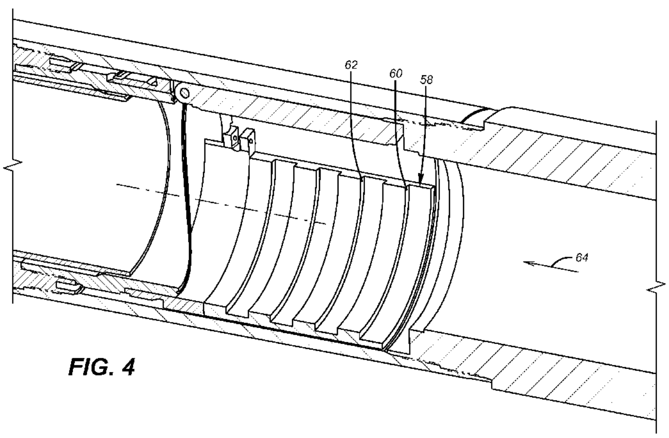

FIG. 4

(57) Abstract: The problem of flappers that will not close due to high velocity gas rushing past and creating a vortex that has zones of high pressure pressing the flapper against the force of the torsion spring is reduced or overcome with modifications in the passage through a subsurface safety valve so as to reduce the intensity of the vortex to allow the torsion spring to pivot the flapper to closed position. Various shapes are inserted adjacent the flapper base to create turbulence to minimize or prevent the vortex and the associated pressure increases that would otherwise prevent flapper closure with the flow tube retracted. Inserts that create turbulence are placed in a recess that in part holds the flapper when it is rotated to the open position.

WO 2012/015748 A2

PRESSURE VORTEX DEVICE TO ALLOW FLAPPER CLOSURE IN HIGH VELOCITY FLUID APPLICATIONS

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FIELD OF THE INVENTION

[0001] The field of the invention is subterranean safety valves of the flapper type and more particularly vortex control features that allow the flapper to close in high velocity fluid flow applications.

BACKGROUND OF THE INVENTION

[0002] Subsurface safety valves generally have a flapper that is closed by a torsion spring that is mounted on a pivot pin for the flapper. A hydraulic control system actuates a piston to move a flow tube in the valve passage against the flapper to hold it open. If pressure in the hydraulic system is removed or lost, the closure spring acts on the flow tube to lift it away from the flapper that until that time had been behind the flow tube in a recess in the housing. Once the flow tube moves up the torsion spring in the flapper pivot shaft would do the work of starting rotational movement of the flapper toward its conforming seat. When the flapper contacted the seat the pressure of the fluid below kept the flapper in that closed position sealed against the flapper seat. Pressurizing the control system again brought the flow tube against the closed flapper and made it pivot off the seat back to the open position.

[0003] As safety valves were made with larger flow bores and dealt with higher velocities particularly in gas service transient vortexes were formed of high pressure zones that changed location depending on the velocity. At certain flow passage dimensions and flow velocities these high pressure zones occurred in front of an open flapper to create a sufficient hold open force that the torsion spring was unable to move the flapper to the closed position even after the flow tube was raised to allow such flapper movement.

[0004] In the past, in addressing the larger sized flapper safety valves and the limitations of the torsion spring to move an ever heavier flapper, designs were developed along the lines of providing an assist to the torsion spring to start the flapper moving toward the closed position when the flow tube was raised up. USP 6,227,299 used a leaf spring 122 located behind the flapper 86 to add a closing force. US Publication 2009/0151924 uses a shape memory alloy closure spring to get a boost in the flapper closing force. Going in the opposite direction, USP 7,703,532 holds the flapper open with movably mounted magnets and USP 7,270,191 provides a mechanism to open the flapper when it will not go from the closed to the open position with the hydraulic system. US Publication 2009/0032238 uses repelling magnets in the housing and the flapper to give an assist to a torsion spring on the flapper pivot pin. USP 7,448,219 is a hingeless flapper design that shapes the flapper to be aerodynamic so that it can operate responsive to the flow passing by in an automotive application. USP 7,644,732 uses a bypass technique for dealing with pressure surges in a lubrication system when the circulating oil is still cold.

[0005] The various solutions discussed above have in common a focus on adding a closing force when it is time for the flapper to go to the closed position. The present invention addresses the configuration of the flow passage to reduce or eliminate the effect of flow induced pressure transients that can overcome the ability of the flapper torsion spring to close it in high velocity fluid flow situations in the order of 300 feet per second or higher. Rather than adding to the mechanical closing force applied to the flapper, the present invention focuses on dissipation of flow induced moving pressure gradients that can act on the flapper at the time it needs to close and reducing their affects by shaping the profile of the flow passage in the vicinity of the flapper or the flapper itself so that the localized pressure differentials are not large enough to overcome the torsion spring trying to close the flapper. Those and other aspects of the present invention will become more apparent to those skilled in the art from a review of the description of the preferred embodiment and the associated drawings while recognizing that the full scope of the invention is provided by the appended claims.

SUMMARY OF THE INVENTION

[0006] The problem of flappers that will not close due to high velocity gas rushing past and creating a vortex that has zones of high pressure pressing the flapper against the force of the torsion spring is reduced or overcome with modifications in the passage through a subsurface safety valve so as to reduce the intensity of the vortex to allow the torsion spring to pivot the flapper to closed position. Various shapes are inserted adjacent the flapper base to create turbulence to minimize or prevent the vortex and the associated pressure increases that would otherwise prevent flapper closure with the flow tube retracted. Inserts that create turbulence are placed in a recess that in part holds the flapper when it is rotated to the open position. Additionally and alternatively the flapper itself can be machined so as to create a larger annular space behind the flapper when it is open so that some part of the generated vortex can be used to push the flapper to the closed position and to offset the high pressure zones created on the other side of the open flapper.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. 1 is a prior art view of a flapper in the open position even after the flow tube moves uphole and flow passing through the passage that holds the flapper open due to a vortex causing high pressure;

[0008] FIG. 2A schematically shows the vortex against the flapper to hold it open;

[0009] FIG. 2B illustrates the vortex shown in FIG. 2A and the high velocity flow passing straight through as the flapper is held open;

[0010] FIG. 3 shows one form of a device to reduce the pressure in the vortex using a partial sleeve that comes to a point directed at the incoming flow and has opposed sides sloping away from the leading point;

[0011] FIG. 4 puts an insert in the groove where the flapper is located when it is open showing a series of transverse ridges; and

[0012] FIG. 5 shows an insert member in the groove where the flapper is located in the open position where the insert has an internal open space.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0013] As an introduction to the issue addressed by the invention FIG. 1 illustrates a tubular string **10** that has a safety valve housing **12** secured to the string **10** at opposite ends **14** and **16**. In the position of FIG. 1 the flow tube (not shown) has already been raised by a control system (not shown).

Normally, the raising of the flow tube allows a torsion spring **20** about a pivot shaft **18** to apply its stored potential energy force and rotate the flapper **22** toward a schematically illustrated seat **24**. All the components of the housing **12** are not shown to add clarity to the identification of the issue using FIG. 1. Arrow **26** represents the incoming high velocity stream that is most likely to be gaseous and in the order of about 300 feet per second or higher to cause the problem. Flow lines **28** graphically illustrate how most of the flow goes straight through the housing **12** in a direction toward the surface. However, depending on the velocity and the composition of the passing fluid some of the flow begins to ebb into the recess **30** and create a vortex **32** generally that begins away from the location of the flapper **22** and works its way around the housing **12** in the recess **30**. The vortex creates a high pressure concentration that is shiftable with the velocity that passes through the housing **12**. In the beginning as the velocity picks up the vortex **32** is located near the lower end **34** of the flapper **22**. At that location, the vortex **32** can actually be an aid to closure of the flapper **22** as it can pass through the gap **36** between the inside of the recess **30** and the housing **12**. Once reaching the small annular space **38** defined by the tapered surface **40** on flapper **22** and the housing **12**, the presence of the higher pressure at location **38** helps push the flapper away from wall **42**. However as the velocity increases and the center of the higher pressure vortex **32** moves closer to the surface and toward the pivot shaft **18** the moment balance shifts and there is an ever greater moment acting on the top side **44** of the flapper that can be easily in excess of the closing moment applied by the torsion spring **20** as aided by what remaining portions of the vortex **32** still in the vicinity of the gap **36**.

[0014] FIG. 2A adds to the schematic representation of how the vortex **32** works its way circumferentially to the top surface **44** of the flapper **22**. FIG. 2B is the same illustration as FIG. 2A but showing a different viewing angle for more of a perspective view. Should the velocity at the time the flow tube is raised in an effort to have the torsion spring **20** rotate the flapper **22** to a closed position against its seat **24**, the result can be that there is no flapper **22** movement at all. This can defeat the operation of the safety valve and can cause a blowout that would otherwise be prevented by the proper operation of the safety valve.

[0015] There are several ways that this situation can be addressed and three variations are illustrated in FIGS. 3-5 as preferred without any intent on limiting the variety of the approaches that look to reconfigure the internal passage in the housing **12** or the relation of the passage **44** to the flapper **22** or/and shaping of the flapper so that the vortex **32** is minimized in its intensity to the point where the torsion spring **20** can close the flapper **22'** as needed or in the ideal case prevent the vortex **32** from forming at all. In FIG. 3 the shoulder **46** and the flapper base **48** define the recess **30'** between them. Since the view in FIG. 3 is in section, only one half of the insert **50** is illustrated. The balance of the insert **50** that is not shown is preferably the mirror image of what is depicted. As a result the shape forms a downhole oriented point that can be sharp or blunt **52** from which opposed sides **54** extend and diverge in a direction toward the surface. The flow direction is given by arrow **56**. The thickness of the insert **50** as well as its shape can be optimized using Computational Flow Dynamics software that can create a three dimensional model of the flow regime through the passage **44**. Thus the height of the insert **50** can be varied to be taller, shorter or about the same height as the shoulder **46** that defines the recess **30'**.

[0016] n a variation of the FIG. 3 design the insert **50** can be shaped to be a cylindrical member that fills partially to totally that portion of the recess **30'** that continues beyond the sides of the flapper **22'** so that in essence the circumferential extent of the recess **30'** is somewhat wider that the width of the flapper **22'** and that is it. Alternatively the flapper base **48** can be extended to accomplish the same result in a one piece rather than a two piece construction.

[0017] Another option is shown in FIG. 4 where the insert **58** is similarly positioned as in FIG. 3 and this time has a series of ridges such as **60** and **62** that are transverse to the direction of flow **64** that would otherwise cause the vortex **32** to form. The number and height and orientation of the ridges can also be optimized for the expected flow velocities. There can be ridge combinations that are transverse as shown in FIG. 4 combined with some ridges that are closer to parallel to the flow direction. A surface roughening on the face of the insert that faces the passage **44** is another alternative to control the vortex **32'**.

[0018] Another approach is seen in FIG. 5 where the insert **65** has a void **66** that in the FIG. 5 is illustrated as square. Here again as in FIGS. 3 and 4 what is shown is a part of the insert **64** without the mirror image of it that is not in the illustration. Here again the void shape can be varied and optimized by mathematical modeling. There are other options for vortex control that can be implemented. For one the width of the gap **36** can be varied. Another approach is to increase the volume of the space behind the flapper and the surrounding housing. One example is to machine grooves on the back side of the flapper that faces the wall **42'** such as schematically illustrated by the dashed line **68**. There is a limit to the extent that the grooves on the back of the flapper can be used especially in the larger sizes as the flapper has to take large pressure differentials when closed and adding grooves can promote flapper distortion under maximum working pressure differentials to the point where leakage can occur. The idea on the back of the flapper is to create empty space behind the flapper to enable the vortex **32** to get into that space and add a closing moment that can help the torsion spring close the flapper.

[0019] It should also be noted that as the velocity increases the vortex **32** moves closer to the pivot shaft **18** and has a much smaller moment arm in the high pressure zone that it creates. That is one reason that the various inserts of FIGS. 3-5 end at the flapper base **48**. Optionally there can be a gap between the insert of any of the illustrated configurations or others that can be developed with mathematical modeling and the flapper base.

[0020] Another option to get an assist to the flapper **22'** is illustrated in FIG. 3. A passage or passages **70** can start at passage **44** at a location **72** that is above the shoulder **76** where the flow tube **77** lands when the valve is in the open position. When the vortex **32** is centered on the flapper **22',** the tubing pressure in the passage **44** can be communicated to the zone behind the flapper **22'** at **74**. The passage **70** can be run as shown in FIG. 3 or it can use an external jumper if the passage from location **72** is run to the exterior face **79** and then jumpered to the outer face and into a lateral bore of the housing **81** in behind the flapper **22'**.

[0021] While the illustrated valve is shown as operated with a flow tube **77** other designs using flappers that operate without a flow tube are also contemplated. Such devices can be powered by magnetic or other force fields to move the flapper between the open and closed positions.

[0022] The above description is illustrative of the preferred embodiment and various alternatives and is not intended to embody the broadest scope of the invention, which is determined from the claims appended below, and properly given their full scope literally and equivalently.

We claim:

1. A valve for subterranean use in a tubular string, comprising:

a housing with end connections adapted for mounting the housing to the string;

a flapper pivotally mounted in a recess adjacent a passage in said housing, said passage extending between said ends, said flapper mounted on a pivot and biased to move toward a seat that surrounds said passage when said flapper is not selectively retained in said recess, said flapper defining the closed position by contacting said seat; and

an insert mounted at least in part in said recess said insert acting to at least reduce a flow induced vortex in said passage adjacent said flapper, said vortex, without said insert, otherwise raising pressure adjacent the flapper to a level that retains said flapper in said recess by overcoming said bias to said closed position when said flapper is not selectively retrained in said open position.

2. The valve of claim **1**, wherein:

said insert is a shape integrated into a flapper base that is disposed in said recess and pivotally supports said flapper.

3. The valve of claim **1**, wherein:

said insert is spaced apart from a flapper base that is disposed in said recess and pivotally supports said flapper.

4. The valve of claim **1**, wherein:

said insert is wider adjacent a flapper base located in said recess than at an opposite end thereof.

5. The valve of claim **1**, wherein:

said insert comprises at least one ridge.

6. The valve of claim **5**, wherein:

said ridge comprises a plurality of aligned ridges oriented parallel, perpendicular or obliquely to the flow through said passage.

7. The valve of claim **4**, wherein:

said opposite end of said insert defines a sharp or blunt pointed end with side edges that taper away from each other in the flow direction through said passage with said flapper open.

8. The valve of claim **1**, wherein:

said insert comprises at least one internal opening.

9. The valve of claim **8**, wherein:

said opening has a quadrilateral shape.

10. The valve of claim **1**, wherein:

said insert is axially aligned with said flapper when said flapper is in said open position and occupies the balance of said recess circumferentially around said flapper when said flapper is in said open position.

11. The valve of claim **1**, wherein:

said flapper has at least one groove in its surface facing into said recess.

12. The valve of claim **1**, wherein:

said insert extends circumferentially in said recess for at least 180 degrees.

13. The valve of claim **1**, wherein:

said housing comprises a path starting from said passage and extending into said recess to direct pressure against said flapper that urges it toward said closed position.

14. The valve of claim **13**, wherein:

said flapper is selectively retained in said open position by a flow tube that covers an inlet to said path and uncovers said inlet on initial movement of said flow tube away from said flapper.

15. The valve of claim **1**, wherein:

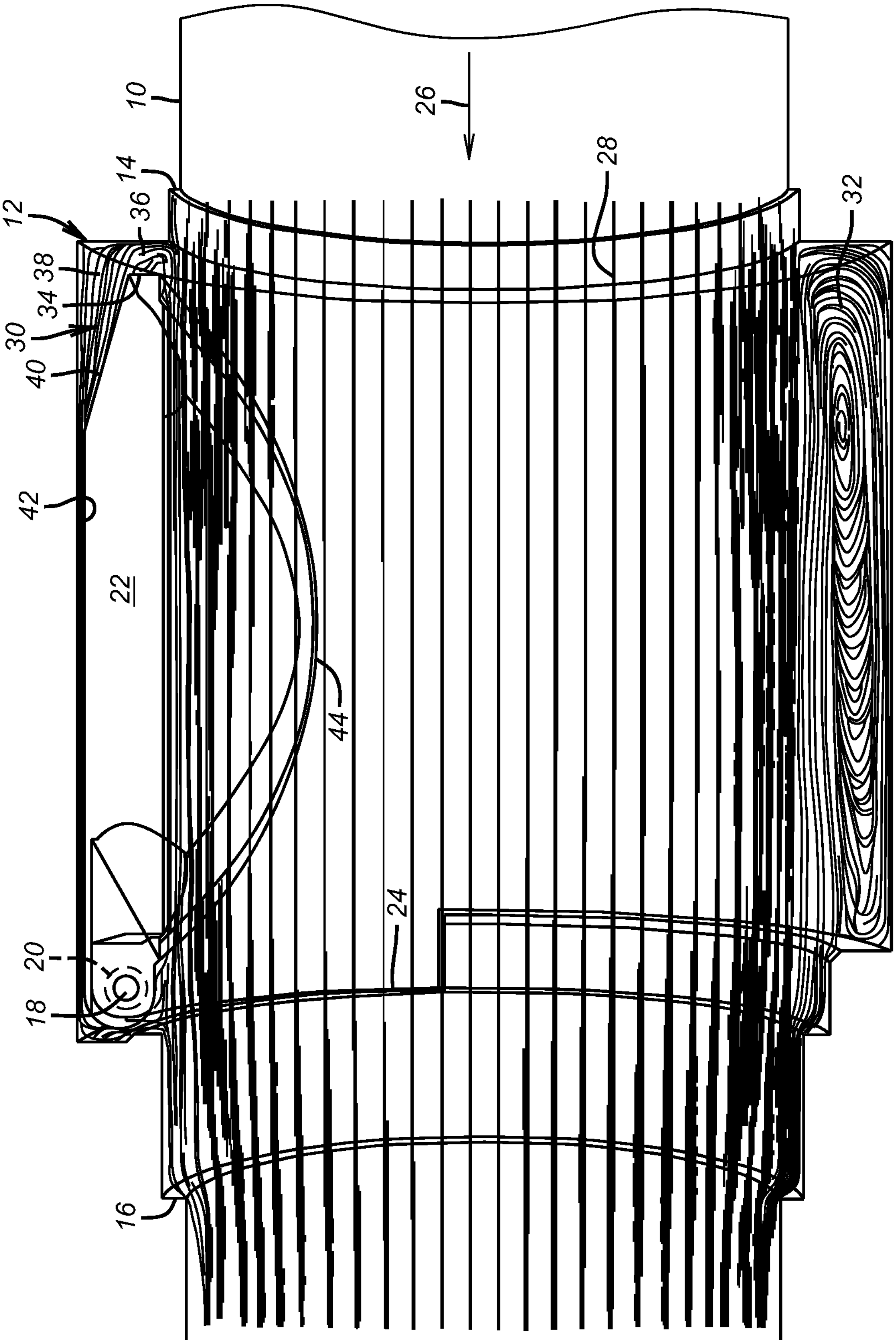
said insert is wholly within said recess.

16. The valve of claim **1**, wherein:

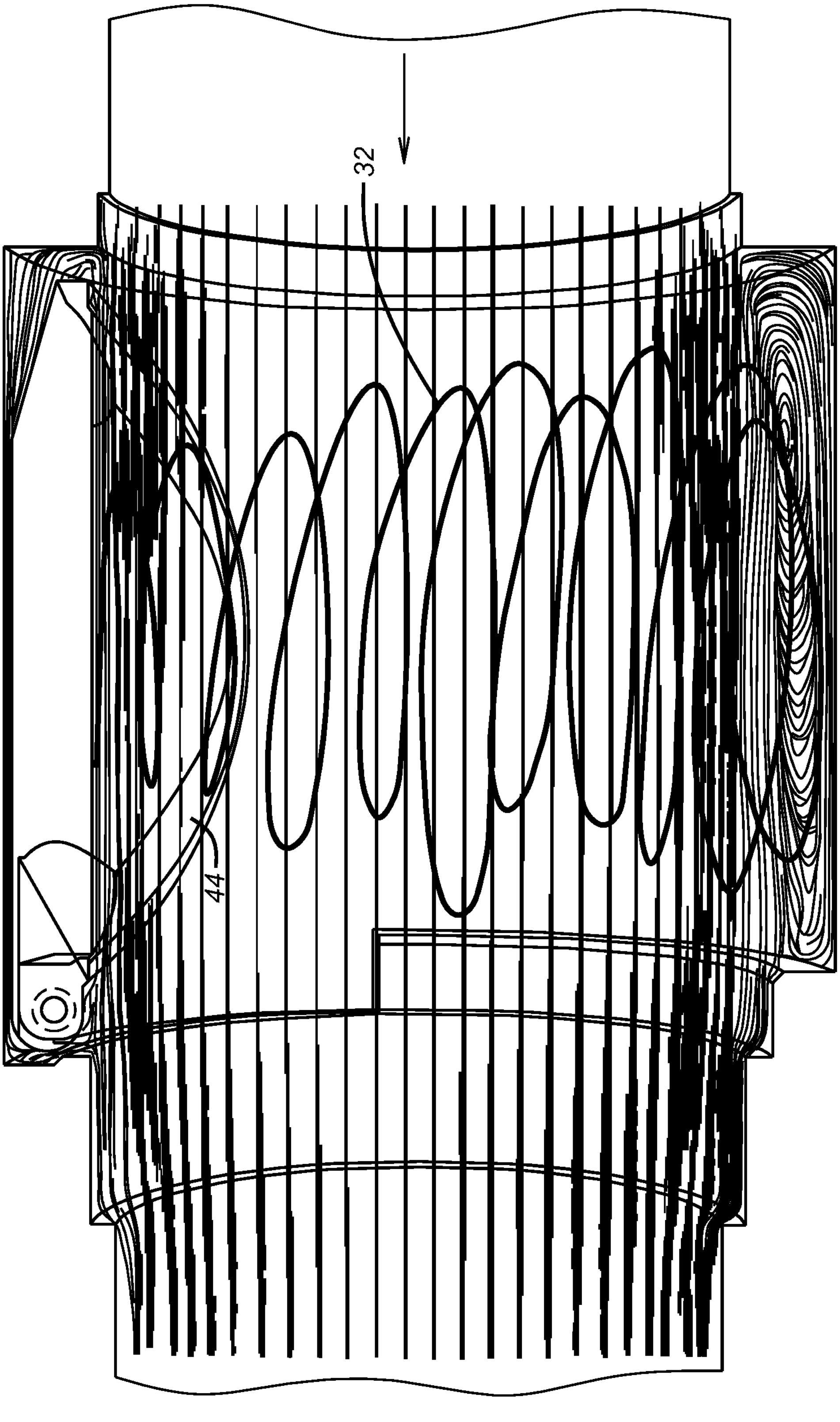
said insert extends out of said recess and into said passage.

17. The valve of claim **1**, wherein:

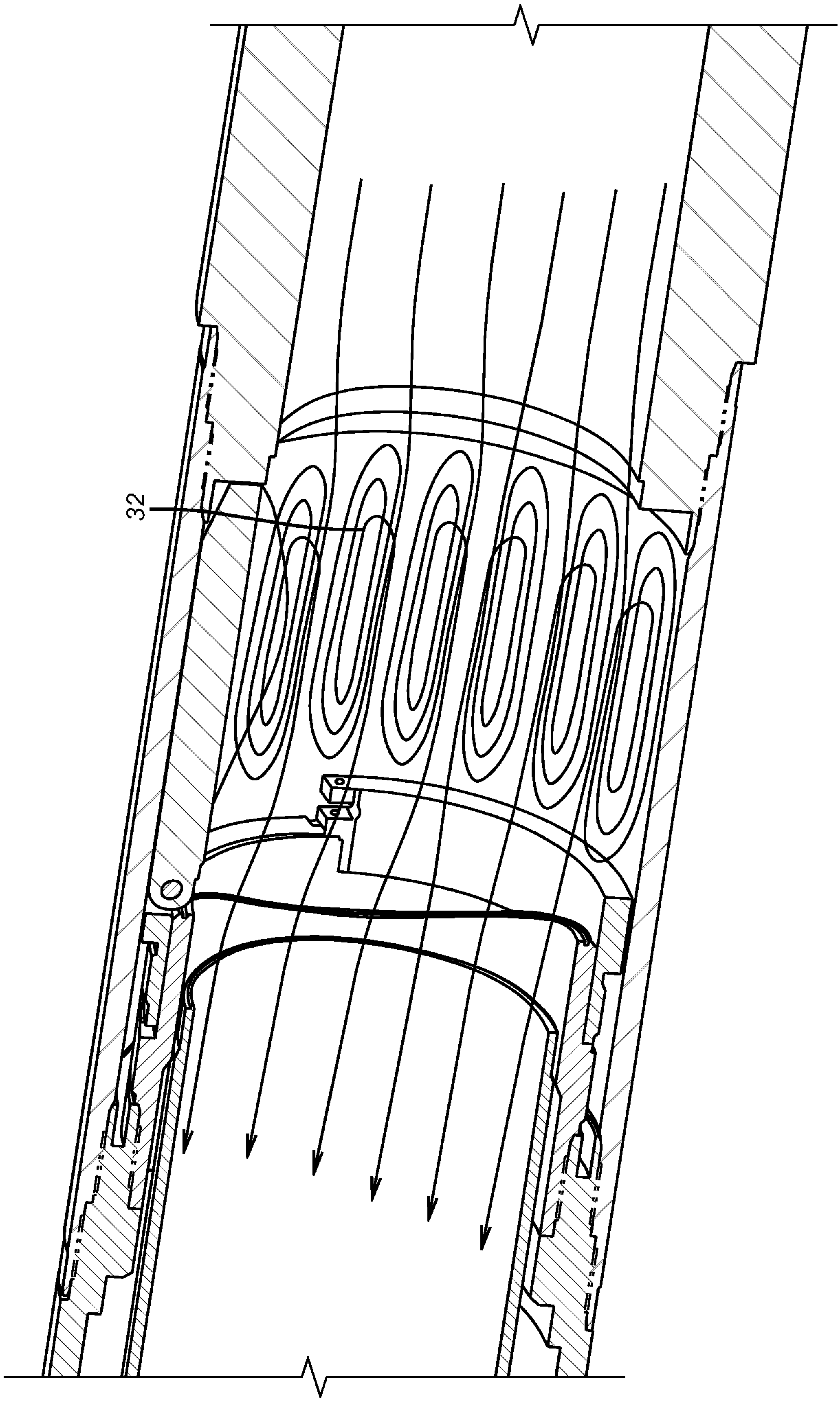
said insert has a roughened surface that faces said passage.



(PRIOR ART)
FIG. 1



(PRIOR ART)
FIG. 2



(PRIOR ART)
FIG. 2B

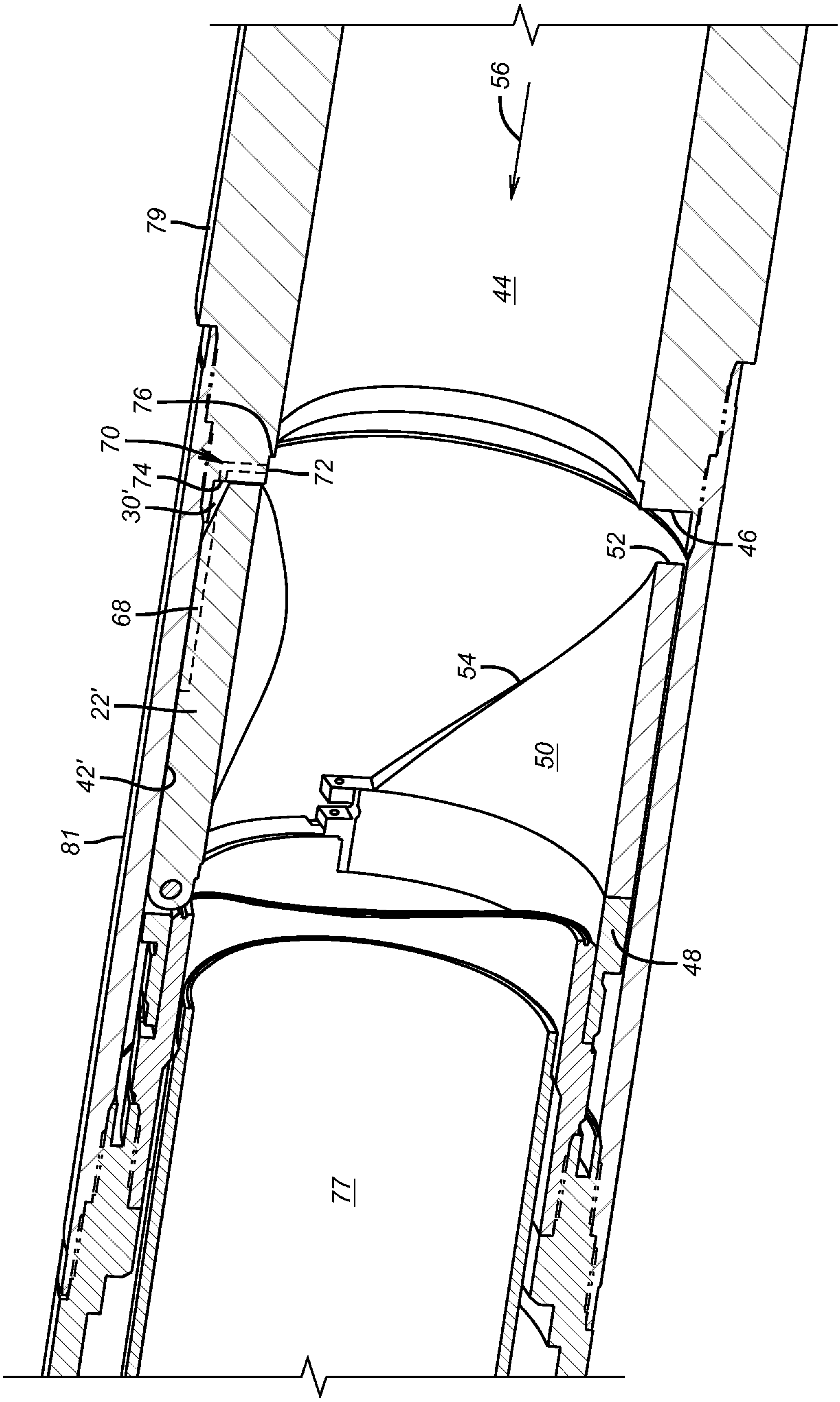


FIG. 3

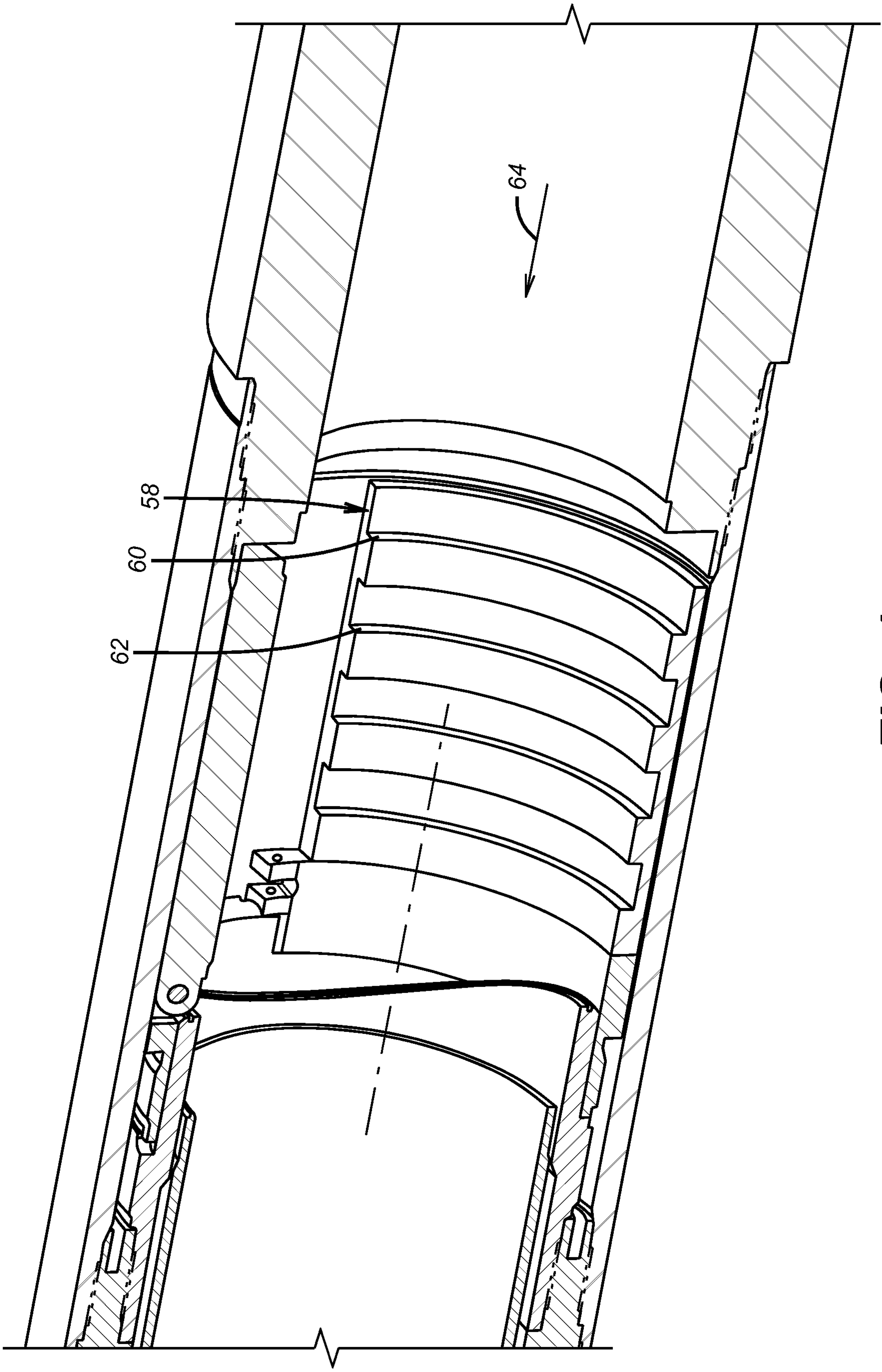


FIG. 4

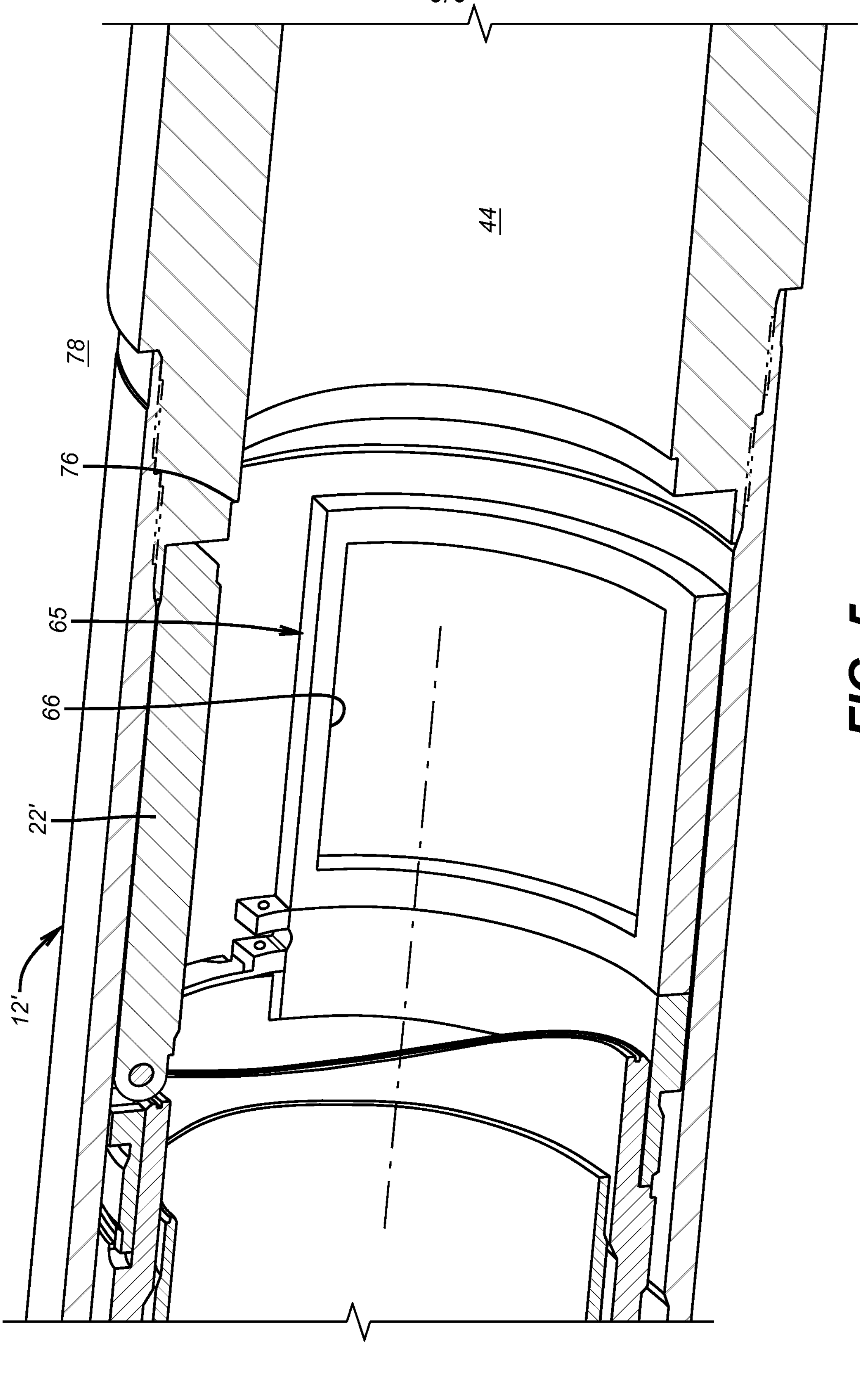


FIG. 5