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Canadian Intellectual Property Office

CA 2966899 C 2018/05/08

(11)(21) **2 966 899**

(12) **BREVET CANADIEN**
**CANADIAN PATENT**

(13) **C**

(22) Date de dépôt/Filing Date: 2017/05/10
(41) Mise à la disp. pub./Open to Public Insp.: 2017/07/14
(45) Date de délivrance/Issue Date: 2018/05/08

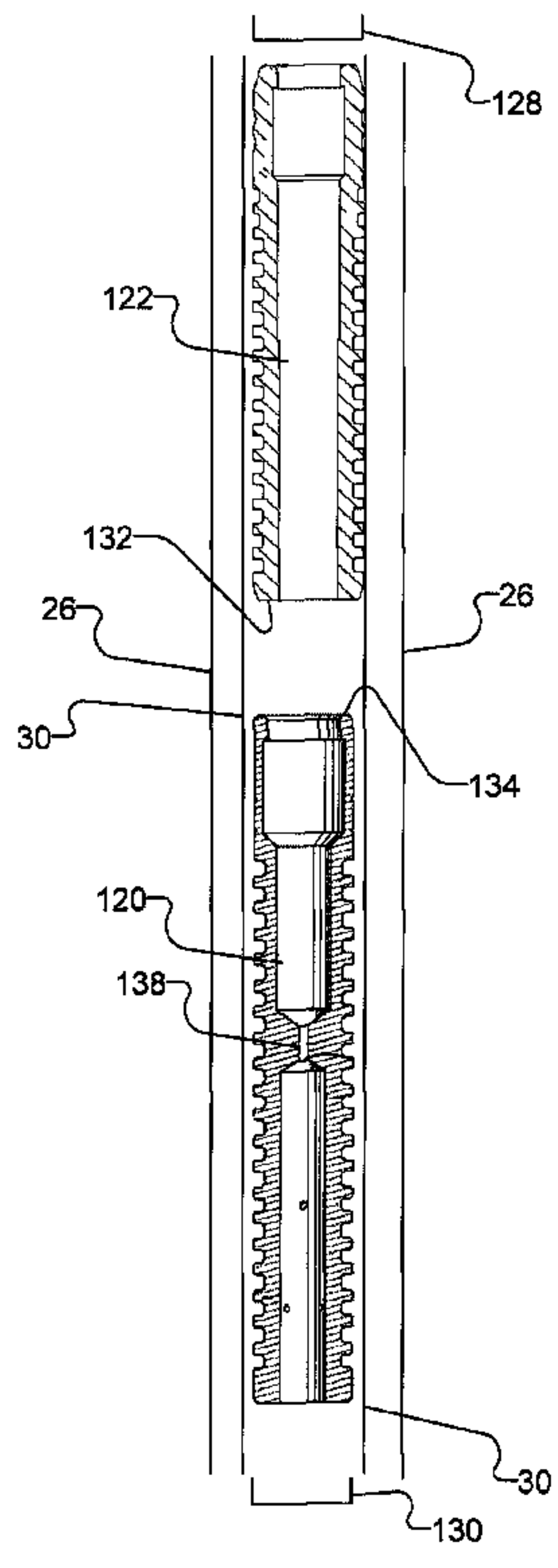
(51) Cl.Int./Int.Cl. *E21B 47/08* (2012.01), *E21B 47/008* (2012.01)

(72) Inventeur/Inventor:
NADKRYNECHNY, RICK, CA

(73) Propriétaire/Owner:
T-RAM CANADA, INC., CA

(74) Agent: OYEN WIGGS GREEN & MUTALA LLP

(54) Titre : METHODES ET APPAREIL DESTINES A AUGMENTER LA PRODUCTION DE FLUIDE D'UN PUITS
(54) Title: METHODS AND APPARATUS FOR ENHANCING FLUID PRODUCTION FROM A WELL




(57) Abrégé/Abstract:
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ABSTRACT

A method of enhancing fluid production from a well is provided. A downhole plunger having the maximum permissible outer diameter for the well is installed in the well. Methods and apparatus for determining the maximum permissible outer diameter for a downhole plunger for use in the well are provided.

# METHODS AND APPARATUS FOR ENHANCING FLUID PRODUCTION FROM A WELL

## Technical Field

**[0001]** Some embodiments of the present invention relate to methods for improving fluid production from oil and gas wells. Some embodiments of the present invention relate to apparatus for improving fluid production from oil and gas wells. Some embodiments of the present invention relate to downhole plungers having a variety of different diameters that can be used to improve fluid production from oil and gas wells.

## Background

**[0002]** In an oil or gas well, the bottom hole pressure and the gas to liquid ratio will eventually not support a natural flow therefrom. The well operator at that time must select an artificial lift to remove fluid from the well so as to resume production. A plunger lift is a form of artificial lift which may be utilized in maintaining production levels and stabilizing the rate of decline of production of oil and gas from a well.

**[0003]** Plunger lift is an established method for enhancing the removal of liquids from a well that is producing at least some natural gas. The liquids may be oil, hydrocarbon condensates, water, or any combination thereof. If permitted to accumulate in a well bore, these liquids build up to create a hydrostatic back pressure against the formation, which in turn reduces production and may ultimately stop production completely.

**[0004]** As the oil or gas flow rate and pressure decline in a well, the lifting efficiency declines. The well then may begin to "load up" and "log off". This means that gas being produced into the well bore can no longer carry the fluid produced to the surface. One reason for this is that, as liquid comes in contact with the wall of the production string or tubing, friction will occur. The velocity of that liquid is thus reduced and some of the liquid adheres to the tubing wall, creating a film of liquid on that tubing wall. Thus, that liquid does not reach the well head at the surface.

**[0005]** Additionally, as the flow continues to slow, the gas phase can no longer support liquid in either slug form or droplet form. This liquid along with the liquid film on the sides of the tubing begins to fall back to the bottom of the well. In a very aggravated situation there will be liquid in the bottom of the well with only a small amount of gas being produced at the surface. The produced gas must bubble through the liquid at the bottom of the well and then flow to the surface. Because of the low velocity, very little liquid if any is carried to the surface of the well by the gas.

**[0006]** The corresponding head of liquid in the bottom of the well exerts a back pressure against the producing formation, with a value corresponding to the vertical elevation of the liquid in the well, effectively terminating the well's ability to produce. A properly applied plunger lift system is able to bring such a well back to life and make it profitable.

**[0007]** A plunger lift system permits the well to be opened and closed so as to generate a sufficient pressure permitting the well to flow into the flow line. The plunger travels freely back and forth within the vertical tubing string, from the bottom of the well to the surface and back to the bottom. The plunger is used as a mechanical interface between the gas phase and the fluid phase in the well. When the well is closed at the surface, the plunger rests at the bottom of the well on top of a spring assembly. Pressure within the well rises as gas enters the well. When the well is opened at the surface, with all production being through the tubing, the well begins to flow and the pressure in the tubing decreases. Because the trapped gas in the casing/tubing annulus remains at a higher pressure than the tubing, the differential pressure between the two increases. The liquid level in the annulus decreases as the liquid is pushed downward where it "U tubes" into the tubing.

**[0008]** The mechanical tolerance between the outside diameter of the plunger and the inside of the tubing leaves sufficient space for the liquid to bypass the plunger, allowing the plunger to remain initially resting on the bottom. Eventually gas within the tubing causes the plunger to move up the tubing string carrying the fluid load on top. A small amount of gas will bypass the plunger. This is useful as it scours the plunger and the tubing wall of fluid keeping all the fluid on top of the plunger. If the system has been properly engineered, most of the liquid can be removed from the well to permit the well to flow at the lowest production pressure possible. The use of such a plunger in the tubing minimizes any fluid fallback over the entire length of the tubing, irrespective of the depth of the well. Such a well may be operated at a lower bottom hole pressure since substantially all the liquid is removed from the well bore, thus enhancing its production.

**[0009]** The operation of a plunger within a well is carefully controlled. With too much pressure, the plunger ascends too quickly (>1000 ft/min), potentially damaging surface equipment upon impact. With too little pressure (<500 ft/min), fluid slips around the plunger, preventing it from rising. According to accepted practice, an ideal lift speed is around 750 ft/min. A goal of utilizing plunger lift systems is generally to start the well as soon as enough energy/pressure is available.

**[0010]** There should be a sufficiently tight fit of the plunger within the tubing to afford a sufficiently effective seal during lifting. However, the mechanical tolerance between the outside diameter of the plunger and the inside diameter of the tubing must leave sufficient space to allow descent of the plunger through the tubing string at a practical rate and to avoid the plunger becoming lodged in the tubing.

**[0011]** Pad plungers are known for use in wells with tubing deviations. A pad plunger incorporates a body having metal pads, such as spring-loaded metal pads, that expand or contract to compensate for tubing irregularities and to keep the outside diameter of the plunger in contact with the tubing walls. This allows the plunger to maintain its seal with the tubing walls during lifting in order to reduce fluid fallback over the entire length of the tubing. However, spring-loaded metal pads wear and are prone to mechanical failure.

**[0012]** Under ever changing well conditions, the inside diameter of a well's tubing may vary throughout the life cycle of the well. As the well conditions change, the fit of the plunger within the tubing may change, potentially affecting the seal between the plunger and the tubing walls.

**[0013]** Conventional thinking in the field of gas well plunger lift systems has historically assumed the maximum outer diameter of plunger tools to be a fixed value based on tubular tables supplied by tubing manufacturers. The conventional maximum diameter for a downhole plunger was thought to be smaller than the actual internal diameter of the tubing of the well. For example, for a well having a tubing with an internal diameter of 2", conventional thinking is that the largest outer diameter for a plunger suitable for use in the well is 1.90". This suggests that downhole plungers having larger diameters could potentially be used within the tubing. However, due to inconsistences introduced during the completion part of the well process, this is not the case. For example, when the tubing strings are torqued together with service rigs, connections are sometimes overtightened resulting in "tight" spots. Features such as this make it impossible to predict what the maximum diameter for a downhole plunger in any given well would be. The inventor has even encountered wells in which downhole plungers having a conventional "normal" size would not fully travel the entire length of the tubing string.

**[0014]** There remains a need to optimize plunger fit within the tubing of a well to maintain sealing tolerances over extended periods of use of the plunger.

**[0015]** The foregoing examples of the related art and limitations related thereto are intended to be illustrative and not exclusive. Other limitations of the related art will become apparent to those of skill in the art upon a reading of the specification and a study of the drawings.

## Summary

**[0016]** The following embodiments and aspects thereof are described and illustrated in conjunction with systems, tools and methods which are meant to be exemplary and illustrative, not limiting in scope. In various embodiments, one or more of the above-described problems have been reduced or eliminated, while other embodiments are directed to other improvements.

**[0017]** One aspect of the invention provides a method of enhancing fluid production from a well by installing a plunger having the maximum permissible outer diameter for the well in the well.

**[0018]** One aspect of the invention provides a method of enhancing fluid production from a well, the method having the steps of evaluating whether a downhole plunger having a first outer diameter can travel freely within a tubing of the well; if the downhole plunger having the first outer diameter can travel freely within the tubing of the well, evaluating whether a downhole plunger having a second outer diameter that is larger than the first outer diameter can travel freely within the tubing of the well; and if the downhole plunger having the second outer diameter cannot travel freely within the tubing of the well, installing a downhole plunger having the first outer diameter in the well and performing artificial lift using the downhole plunger having the first outer diameter.

**[0019]** One aspect of the invention provides a method of enhancing fluid production from a well, the method having the steps of evaluating whether a downhole plunger having a first outer diameter can travel freely within a tubing of the well, if the downhole plunger having the first outer diameter cannot travel freely within the tubing of the well, evaluating whether a downhole plunger having a second outer diameter that is smaller than the first outer diameter can travel freely within the tubing of the well; and, if the downhole plunger having the second outer diameter can travel freely within the tubing of the well, installing a downhole plunger having the second outer diameter in the well and performing artificial lift using the downhole plunger having the second outer diameter.

**[0020]** One aspect of the invention provides a method of determining the maximum permissible diameter for a downhole plunger that can be used in a well, the method having the steps of evaluating a plurality of different plunger outer diameters to determine whether plungers having at least two of the plurality of different plunger outer diameters can travel freely in a tubing of the well; and concluding that the maximum permissible diameter for a downhole plunger that can be used in the well is equal to the largest one of the plurality of different plunger outer diameters that will still allow a plunger to travel freely in the well.

**[0021]** One aspect of the invention provides a method of determining whether a downhole plunger having a first outer diameter can travel freely within a well, the method having the steps of dropping a drive plunger in a tubing of the well below a measuring sleeve, the measuring sleeve having an outer diameter equal to the first outer diameter; allowing the drive plunger and the measuring sleeve to fall in the tubing; and if the measuring sleeve becomes lodged in the tubing, concluding that a downhole plunger having the first outer diameter cannot travel freely within the well; or if the measuring sleeve does not become lodged in the tubing, concluding that a downhole plunger having the first outer diameter can travel freely within the well.

**[0022]** One aspect of the invention provides an apparatus for determining the maximum permissible outer diameter of downhole plunger that can be used in a well, the apparatus having a measuring sleeve comprising a generally cylindrical outer shell defining an outer diameter and a hollow interior defining a fluid path through the measuring sleeve.

**[0023]** One aspect of the invention provides a kit having a drive plunger and a plurality of measuring sleeves, each one of the plurality of measuring sleeves having a different outer diameter.

**[0024]** One aspect of the invention provides a plunger lift gauging tool for determining a maximum diameter of a plunger that can be used in a gas-producing well, the tool having a pad plunger body having compressible pads; and a plurality of radially outwardly extending tabs made from a material that retains its shape after deformation, the radially outwardly extending tabs extending outwardly to define a predetermined outer diameter.

**[0025]** One aspect of the invention provides a plunger lift gauging tool for determining a maximum diameter of a plunger that can be used in a gas-producing well, the tool having a central shaft; a pad comprising a plurality of spring-loaded pad sections mounted on the central shaft to maintain an approximately even degree of contact with an inside surface of a tubing of the well when the tool is in use; and a measuring ring having at least one radially outwardly extending tab, the tab protruding outwardly to define a predetermined outer diameter.

**[0026]** In addition to the exemplary aspects and embodiments described above, further aspects and embodiments will become apparent by reference to the drawings and by study of the following detailed descriptions.

## Brief Description of the Drawings

**[0027]** Exemplary embodiments are illustrated in referenced figures of the drawings. Like reference numerals have been used to refer to the components of the various embodiments that perform a similar function. It is intended that the embodiments and figures disclosed herein are to be considered illustrative rather than restrictive.

**[0028]** FIG. 1 shows an example of a typical prior art gas-producing well incorporating a plunger lift system.

**[0029]** FIG. 2 shows an example embodiment of a method of enhancing fluid production from a gas-producing well.

**[0030]** FIG. 3 shows an example embodiment of an apparatus for determining the maximum permissible diameter of plunger that can be used to enhance production of fluid from a well.

**[0031]** FIG. 4A shows a side view of an example embodiment of a measuring sleeve for use in the embodiment of FIG. 3, and FIG. 4B shows a cross-sectional view thereof.

**[0032]** FIG. 5 shows a flowchart illustrating an exemplary method of enhancing fluid production from a well.

**[0033]** FIG. 6 shows a side view of an example embodiment of a plunger lift gauging tool.

**[0034]** FIG. 7 shows a perspective view of an example embodiment of a plunger lift gauging tool, in which no springs are provided under the pads of the plunger (i.e. showing the pads in the equivalent position of their fully compressed state).

**[0035]** FIG. 8 is a sketch showing an example embodiment of a plunger lift gauging tool with the pads and measuring rings removed.

**[0036]** FIG. 9 is a sketch showing an example embodiment of a plunger lift gauging tool with the pads and measuring rings inserted over the central shaft thereof.

**[0037]** FIG. 10A is a side view and FIG. 10B is a top view of a pad used in some example embodiments.

**[0038]** FIG. 11 is a top view of a measuring ring according to an example embodiment.

**[0039]** FIG. 12 is a top view of an example embodiment of a plunger lift gauging tool, in which no springs are provided under the pads of the plunger (i.e. showing the pads in the equivalent position of their fully compressed state so that the measuring rings extend beyond the outer diameter of the pads).

**[0040]** FIG. 13 shows a partial side view of an example embodiment of a plunger lift gauging tool, in which one of the collars and one of the pad sections has been removed from the tool.

**[0041]** FIG. 14 shows a partial side view of an example embodiment of a plunger lift gauging tool, in which the pad sections have been manually forced radially outwardly.

**[0042]** FIG. 15A shows an example embodiment of a plunger lift gauging tool in its assembled configuration, with the springs beneath the pads in their uncompressed (i.e. default) position. FIG. 15B shows the embodiment of FIG. 15A, in which the pads have been manually pressed to compress the springs beneath the pads.

**[0043]** FIG. 16 shows a side view of the example embodiment of FIG. 15A, with the springs beneath the pads in their uncompressed (i.e. default) position.

## Description

**[0044]** Throughout the following description specific details are set forth in order to provide a more thorough understanding to persons skilled in the art. However, well known elements may not have been shown or described in detail to avoid unnecessarily obscuring the disclosure. Accordingly, the description and drawings are to be regarded in an illustrative, rather than a restrictive, sense.

**[0045]** The inventor has now surprisingly determined that it is possible in at least some wells to use a plunger having a diameter larger than was thought possible according to conventional thinking in the field of plunger lift systems. The inventor has also found that the use of a plunger having a larger diameter can in some wells increase the production of gas from the well.

**[0046]** One aspect of the invention provides a method of enhancing fluid production from a well by selecting and using a downhole plunger having a maximum permissible diameter for a given well. As used herein, the term “maximum permissible diameter” of a plunger for a given well means a plunger having the largest outer diameter that can fit into the well while still allowing the plunger to travel freely through the entire length of the tubing of the well.

**[0047]** One aspect of the invention provides a method of enhancing fluid production from a well by analyzing the internal diameter of a tubing of the well to determine the maximum permissible diameter for a downhole plunger for use in the well. In some embodiments, the plunger is a Venturi plunger, for example as described in US Patent Nos. 8464798 and 8627892 to Nadkrynechny, both of which are incorporated herein by reference.

**[0048]** One aspect of the invention provides a method for determining what diameter of plunger should be used to maximize the efficiency of plunger lift in a well. In some embodiments, maximizing the efficiency of plunger lift in a well comprises analyzing the internal diameter of the tubing of the well, and using the results of that analysis to select a plunger having the widest possible diameter, without an unacceptably high risk that the plunger will become stuck in the tubing of the well. In some embodiments, the plunger is a venturi plunger such as that described in U.S. patent No. 8464798 or U.S. patent No. 8627892 to Nadkrynechny.

**[0049]** One aspect of the invention provides a method of enhancing fluid production from a well by installing in the well a downhole plunger having the maximum permissible diameter for the well.

**[0050]** In some embodiments, a gauging tool is used to determine what diameter of plunger should be used to maximize the beneficial effect of gas flowing through the aperture of a venturi plunger. In some embodiments, the gauging tool has a plunger body that is configured to allow the gauging tool to move up and down inside a well and a plurality of radially outwardly extending deformable tabs. In some embodiments, the deformation of the radially extending deformable tabs after the gauging tool has been run inside a well is used to determine what diameter of plunger should be used in the well. Methods of using the gauging tool to determine what diameter of plunger should be used in a given well are provided.

**[0051]** Another aspect of the invention provides a method of determining what diameter of plunger should be used to optimize the production of fluid from a given well.

**[0052]** As used in this specification, “upper” means in the direction of the surface of a well when a tool is in use and “lower” means in the direction towards the bottom of the well when the tool is in use. It will be appreciated that the tools described herein could have other orientations when not in use.

**[0053]** As used in this specification, "inwardly" means a direction towards the central axis of the plunger lift gauging tool, and "outwardly" means a direction towards the outer edge of the plunger lift gauging tool.

**[0054]** As used herein, the concept that a plunger can "travel freely in a well" means that the plunger can rise and fall within the well under a range of ordinary expected operating conditions, and not have a high likelihood of becoming stuck or lodged in the tubing during ordinary operation.

**[0055]** As used herein, the term "enhancing the production of fluids from a well" means that an improvement in at least one aspect of the operation of the well is observed. In some embodiments, the aspect of the operation of the well that is improved is gas production. In some embodiments, gas production is increased by at least 5%. In some embodiments, the aspect of the operation of the well that is improved is that the lift pressure required to carry out artificial lift in the well using a downhole plunger is reduced. In some embodiments, the lift pressure required to carry out artificial lift in the well using a plunger is reduced by at least 5%. In some embodiments, even if the gas production of the well at a single point in time is not increased, the production of fluids from the well can be said to be enhanced if the performance of the well is enhanced in other ways, for example, the plunger becoming stuck within the tubing less frequently so that well shut-in times are reduced.

**[0056]** A typical prior art well arrangement incorporating a plunger lift system is shown in FIG. 1. A well **20** is drilled into the ground from the surface **22** to any producing underground formation **24**. A production casing **26** is placed into the well bore, and perforations **28** are created in the casing at the level of formation **24** to allow gas and liquid to enter the well bore. A production tubing **30** is placed inside casing **26** and forms a continuous conduit for producing gas and liquid up through to a wellhead lubricator **32**. Lubricator **32** is arranged to place a conventional plunger **46** in well **20** and to retrieve plunger **46** from well **20** without having to kill well **20**. The lubricator **32** may have a sensor, shown schematically as **98**, to detect the arrival of plunger **46** at the surface **22**, sending a signal to a control system **42** for various controller functions to help optimize production. Sensor **98** may comprise a magnetic sensor. The produced fluid exits through exit tubing **34** via a control valve **36** to move on to the next stage of collection, as indicated by arrow

**38**.

**[0057]** Well **20** includes a master valve **40**, which can be used to stop the flow from well **20**. Control valve **36** is regulated based on inputs from control system **42**, which signals a valve actuator **44** configured to regulate control valve **36**.

**[0058]** In operation, a plunger **46** is inserted into well **20** as follows. Well **20** is prevented from flowing by closing master valve **40**. A plunger **46** is inserted into lubricator **32** by removing a cap **43**, inserting plunger **46** into lubricator **32**, and replacing cap **43**. Control valve **36** is kept in the closed position by valve actuator **44**, which is controlled by input from control system **42**. Master valve **40** is then opened, and typically control system **42** is then set to proceed with an operating mode and allowed to operate the well.

**[0059]** In the operating mode, when control valve **36** is in the closed position so that well **20** is shut in, plunger **46** free falls by gravity for a period of time, to allow plunger **46** to arrive at the bottom of well **20**, contacting a bottom-hole stop **48**, which may incorporate a spring **50**. Bottom-hole stop **48** absorbs impact and prevents plunger **46** from passing through the bottom of production tubing **30**.

**[0060]** After a period of time in the operating mode, control system **42** will signal valve actuator **44** to open control valve **36**. This time period may be an established set time; a time calculated from other parameters such as plunger arrival time; a time calculated from pressure readings from casing **28**, tubing **34**, or a downstream collection system; or some combination of the foregoing; or, the time frame may be established in any other suitable manner. Control system **42** may also be manually operated to open control valve **36**.

**[0061]** Upon control valve **36** opening, gas pressure which has accumulated in the annulus **52** between casing **26** and tubing **30** will flow through bottom-hole stop **48**. Plunger **46** acts like a piston, providing a seal between the gas and liquid entering from below plunger **46** and the gas and liquid above plunger **46**. Plunger **46** pushes liquid that has accumulated above plunger **46** to the surface **22**, where it exits the pumping system, as shown by arrow **38**, and is transported to a downstream separation and gathering apparatus.

**[0062]** Plunger **46** may remain in well **20** for a period of operation which may be from days or weeks up to several years depending on performance, well conditions, and the nature of plunger **46** or other well components used.

**[0063]** Conventional thinking in the field of gas well plunger lift systems has historically assumed the maximum outer diameter of plunger tools to be a fixed value based on tubular tables supplied by tubing manufacturers. The conventional maximum diameter for a downhole plunger such as plunger **46** was thought to be smaller than the actual internal diameter of the tubing **30** of the well. For example, for a well **20** having a tubing **30** with an internal diameter of 2", conventional thinking is that the largest outer diameter for a plunger **46** suitable for use in the well is 1.90".

**[0064]** However, the inventor has now found that selection of a downhole plunger having the largest diameter that reasonably will not become lodged within the tubing **30** (referred to herein as "the maximum permissible diameter") for use in a given well can allow reductions in flowing bottom hole pressures in producing wells, which can increase production. Use of a plunger having the maximum permissible diameter for use in the given well can also minimize risk of damage to surface equipment. For example, a first plunger having a relatively larger diameter than a second plunger will tend to travel more slowly within tubing **30** of the well than the second plunger, and therefore enters lubricator **32** at a lower speed than the second plunger.

**[0065]** The examples described herein establish that plungers having relatively larger outer diameters can be supported by less flow than a corresponding plunger having a narrower outer diameter. The examples further establish that the use of a plunger having the maximum permissible outer diameter can considerably enhance the production of fluid from a well in the field.

**[0066]** With reference to FIG. 2, a method **100** of enhancing fluid production from a well is illustrated schematically. At **102**, an evaluation of whether a plunger having a first outer diameter ("OD") can travel freely within the well is made. At **104**, an evaluation of whether a plunger having a second outer diameter ("OD") can travel freely within the well is made. The outer diameter selected for evaluation at step **104** is determined based on the outcome of the evaluation of the first outer diameter at step **102**. For example, if it is determined at step **102** that a plunger having the first outer diameter can travel freely in the well, then the second outer diameter selected for evaluation at step **104** will be larger than the first outer diameter. On the other hand, if it is determined at step **102** that a plunger having the first outer diameter cannot travel freely in the well, then the second outer diameter selected for evaluation at step **104** will be smaller than the first outer diameter.

**[0067]** At step **106**, steps **102** and **104** are repeated again as necessary with plungers having different outer diameters, to determine the maximum permissible diameter of plunger that can travel freely within the well. In some cases, step **106** is not carried out. For example, if at step **102** it is determined that a plunger having the first outer diameter can travel freely within the well, and at step **104** it is determined that a plunger having the second outer diameter cannot travel freely within the well, and the second outer diameter is larger than the first outer diameter by an amount that represents the next available plunger size, then it is concluded that the maximum permissible diameter for a plunger for use in that well is equal to the first outer diameter, and step **106** is not needed. On the other hand, if at step **102** it is determined that a plunger having the second outer diameter can travel freely within the well, then at step **106** it is determined whether a plunger having a third outer diameter that is larger than the first and second outer diameters can travel freely within the well, and step **106** is repeated as necessary until the maximum permissible diameter for the well has been determined.

**[0068]** One skilled in the art would be able to carry out steps **102**, **104**, **106** using plungers having a plurality of different diameters or using any of the apparatus described in this specification in any order to determine the maximum permissible diameter of plunger that can be used with that particular well.

**[0069]** As a specific and non-limiting example, if the available plunger outer diameters are 1.90", 1.91", 1.92", 1.93", 1.94" and 1.95" and at step **102** it is determined that a plunger having an outer diameter of 1.91" will be able to travel freely within the well, and at step **104** it is determined that a plunger having an outer diameter of 1.92" will not be able to travel freely within the well, then at step **108** it is determined that the maximum permissible diameter of plunger for that well has an outer diameter of 1.91", and at step **110** a new downhole plunger having an outer diameter of 1.91" is installed in the well.

**[0070]** As another specific and non-limiting example using the same available plunger outer diameters, if at step **102** it is determined that a plunger having an outer diameter of 1.91" will be able to travel freely within the well, and at step **104** it is determined that a plunger having an outer diameter of 1.93" will not be able to travel freely within the well, then step **106** is carried out to determine if a plunger having an outer diameter of 1.92" will be able to travel freely within the well. If the outcome of step **106** is that a plunger having an outer diameter of 1.92" will be able to travel freely in within the well, then at step **108** it is determined that the maximum permissible diameter of plunger for use with that well has an outer diameter of 1.92", and at step **110**, a new plunger having an outer diameter of 1.92" is installed in the well. On the other hand, if the outcome of step **106** is that a plunger having an outer diameter of 1.92" will not be able to travel freely within the well, then at step **108** it is determined that the maximum permissible diameter of plunger for use in that well has an outer diameter of 1.91", and at step **110**, a new plunger having an outer diameter of 1.91" will be installed in the well.

**[0071]** In alternative embodiments, other plunger outer diameters could be selected for use as appropriate depending on the diameter of the tubing string in which the downhole plunger is to travel. For example, in wells using larger tubing strings, for example, having a 73 mm tubing string (approximately 2.87"), a typical plunger outer diameter for use for artificial lift in such a well would be 2.34". In such embodiments, the maximum permissible diameter of plunger for use in that well would be determined by evaluating whether plungers having an outer diameter of 2.35", 2.36", 2.37", 2.38", 2.39", 2.40" or larger could freely travel in the well.

**[0072]** In one example embodiment, as illustrated with reference to FIGs. 3, 4A and 4B, a drive plunger **120** and a measuring sleeve **122** are used to carry out method **100**. As illustrated schematically in FIG. 3, in use, the drive plunger **120** is dropped in well **20** below measuring sleeve **122**. Drive plunger **120** is used to both limit the fall rate of measuring sleeve **122** in the well, and to dislodge measuring sleeve **122** upwardly if measuring sleeve **122** becomes lodged in tubing **30**, so that measuring sleeve **122** can be returned to the surface without the need to invoke conventional wireline plunger retrieval techniques ordinarily used to dislodge plungers that become stuck in wells.

**[0073]** Any type of known plunger can be used to provide drive plunger **120**, including for example a venturi plunger, a pad plunger, a brush plunger, a bar stock plunger, a bypass plunger, a ball and sleeve plunger, a sand plunger, or the like. In some embodiments, drive plunger **120** is a plunger that seals well within tubing **30**, so that plunger **120** will maintain a relatively low velocity when moving within tubing **30**. In some embodiments, drive plunger **120** is a venturi plunger or a pad plunger. Example embodiments of suitable venturi plungers for use as drive plunger **120** are described in United States patent Nos. 8464798 and 8627892 to Nadkrynechny, which are both incorporated by reference herein for all purposes.

**[0074]** With reference to FIGs. 4A and 4B, in the illustrated embodiment measuring sleeve **122** is a generally cylindrical tubular structure having an outer shell **124** and a hollow interior region **126**. In the illustrated embodiment, the outer surface of outer shell **124** is provided with a plurality of ribs **125**, as are commonly used on the outer surfaces of several different types of downhole plungers. In alternative embodiments, ribs **125** are omitted and outer shell **124** is provided with a plain external surface, or with any other configuration as may be used for the external surface of a downhole plunger.

**[0075]** In the illustrated embodiment, measuring sleeve **122** is also provided with an internal fishneck **127**, to facilitate removal of sleeve **122** by wireline tools should that become necessary. In other embodiments, internal fishneck **127** is omitted.

**[0076]** The outer circumference of outer shell **124** defines an outer diameter **128** of the measuring sleeve **122**. While in the illustrated embodiment, outer shell **124** has been illustrated as having a generally cylindrical shape and therefore a generally uniform outer circumference, in embodiments in which the outer shell is not generally cylindrical in shape, the largest external diameter at any given longitudinal cross-section of measuring sleeve would provide the outer diameter of that particular measuring sleeve.

**[0077]** The inner circumference of outer shell **124** defines an inner diameter **129** of measuring sleeve **122**, and provides a fluid path through measuring sleeve **122**. As can be seen in the illustrated embodiment, the inner diameter **129** of measuring sleeve **122** can vary somewhat along the length of measuring sleeve **122**. However, significant constrictions or solid points that would significantly inhibit or block the flow of fluid through measuring sleeve **122** should be avoided. As described below, when measuring sleeve **122** becomes lodged in tubing **30**, drive plunger **120** can be surfaced to dislodge and thereby surface measuring sleeve **122**. However, if the flow of fluid within the tubing **30** is significantly inhibited by measuring sleeve **122** (when in its stuck configuration), then drive plunger **120** will not be able to rise within tubing **30**, and measuring sleeve **122** will need to be removed from its stuck configuration by conventional plunger removal techniques, e.g. wireline retrieval.

**[0078]** In one example non-limiting embodiment, the outer diameter of measuring sleeve **122** is 2.35", and the minimum inner diameter **129** of the measuring sleeve at any point along its length is approximately 1". However, any desired inner diameter **129** could be used, so long as contact surface **132** is sufficiently large to contact contact surface **134** of drive plunger **120**, and so long as inner diameter **129** is not so narrow as to prevent or significantly inhibit drive plunger **120** from rising within tubing **30** when measuring sleeve

**122** becomes lodged in tubing **30**.

**[0079]** Generally, drive plunger **120** is provided with an outer diameter **130** (FIG. 3) that is smaller than the outer diameter **128** of measuring sleeve **122**. In this way, the chances that drive plunger **120** will become lodged within tubing **30** are minimized. Also, generally the outer diameter of drive plunger **120** is not varied, while a plurality of different measuring sleeves **122** having a plurality of different outer diameters are tested in well **20**.

**[0080]** In one exemplary embodiment, both drive plunger **120** and measuring sleeve **122** are provided with a longitudinal length of 10", although other lengths could be used and this example is not limiting.

**[0081]** The thickness of outer shell **124** of measuring sleeve **122** is sufficiently large that the bottom surface of measuring sleeve **122** can be supported on the top surface of drive plunger **120** by respective contact surfaces **132**, **134** when measuring sleeve **122** and drive plunger **120** are falling in the well, and so that the upper surface of drive plunger **120** will contact measuring sleeve **122** when drive plunger **120** is rising in the well, including to dislodge measuring sleeve **122** if measuring sleeve **122** has become lodged in tubing **30**.

**[0082]** In use, well **20** is shut in, and drive plunger **120** is dropped into well **20** below measuring sleeve **122**. Once drive plunger **120** and measuring sleeve **122** have reached the bottom of well **20**, production is resumed and measuring sleeve **122** and drive plunger **120** return to the surface.

**[0083]** If a first measuring sleeve **122** is able to travel freely within tubing **30** without becoming stuck, then this is a good indication that a plunger having an outer diameter equal to the first outer diameter **128** of first measuring sleeve **120** will be able to freely travel within tubing **30** of well **20**. Accordingly, to determine the maximum permissible diameter of plunger that can be used with well **20**, the first measuring sleeve **122** is removed from the well, and a second measuring sleeve **122** having a second outer diameter **128** that is larger than the first outer diameter of the first measuring sleeve is dropped into well **20** above drive plunger **120**. If the second measuring sleeve **122** similarly does not become lodged within tubing **30**, then this is a good indication that a plunger having an outer diameter equal to the second, larger outer diameter **128** will be able to freely travel within well **20**. The testing process can therefore be repeated using a third measuring sleeve **122** having a third outer diameter **128** that is larger than the second outer diameter tested.

**[0084]** On the other hand, if the second measuring sleeve **122** becomes lodged in tubing

**30**, then this is a good indication that a plunger having an outer diameter equal to the second, larger outer diameter **128** is likely to become lodged within tubing **30**. Accordingly, the testing process can be repeated with a third measuring sleeve **122** having a third outer diameter **128** that is intermediate between the first and second outer diameters tested. Alternatively, where the diameter of the second measuring sleeve **122** is larger than the first measuring sleeve **122** by only the smallest size increment available, it can be concluded that the maximum permissible diameter of plunger that can be used in well **20** has an outer diameter equal to the first outer diameter **128** tested.

**[0085]** Thus, generally speaking, the maximum permissible diameter of plunger that can be used in a given well **20** can be determined by dropping drive plunger **120** in turn with a plurality of different measuring sleeves **122** having a plurality of different outer diameters **128**. The outer diameter **128** of the largest (i.e. largest outer diameter) measuring sleeve **122** that can freely travel within tubing **30** without becoming lodged therein can be concluded to be the maximum permissible diameter of plunger for use in well **20**, and a plunger having that maximum permissible diameter as its outer diameter can be installed in well **20** to enhance the production of fluids therefrom.

**[0086]** In some embodiments, as illustrated with reference to the method of FIG. 5, tools are used to track the movement of drive plunger **120** and measuring sleeve **122** within tubing **30**. In the exemplary method **200** illustrated in FIG. 5, an echometer is used to monitor the movement of drive plunger **120** and/or measuring sleeve **122** within tubing **130**.

**[0087]** At step **202**, a tubing shot is optionally performed by introducing compressed carbon dioxide ($CO_2$) or other suitable gas into the well to produce an acoustic wave that travels down the well and is monitored by the echometer. The tubing shot carried out at step **202** provides a baseline image of the internal configuration of the tubing of the well in the form of an acoustic trace pattern (showing, for example, tubing collars and other structures present in the well).

**[0088]** At step **204**, the well is shut in for a suitable period (which can be 1-2 days in some embodiments, but could be longer or shorter depending on the prevailing conditions at the particular well), and a drive tool, e.g. drive plunger **120**, and a sizing tool, e.g. measuring sleeve **122**, are dropped into the tubing of the well. The well head valves are opened and drive plunger **120** and measuring sleeve **122** are permitted to fall together in the well, drive plunger **120** being positioned below measuring sleeve **122** as shown in FIG. 3. The movement of the drive plunger **120** and the measuring sleeve **122** are tracked using the echometer in a manner similar to that known in the art for monitoring plunger lift.

**[0089]** Because drive plunger **120** has an internal orifice **138** which is narrower than the hollow internal region **126** of measuring sleeve **122**, drive plunger **120** falls more slowly in well **20** than measuring sleeve **122**. Since measuring sleeve **122** is supported above drive plunger **120** by the contact of contact surface **132** of measuring sleeve **122** on contact surface **134** of drive plunger **120**, measuring sleeve **122** and drive plunger **120** fall together to the bottom of well **20**.

**[0090]** Once the drive plunger **120** and measuring sleeve **122** are at the bottom of the well, a second tubing shot is optionally carried out at step **206** to confirm that the real-time tracking data obtained as the drive plunger **120** and measuring sleeve **122** are falling is correct. At step **208**, the drive plunger **120** and measuring sleeve **122** are surfaced. At step **210**, steps **204**, **206** and **208** are repeated again, but using a measuring sleeve **122** having a larger outer diameter. Steps **204**, **206**, **208** and **210** are repeated as many times as desired, until the measuring sleeve **122** becomes stuck in the well.

**[0091]** Without being bound by theory because measuring sleeve **122** is supported by drive plunger **120** while the two are falling within well **20**, measuring sleeve **122** is falling with a relatively low velocity within tubing **30**, and will only become gently stuck in tubing **30**.

**[0092]** When measuring sleeve **122** becomes stuck in the tubing, the method proceeds to step **212**. The data obtained by the echometer can be used as a second means to determine that measuring sleeve **122** has become stuck in the tubing. When measuring sleeve **122** becomes stuck, drive plunger **120** continues to fall to the bottom of the well. The data obtained by the echometer can be used to confirm that drive plunger **120** is still falling within well **20** while measuring sleeve **122** has stopped.

**[0093]** Once drive plunger **120** reaches the bottom of well **20**, control valve **36** can be opened to surface drive plunger **120**. At step **214**, drive plunger **120** is used to dislodge measuring sleeve **122** from tubing **30** so that both drive plunger **120** and measuring sleeve **122** are returned to the surface and removed from well **20** at step **216**.

**[0094]** Based on the fact that measuring sleeve **122** having a given outer diameter **128** became stuck in tubing **30**, it can be concluded that the maximum permissible diameter of plunger for use in well **20** is narrower than that outer diameter **128**. Thus, at step **218**, a new plunger having the maximum permissible diameter as determined by carrying out steps

**202** to **216** can be installed in well **20**. In some embodiments, the new plunger having the maximum permissible diameter comprises a venturi plunger, a brush plunger, a bar stock plunger, a bypass plunger, a ball and sleeve plunger, or a sand plunger.

**[0095]** At step **220**, the well settings are optionally adjusted and/or documented based on the new plunger having the maximum permissible diameter. At step **222**, applicable well head tags are optionally hung on the head of the well to confirm what type of plunger has been installed and/or the maximum permissible diameter of plunger that can be used in that well. In some embodiments, data logging equipment is optionally left in place for a period of time, e.g. about one week, to monitor performance of the well and ensure the new plunger having the maximum permissible diameter is functioning properly.

**[0096]** In some embodiments, well **20** is shut in for 1-2 days prior to carrying out method **100** or **200**, to allow buildup of sufficient pressure so that drive plunger **120** and measuring sleeve **122** will fall as slowly as possible. Without being bound by theory, it is believed that if measuring sleeve **122** falls more slowly and becomes lodged in tubing **30**, less upward force will need to be applied by drive plunger **120** to dislodge measuring sleeve **122** than if measuring sleeve **122** was permitted to fall rapidly within tubing **30**.

**[0097]** In some embodiments, a kit for optimizing the production of fluid from a well is provided that includes a drive plunger **120** and a plurality of measuring sleeves **122**, each one of the plurality of measuring sleeves **122** having a different outer diameter **128**. In one example embodiment, such a kit includes a drive plunger having an outer diameter of 1.90" and a plurality of measuring sleeves having outer diameters of 1.91", 1.92", and 1.93", respectively, and optionally further includes measuring sleeves having larger outer diameters, e.g. 1.94" and 1.95". In one example embodiment, such a kit includes a drive plunger having an outer diameter of 2.34" and a plurality of measuring sleeves having outer diameters of 2.35", 2.36", and 2.37", respectively, and optionally further includes measuring sleeves having larger outer diameters, e.g. 2.38", 2.39" and 2.40".

**[0098]** In alternative embodiments, a plunger lift gauging tool is used to carry out method **100**. With reference to FIG. 6, an example embodiment of a plunger lift gauging tool **1000** is shown. Plunger lift gauging tool **1000** has an upper portion **1002**. In the illustrated embodiment, upper portion **1002** is formed as external fishneck **1004**, to allow retrieval and removal of plunger lift gauging tool **1000** by wireline or other conventional plunger retrieval methods in the event tool **1000** becomes stuck in a well. In alternative embodiments, an internal fishneck could be provided in place of external fishneck **1004**, or an upper end with no fishneck could be used.

**[0099]** Tool **1000** has a base portion **1006**. Interposing upper portion **1002** and base portion **1006** is at least one pad **1008**. Pad **1008** comprises a spring-mounted pad typical of those used in pad plungers. The embodiment of plunger lift gauging tool **1000** illustrated in FIGs. 6 and 7 has one pad **1008**, which is formed of a plurality of longitudinally aligned pad sections **1012**.

**[0100]** In the illustrated embodiment of FIGs. 6 and 7, each pad **1008** comprises a plurality of longitudinally aligned pad sections **1012** and a pair of collars **1014**. Pad sections **1012** have a curved outer circumference and a curved inner circumference, so that the plurality of longitudinally aligned pad sections **1012** define a generally cylindrical structure. Collars **1014** are provided at each of the top and bottom ends of pad **1008**, to retain pad **1008** in place.

**[0101]** With reference to FIG. 8, which shows a side view of a plunger lift gauging tool **1000** in a disassembled configuration with the pad **1008** and measuring rings **1020** removed, the illustrated example plunger lift gauging tool **1000** has a central shaft **1010**. The bottom end of central shaft **1010** has a threaded region **1018**, for receiving a correspondingly threaded surface provided on the interior of base portion **1006**.

**[0102]** With reference to FIG. 9, in the assembled configuration one or more pads **1008** (three in the illustrated embodiment, although the number could be varied, e.g. one, two, four or five) are provided on central shaft **1010**. The pad sections **1012** project radially outwardly from central shaft **1010**, and together provide tool **1000** with a cylindrical outer diameter, so that tool **1000** can be run in a well in the same manner as a conventional plunger. Central shaft **1010** assembled together with pads **1008** is generally similar to a typical pad plunger, which is referred to herein as a “pad plunger body”.

**[0103]** FIG. 10A shows a side view and FIG. 10B shows a top view of a pad **1008**. As best shown in FIG. 10B, a plurality of pad sections **1012** are longitudinally aligned so that their curved outer perimeters define an outer pad perimeter **1034**. Each pad **1008** also has a generally cylindrical central aperture **1036** having a generally circular cross-section, to facilitate inserting each pad **1008** onto central shaft **1010**. While central shaft **1010** has been described as generally cylindrical and central aperture **1036** has been described as having a generally circular cross-section, it will be appreciated by one skilled in the art that these shapes could be varied (e.g. central shaft **1010** could have a generally triangular or square cross-section and central aperture **1036** of each pad **1008** could be provided with a corresponding generally triangular or square cross-section, respectively), so long as pads **1008** and (measuring rings **1020** as described below) can be slid onto central shaft **1010**.

**[0104]** In the illustrated embodiment of FIGs. 6 and 7, a pair of measuring rings **1020** are provided for mounting on tool **1000**. With reference to FIG. 11, an example embodiment of a measuring ring **1020** has a plurality of radially outwardly projecting tabs **1022** formed thereon. In the illustrated embodiment, measuring ring **1020** is shown as having six approximately equidistantly spaced projecting tabs **1022**. However, in alternative embodiments, measuring ring **1020** could be provided with any desired number of projecting tabs, e.g. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 or more, and the projecting tabs need not be spaced equally or positioned symmetrically.

**[0105]** Projecting tabs **1022** extend radially outwardly from a main body **1024** of measuring ring **1020**. Main body **1024** has a central aperture **1026** formed therethrough, so that measuring rings **1020** can be inserted over central shaft **1010** in use. The internal diameter **1028** of main body **1024** is shaped and configured to fit around central shaft **1010**. In the illustrated embodiment, central shaft **1010** is generally cylindrical and measuring ring **1020** is formed as a generally circular disc with a circular central aperture **1026**, so that measuring ring **1020** can be aligned concentrically with central shaft **1010**. In some embodiments, the fit between internal diameter **1028** of measuring rings **1020** and central shaft **1010** is very tight, so that measuring rings **1020** do not easily wiggle or move with respect to central shaft **1010**. In some embodiments, the internal diameter **1028** of measuring rings **1020** is sufficiently small that measuring rings **1020** effectively have to be threaded onto central shaft **1010**. As outlined above with respect to central aperture **1036** of pads **1008**, changes could be made to the cross-sectional shape of central shaft **1010** and central aperture **1026** of measuring ring **1020** (e.g. triangular, square, asymmetrical, etc.) so long as measuring ring **1020** can be slid onto central shaft **1010**.

**[0106]** The outer diameter **1032** of measuring ring **1020** is defined by the outermost portions of two opposed projecting tabs **1022**, as illustrated in FIG. 11. While in the illustrated embodiment, projecting tabs **1022** are illustrated as being provided in opposed pairs to define the outer diameter **1032**, because the plunger lift gauging tool **1000** is positioned within the well tubing by pads **1008** as described in more detail below, it is not necessary that projecting tabs **1022** be provided as opposed pairs. That is, while the outer diameter **1032** of measuring ring **1020** is notionally defined by the distance between two opposed projecting tabs **1022** as illustrated in FIG. 11, the tabs themselves could be offset with respect to one another and still provide the same effective outer diameter **1032** by projecting outwardly with the same radius but at different locations around measuring ring **1020**. Thus, in embodiments in which projecting tabs **1022** are not provided as opposed pairs, the effective outer diameter **1032** of measuring ring **1020** would be twice the value of the radius measured from the axial centre of tool **1000** to the outside edge of one projecting tab **1022**. This value is included within the meaning of the term "outer diameter" as used herein.

**[0107]** To install pads **1008** and measuring rings **1020** on plunger lift gauging tool **1000**, base portion **1006** is removed from central shaft **1010**. The central aperture **1026** of each measuring ring is inserted over central shaft **1010**, and the central aperture **1036** of each pad **1008** is inserted over central shaft **1010**. The pads **1008** and measuring rings **1020** can be inserted in any desired number and orientation. At least one pad **1008** and one measuring ring **1020** must be provided. However, more reliable results may be achieved by using more than one measuring ring. For example, the example embodiment illustrated in FIGs. 6 and 7 has two measuring rings **1020**, with one pad **1008** interposing the two measuring rings. The example embodiment illustrated in FIG. 9 has four measuring rings **1020** and three pads **1008**, with one pad **1008** interposing each pair of adjacent measuring rings **1020**. In alternative embodiments, one or more of the measuring rings **1020** illustrated in FIG. 6 could be omitted, to a minimum of one measuring ring **1020**.

**[0108]** In the illustrated embodiment, at least one measuring ring **1020** is required to provide at least one projecting tab **1022**. However, if projecting tab **1022** was secured to central shaft **1010** in some other manner (for example by being integrally formed therewith or directly coupled thereto), use of a measuring ring **1020** would not be required.

**[0109]** To maintain the positioning of plunger lift gauging tool **1000** within a tubing of a well, each pad section **1012** is spring-loaded as in a conventional pad plunger. The springs bias pad sections **1012** outwardly with respect to central shaft **1010**, but also allow pad sections **1012** to be compressed inwardly towards central shaft **1010**, for example if that pad section **1012** is contacted by a portion of tubing with a narrower diameter than the rest of the tubing. In this manner, pad sections **1012** can move inwardly and outwardly in response to changes in the internal diameter of the downhole tubing in which tool **1000** is operated. Pad sections **1012** are generally forced outwardly away from central shaft **1010** by the springs, so that good contact is maintained between pad sections **1012** and the tubing of the well. The outer edges of pad sections **1012** define an outside diameter of the pads (i.e. pad outer perimeter **1034**) when pad sections **1012** are fully extended outwardly by the springs to their fully extended state.

**[0110]** This contact maintains a generally consistent vertical orientation of tool **1000** within the tubing. Maintaining a generally consistent vertical orientation of tool **1000** within the tubing helps to prevent tool **1000** from bumping laterally within the tubing, which might cause projecting tabs **1022** to be deflected even though the internal diameter of the tubing is sufficiently large to accommodate the full outer diameter **1032** of projecting tabs **1022**.

**[0111]** FIGs. 6 and 7 show an example embodiment of a plunger lift gauging tool **1000** in which no springs are fitted inside pad **1008** (i.e. in which pad sections **1012** are in a position equivalent to their fully compressed position) for the purpose of better showing how rings **1020** are placed on tool **1000**. FIG. 12 illustrates a top view of this configuration to more clearly show this configuration. In this fully compressed position, the outer diameter **1032** of projecting tabs **1022** of measuring ring **1020** is larger than the diameter of outer pad perimeter **1034**. In this configuration, tabs **1022** are exposed to contact with the tubing of a well in which plunger lift gauging tool **1000** is cycled, and tabs **1022** will be deflected if they make contact with a region of the tubing.

**[0112]** FIGs. 13 and 14 show how pad sections **1012** are secured on central shaft **1010** in a manner known in the art. Central shaft **1010** has a plurality of radially inwardly extending depressions **1038**. A corresponding plurality of radially outwardly extending depressions **1040** are provided on the inside surface of pad sections **1012**, so that depressions **1038**, **1040** are aligned when pad sections **1012** are assembled onto central shaft **1010**. A plurality of springs **1042** are inserted within the depressions **1038**, **1040**, so that a spring **1042** is secured in place between central shaft **110** and pad sections **1012** within a pair of corresponding depressions **1038**, **1040**. Springs **1042** apply a radially outward biasing force against pad sections **1012**, so that pad sections **1012** are biased to move radially outwardly in portions of the tubing that have a wider internal diameter, to thereby maintain a generally consistent orientation of plunger lift gauging tool **1000** within the tubing.

**[0113]** To hold pad sections **1012** in place, each pad section contains a locking receptacle

**1044** on a first longitudinal edge thereof, and a locking tongue **1046** on the opposite longitudinal edge thereof. The locking tongue **1046** of a first pad section **1012** is inserted into the locking receptacle **1044** of an adjacent pad section **1012** to thereby secure pad sections **1012** onto central shaft **1010**. Pad sections **1012** are further secured on central shaft **1010** by engagement of axially extending indentations **1048** formed at the transverse ends of pad sections **1012** with axially extending projections **1050** formed on collars **1014** that secure pad sections **1012** in place. FIG. 14 shows an example embodiment of a plunger lift gauging tool in which the pad sections **1012** have been pulled back from the central shaft **1010** to better illustrate how springs **1042** function to apply a radially outward biasing force against pad sections **1012**.

**[0114]** As described above, however, in normal use, pad sections **1012** are forced outwardly by springs **1042** provided within pad **1008**. The default or fully expanded state of plunger lift gauging tool, i.e. when springs **1042** are fully extended to their default position, is illustrated in FIGs. 15A and 16, where it can be seen that outer pad perimeter **1034** extends radially outwardly to a greater extent than measuring rings **1022**.

**[0115]** In this way, the pad sections **1012** (not projecting tabs **1022**) are generally in contact with the inner diameter of the tubing in which tool **1000** is run, so that inward and outward movement of spring-loaded pad sections **1012** can compensate for any changes in internal diameter of the tubing and maintain a generally vertical orientation of tool **1000**. However, as pad sections **1012** are compressed inwardly by any decreases in internal diameter of the tubing, projecting tabs **1022** will become exposed to contact with the tubing, and will be deflected (i.e. bent) by making contact with the internal diameter of the tubing. That is, as pad sections **1012** move inwardly to a sufficient extent due to compression within any narrowed regions of the tubing of the well, projecting tabs **1022** will be exposed to contact with that narrowed region of tubing, and will be deflected if the outer diameter **1032** of the projecting tabs **1022** is greater than the diameter of that narrowed region of tubing. This is illustrated more clearly in FIG. 15B, in which manual pressure has been applied to compress springs **1042**, so that the outer edges of the pad sections **1012** are radially inward of projecting tabs **1022**. Thus, as the internal diameter of the tubing narrows, pad sections **1012** are compressed radially inwardly, and projecting tabs **1022** become exposed to contact with the internal diameter of the tubing, which causes projecting tabs **1022** to be bent or deflected.

**[0116]** In use, a user inserts plunger lift gauging tool **1000** into the tubing of a gas producing well when the well is shut-in, as is conventional in the operation of plunger lift tools. When the well is shut-in, plunger lift gauging tool **1000** falls to the bottom of the well under the force of gravity. When the well is moved to the open configuration, plunger lift gauging tool **100** is lifted back to the surface under the force of sufficient gas pressure, in the same manner as a conventional plunger. Unlike a conventional plunger, which is cycled repeatedly within a well, typically plunger lift gauging tool **1000** is cycled only once within the well.

**[0117]** As plunger lift gauging tool **1000** travels through the tubing of the well, projecting tabs **1022** contact and are bent by any regions of the tubing that have a narrower diameter than the outer diameter **1032** of measuring ring **1020**. Thus, after plunger lift gauging tool **100** has been cycled through the well, manual inspection of projecting tabs **1022** provides a visual indication of whether a plunger having a diameter corresponding to the outer diameter **1032** of measuring ring **1020** can be used in that particular well.

**[0118]** In particular, if none of projecting tabs **1022** are bent or deformed after plunger lift gauging tool **1000** has been cycled through the well, a plunger having a diameter at least as large as the outer diameter **1032** of measuring ring **1020** can be used in that well. If one or more of projecting tabs **1022** are bent or deformed after plunger lift gauging tool **1000** has been cycled through the well, a plunger having a diameter as large as the outer diameter **1032** of measuring ring **1020** cannot be used in that well, and is likely to become stuck in the tubing if used. In such a situation, an operator may choose to mount a measuring ring **1020** having a smaller outer diameter **1032** on plunger lift gauging tool **1000** and cycle the tool **1000** through the well again, to see if the well will accommodate a plunger having the same diameter as the measuring ring **1020** with the smaller outer diameter **1032**.

**[0119]** Suitable outer diameters **1032** of the measuring rings **1020** to be selected for use with tool **1000** depend on the anticipated diameter of the tubing of the well into which tool **1000** is to be inserted. A typical well tubing has a diameter of 2", although drifting of the tubing (i.e. flaring of the ends of the tubing at the joints during construction of the well) and buildup of waxes or other substances within the tubing can result in local variations in the diameter of the tubing of any given well. In a typical well, the tubing will have an internal diameter of at least 1.90"but less than 1.995". In some embodiments of plunger lift gauging tool **1000** intended for use with such wells, measuring rings **1020** are provided with a range of outer diameters **1032** in the range of 1.91" to 1.95", including any value therebetween, e.g. 1.92", 1.93" or 1.94". Such measuring rings **1020** are useful for wells having tubing with an internal diameter of 2". It will be appreciated that measuring rings **1020** having different ranges of outer diameters **1032** should be used for wells having a tubing with an internal diameter other than 2", and such measuring rings **1020** fall within the scope of some embodiments of the present invention. Also, in some embodiments intended for use in wells with tubing having an internal diameter of 2", smaller diameters could be used, e.g. 1.85", 1.86", 1.87", 1.88", 1.89" or 1.90", so e.g. any range between 1.85" and 1.94".

**[0120]** In some embodiments, plunger lift gauging tool **1000** is cycled within a given well multiple times, and the outer diameter **1032** of the measuring ring or rings **1020** provided on plunger lift gauging tool is changed between each cycle in order to determine the maximum permissible diameter of plunger that can be used in that given well with a minimal likelihood that the plunger will become trapped in a region of the tubing with a lower effective diameter than the remainder of the tubing. This is the diameter of plunger that is likely to provide the most efficient plunger lift for that particular well. For example, a user may initially provide a plunger lift gauging tool **1000** with one or more measuring rings **1020** having an outer diameter **1032** of 1.94". If one or more projecting tabs **1022** is deflected after that tool **1000** has been cycled through the well once on this first cycle, a user may remove the pads **1008** and measuring rings **1020** from tool **1000** by unthreading base portion **1006** and sliding pads **1008** and measuring rings **1020** off of central shaft **1010**.

**[0121]** A user may then insert one or more measuring rings **1020** having a narrower outer diameter **1032**, for example 1.92", onto central shaft **1010** and insert one or more pads **1008** onto central shaft **1010**, threadably engage base portion **1006** onto threaded region **1018** of central shaft **1010** so that tool **1000** is in the assembled configuration, and cycle the tool **1000** through the well again for a second cycle. If none of the projecting tabs **1022** are deflected on the second cycle of tool **1000**, a user may repeat this process of disassembling and reassembling tool **1000** using one or more measuring rings **1020** having an outside diameter **1032** intermediate between that used in the first and second cycle, for example 1.93"in this example embodiment.

**[0122]** The user may then cycle tool **1000** through the well again for a third cycle. If any of the projecting tabs **1022** are deflected on the third cycle, a user would know that the largest diameter of plunger that should be used in the well is 1.92". In contrast, if none of the projecting tabs **1022** are deflected on the third cycle, a user would know that the largest diameter of plunger that should be used in the well is 1.93". Selection of the largest possible plunger diameter in this manner can help a user select a plunger diameter that is likely to give the most effective artificial lift within the well, particularly in the case of venturi plungers which have an internal orifice through which gas and fluid can pass (in addition to the passage of gas and fluid past the outside diameter of the plunger, as occurs to some extent for all plungers).

**[0123]** It will be clear to those skilled in the art that the exact order in which the outer diameter **1032** of measuring ring(s) **1020** on plunger lift gauging tool **1000** is varied is not critical. Also, the number of different outer diameters **1032** that are tested is not critical, although testing a wider range of diameters will allow a user to make a more precise determination of the maximum permissible diameter of plunger that should be used in a particular well. For example, a user could carry out only one cycle of plunger lift gauging tool **1000** having a first outer diameter **1032.** If none of the projecting tabs **1022** are deflected, a user will know that a plunger having a diameter generally the same as the first outer diameter **1032** can be used in the well with a low likelihood of becoming stuck in the tubing, although it would be possible that a larger diameter plunger could be used. By conducting additional measurements using a plurality of different outer diameters **1032**, a better assessment of the maximum diameter of plunger that can be used in the well can be made.

**[0124]** In some embodiments, the determination of what size of outer diameter **1032** of measuring ring **1020** to use initially within a given well is made based on an objective evaluation of the likely internal diameter of the tubing of that given well. For example, an older well is likely to have a narrower internal diameter of the tubing. A well with known issues (i.e. known narrow regions of tubing discovered in previous operations) will also be likely to have a narrower internal diameter of the tubing.

**[0125]** In some embodiments, two or more measuring rings **1020** having different outer diameters **1032** could be installed on a single plunger lift gauging tool **1000**. In some cases, the projecting tabs **1022** on the measuring ring **1020** having the larger outer diameter **1032** might be deflected, while the projecting tabs **1022** on the measuring ring having the smaller outer diameter **1032** might not be deflected. This would tell the user of tool **1000** that a plunger having a diameter smaller than the outer diameter **1032** of the measuring ring **1020**

but at least as large as the smaller outer diameter **1032** should be used in the well. While such an approach might allow a user to determine with only one cycle of tool **1000** what diameter of plunger can be used within the well, it is believed that more reliable results may be obtained by conducting multiple cycles of a plunger lift gauging tool **1000** having one or more measuring rings **1020** having the same outer diameter **1032** on each individual cycle, as in the example embodiment described above.

**[0126]** In some embodiments, a kit for determining what size of plunger should be used in a well is provided. The kit has a plunger lift gauging tool **1000** with removable measuring rings **1020** and pads **1008** as described above. The kit includes a plurality of different measuring rings **1020** having a plurality of different outer diameters **1032**, so that an operator can iteratively mount different-sized measuring rings **1020** on plunger lift gauging tool **1000** to determine the maximum size of plunger that can likely be used within a given well.

**[0127]** While in the example embodiments described herein projecting tabs **1022** have been described as being provided on measuring rings **1020** to facilitate easily changing the outer diameter **1032** thereof, projecting tabs extending outwardly to a desired outer diameter **1032** can be provided affixed to any suitable component of a pad plunger body. For example, one or more projecting tabs **1022** could be mounted to upper portion **1002** or base portion **1006** of plunger lift gauging tool **1000**, or one or more projecting tabs **1022** could be affixed to central shaft **1010** and pads **1008** clamped around central shaft **1010**, rather than being slid thereon.

**[0128]** Suitable materials for the manufacture of plunger lift gauging tool **1000** can be selected by those skilled in the art. Central shaft **1010** and pad sections **1012** are typically made from a rigid metallic material, as is known in the art of plunger construction. In some embodiments, measuring rings **1020** are made from a malleable material having good mechanical strength so that measuring rings **1020** can be deflected or otherwise bent by contact with a tubing of a well and retain that deflection or bend so that it can be identified by a visual inspection when tool **1000** is removed from the well. In some embodiments, measuring rings **1020** are made from a metallic material, for example aluminum or brass. The materials used in the construction of plunger lift gauging tool **1000** should be resistant to corrosion and any chemicals or fluids with which tool **1000** may come into contact with in a well.

## Examples

**[0129]** Some embodiments of the present invention are further described with reference to the following examples, which are intended to be illustrative and not limiting in nature.

*Example 1.0 – Lab Well Test Model*

**[0130]** The first phase of work done involved a laboratory well test model. Testing was carried out using plungers having varying outer diameters to better understand how the tools behaved in the well model. Data was collected with various outer diameter sizes of downhole plungers. To test the plungers with the larger diameters, the inventor used a full scale well model which consists of conventionally sized tubing having an inner diameter of 2", a water pump and an air compressor. The amount of water pumped into the well model can be adjusted, and the air flow can be adjusted to simulate real life situations in gas wells. Four different Venturi plungers were used for testing: a conventional Venturi plunger having an outer diameter of 1.90", and three Venturi plungers having larger outer diameters of 1.91", 1.92" and 1.93", respectively.

**[0131]** The plungers were floated at three different heights (1.0 m, 2.0 m and 3.0 m) in the tubing, and the flow rate, pressure and temperature were recorded. The effect of the different outer diameters of the plungers on the amount of flow and pressure it took to hold it in one position was recorded. Three trials were conducted for each plunger.

**[0132]** The results were quite similar at all three heights, giving a consistent result for the flow required to support each plunger. At all three heights it took approximately 13% less flow to float a plunger having an outer diameter of 1.91", 21% less flow to float a plunger having an outer diameter of 1.92", and 32% less flow to float a plunger having an outer diameter of 1.93", as compared with a standard reference plunger having an outer diameter of 1.94". Results of these experiments are shown in Table 1.

**Table 1.** Results for Lab Testing of Different Plunger Outer Diameters

| Flow Rate: MCF | Trial 1 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Pressure: kpa | 1.00m | | | 2.00m | | | 3.00m | | |
| Temp: deg celsius | Flow Rate | Pressure | Temp | Flow Rate | Pressure | Temp | Flow Rate | Pressure | Temp |
| New Venturi 1.93" short | 28.5 | 17.6 | 19.1 | 32.7 | 17.6 | 19.1 | 35.4 | 18 | 19 |
| New Venturi 1.92" short | 33.3 | 17.2 | 19.5 | 37.9 | 17.8 | 19.6 | 41.3 | 18.6 | 19.6 |
| New Venturi 1.91" short | 39.5 | 19.3 | 20.8 | 41.8 | 18.4 | 20.5 | 44.7 | 20.2 | 20 |
| New Venturi 1.90" short | 45.3 | 19.7 | 20.1 | 49.1 | 19.7 | 20.2 | 51.6 | 19.6 | 20.1 |

| Flow Rate: MCF | Trial 2 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Pressure: kpa | 1.00m | | | 2.00m | | | 3.00m | | |
| Temp: deg celsius | Flow Rate | Pressure | Temp | Flow Rate | Pressure | Temp | Flow Rate | Pressure | Temp |
| New Venturi 1.93" short | 30.8 | 17.2 | 18.8 | 32.9 | 16 | 18.8 | 37.1 | 17.6 | 18.5 |
| New Venturi 1.92" short | 36.7 | 16.4 | 19.5 | 39.4 | 17.2 | 19.3 | 42 | 18 | 19.3 |
| New Venturi 1.91" short | 39.3 | 18.2 | 19.5 | 43.4 | 18.8 | 19.3 | 45.1 | 19.6 | 19.1 |
| New Venturi 1.90" short | 45.8 | 19.8 | 20 | 48.9 | 19.8 | 20.1 | 51.5 | 19.7 | 20.1 |

| Flow Rate: MCF | Trial 3 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Pressure: kpa | 1.00m | | | 2.00m | | | 3.00m | | |
| Temp: deg celsius | Flow Rate | Pressure | Temp | Flow Rate | Pressure | Temp | Flow Rate | Pressure | Temp |
| New Venturi 1.93" short | 30.1 | 15.1 | 18.3 | 32.8 | 16.3 | 18.3 | 37.2 | 16.8 | 18.2 |
| New Venturi 1.92" short | 35.4 | 16.6 | 19.6 | 39.1 | 17.2 | 19.4 | 41.9 | 18.2 | 19.4 |
| New Venturi 1.91" short | 39.3 | 18.3 | 19.6 | 43.3 | 18.9 | 19.3 | 45.2 | 19.5 | 19.5 |
| New Venturi 1.90" short | 45.6 | 19.6 | 19.9 | 48.7 | 19.8 | 20.2 | 51.4 | 19.8 | 19.9 |

<u>Example 2.0 – Field Testing</u>

**[0133]** Following completion of lab tests, field tests were conducted on producing gas wells. The procedure on plunger lift wells in the field was as follows:

- Remove existing plunger;
- Perform acoustic fluid test to establish baseline parameters;
- Drop and track drive plunger and measuring sleeve starting with the smallest diameter measuring sleeve;
- Perform acoustic fluid test after each measuring sleeve run;
- Continue sizing process with larger plunger outer diameter intervals;
- Hang applicable well head tags confirming the well has been gauged to run a specific plunger size;
- Adjust and document new well control system parameters based on tool selection;
- Completion of well follow up process.

**Table 2.** Results of Field Testing of Maximum Plunger Outer Diameter.

| Well Location | Previous Daily Gas Prod. e3m3/ Day | New Daily Gas Prod. e3m3/ Day | Increased Gas Prod. e3m3/ Day | Increased Gas Prod. % | Original Lift Pressure (Kpa) | Oversize Venturi Lift Pressure (Kpa) | Lift Pressure Decrease % | Original Plunger Type | 10" Long Venturi O.D. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.850 | 2.340 | 0.49 | 26% | 360 | 330 | 8% | Venturi Steel 4.7mm | 1.920 |
| 2 | 2.400 | 2.660 | 0.26 | 11% | 425 | 310 | 27% | Solid Ring | 1.910 |
| 3 | 2.940 | 2.940 | 0.00 | 0% | 460 | 400 | 13% | Fishbone | 1.920 |
| 4 | 2.620 | 2.870 | 0.25 | 10% | 390 | 310 | 21% | Solid Ring | 1.900 |
| 5 | 2.410 | 3.000 | 0.59 | 24% | 450 | 400 | 11% | Solid Ring | 1.920 |
| 6 | 3.970 | 5.010 | 1.04 | 26% | 510 | 460 | 10% | Solid Ring | 1.910 |
| 7 | 1.580 | 1.710 | 0.13 | 8% | 490 | 400 | 18% | Venturi Steel 4.7mm | 1.910 |
| 8 | 1.770 | 2.330 | 0.56 | 32% | 480 | 300 | 38% | 12" Solid Ring | 1.900 |
| 9 | 1.470 | 1.490 | 0.02 | 1% | 470 | 400 | 15% | Dual Pad | 1.910 |
| 10 | 0.830 | 1.050 | 0.22 | 27% | 520 | 400 | 23% | Solid Ring | 1.910 |
| 11 | 4.110 | 4.550 | 0.44 | 11% | 490 | 300 | 39% | Solid Ring | 1.920 |
| 12 | 2.750 | 4.600 | 1.85 | 67% | 510 | 400 | 22% | Venturi Long Steel L80 4.7mm | 1.930 |
| 13 | 4.040 | 6.500 | 2.46 | 61% | 500 | 400 | 20% | Venturi Steel L80 4.7mm | 1.930 |
| 14 | 5.230 | 5.800 | 0.57 | 11% | 520 | 400 | 23% | Venturi Steel L80 4.7mm | 1.930 |
| 15 | 1.630 | 2.000 | 0.37 | 23% | 560 | 500 | 11% | Venturi Steel L80 4.7mm | 1.910 |
| 16 | 4.380 | 5.600 | 1.22 | 28% | 490 | 400 | 18% | Venturi Steel L80 4.7mm | 1.920 |
| 17 | 5.820 | 6.200 | 0.38 | 7% | 590 | 500 | 15% | Venturi Long Steel L80 4.7mm | 1.930 |
| 18 | 2.190 | 3.000 | 0.81 | 37% | 470 | 400 | 15% | Venturi Long Steel L80 4.7mm | 1.920 |
| 19 | 3.400 | 3.400 | 0.00 | 0% | 490 | 280 | 43% | Venturi Steel L80 4.7mm | 1.930 |
| 20 | 5.470 | 6.100 | 0.63 | 12% | 500 | 435 | 13% | Venturi Long Steel L80 4.7mm | 1.910 |
| 21 | 1.860 | 2.100 | 0.24 | 13% | 550 | 360 | 35% | Venturi Long Steel L80 4.7mm | 1.910 |
| 22 | 1.350 | 1.500 | 0.15 | 11% | 550 | 295 | 46% | Venturi Steel L80 4.7mm | 1.920 |
| 23 | 4.180 | 4.700 | 0.52 | 12% | 450 | 405 | 10% | Venturi Steel L80 4.7mm | 1.930 |
| 24 | 1.130 | 1.300 | 0.17 | 15% | 420 | 290 | 31% | Venturi Long Steel L80 4.7mm | 1.920 |
| 25 | 4.300 | 5.180 | 0.88 | 20% | 420 | 290 | 31% | Venturi Long Steel L80 4.7mm | 1.930 |

**[0134]** The results of this experiment demonstrate that the use of a plunger having the maximum permissible diameter can potentially considerably enhance the production of fluid from a well.

**[0135]** While a number of exemplary aspects and embodiments are discussed herein, those of skill in the art will recognize certain modifications, permutations, additions and sub-combinations thereof. To the extent that they are not mutually exclusive, features of the embodiments described herein can be combined with features of other embodiments to yield additional embodiments of the invention. It is therefore intended that the following appended aspects and claims and claims hereafter introduced are to be given the broadest interpretation consistent with the specification as a whole.

WHAT IS CLAIMED IS:

1. A method of enhancing fluid production from a well, the method comprising the steps of:

(a) evaluating whether a downhole plunger having a first outer diameter can travel freely within a tubing of the well by

(i) dropping a drive plunger and a measuring sleeve within the tubing of the well, the measuring sleeve having the first diameter and the drive plunger having a diameter less than the first diameter and being positioned below the measuring sleeve in the tubing;

(ii) if the measuring sleeve becomes lodged in the tubing, concluding that a downhole plunger having the first outer diameter cannot travel freely within the tubing of the well and using the drive plunger to dislodge and surface the measuring sleeve; or

(iii) if the measuring sleeve does not become lodged in the tubing, concluding that a downhole plunger having the first outer diameter can travel freely within the tubing of the well;

(b) if the downhole plunger having the first outer diameter can travel freely within the tubing of the well, evaluating whether a downhole plunger having a second outer diameter that is larger than the first outer diameter can travel freely within the tubing of the well by repeating steps (i), (ii) and (iii) using a measuring sleeve having the second outer diameter; and

(c) if the downhole plunger having the second outer diameter cannot travel freely within the tubing of the well, installing a downhole plunger having the first outer diameter in the well and performing artificial lift using the downhole plunger having the first outer diameter.

2. The method as defined in claim 1, further comprising the steps of:

(d) if the downhole plunger having the second outer diameter can travel freely within the tubing of the well, evaluating whether a plunger having a third outer diameter that is larger than the second outer diameter can travel freely within the tubing of the well by repeating steps (i), (ii) and (iii) using a measuring sleeve having the third outer diameter; and

(e) if the downhole plunger having the third outer diameter cannot travel freely within the tubing of the well, installing a downhole plunger having the second outer diameter in the well and performing artificial lift using the downhole plunger having the second outer diameter.

3. The method as defined in claim 2, further comprising the steps of:

(f) if the downhole plunger having the third outer diameter can travel freely within the tubing of the well, evaluating whether a plunger having a fourth outer diameter that is larger than the third outer diameter can travel freely within the tubing of the well by repeating steps (i), (ii) and (iii) using a measuring sleeve having the fourth outer diameter; and

(g) repeating step (f) as required for downhole plungers having successively larger outer diameters until the largest plunger diameter that can travel freely in the well has been determined, and installing a downhole plunger having the largest plunger diameter that can travel freely in the well in the well and performing artificial lift using the downhole plunger having the largest plunger diameter that can travel freely in the well.

4. A method of enhancing fluid production from a well, the method comprising the steps of:

(a) evaluating whether a downhole plunger having a first outer diameter can travel freely within a tubing of the well by

(i) dropping a drive plunger and a measuring sleeve within the tubing of the well, the measuring sleeve having the first diameter and the drive plunger having a diameter less than the first diameter and being positioned below the measuring sleeve in the tubing;

(ii) if the measuring sleeve becomes lodged in the tubing, concluding that a downhole plunger having the first outer diameter cannot travel freely within the tubing of the well and using the drive plunger to dislodge and surface the measuring sleeve; or

(iii) if the measuring sleeve does not become lodged in the tubing,



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concluding that a downhole plunger having the first outer diameter can travel freely within the tubing of the well;

(b) if the downhole plunger having the first outer diameter cannot travel freely within the tubing of the well, evaluating whether a downhole plunger having a second outer diameter that is smaller than the first outer diameter can travel freely within the tubing of the well by repeating steps (i), (ii) and (iii) using a measuring sleeve having the second outer diameter; and

(c) if the downhole plunger having the second outer diameter can travel freely within the tubing of the well, installing a downhole plunger having the second outer diameter in the well and performing artificial lift using the downhole plunger having the second outer diameter.

5. A method as defined in claim 4, further comprising the steps of:

(d) if the downhole plunger having the second outer diameter cannot travel freely within the tubing of the well, evaluating whether a downhole plunger having a third outer diameter that is smaller than the second outer diameter can travel freely within the tubing of the well by repeating steps (i), (ii) and (iii) using a measuring sleeve having the third outer diameter; and

(e) if the downhole plunger having the third outer diameter can travel freely within the tubing of the well, installing a plunger having the third outer diameter in the well and performing artificial lift using the downhole plunger having the third outer diameter.

6. A method as defined in claim 5, further comprising the steps of:

(f) if the downhole plunger having the third outer diameter cannot travel freely within the tubing of the well, evaluating whether a plunger having a fourth outer diameter that is smaller than the third outer diameter can travel freely within the tubing of the well by repeating steps (i), (ii) and (iii) using a measuring sleeve having the fourth outer diameter; and

(g) repeating step (f) as required for downhole plungers having successively smaller outer diameters until the largest plunger diameter that can travel freely in the well has been determined, and installing a downhole plunger having the largest plunger diameter that can travel freely in the well in the well and performing artificial lift using the downhole plunger having the largest plunger diameter that can travel freely in the well.

7. The method as defined in any one of claims 1 to 6, wherein the movement of the drive plunger or the measuring sleeve within the tubing is monitored using an echometer.

8. A method of determining the maximum permissible diameter for a downhole plunger that can be used in a well, the method comprising the steps of:

evaluating a plurality of different plunger outer diameters to determine whether plungers having at least two of the plurality of different plunger outer diameters can travel freely in a tubing of the well by repeating, for the plurality of different plunger outer diameters, the steps of

(i) selecting a first one of the plurality of different plunger outer diameters for analysis;

(ii) dropping a drive plunger and a first measuring sleeve within the tubing of the well, the first measuring sleeve having the first one of the plurality of different plunger outer diameters, and the drive plunger having a diameter that is smaller than the first one of the plurality of different plunger outer diameters and being positioned below the first measuring sleeve in the tubing;

(iii) if the first measuring sleeve becomes lodged in the tubing, concluding that a downhole plunger having the first one of the plurality of different plunger outer diameters cannot travel freely within the tubing of the well and using the drive plunger to dislodge and surface the first measuring sleeve; or

(iv) if the first measuring sleeve does not become lodged in the tubing, concluding that a downhole plunger having the first one of the plurality of different plunger outer diameters can travel freely within the tubing of the well; and

concluding that the maximum permissible diameter for a downhole plunger that can be used in the well is equal to the largest one of the plurality of different plunger outer diameters that will still allow a plunger to travel freely in the well.

9. The method as defined in claim 8, comprising repeating the steps of dropping a drive plunger and a measuring sleeve having one of the plurality of different plunger outer diameters within the tubing of the well for as many of the plurality of different plunger outer diameters as is required to determine the maximum permissible diameter for a downhole plunger that can be used in the well.

10. The method as defined in any one of claims 8 or 9, wherein the movement of the drive plunger or the measuring sleeve within the tubing is monitored using an echometer.

11. A method of determining whether a downhole plunger having a first outer diameter can travel freely within a well, the method comprising the steps of:

dropping a drive plunger in a tubing of the well below a measuring sleeve, the measuring sleeve having an outer diameter equal to the first outer diameter and the drive plunger having an outer diameter smaller than the first outer diameter;

allowing the drive plunger and the measuring sleeve to fall in the tubing; and

if the measuring sleeve becomes lodged in the tubing, concluding that a downhole plunger having the first outer diameter cannot travel freely within the well and using the drive plunger to dislodge and surface the measuring sleeve; or

if the measuring sleeve does not become lodged in the tubing, concluding that a downhole plunger having the first outer diameter can travel freely within the well.

12. The method as defined in claim 11, comprising surfacing both the measuring sleeve and the plunger if the measuring sleeve does not become lodged in the tubing.

13. The method as defined in any one of claims 11 or 12, further comprising monitoring movement of the drive plunger or the measuring sleeve using an echometer.



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14. An apparatus for determining the maximum permissible outer diameter of downhole plunger that can be used in a well, the apparatus comprising:

a measuring sleeve comprising a generally cylindrical outer shell defining an outer diameter and a hollow interior defining a fluid path through the measuring sleeve; and

a drive plunger having an outer diameter smaller than the measuring sleeve for surfacing the measuring sleeve if the measuring sleeve becomes lodged in the tubing.

15. An apparatus as defined in claim 14, wherein the drive plunger comprises a venturi plunger or a pad plunger.

16. A kit comprising a drive plunger and a plurality of measuring sleeves, each one of the plurality of measuring sleeves comprising a different outer diameter.

17. A kit as defined in claim 16, wherein the drive plunger has an outer diameter of 1.90", and wherein the plurality of measuring sleeves comprise measuring sleeves having outer diameters of 1.91", 1.92" and 1.93".

18. A kit as defined in claim 17, wherein the plurality of measuring sleeves further comprise measuring sleeves having outer diameters of 1.94" and 1.95".

19. A kit as defined in claim 16, wherein the drive plunger has an outer diameter of 2.34", and wherein the plurality of measuring sleeves comprise measuring sleeves having outer diameters of 2.35", 2.36" and 2.37".

20. A kit as defined in claim 19 wherein the plurality of measuring sleeves further comprises measuring sleeves having outer diameters of 2.38", 2.39" and 2.40".

21. A kit as defined in any one of claims 16 to 20, wherein the drive plunger comprises a venturi plunger or a pad plunger.



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22. A kit as defined in any one of claims 16 to 21, wherein a minimum internal diameter of each one of the plurality of measuring sleeves along its length comprises at least 1".

23. A kit as defined in any one of claims 16 to 22, further comprising an echometer.

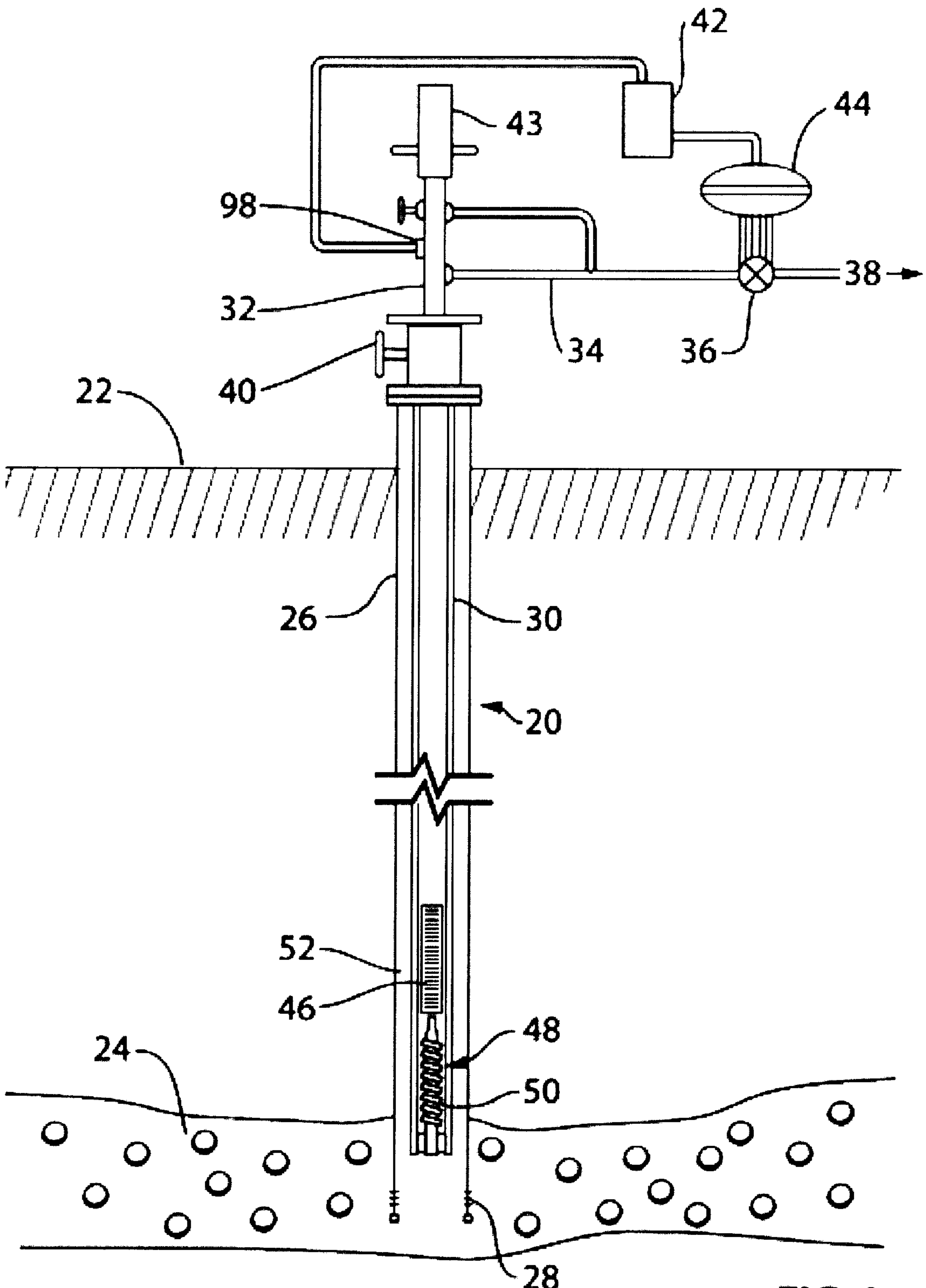



FIG. 1

PRIOR ART

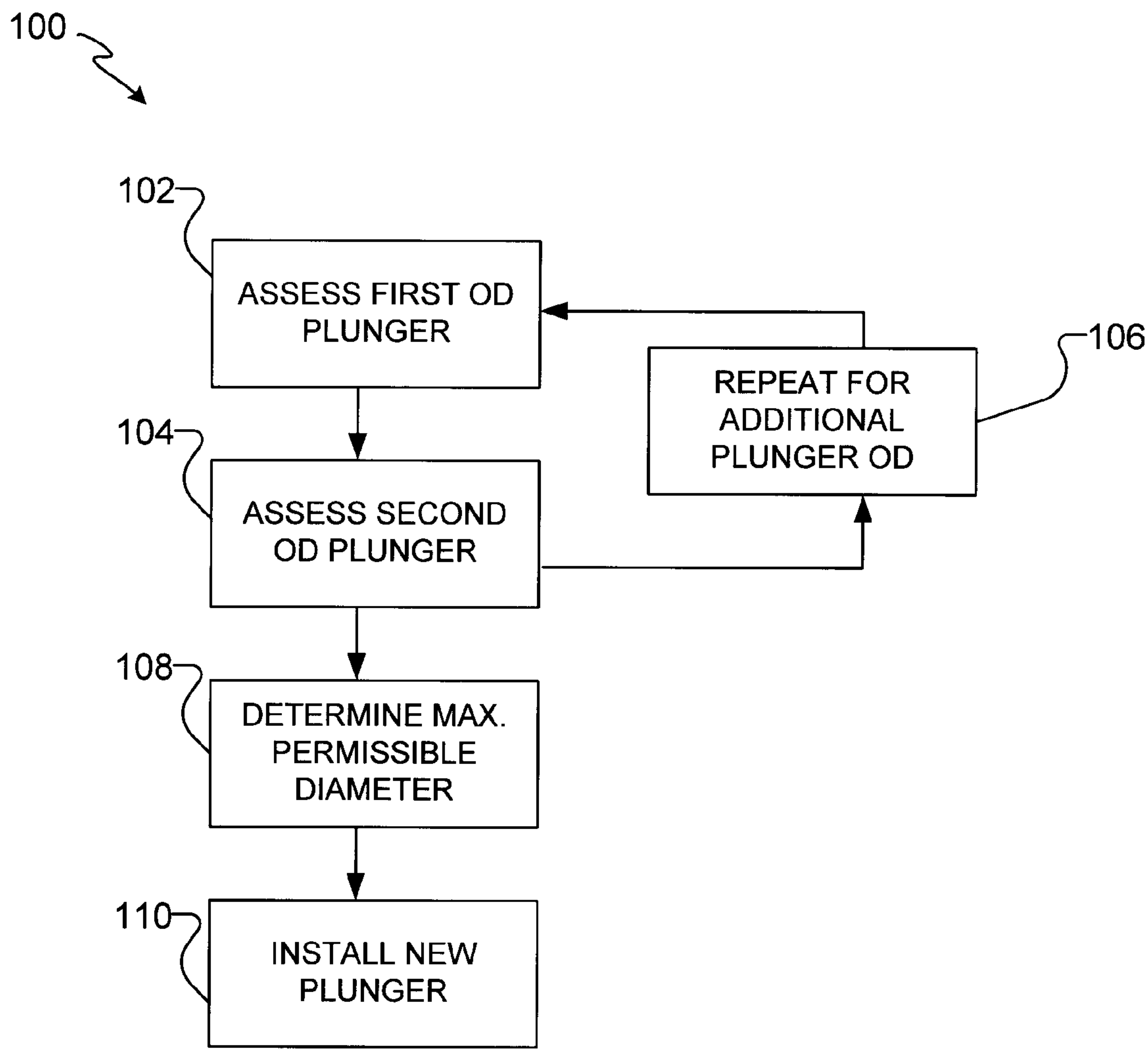

100
102
ASSESS FIRST OD PLUNGER
104
ASSESS SECOND OD PLUNGER
106
REPEAT FOR ADDITIONAL PLUNGER OD
108
DETERMINE MAX. PERMISSIBLE DIAMETER
110
INSTALL NEW PLUNGER

FIG. 2

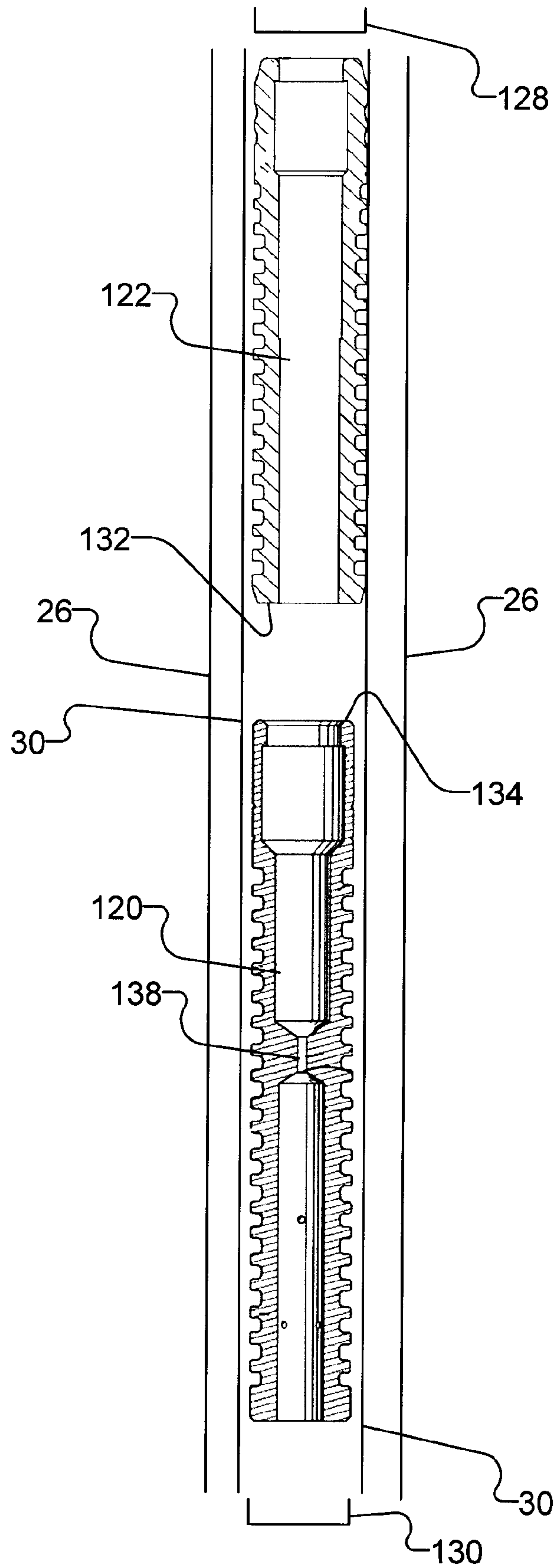



FIG. 3

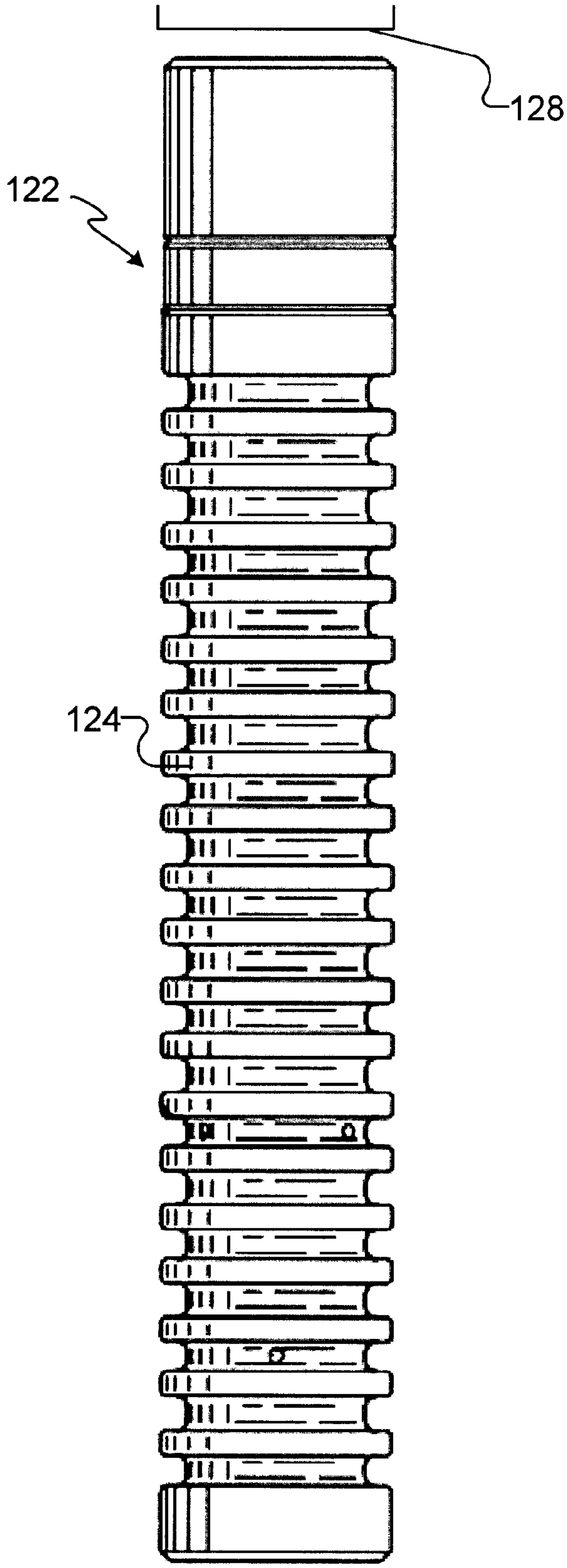



FIG. 4A

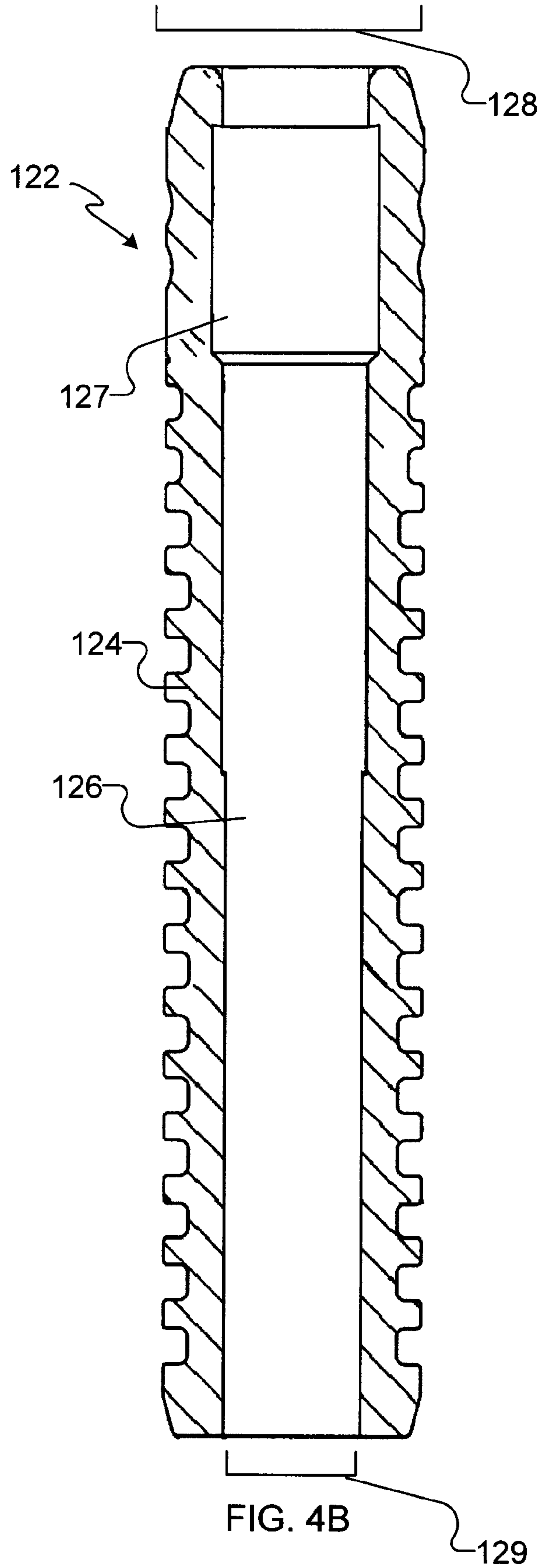



FIG. 4B

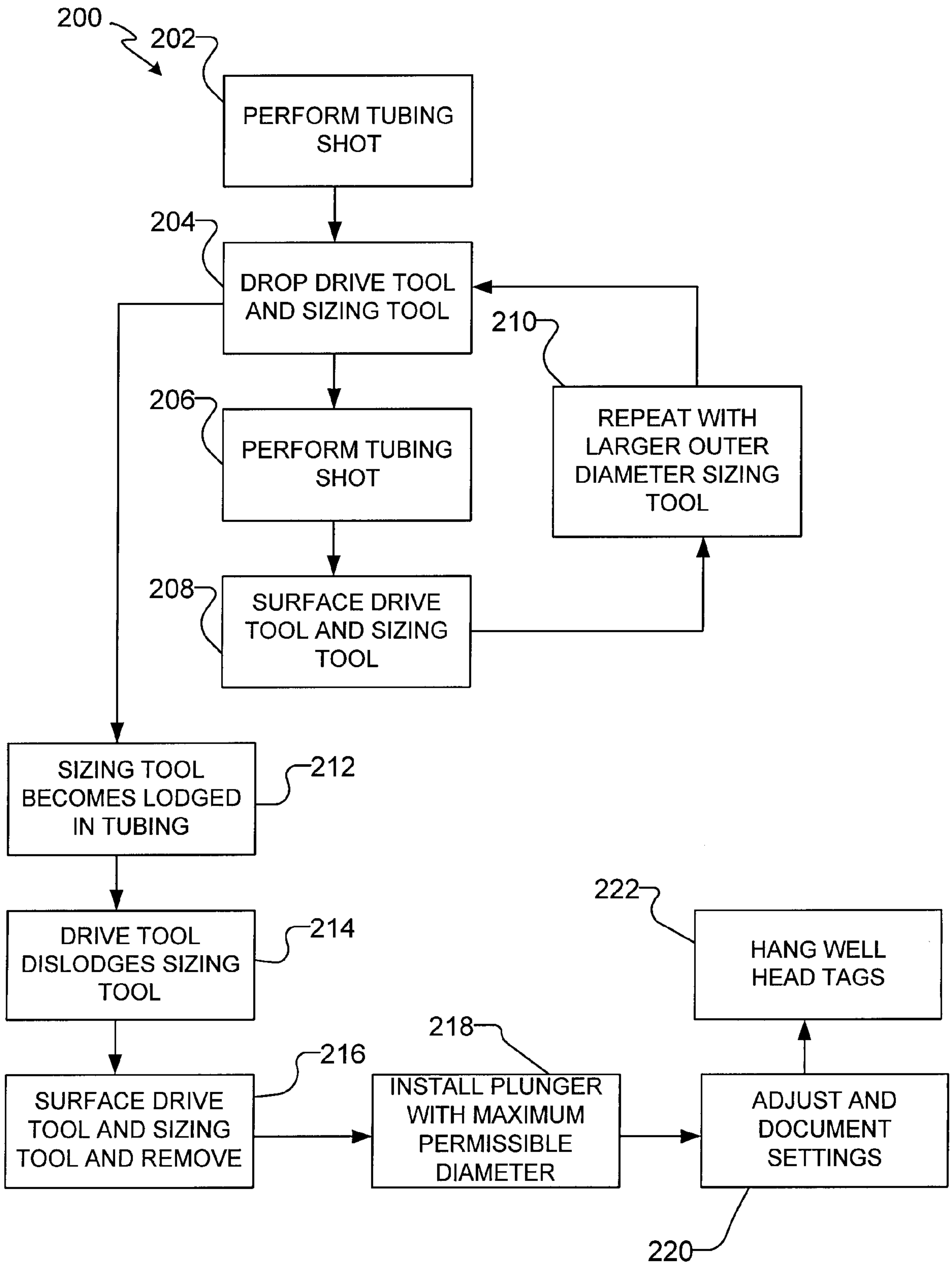

200
202
PERFORM TUBING SHOT
204
DROP DRIVE TOOL AND SIZING TOOL
206
PERFORM TUBING SHOT
208
SURFACE DRIVE TOOL AND SIZING TOOL
210
REPEAT WITH LARGER OUTER DIAMETER SIZING TOOL
SIZING TOOL BECOMES LODGED IN TUBING
212
DRIVE TOOL DISLODGES SIZING TOOL
214
SURFACE DRIVE TOOL AND SIZING TOOL AND REMOVE
216
218
INSTALL PLUNGER WITH MAXIMUM PERMISSIBLE DIAMETER
ADJUST AND DOCUMENT SETTINGS
220
222
HANG WELL HEAD TAGS

FIG. 5

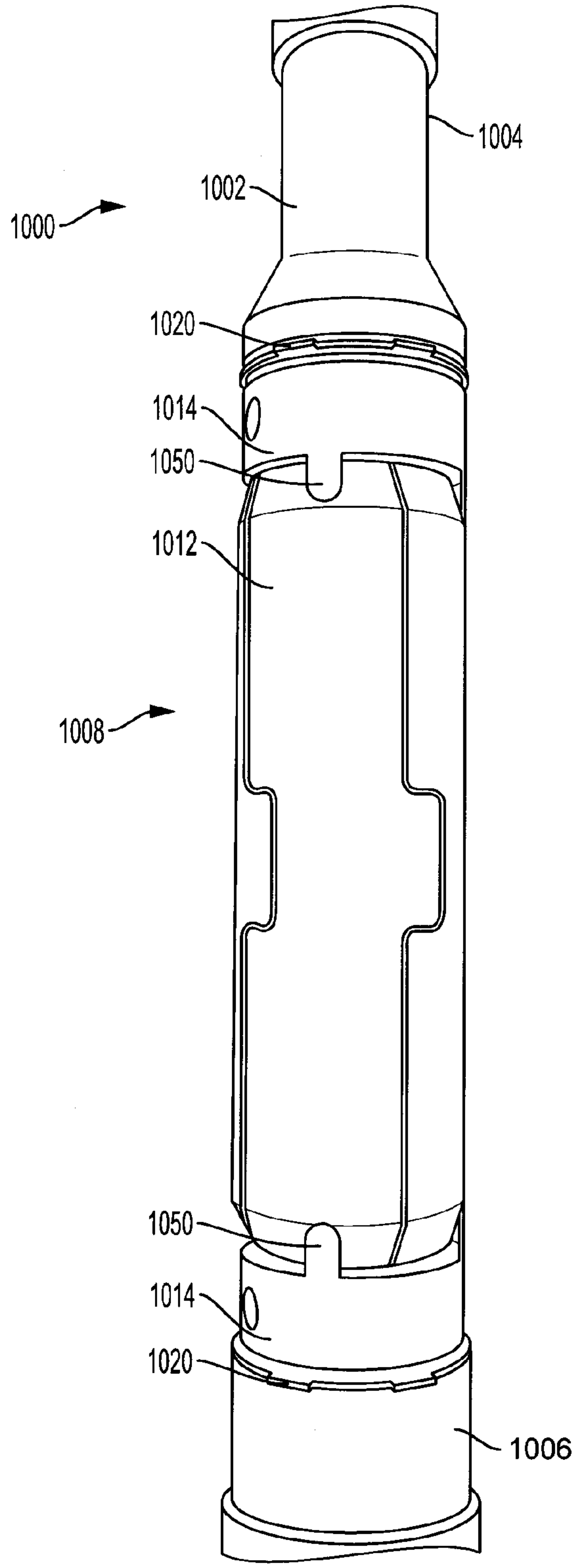



FIG. 6

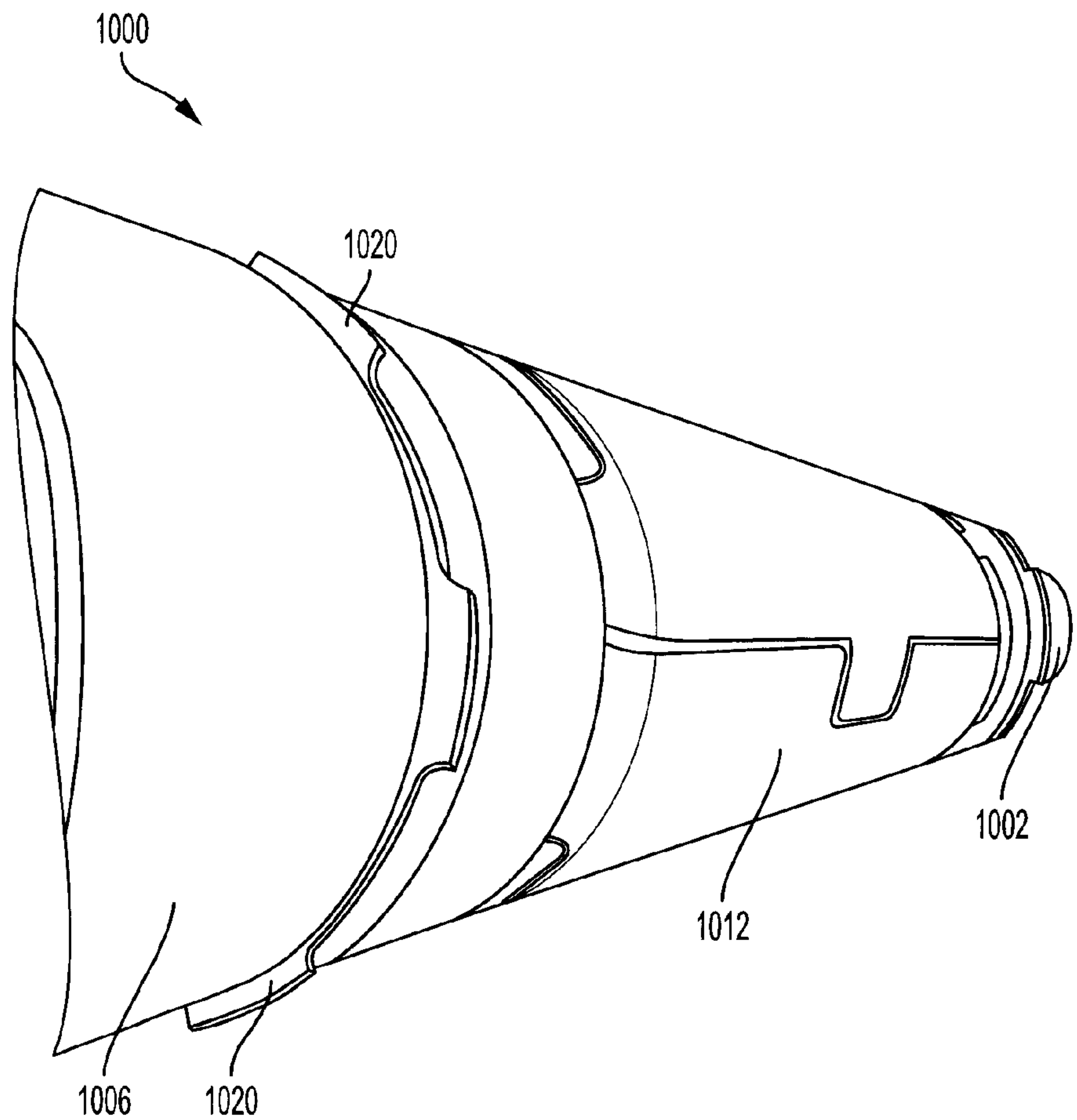



FIG. 7

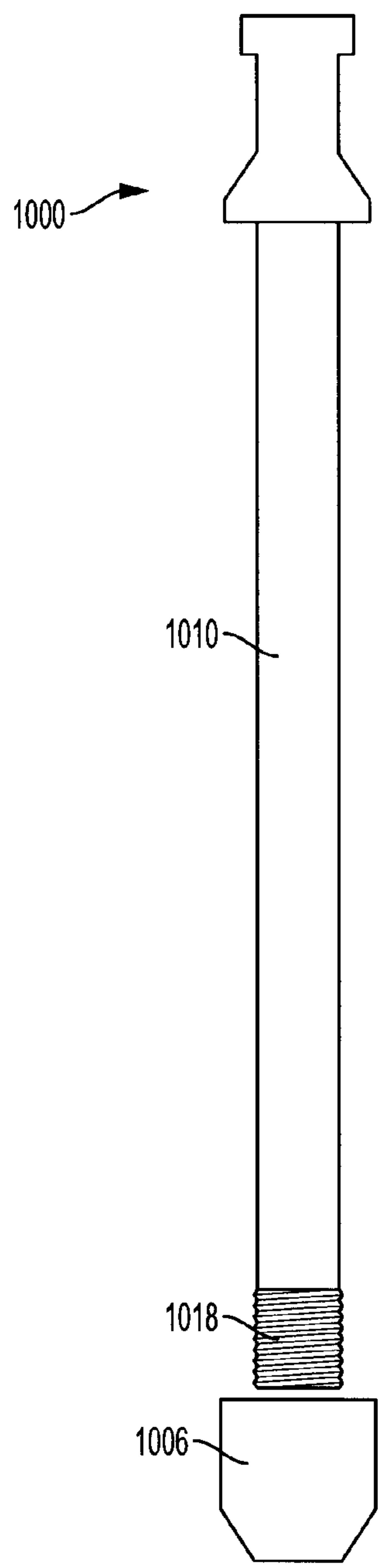



FIG. 8

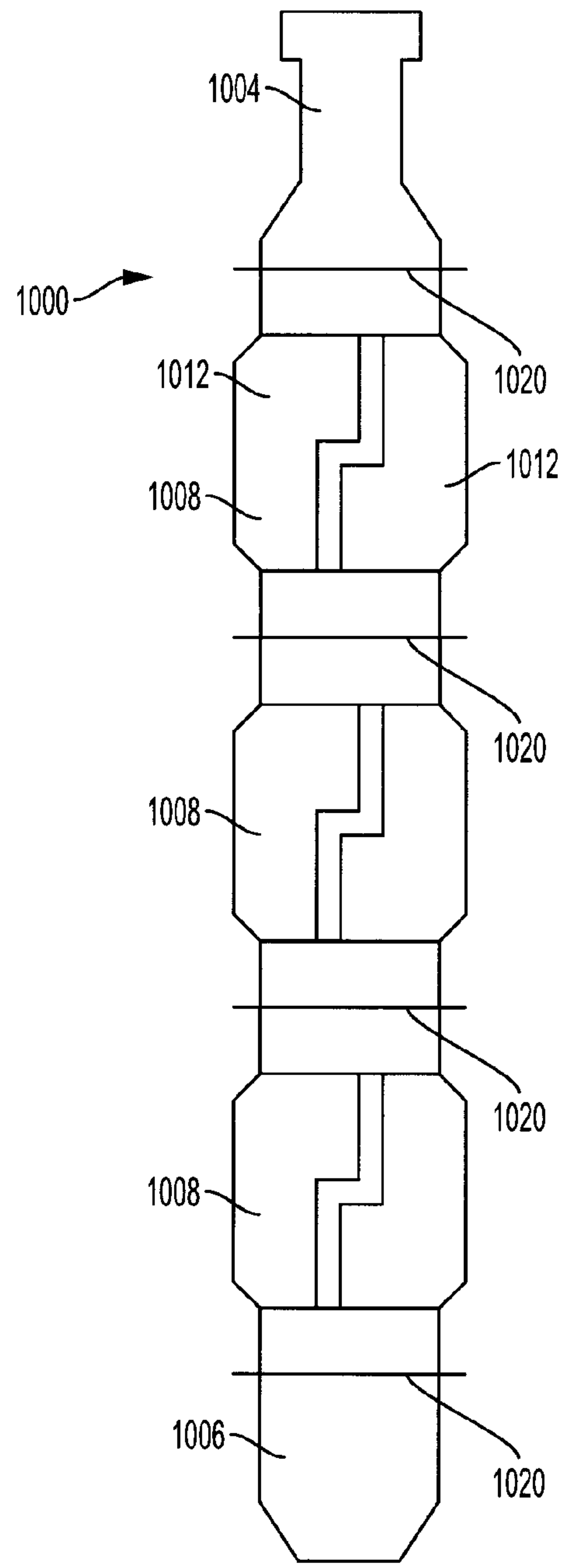



FIG. 9

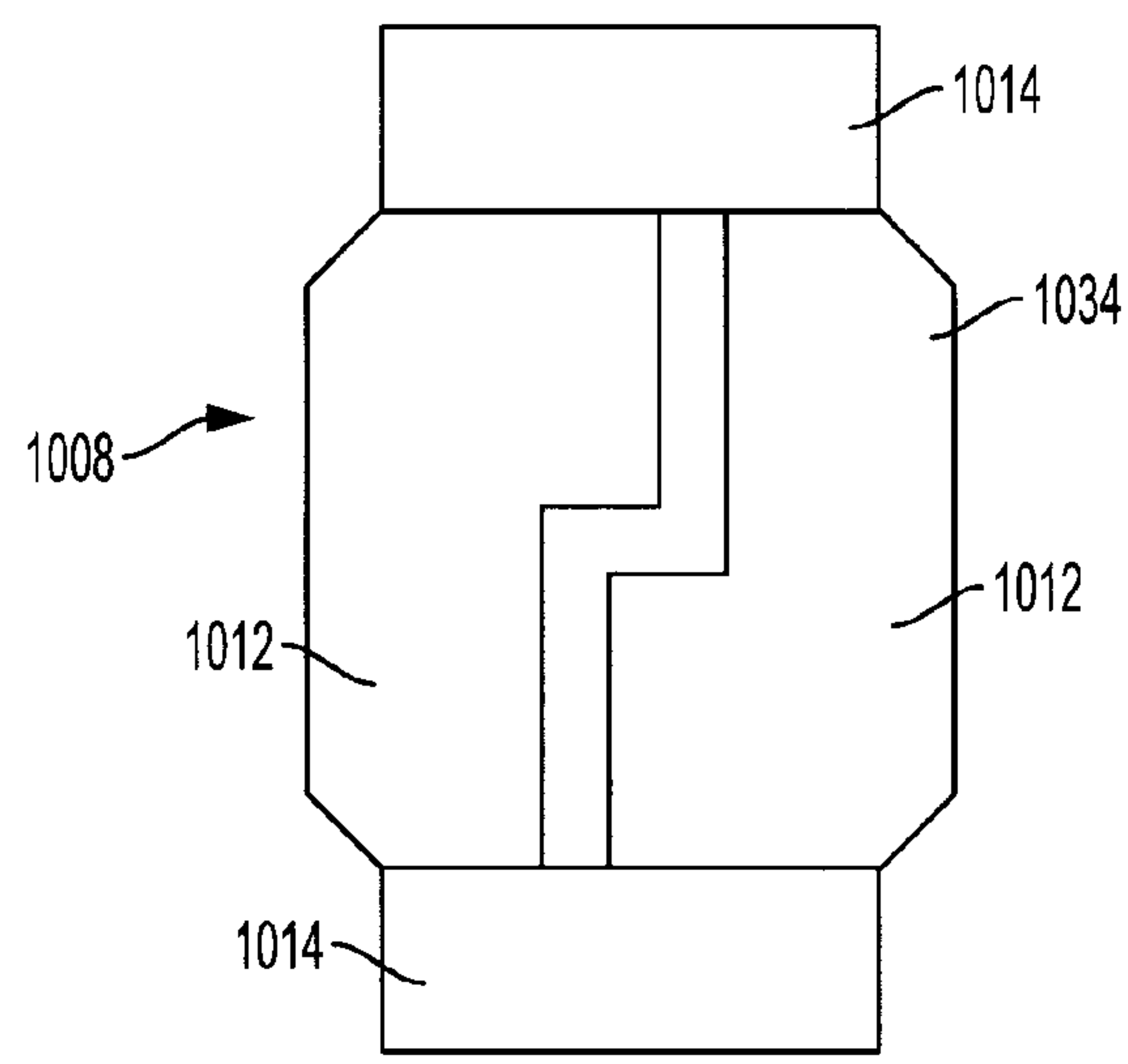



FIG. 10A

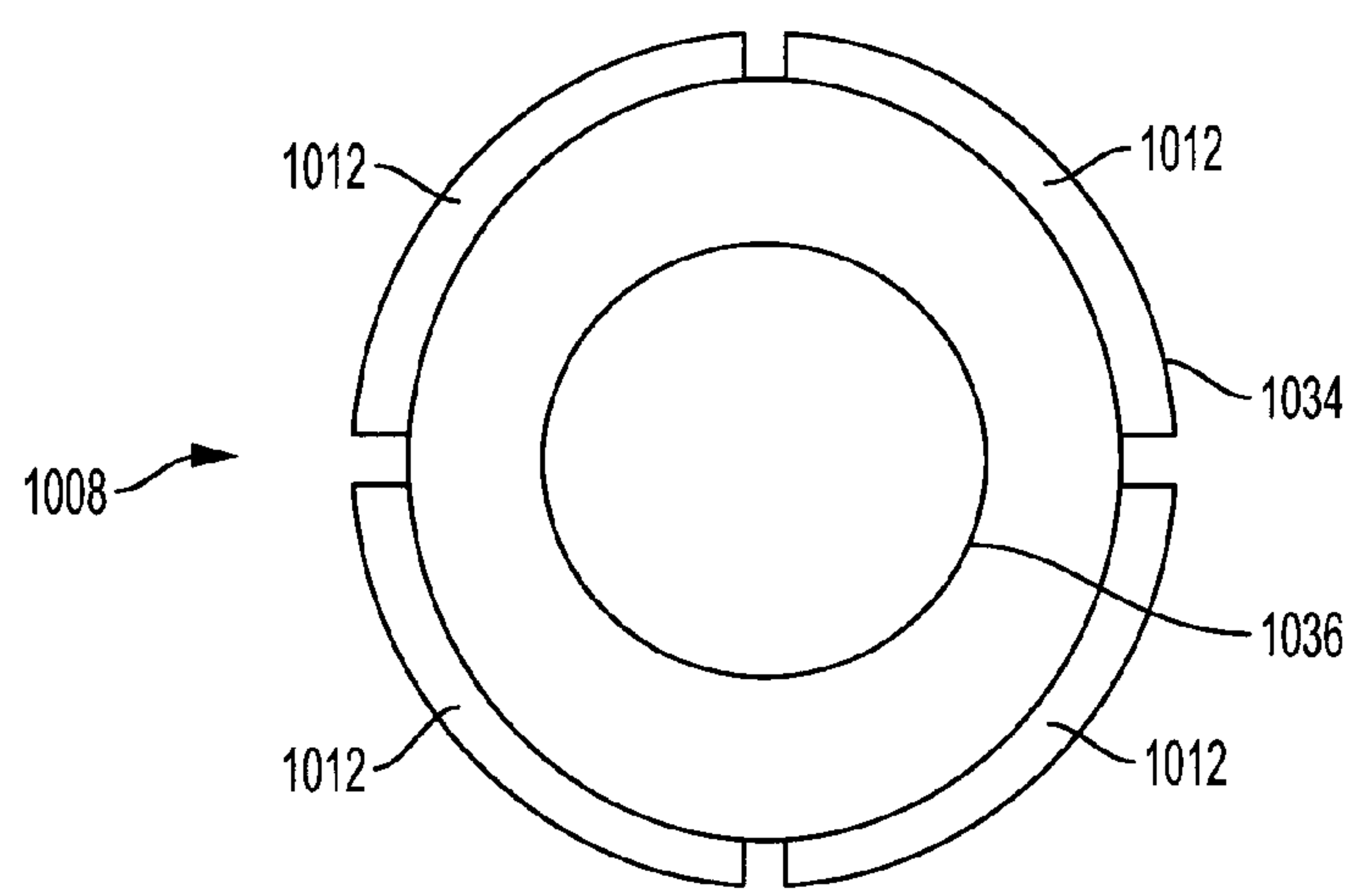



FIG. 10B

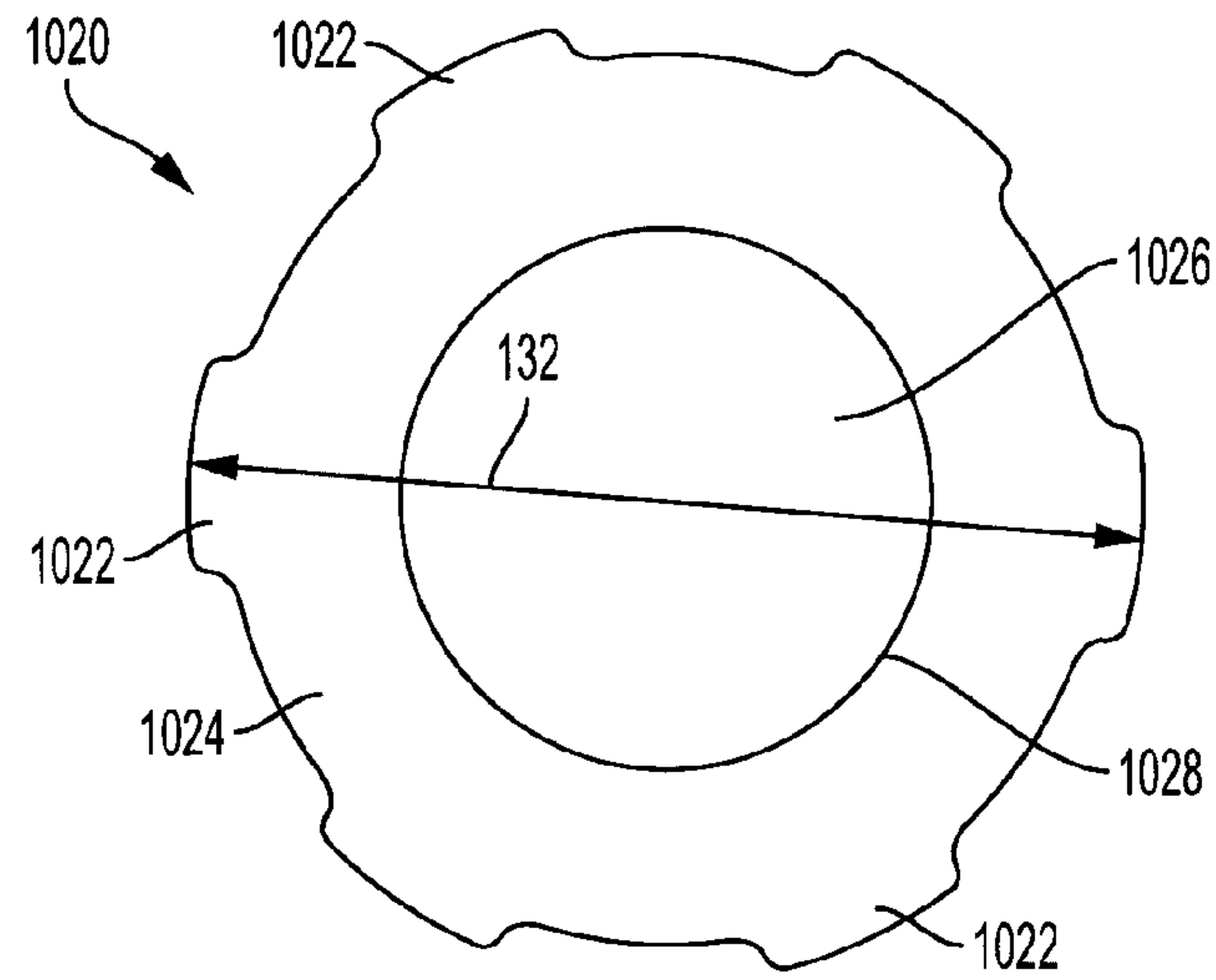

1020
1022
1026
132
1022
1024
1028
1022

FIG. 11

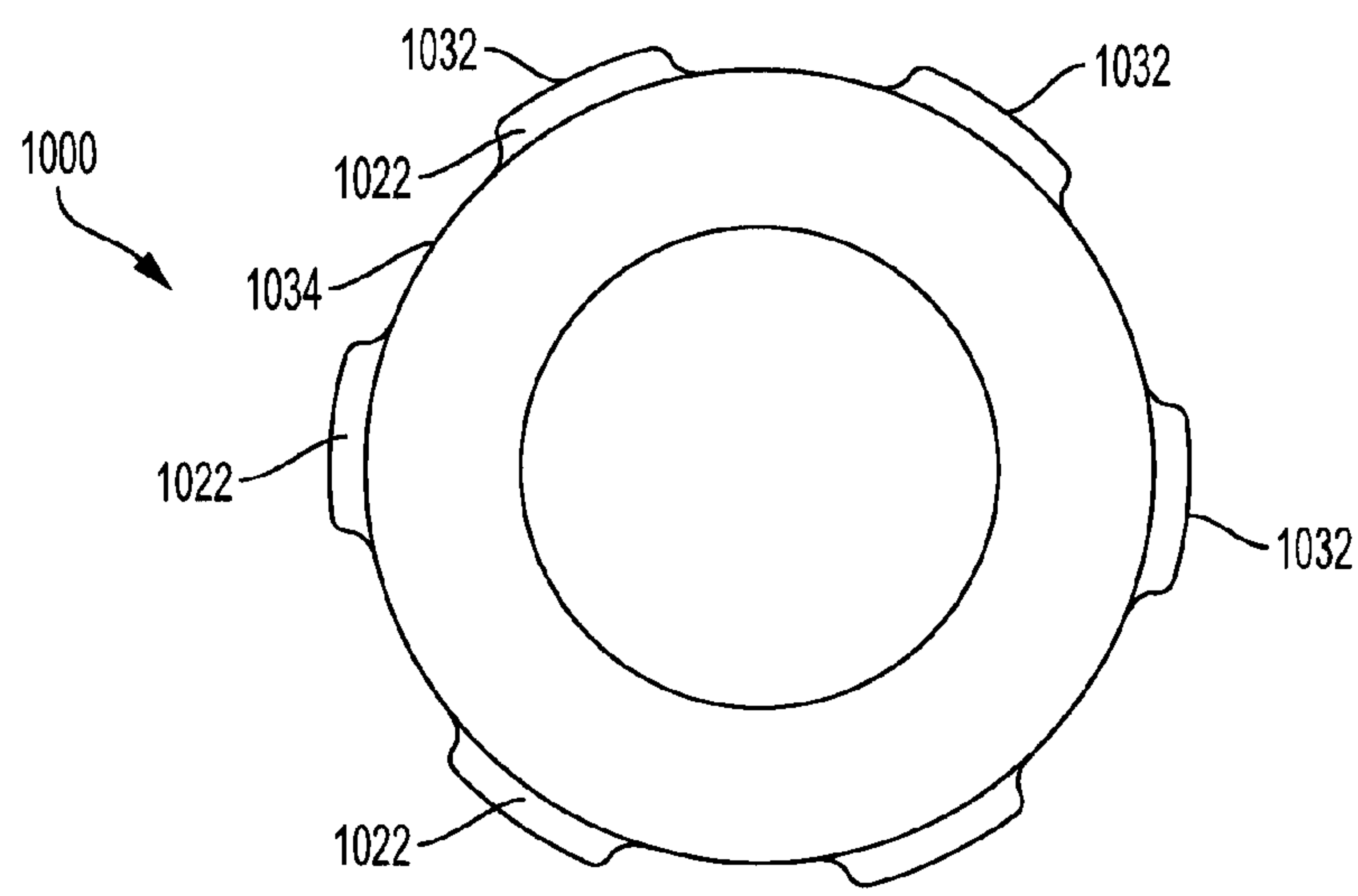

1032
1032
1000
1022
1034
1022
1032
1022

FIG. 12

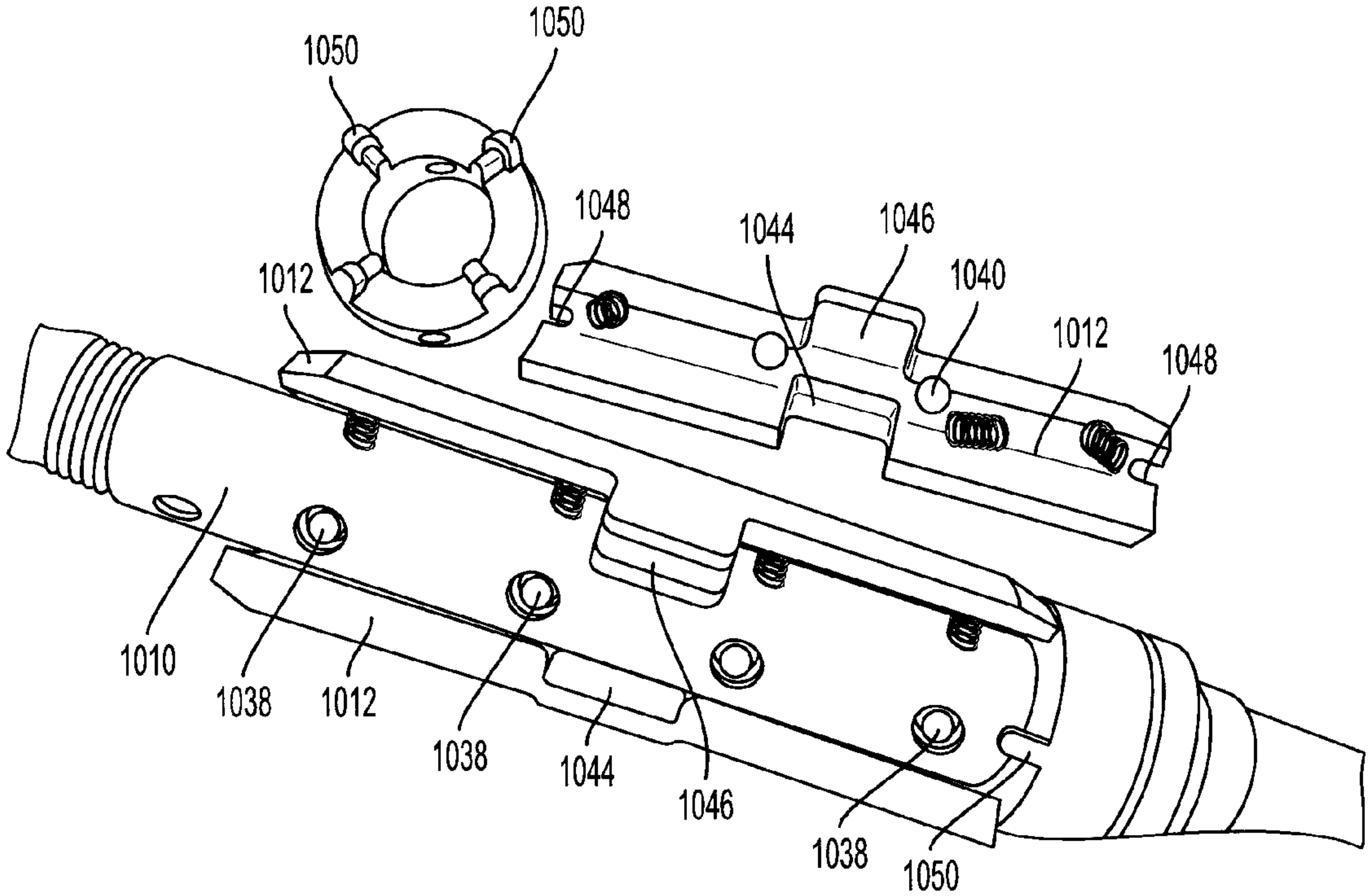

1050
1050
1048
1044
1046
1040
1012
1012
1048
1010
1038
1012
1038
1044
1046
1038
1050

FIG. 13

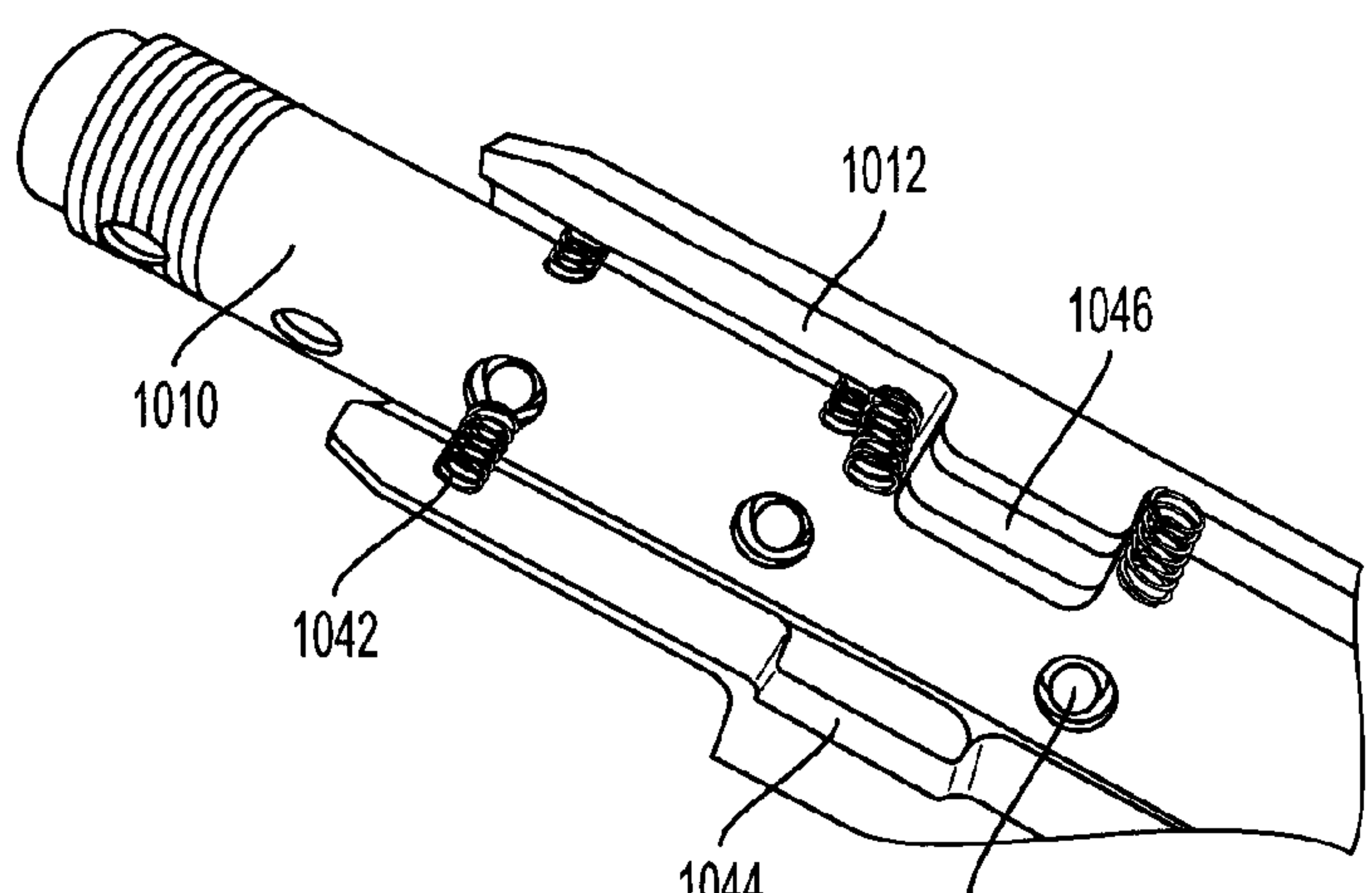

1012
1046
1010
1042
1044
1038

FIG. 14

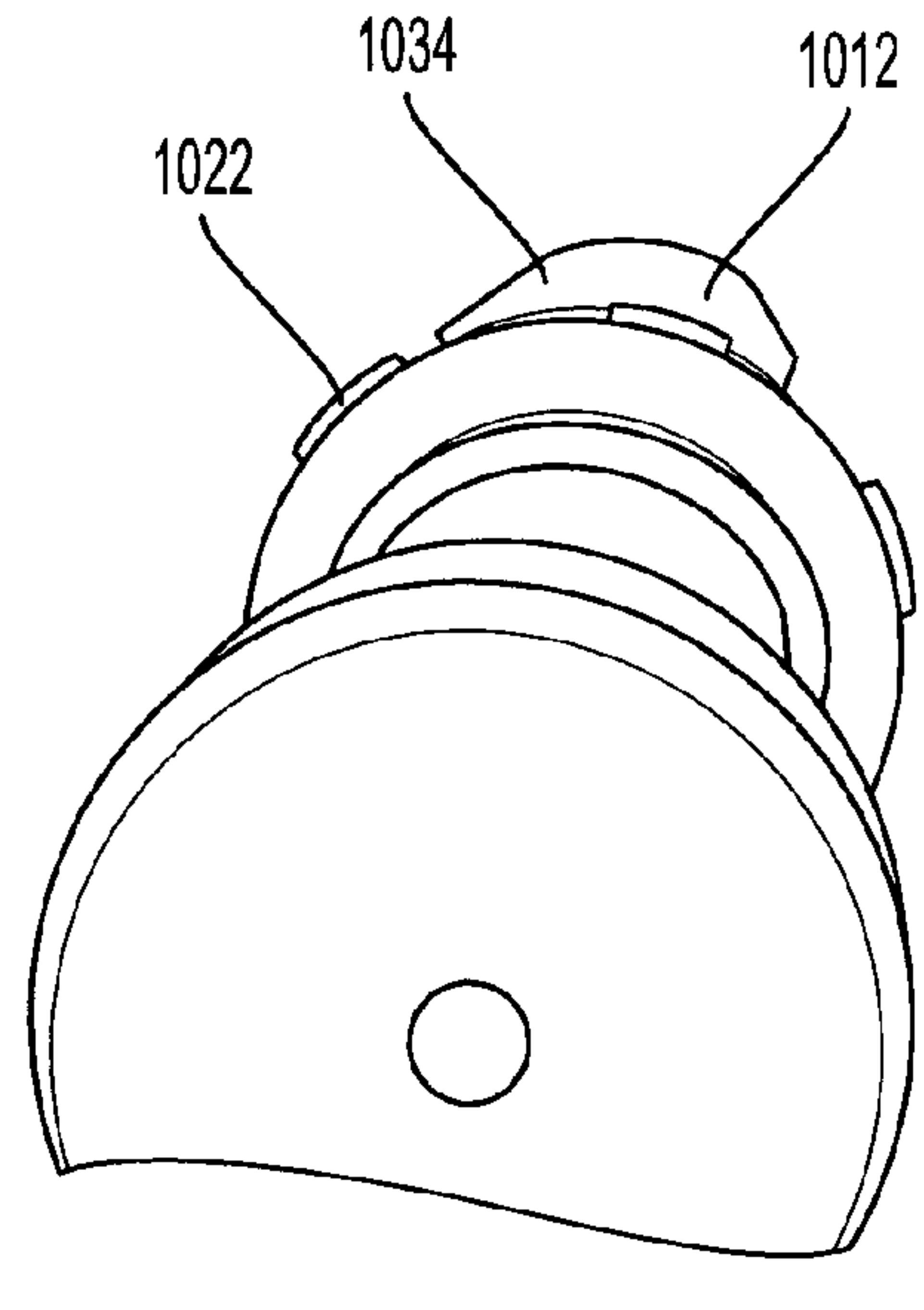



FIG. 15A

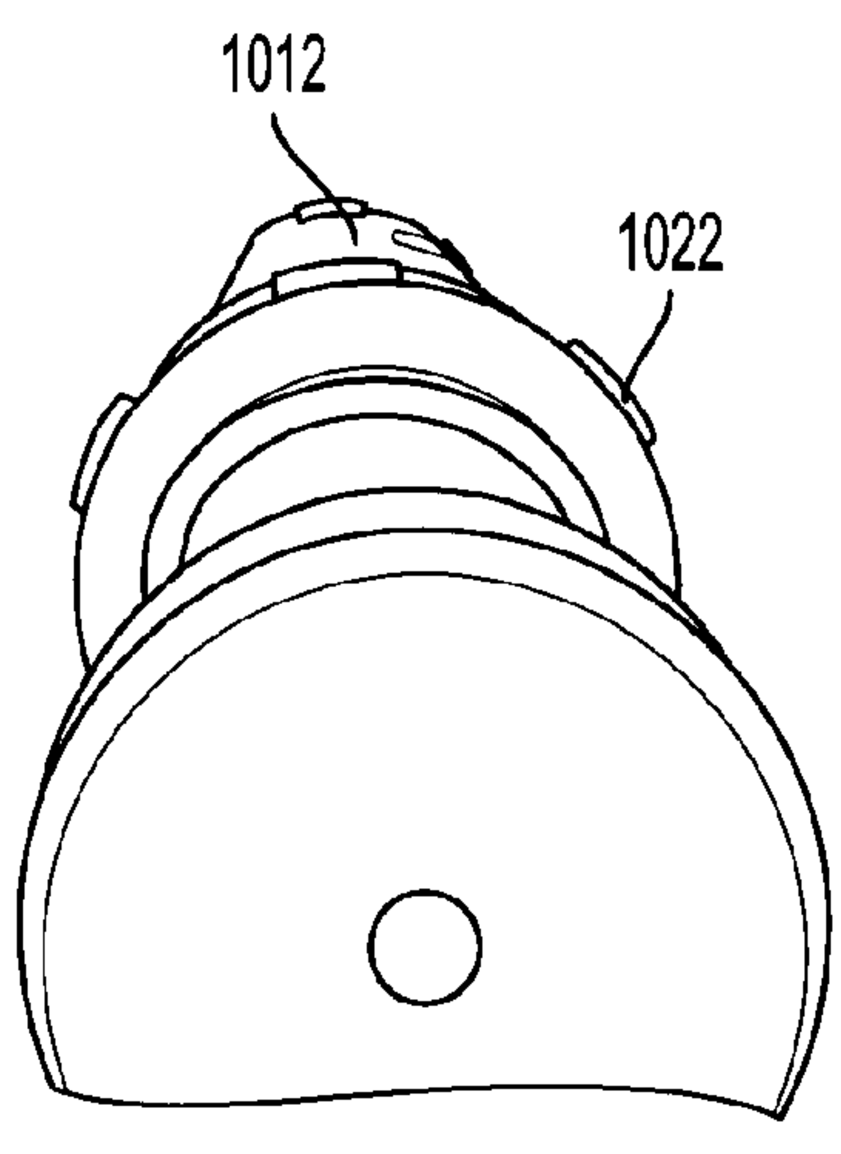



FIG. 15B

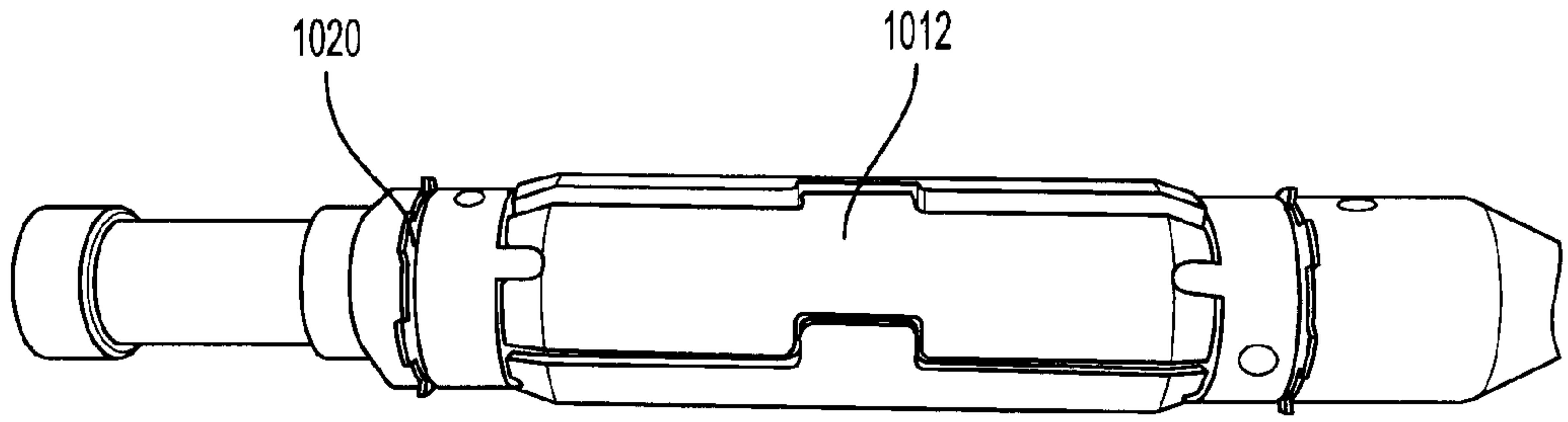
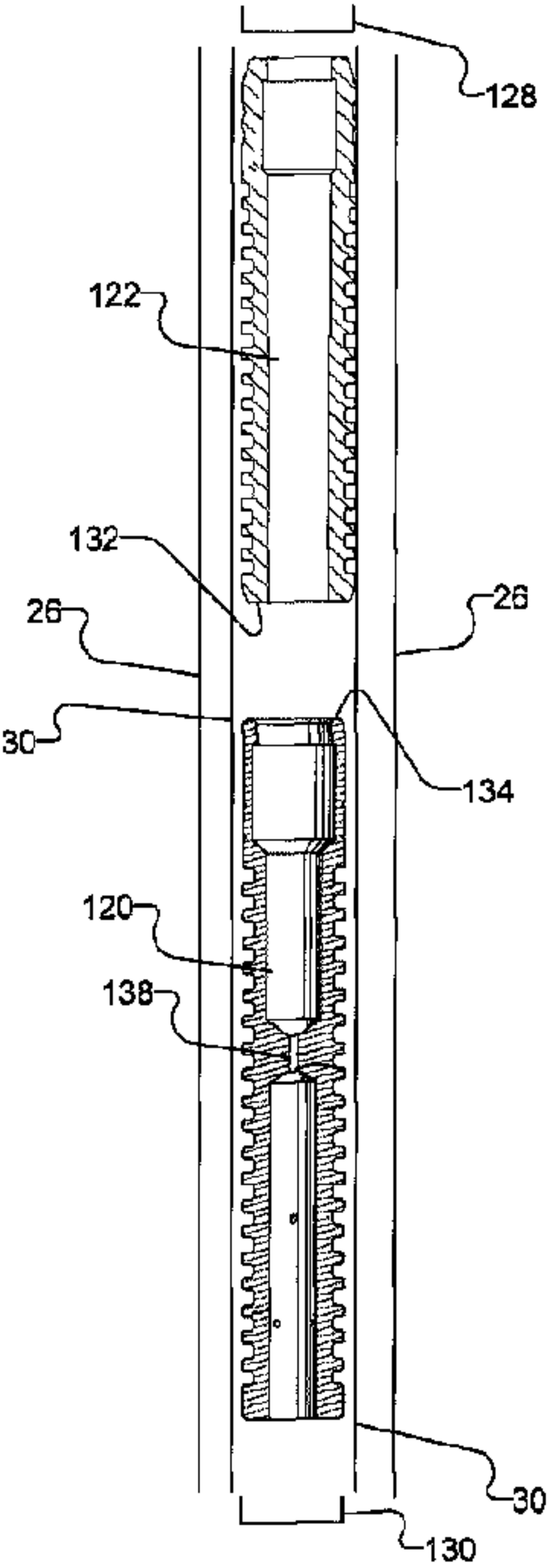



FIG. 16


128
122
132
26
26
30
134
120
138
30
130