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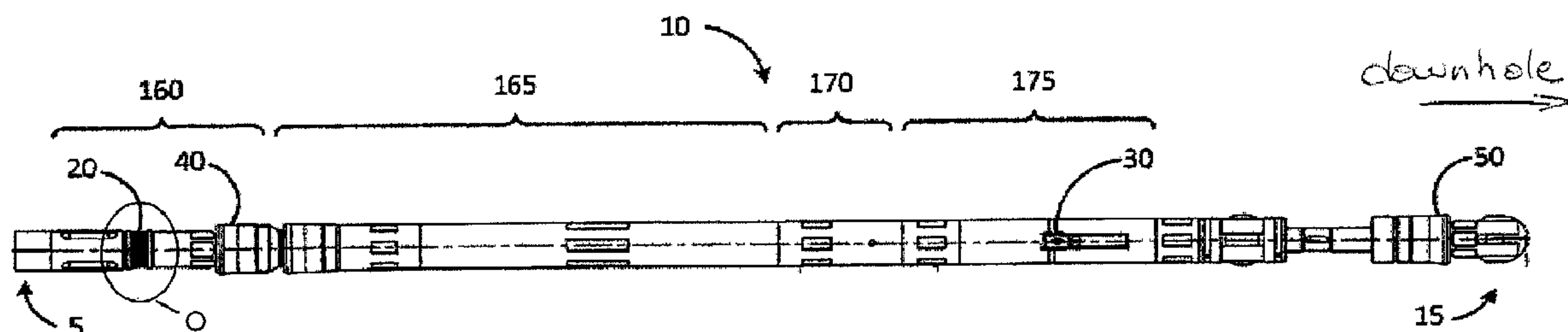
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(54) Titre : OUTIL D'HYDOFRACTURATION ET DE PERFORATION COMBINEES

(54) Title: A COMBINED PERFORATING AND FRACKING TOOL



(57) Abrégé/Abstract:

A combined perforating and fracking tool, and method for using same, for perforating a hydrocarbon well casing and for subsequently fracturing the formation while maintaining the tool in situ. The combined perforating and fracking tool comprises, in a preferred embodiment, a series of connected cylinders arranged to be disposed in a well casing, each of the cylinders comprising a cooperating piston whereby a magnification of hydraulic force is generated. The series of pistons operate to actuate a punch assembly disposed at a downhole end of the series of connected cylinders to perforate the casing. A fluid injection port, in operation with at least one sealing member disposed at each end of the series of connected cylinders, allows fluid to be diverted into the formation through the perforations created in the well casing to induce fracturing in the formation.

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ABSTRACT

A combined perforating and fracking tool, and method for using same, for perforating a hydrocarbon well casing and for subsequently fracturing the formation while maintaining the tool *in situ*. The combined perforating and fracking tool comprises, in a preferred embodiment, a series of connected cylinders arranged to be disposed in a well casing, each of the cylinders comprising a cooperating piston whereby a magnification of hydraulic force is generated. The series of pistons operate to actuate a punch assembly disposed at a downhole end of the series of connected cylinders to perforate the casing. A fluid injection port, in operation with at least one sealing member disposed at each end of the series of connected cylinders, allows fluid to be diverted into the formation through the perforations created in the well casing to induce fracturing in the formation.

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A COMBINED PERFORATING AND FRACKING TOOL

FIELD OF THE INVENTION

[0001] The present disclosure relates to the field of hydrocarbon extraction from subterranean formations and, in particular, to a combined perforating and fracking tool for hydrocarbon well completion and stimulation.

BACKGROUND OF THE INVENTION

[0002] The extraction of hydrocarbons from subterranean formations involves drilling a well and undertaking completion operations to transform the drilled well into a producing one. The completion process typically involves casing the wellbore to ensure that the well does not close in upon itself. The casing is typically steel piping that is cemented into place to line the well. In order to achieve production, the casing and cement must be perforated to allow for the flow of hydrocarbons into the wellbore, but still provide a suitable amount of support and protection for the well.

[0003] Stimulation techniques have been developed to further improve the efficiency of hydrocarbon extraction. One such technique is hydraulic fracturing ("fracking") which involves the injection of highly pressurized fracking fluids through the perforated casing and into the formation. Injection of such fluids creates small fractures/fissures that extend substantially perpendicularly outwardly from the well into the formation, through which distantly-located hydrocarbons can thereby flow into, and thus flow therealong and into the wellbore for pumping to surface.

[0004] Generally, perforating and fracking a well have involved separate processes in which a well casing is first perforated followed by the injection of high pressure fracking fluid. Processes for perforating the well casing have included, for example, running a perforation gun into the wellbore to discharge high pressure jets of fluid to penetrate the casing at various locations, or to fire "shaped" explosive charges at various intervals along the wellbore into

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the sides of the casing to create the perforations. Once the perforations are formed, the fracking fluid is pumped into the well to fracture the formation in the region surrounding the wellbore and preferably in outwardly extending fissures which extend perpendicularly outwardly from the wellbore. Disadvantageously, however, apart from the additional time and expense of a two step discrete process of inserting the perforating gun, perforating, and removing such perforating gun before perforating can occur, such prior art methods are further unsatisfactory, since the problem with prior art devices and methods which separately perforate the well bore with perforating "guns" which use explosive charges, withdrawing the guns, and then inserting the fracking tool, is that the fracking tool does not necessarily align with the created perforations. Such prior art methods are thus for this reason as well unsatisfactory.

[0005] Specialized tools have been described to improve the efficiency of such methods. United States Patent No. 7,337,844 describes a perforating and fracturing tool that perforates the well using a jetting sub and a plurality of jets which eject high pressure fluid to perforate the well casing. The device comprises a fluid distributor which may be selectively configured to communicate high pressure fluid to supply the perforating operation or to concurrently or simultaneously communicate the high pressure fluid to supply the fracturing operation. By diverting the fluid flow, perforating and fracturing operations can be achieved while keeping the device in the wellbore.

[0006] Other tools have been described which involve mechanically perforating the well casing. United States Patent No. 2,638,801 teaches a casing perforator that is attachable to a drill string in driving connection with at least one rotating drill. The casing perforator is lowered into a pipe or well casing to drill ports into the casing, and fluid under high pressure is then passed down through the drill string through the perforator and out through the drill while the drill is within the ports. Fluid is discharged through the hollow interior of the drill to hydraulic passages out into the surrounding formation. In this way, the drilling of the casing and the fracking of the formation are accomplished consecutively while maintaining the perforator in one position.

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[0007] Similarly, Russian Patent No. 2069741 describes a device for mechanical perforation of wells in which a pair of hydraulically actuated puncturing units are caused to extend radially outwardly from the tool to pierce the casing. Fluid jets built within the puncturing units inject fluid through these puncturing units and into the formation to open channels therein. In this way, the device can mechanically puncture the casing while simultaneously opening channels in the formation while maintaining the device in one position.

[0008] International Patent Publication No. WO 2012/098377 describes a perforating tool that utilizes a plurality of pistons that cooperatively operate to outwardly deploy a cutter block along tracks to enable large perforations to be cut into the well casing. Once the perforations are made, the cutter block is inwardly retracted to allow the work string to be lowered in order to position a packer apparatus below the perforated section of the well casing. With the work string in this position, high pressure pumping of hydraulic fracturing fluid can be commenced to conduct a hydraulic fracturing operation.

[0009] This background information is provided for the purpose of making known information believed by the applicant to be of possible relevance to the present invention. No admission is necessarily intended, nor should be construed, that any of the preceding information constitutes prior art against the present invention.

SUMMARY OF THE INVENTION

[0010] An object of the present invention to provide a tool capable of providing the combined functions of both perforating and fracking of a wellbore, to avoid having to “trip-out” a perforating tool from a well in order to then be able to frack a well.

[0011] In a preferred embodiment, the tool has means, as described below, to allow lowering of the tool within the well when the well has fluid therein, and prevent passage uphole of downhole fluid when the tool is in the wellbore, where such downhole fluid typically contains sand. Such mechanisms of the tool of the present invention avoids and/or reduces the tendency of the tool to become “sanded in” within the wellbore and not able to be withdrawn

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therefrom after various perforating and fracking operations within the wellbore at various locations therein have been completed.

[0012] In one broad aspect of the tool of the present invention, a combined perforating and fracking tool for perforating a hydrocarbon well casing disposed in a formation, and for subsequently fracturing the formation while maintaining the tool *in situ*, is provided, the tool comprising:

(a) at least one cylinder arranged to be disposed in a well casing and adapted at an uphole end to receive fluid, said cylinder comprising a cooperating piston;

(b) a punch assembly disposed at a downhole end of said cylinder and cooperating piston, the punch assembly comprising a punch comprising a pointed piercing member for perforating the casing, wherein the punch assembly is actuated by the fluid exerting a pressure on the cooperating piston, and the cooperating piston exerting a force which causes outward extension of the pointed piercing member to perforate the casing;

(c) a fluid injection port disposed at an upper end of the tool to allow fluid to be injected into the formation through the perforations created in the well casing by the tool; and

(d) at least one sealing member disposed proximate an upper uphole end of the cylinder, downhole of said fluid injection port, adapted to prevent fracking fluid from travelling, when such tool is in a well casing, outside the cylinder in a direction downhole;

wherein fluid may be provided in a bore defined along the longitudinal axis of the cylinder; and

whereby a force is generated by fluid under pressure travelling in said bore and acting on the cooperating piston which then actuates the punch assembly to actuate, in a radially-outwardly protruding manner, said pointed piercing member to perforate the casing.

[0013] In a further refinement, the tool may comprise a plurality of sequential cylinders adapted to be disposed in a well casing and adapted at an uphole end to receive fluid, each of

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said cylinders comprising a cooperating piston, wherein each piston defines a bore along its longitudinal axis and an associated port for conducting fluid flow from the bore into each cylinder.

[0014] Accordingly, in a further preferred embodiment, the invention comprises a combined perforating and fracking tool for perforating a well casing disposed in an underground formation and for subsequently fracturing the formation while maintaining the tool *in situ*, the tool comprising:

- (a) at least a pair of cylinders arranged to be disposed in a well casing and adapted at an uphole end to receive fluid, each of said cylinders comprising a cooperating piston, wherein each piston defines a bore along its longitudinal axis and an associated port for conducting fluid flow from the bore into each cylinder;
- (b) a punch assembly disposed at a downhole end of the cylinders, the punch assembly comprising a punch for perforating the casing, wherein the punch assembly is actuated by a piston which outwardly extends a punch to perforate the casing;
- (c) a fluid injection port disposed at the uphole end of the tool, and a valve member, to allow fluid to be diverted from the cylinders and injected into the formation through the perforations created in the well casing; and
- (d) at least a pair of sealing members respectively disposed respectively at an upper and lower end of the tool, forming a seal between the casing and the tool such that fluid can be diverted through the fluid injection port for fracturing the formation;

wherein the cylinders remain isolated from the injected fluid flowing between the tool and well casing during fracturing; and

wherein during a perforation step fluid flowing through a bore defined along the longitudinal axis of tool sequentially fills each of the cylinders whereby a magnification of hydraulic force is generated by the cooperating pistons to actuate the punch.

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[0015] In accordance with another aspect of the present invention, there is described a combined perforating and fracking tool for perforating a hydrocarbon well casing disposed in a formation, and for subsequently fracturing the formation while maintaining the tool *in situ*, the tool comprising:

(a) a series of connected cylinders arranged to be disposed in a well casing and adapted at an uphole end to receive fluid, the series of connected cylinders comprising:

a first cylinder comprising a valve assembly for controlling activation of the punch assembly;

a second cylinder comprising an associated piston, the associated piston in fluid connection with the valve assembly such that when the valve assembly is in an open position fluid is allowed to flow through the associated piston and associated ports to fill the second cylinder fluid pressure within the second cylinder increases to cause the associated piston to move therein;

(b) a punch assembly disposed at a downhole end of the series of connected cylinders, the punch assembly comprising a pointed punch member for perforating the casing, wherein the punch assembly is actuated by the first and second pistons to outwardly extend the punch member to perforate the casing;

(c) a fluid injection port disposed at the uphole end of the series of connected cylinders to allow fluid to be diverted from the series of connected cylinders and injected into the formation through the perforations created in the well casing; and

(d) at least one sealing member disposed at each end of the series of connected cylinders, each sealing member forming a seal between the casing and the tool such that fluid can be diverted through the fluid injection port for fracturing the formation, and wherein the series of cylinders remains isolated from the injected fluid flowing between the tool and well

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casing;

wherein fluid flowing through the second cylinder results in a force supplied by the associated piston to actuate indirectly or directly the punch assembly.

[0016] In a particular embodiment of the above aspect the valve assembly (and in particular the first cylinder thereof) comprises a slidable sleeve having a fluid passageway, and further preferentially a "J" type sleeve to allow a plurality of up and down movements of the tool prior to actuating the slidable sleeve in the manner set out below, said slidable sleeve being slidable along a mandrel on the tool at a location on the tool having radial aperture therein, said slidable sleeve on its exterior having a friction member to consistently frictionally engage the casing, wherein when the tool is lowered to a desired position downhole, upward movement of the tool thereafter and resultant frictional engagement of said friction member with said casing causes relative movement of said slidable sleeve relative to said mandrel and thus repositioning of said passageway therein so as to then become in fluid communication with said radial aperture so as to cause such valve assembly to be in an open position and allow supply of fluid to downstream pistons to thereby allow actuation of said punch.

[0017] In such above embodiment the sealing members disposed at each of the tool (but at the upper end of the tool the associated sealing member being disposed below the fluid injection port) also, on either end of the tool, advantageously prevent fluid (and any sand entrapped therein) being introduced in the wellbore area between the tool and the casing which could otherwise cause the tool to become "sanded in". Specifically, such sealing members, preferably cup seals, are positioned and arranged on the tool so as to allow the upper seal to cause fracking fluid to flow into the formation via the created perforations in the casing during fracking and prevent such injected fluid from flowing past the tool downhole, and the lowermost cup seal prevents downhole fluids from flowing uphole past the tool during fracking and perforation operations to thereby avoid possibly entraining sand in the region of the wellbore between the tool and the wellbore, and thus the "sanding in" of the tool within the wellbore.

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[0018] A selectively-operable bypass means is provided on the tool, however, to allow fluid in the wellbore which may come from perforations and fracking of the wellbore to bypass the downhole seal member so that such fluid may be displaced uphole during lowering of the tool into the wellbore. Such bypass means allows lowering of the tool in the wellbore where such lowering would otherwise be prevented by existing presence of fluid in the wellbore.

[0019] In accordance with a further aspect of the present invention, there is described a method for perforating a well casing disposed in a formation and for subsequently fracturing the formation while maintaining the tool *in situ* using a tool of any of the configurations described above. In accordance with such further aspect/method, such method comprises the steps of:

(a) supplying fluid to the combined perforating and fracking tool in any of the embodiments described above when such tool is disposed within a well casing, activating a valve therein so as to provide fluid flow through the series of connected cylinders and associated pistons whereby a combined force is generated by such pistons to actuate the punch assembly to form created perforations in the well casing;

(b) lowering the combined perforating and fracking tool to position the fluid injection port thereon adjacent to the created perforations in the well casing and to position the at least one sealing member downhole of the created perforations in the well casing; and

(c) pumping fluid through the fluid injection port and created perforations to fracture the formation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] These and other features of the invention will become more apparent in the following detailed description in which reference is made to the appended drawings.

[0021] **Fig. 1a** is a side exterior view of a first embodiment of the combined perforating and fracking tool of the present invention;

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[0022] **Fig. 1b** is a longitudinal cross-sectional view of the combined perforating and fracking tool along the plane of the arrows shown in **Fig. 1a**;

[0023] **Fig. 2a** is a close-up view of the fluid injection assembly (region "O") of the combined perforating and fracking tool shown in **Fig. 1b** ;

[0024] **Fig. 2b** is a longitudinal cross-sectional view of the fluid injection assembly shown in **Fig. 2a**, and is also an enlarged view of region "A" of **Fig. 1b**;

[0025] **Fig. 3a** is an enlarged view of the activation assembly (region "C") of the combined perforating and fracking tool shown in **Fig. 1b**;

[0026] **Fig. 3b** is an enlarged view of the lower end of the activation assembly (region "D") shown in **Fig. 1b**;

[0027] **Fig. 4a** is an enlarged view of the upper end (region "E") of the magnifying assembly of the combined perforating and fracking tool shown in **Fig. 1a**;

[0028] **Fig. 4b** is an enlarged view of the lower end (region "F") of the magnifying assembly shown in **Fig. 4a**;

[0029] **Fig. 5a** is an enlarged view of one embodiment of the punching assembly (region "G") of the combined perforating and fracking tool shown in **Fig. 1a**;

[0030] **Fig. 5b** is an enlarged exterior view of the punch assembly shown in **Fig. 5a**, according to one embodiment of the disclosure;

[0031] **Fig. 6** is a longitudinal cross-sectional view of the combined perforating and fracking tool shown in **Fig. 1a**, showing areas A1, A2 of the pistons so as to illustrate the magnification of force in the combined perforating and fracking tool according to a preferred embodiment of the present invention;

[0032] **Fig. 7** is a view on a further embodiment of the tool of the present invention, utilizing

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a single ball as a seal;

[0033] **Fig. 8** is a longitudinal cross-sectional view along the plane defined by the arrows in **Fig. 7**, when the punch assembly is in the non-actuated position;

[0034] **Fig. 9a** is an enlarged view of region "X" of **Fig. 8** when the punch assembly of the tool is not actuated ;

[0035] **Fig. 9b** is a similar enlarged view of region "X" of **Fig. 8**, when the punch assembly of the tool is actuated ;

[0036] **Fig. 10** is an enlarged view of region "I" of **Fig. 9a**, namely when the tool and the punch assembly is non-actuated;

[0037] **Fig. 11** is an enlarged view of region "K" of **Fig. 9b**, namely when the tool and the punch assembly is actuated;

[0038] **Fig. 12** is an enlarged view of region "J" of **Fig.'s 9a, 17a, & 23a** (and similarly of region "G") of **Fig. 1B**), when the tool and the punch assembly thereof is non-actuated;

[0039] **Fig. 13** is an enlarged view of region "L" of **Fig.'s 9b, 17b, & 23b**, namely when the tool and the punch assembly thereof is actuated;

[0040] **Fig. 14** is an enlarged perspective view of a cross section through one embodiment of the punch assembly of the present invention shown in **Fig.'s 12 & 13**;

[0041] **Fig. 14a** is an enlarged perspective view of one component of the punch assembly shown in **Fig.'s 12 & 13**, namely one of the pointed members thereof;

[0042] **Fig. 14b** is an enlarged perspective sectional view of another component of the punch assembly shown in **Fig.'s 12 & 13**, namely one of members for retaining an associated pointed member in a desired position;

[0043] **Fig. 14c** is an enlarged perspective sectional view of another component of the punch

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assembly shown in **Fig.'s 12 & 13**, namely one of members for retaining an associated pointed member in a desired position;

[0044] **Fig. 15** is a side exterior view of a second embodiment of the combined perforating and fracking tool of the present invention;

[0045] **Fig. 16** is a longitudinal cross-sectional view of another embodiment of the combined perforating and fracking tool of the present invention which uses a "two ball" valve, taken along the plane of the arrows shown in **Fig. 15**;

[0046] **Fig. 17a** is an enlarged cross sectional view of a portion of the combined perforating and fracking tool shown in **Fig. 16**, when such tool, and the punch members thereof are in the non-actuated state;

[0047] **Fig. 17b** is an enlarged cross sectional view of a portion of the combined perforating and fracking tool shown in **Fig. 16**, when such tool and the punch members thereof are in the actuated state;

[0048] **Fig. 18** is an enlarged view of region "M" of **Fig. 17a**;

[0049] **Fig. 19** is an enlarged view of region "M" of **Fig. 17a**, when the tool , and in particular the valve in region "M" , is in the partially actuated state;

[0050] **Fig. 20** is an enlarged view of region "N" of **Fig. 17a**, when the tool is in the fully actuated state and the punch members are actuated;

[0051] **Fig. 21** is a side elevation view on a further embodiment of the tool of the present invention, which uses a "J" slot actuating member;

[0052] **Fig. 22** is an enlarged cross sectional view of the combined perforating and fracking tool shown in **Fig. 21**, when such tool, and the punch members thereof are in the non-actuated state, taken in the direction of the arrows in **Fig. 21**;;

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[0053] **Fig. 23a** is a cross sectional view of a portion “S” of the combined perforating and fracking tool shown in **Fig. 22**, when such tool and the punch members thereof are in the non-actuated state;

[0054] **Fig. 23b** is a cross sectional view of a portion “S” of the combined perforating and fracking tool shown in **Fig. 22**, when such tool and the punch members thereof are in the actuated state;

[0055] **Fig. 24a** is an enlarged view of region “T” of **Fig. 23a**;

[0056] **Fig. 24b** is an enlarged view of region “U” of **Fig. 23b**;

[0057] **Fig. 25** is a perspective view of the “J” type mandrel which forms part of the valve means for actuating the punch assembly;

[0058] **Fig. 26** is an enlarged view of region “Q” of **Figs. 8, 16, & 22**

[0059] **Fig. 27a** is an enlarged view of region “B” of **Fig. 1b**;

[0060] **Fig. 27b** is an enlarged view of region “R” of **Fig. 22**;

[0061] **Fig. 28** is an enlarged view of region “H” of **Fig. 1b & Fig. 16**, when such tool is being lowered into the wellbore; and

[0062] **Fig. 29** is an enlarged view similar to **Fig. 28**, taken when such tool is in position for actuation within the wellbore.

DETAILED DESCRIPTION OF THE INVENTION

Definitions

[0063] Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs.

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[0064] As used herein, the term “hydrocarbon formation”, “subterranean formation”, or “formation”, may be used interchangeably to refer to subterranean formations that are explored and exploited for hydrocarbon resources through drilling and extraction techniques.

[0065] As used herein, the term “about” refers to an approximately +/-10% variation from a given value. It is to be understood that such a variation is always included in any given value provided herein, whether or not it is specifically referred to.

[0066] Completing a hydrocarbon well for production typically involves perforating the well casing to enable hydraulic fracturing techniques (“fracking”) to be used to facilitate the production the hydrocarbons flowing into the wellbore. Typically, perforating the well casing and fracking the formation are separately carried out using a variety of known techniques often requiring multiple tools and processes to be used. Thus, well completion can become inefficient and cumbersome to achieve.

[0067] The embodiments of the present disclosure provide in a single tool both perforating and fracking operability. By combining both functionalities in a single tool, hydrocarbon well completion can be achieved in a more efficient, reliable, and repeatable manner.

Perforating the Well Casing

[0068] Reference is to be had to **Figs. 1-29** of the drawings wherein similar components are identified with like reference numerals.

[0069] The combined perforating and fracking tool **10** of the present invention combines a fracking assembly **160**, activation assembly **165**, force-magnifying assembly **170**, and punch assembly/mechanism **175** comprising mechanical piercing means **130** for piercing/perforating a casing of a well, all of which synergistically operate together to allow the single tool **10** to perforate and thereafter frack a well to thereby achieve well completion.

[0070] Referring to **Figs. 1a** and **1b**, the respective assemblies **160**, **165**, **170**, and **175** in a preferred embodiment are arranged sequentially, in a series of connected cylinders within tool

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10, to be disposed in a well casing. The tool **10** is adapted at an uphole end **5** to receive fluid and comprises a first cylinder **95** containing the activation assembly **165**, and a further series of further successive cylinders, namely a second cylinder **105** forming a first stage of a magnifying assembly **170**, and a third cylinder **115** that contains the punch assembly **175**. As shown in **Fig. 1b**, the assemblies are sequentially arranged in fluid connection, thereby allowing the entering fluid to flow through each cylinder whereby a magnification of hydraulic force is generated to actuate the punch assembly **175** to form perforations (not shown) through a well casing (not shown).

[0071] At the uphole end **5** of the tool **10**, the activation assembly **165** is comprised of a valve assembly **69** that operates to control activation of the perforating function of the tool **10**. In one embodiment of valve assembly **69** shown in **Fig. 3a**, the valve assembly **69** comprises a valve stem **70** over which is a sliding sleeve **71** which is operatively connected to a first (activating) piston **80**, which is biased to the (closed) position shown in **Fig. 3a**. Hydraulic pressure in region **72** must be sufficient and reach a high enough pressure (ie higher than normal fracing pressure) to move sleeve **71** and associated piston **80** downhole against biasing force created by biasing mechanism/ spring **90** on spring mandrel **100** a sufficient distance to cause sleeve **72** to uncover port **75**, whereby pressurized fluid may then flow to the actuation means **165** and force-magnifying assemblies **170**, to thereafter actuate the punch mechanism **175**. Biasing mechanism **90** located at the opposing end of the first piston **80** further ensures that the first piston **80** moves uphole within the first cylinder **95** to return the valve **70** to a closed position when fluid pressure is reduced.

[0072] The biasing mechanism **90** in the preferred embodiment comprises a plurality of circular washers **90** supported by a spring mandrel **100** (**Fig. 3b**). The spring mandrel **100** comprises a bore **60** through which fluid entering the tool **10** at the uphole end **5** flows when the floating valve **70** is actuated to an open position. The spring mandrel **100** fluidly connects the first cylinder **95** to the adjacent second cylinder **105** containing the magnifying assembly **170**. Specifically, as shown in **Fig. 3b** and **4a**, the spring mandrel **100** is in fluid connection with a second (additive) piston **110** of cross-sectional area **A1** disposed within the adjacent

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second cylinder 105. When in the open position, fluid is allowed to flow through the spring mandrel 100 and out through the associated ports 85 to fill the second cylinder 105. Fluid pressure P within the second cylinder 105 increases to as to cause second (magnifying) piston 110 of cross-sectional area A1 to move downhole therein.

[0073] As shown in Fig. 4b, the second piston 110 of cross sectional area A2 fluidly connects the second cylinder 105 to the adjacent third cylinder 115 containing the punch assembly/mechanism 175 comprising punch piston 120 having pointed member 150 thereon. Specifically, as shown in Fig. 4b, the second piston 110 is in contact, and in fluid communication with, a third (punch) piston 120 disposed within the adjacent third cylinder 115. Fluid flowing through the fluidly connected second piston 110 enters the third cylinder 115 through the associated ports 140 to fill the third cylinder 115 whereby fluid pressure within the third cylinder 115 increases to cause the third (punch) piston 120 to move downhole therein. The third (punch) piston 120 is a closed member such that fluid can only be directed through ports 140 to fill, and correspondingly increase the fluid pressure of the third cylinder 115. In this way, the hydraulic force that is generated by the series of pistons on punch piston 120 is increased. The hydraulic force applied to second piston 110 of cross-sectional area A1 may be described in reference to Fig. 4a and Fig. 6 by the following equation:

$$\text{Total Hydraulic force} = P * A1$$

where A1 refers to the area of the piston 110 within the magnifying assembly 170, and P refers to the pressure supplied to such piston 110 of area A1.

Additional pistons add to the force ultimately be applied to actuate the punch assembly. For example, additional third piston 120 will have not only the force exerted by the pressure on A2 (see Fig. 4b), but will further have the force exerted by the pressure on area A1 of second piston 110. In this way, the working force of the tool 10 to operate punch mechanism 175 can be increased by utilizing successive hydraulic addition to increase the hydraulic force generated to actuate the punch assembly. Clearly, additional successive series of hydraulic cylinders and pistons may further be used, in tandem, if further addition of the

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acting force is necessary to achieve perforation of the casing.

[0074] Specifically, it is contemplated that in certain embodiments additional magnifying piston assemblies may be added to the tool by inserting additional cylinders comprising such assemblies. In this way, the total force may be further increased which is applied to the perforating members. Where an additional (third) piston 120 of cross-sectional area A2 is added, in such instance the total hydraulic magnification of force F will increase as follows:

$$F = P * A1 + P * A2$$

[0075] Using such above principle further successive pistons and cylinders may be added to further increase the force which is acting on pointed member end 130, if required.

[0076] Other means of increasing the force exerted by the pointed member end 150 of third piston 120 to cause extension of pointed members 130 and thereby perforation of the well casing will now occur to those of skill in the art of hydraulics.

[0077] For example, hydraulic arrangements where successive pairs of coupled pistons 1-2 and 3-4, each piston of each pair being of alternating larger and smaller respective associated cross-sectional areas A1, A2, A3, A4, where for example $A1 > A2$, $A3 > A2$, and $A3 > A4$, could alternatively be used to obtain further successive increases of hydraulic pressures, where $P1 < P2 < P3$, and where $P2 = P1 \times A1/A2$ and $P3 = P2 \times A3/A4$. Resulting magnified pressure P3 which results from such arrangement of coupled pistons and respective cross-sectional areas produces the following magnified total force on last piston of area A5 (ie on last member 120):

$$F = P3 \times A5$$

or stated otherwise:

$$F = [P1 \times A1/A2 \times A3/A4] \times A5$$

[0078] Referring to Fig. 5a, 5b, Fig. 12, Fig. 13, and Fig. 14, & 14a-14d, the closed last piston, in this embodiment third (punch) piston 120, has a pointed downhole member 150.

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Such pointed downhole member **150** has a slanted pointed extremity which has a slope which corresponds to the slope of inclined surface **140** possessed by each punch member **130**. When the punch mechanism **175** is actuated by the float valve **70** allowing incoming fluid under pressure to displace pistons **100** (of area A_1) and piston **120** of area A_2 downhole, the pair of pointed perforating members **130** are forced apart by the pointed end **150** of the third (punch) piston **120** so as to outwardly extend from the tool **10** and thereby pierce the well casing at the desired location.

[0079] In preferred embodiments, the pair of pointed perforating members **130** are connected by a biasing assembly, which in one embodiment comprises a coupling member **135** and base member **140** to inwardly retract the pair of perforating punch members **130** once the casing has been perforated, the hydraulic pressure reduced, and the punch members **130** thereafter desired to be retracted to allow the tool to be repositioned to allow perforation of the casing at another desired location.

[0080] Alternatively, instead of using a coupling member **135** and a base member **140** to bias the perforating member **130** within the tool **10** as best shown in **Fig. 14** and **Figs 14a-14d**, other biasing means could be used and will now readily occur to persons of skill in the art.

[0081] For example, a pair of resiliently-biased helical springs (not shown) could alternatively be used to bias the perforating members **130** inwardly when not in the actuated position, to thereby allow displacement of the tool **10** uphole or downhole to a new fracking or perforating location after the perforations have been created in the casing.

Hydraulic Fracturing of the Formation

[0082] When the perforation operation has been completed at one location along the wellbore, in one embodiment of the method of the present invention the tool **10** is simply lowered further downhole in the well. Slidable member **205** (see **Fig. 27**) due to frictional engagement with the well casing, is then caused to slide uphole thereby exposing fluid egress port **251** (see **Fig. 27**) which thereby allows fluid which is being displaced by the downward

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movement of the tool 10 to bypass downhole cup seal 50 and thereby allow continued movement of tool 10 downhole. Fracking injection ports 20 on tool 10 can then be positioned directly opposite previously-created perforations in the casing, in order to carry out the fracking operation and inject fluid into the formation by causing such fluid to be injected downhole and egress through fracking injection ports 20 and thereafter into the formation through the created perforations in the casing. In this way, the tool 10 achieves both perforating and fracking operations in the well without removal of the tool 10 between operations. Accordingly, both perforating and fracking operations can be conducted while maintaining the tool *in situ*.

[0083] Referring to Figs. 1a and 1b and Fig. 25, the tool 10 comprises a fracking assembly 160 comprising an upper fracking mandrel 47 connected to the first cylinder 95 containing the activation assembly 165. An upper mandrel 35, to which the fracking mandrel 47 is coupled, is in turn coupled to the valve assembly 69 (see Fig. 3a, 9a, and 17a) in the first cylinder 95. Fluid pumped downhole via a tubing string (not shown) to which fracking mandrel 47 (and thus tool 10) is coupled flows out fracking ports 20. Thereafter such fluid re-enters the tool 10 via injection ports 55 [(which are covered with a protective screen 25 (see Fig. 2a, 2b, and Fig. 25) to reduce cuttings and the like entering the tool 10] and thereafter flows to the valve assembly 69. As discussed, the valve assembly 69, in its various further embodiments described below, operates to control activation of the perforating function of the tool 10. The perforating function of the tool 10 is activated when fluid is injected into the tool 10 at a sufficient hydraulic pressure (ie higher than normal fracking pressure). In one embodiment, the perforating function of the tool 10 is activated, and requires a hydraulic pressure of at least 6,000 psi. in order that valve assembly 69 pass fluid to the force-magnifying assembly 170. As shown in Fig. 1b, fluid injected at pressures less than that required to activate the valve assembly 69 does not flow past the valve assembly 69 and into the force-magnifying assembly 170, since due to the closed valve assembly 69 it is unable to flow into injection ports 55 in the fracking mandrel 47 at the uphole end 5 of the tool 10. When the fracking fluid injection ports 20 are positioned adjacent the perforations that were made in the casing, the diverted fluids are injected into the formation to achieve fracking as discussed.

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[0084] The fracking assembly 160 located at the uphole end 5 of the tool 10, is spaced apart from the punch assembly and punch port 30 located at the downhole end 15 of the tool 10, at a fixed and known distance. Accordingly, when the perforation operation has been completed, the tool 10 can simply be lowered into the well by the fixed distance to position the fracking assembly, and more specifically the fracking fluid injection ports 20, at the perforations made in the casing. In this way, the perforated sections of the casing can be located easily without the need for additional equipment such as cameras or sensors, ensuring accuracy and repeatability of the operation. The length of the tool 10, according to certain embodiments, can be adjusted to the desired operation. In one embodiment, the tool has a length of between about 2,500 to about 3,000 mm. In a further embodiment, the tool has a length of between about 2,600 to about 2,900 mm. In another embodiment, the tool has a length of between about 2,700 to about 2,800 mm.

[0085] In preferred embodiments, the tool 10 comprises at least one sealing member 40 disposed proximate an upper region of the tool 10, and a further sealing member 50 at an opposite downhole end of the tool 10 (Figs. 1a and 1b, and Fig.'s 26-28). A variety of known sealing members may be utilized, however, according to preferred embodiments the sealing members are frustoconically shaped cup seals. Each sealing member 40, 50 is respectively mounted on the tool 10 so that their respective flared ends are oppositely opposed. Specifically, the sealing members 40, 50 are biased into sealing contact with the casing when pressurized fluid flows against the sealing members 40, 50 between the tool and well casing. When fracturing fluid is injected into the well through the fracking fluid injection ports 20, the sealing members 40 expand into sealing contact with the casing walls to prevent flow of fracturing fluid downhole via space between the tool and the casing.

[0086] As shown, one sealing member 40 is located at the uphole end 5 of the tool 10, downhole of the fluid injection port 20, with the flared end oriented uphole (ref. Fig. 1a, and Fig. 26a, 26b). In this way, it is ensured that pressurized fluid that is diverted through the fluid injection ports 20 of the tool 10 is directed through the perforations in the well casing to enter the formation and induce fracturing. A second sealing member 50 is located at the

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downhole end 15 of the tool 10, downhole of the punch port 30. The second sealing member 50 is oriented with its flared end directed downhole such that downhole fluids are prevented from flowing upwardly between the casing and the tool 10. In this way, the sealing members 40, 50 together prevent fluids, and sand entrapped therein, from entering the space between the casing and the tool 10, thereby avoiding "sanding in" of the tool 10 in the well.

[0087] In certain embodiments, an additional third sealing member 45 (ref. Fig. 1b, and Fig. 26a) may be connected to the tool 10 downhole of the first sealing member 40 located at the uphole end 5 of the tool 10, to provide additional back-up should the first sealing member 40 fail under the injected fluid pressure used during fracking and/or perforating.

[0088] In one embodiment of the method of using a combined fracking and perforating tool 10 of the present invention, the process of fracking and perforating may commence from the top of the wellbore, and the tool 10 is lowered downhole an incremental desired distance, the punch members, namely the pointed perforating members 130 actuated to perforate the casing, and then tool 10 is lowered further downhole a known distance, namely the distance on the tool 10 between the perforating members and the frack fluid injection port 20, so as to position the frac port 20 over the created perforation in the well casing. Such process is successively repeated until the tool perforates and fracks along the entire length of the wellbore until the tool reaches the bottom of the wellbore, wherein the tool is then withdrawn from the well.

[0089] In the above method when the tool 10 reaches the bottom of the wellbore the perforations and fracs in the wellbore are all above the tool 10 with direct access to the formation. Ingress of fluid into the wellbore above the tool 10 may contain sand, and with the result with the possible ingress of sand tool 10 could become "sanded in", and thus be not able to be removed from the well.

[0090] Accordingly, in an alternative embodiment of the method of using the combined fracking and perforating tool 10 of the present invention, the process of fracking and perforating may instead commence close to the bottom of the wellbore. In such method, the

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tool **10** is first lowered to the bottom of the wellbore, a slight distance from the bottom of the wellbore. The perforating members **130** are actuated to perforate the casing in such location. Thereafter, tool **10** is lowered further downhole a short known distance, namely the distance on the tool **10** between the perforating members **130** and the frac port **20**, so as to position the frac port **20** over the created perforation in the well casing, and frac fluid supplied to frac port **20** to frac the formation at such location along the wellbore via the created perforations. Thereafter, the tool **10** is raised uphole to a desired further location for perforating and fracking, and the perforating members **130** again actuated to perforate in such location. Tool **10** again lowered the same short known distance to position the frac ports **20** over the newly-created additional perforations in the well casing, and frac fluid supplied to frac port **20** to frac the formation at such new location. The tool **10** is then further moved uphole an incremental distance, and the process repeated until the entirety of wellbore has been perforated and fracked, at which point the tool **10**, now proximate the top of the wellbore, is then removed from the wellbore. In such manner, all communication between the wellbore and the formation is then below the tool **10**, with the result that any potential "sanding in" problems may be avoided.

[0091] As discussed above, **Fig. 3a** shows a valve assembly **69** which is used to allow supply of fluid within bore **60** for actuating pistons **110** and **120**, to cause radial extension of pointed punch members **130** to perforate the casing. Such valve assembly **69**, as discussed above, comprises a valve stem **70** over which, when the valve **69** is in a closed position, a sliding sleeve **71** sits. Upon application of hydraulic pressure greater than fracking pressure and sufficient to overcome spring force exerted by springs **90** on mandrel **100** which bias piston **80** in a closed position, causes the sliding sleeve **71** (part of piston **80**) to be displaced and moved from covering port **75**, thereby allowing flow of fluid into port **75** and thus allowing flow of such hydraulic fluid into bore **60** and thence to pistons **110** and **120**.

[0092] Notably, however, other types of valve assemblies **69** for selectively, when desired, allowing pressurized fluid into bore **60** to actuate downhole pistons such as **110**, and **120** to actuate punch mechanism **175**, are possible.

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[0093] Below described are three(3) further types of valve assemblies 69.

[0094] Specifically, one such other embodiment of valve assembly 69 which may be incorporated in the tool 10 of the present invention is best shown in Fig. 9a and Fig. 10 (un-actuated) and in Fig. 9a and Fig. 11 (actuated). As may be seen, the valve assembly 69 may instead comprise a single ball 300 biased against ball seat 301 by means of washer springs 302. Upon supply of fluid in the direction of the "arrow" shown in Fig. 11 of a pressure sufficient to overcome the biasing force of washer springs 302, thereby displacing ball 300 from ball seat 301, and pressurized fluid is then allowed to flow through ports 304 into radial passageway 306 into radial ports 308, and thereafter into bore 60 for thereafter actuating pistons 110, 120.

[0095] Another embodiment of valve assembly 69 which may be incorporated in the tool 10 of the present invention is best shown in Fig. 17a and Fig. 18 (un-actuated position), partially actuated position (Fig. 19), and in fully actuated position (Fig. 17b and Fig. 20. As may be seen, therefrom, the valve assembly 69 instead comprise a pair of ball valves 69' and 69", each having a respective single ball 300, 310 biased against respective ball seats 301, 311 by means of respective washer springs 302, 312.

Second ball valve 69" in effect acts as a redundancy, to ensure any leakage from ball valve 69' does not inadvertently actuate punch assembly 175.

Upon supply of fluid in the direction of the "arrow" shown in Fig. 18 (of a pressure sufficient to overcome the biasing force of washer springs 302) pressurized fluid is then allowed to flow through ports 304 into radial passageway 306 and thence into radial ports 308, and thereafter into bore 60. This semi-actuated position is shown in Fig. 19.

[0096] Thereafter, continued supply of pressurized fluid to second ball valve 69", as shown in Fig. 20 serves to fully actuate this valve assembly 69 by then further overcoming the biasing force of washer springs 312, thereby displacing ball 310 from ball seat 311. Pressurized fluid is then allowed to flow through ports 314 into radial passageway 316 into

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radial ports **318**, and thereafter into bore **60** for thereafter actuating pistons **110, 120**.

[0097] A third embodiment **69'''** of the valve assembly **69** for the tool **10** of the present invention is shown in **Figs. 21-25**, and in particular best shown in **Fig.'s 23a, 24a** (un-actuated position) and in **Fig.'s 23b, 24b** (actuated position). In such embodiment a slidable hollow cylinder or "J" sleeve **400** is provided, which is slidable on slotted mandrel **438**, such mandrel **438** having hollow longitudinal bores **60', 60''** therein over respective portions of the length thereof. Mandrel **438** is provided with a plurality of radial ports **404, 408**, which are in fluid communication with bores **60'** and **60''** respectively. "O" ring seals **408, 409**, and **411**, are disposed on mandrel **438** on respective lateral sides of each of radial ports **404, 408**. Guide pin **430** is situated in longitudinal slot **410** in mandrel **438**, and maintained in position by cover sleeve **401**. Guide pin **430** serves to permit slidable movement of sliding sleeve **400**, and in particular slot **412** therein, over radial ports **404, 406** in mandrel **438**.

[0098] A plurality of flexible curvilinear spring elements **436** are fixed about an exterior of the valve assembly **69'''**, which spring elements **436** serve, when the tool is inserted in the wellbore, to frictionally engage the interior of the casing of the wellbore. Milled within the interior of sliding sleeve **400** is a slot **412**, which like sliding sleeve **400**, is thus laterally moveable along exterior surface of mandrel **438** and thence positionable over radial ports **404** and **406** to allow fluid communication therebetween.

[0099] In operation, due to frictional engagement of spring elements **436** with exterior of the wellbore casing, upon lowering of the tool **10** downhole within the wellbore, sliding sleeve **400** of valve assembly **69'''** will be moved so that slot **412** in sliding sleeve **400** is positioned over radial ports **404, 406**, thus allowing fluid communication therebetween, and in particular pressurize fluid coming from uphole to be provided to bore **60**. When tool **10** is positioned in the wellbore at a desired location for perforating the casing therein, high pressure fluid may then be supplied to the tool **10** and due to fluid communication permitted between ports **404** and **406** such high pressure fluid is subsequently then supplied to pistons **110, 120** via bore **60''** as shown in **Fig. 24b**, to thereby actuate punch assembly **175** and accomplish perforation

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of the casing at such desired location.

[00100] Thereafter, flow of high pressure fluid to the tool 10 is stopped, and the tool 10 further lowered so that the injection ports 20 thereon are positioned a known short distance below the created perforations. Thereafter, tool 10 is raised the known distance to align the injection ports 20 with the created perforations, and in so raising tool 10 within the wellbore frictional engagement of the spring members 436 thereof with the interior of the wellbore casing causes a slidable repositioning of sliding sleeve 400, wherein slot 412 no longer is positioned over radial ports 404, 406 and fluid communication between them is halted, as shown in Fig. 24a. In such manner fracking fluid, when then supplied to the tool 10 at such new (uphole) location in the wellbore, will then be diverted to the fracing port 20 and thereafter pass through the created perforations in the wellbore into the formation, to thereby frac the formation at such desired location.

[00101] The tool 10 may then be moved uphole to proximate a new (uphole) location for perforating the casing, and then lowered a slight distance to again reposition the sliding sleeve 400 and slot 412 therein over ports 404, 406 to re-establish fluid communication between ports 404 and 406, and the process as above repeated to conduct further perforation and fracing operations until an entire length of formation is fraced, wherein the tool 10 can then be removed from the wellbore.

[00102] Fig. 26 shows an enlarged view of upper fracking mandrel 47, having injection ports 20 milled therein. The upper end of mandrel 47 preferably possesses threads 57 to permit threaded coupling of tool 10 to fluid injection tubing. A port 55, protected by a screen 25, is provided therein, which allows fluid received from injection ports 20 and which flows into port 55 via screen 25, to then pass into bore 60 for subsequent supply downhole, and if valve assembly 69, 69', 69'', or 69''' is open (opened), to thereafter flow within tool 10 to pistons 110, 120 and thereafter actuate punch members 130.

[00103] Fig. 27a shows one embodiment of the upper seal member comprising a pair of cup seals 40, 45, which are positioned with the cup portion of each seal member 40, 45 thereof

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facing uphole, so as to permit biased thereof into sealing contact with the casing when pressurized fluid attempts to enter between the tool 10 and well casing in a region between the upper and lower ends of the tool 10 between the sealing members 40 and 50.

[00104] Fig. 27b shows another embodiment of the upper seal member comprising simply a single cup seal 40, but which again is positioned with the cup portion of seal member 40 thereof facing uphole so as to permit biased thereof into sealing contact with the casing when pressurized fluid attempts to enter between the tool 10 and well casing in a region between the upper and lower ends of the tool 10 between the sealing members 40 and 50.

[00105] Fig. 28 and Fig. 29 show enlarged views of the downhole end of tool 10, and in particular the manner of operation of a bypass mechanism which allows bypass of fluid around tool 10 when tool 10 is being lowered into a wellbore containing fluid. Such bypass mechanism advantageously becomes closed when the tool 10 is raised in the wellbore, thereby preventing downhole fluids in the wellbore (which may have then entered the wellbore due to earlier downhole perforating and fracing operations and which typically possess significant quantities of entrained sand) from moving uphole and entering the region of the wellbore between the tool 10 and the wellbore and potentially causing the tool 10 to become "sanded in".

[00106] Such bypass assembly on tool 10 provides for a sliding cylinder 205, positioned on mandrel 275, further having arcuate flexible spring members 436 thereon which frictionally engage the interior of the wellbore. A cup seal 50 is provided, with the cup positioned downhole to thereby permit the cup seal 50 to be biased into sealing contact with the casing when pressurized fluid attempts to enter a region between the tool 10 and well casing in a region between the upper and lower ends of the tool 10 between the sealing members 40 and 50.

[00107] In operation, when tool 10 is lowered downhole in the wellbore, sliding cylinder 205, positioned on mandrel 275, due to frictional engagement of arcuate flexible spring members 436 thereon which frictionally engage the interior of the wellbore, is caused to move uphole

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relative to mandrel **275**, thereby opening port **251** and allowing downhole fluid which is being displaced by the lowering of the tool **10**, to bypass cup seal **50** via bore **500** and pass uphole in the region intermediate the tool **10** and the wellbore, as shown in Fig. **28**. Such bypass of fluid thereby allows tool **10** to be continued to be lowered in the wellbore.

[00108] Raising of the tool **10** in the wellbore, due to due to frictional engagement of arcuate flexible spring members **436** thereon which frictionally engage the interior of the wellbore, causes slidable cylinder **205** to be slidably repositioned on tool **10**, wherein cylinder **205** then covers, and thereby closes port **251**, as shown in Fig. **29**. Accordingly, uphole flow of downhole fluid past the tool **10**, which downhole fluids may have substantial sand entrained therein, can thereby be prevented.

[00109] The above disclosure represents embodiments of the invention recited in the claims. In the preceding description, for purposes of explanation, numerous details are set forth in order to provide a thorough understanding of the embodiments of the invention. However, it will be apparent that these and other specific details are not required to be specified herein in order for a person of skill in the art to practice the invention.

[00110] The scope of the claims should not be limited by the preferred embodiments set forth in the foregoing examples, but should be given the broadest interpretation consistent with the description as a whole, and the claims are not to be limited to the preferred or exemplified embodiments of the invention.

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

1. A combined perforating and fracking tool for perforating a hydrocarbon well casing disposed in a formation and for subsequently fracturing the formation while maintaining the tool *in situ*, the tool comprising:

(a) at least one cylinder arranged to be disposed in a well casing and adapted at an uphole end to receive fluid, said cylinder comprising a cooperating piston;

(b) a punch assembly disposed at a downhole end of said cylinder and cooperating piston, the punch assembly comprising a punch comprising a pointed piercing member for perforating the casing, wherein the punch assembly is actuated by the fluid exerting a pressure on the cooperating piston, and the cooperating piston exerting a force which causes outward extension of the pointed piercing member to perforate the casing;

(c) a fluid injection port disposed at an upper end of the tool to allow fluid to be injected into the formation through the perforations created in the well casing by the tool; and

(d) at least one sealing member disposed proximate an upper uphole end of the cylinder, downhole of said fluid injection port, adapted to prevent fracking fluid from travelling, when such tool is in a well casing, outside the cylinder in a direction downhole;

wherein fluid may be provided in a bore defined along the longitudinal axis of the cylinder; and

whereby a force is generated by fluid under pressure travelling in said bore and acting on the cooperating piston which then actuates the punch assembly to actuate, in a radially-outwardly protruding manner, said pointed piercing member to perforate the casing.

2. The combined perforating and fracking tool as claimed in claim 1, further having a

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plurality of cylinders and a corresponding plurality of co-operating pistons, whereby a magnification of hydraulic force is generated by the cooperating pistons to actuate said pointed piercing member.

3. The combined perforating and fracking tool as claimed in claim 1, wherein said at least one sealing member comprises a first cup seal member disposed at an upper end of said tool and a second cup seal member disposed at a lower downhole end of said tool, together adapted to prevent fluid from travelling, when such tool is in a well casing for perforating, between such two cup seal members.

4. A combined perforating and fracking tool for perforating a well casing disposed in an underground formation and for subsequently fracturing the formation while maintaining the tool *in situ*, the tool comprising:

(a) at least a pair of cylinders arranged to be disposed in a well casing and adapted at an uphole end to receive fluid, each of said cylinders comprising a cooperating piston, wherein each piston defines a bore along its longitudinal axis and an associated port for conducting fluid flow from the bore into each cylinder;

(b) a punch assembly disposed at a downhole end of the cylinders, the punch assembly comprising a punch for perforating the casing, wherein the punch assembly is actuated by a piston which outwardly extends a punch to perforate the casing;

(c) a fluid injection port disposed at the uphole end of the tool, and a valve member, to allow fluid to be diverted from the cylinders and injected into the formation through the perforations created in the well casing; and

(d) at least a pair of sealing members respectively disposed respectively at an upper and lower end of the tool, forming a seal between the casing and the tool such that fluid can be diverted through the fluid injection port for fracturing the formation;

wherein the cylinders remain isolated from the injected fluid flowing between the tool and

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well casing during fracturing; and

wherein during a perforation step fluid flowing through a bore defined along the longitudinal axis of tool sequentially fills each of the cylinders whereby a magnification of hydraulic force is generated by the cooperating pistons to actuate the punch .

5. The combined perforating and fracking tool according to claim 4, the lower sealing member having a bypass means which may be selectively actuated to allow bypass of the lower seal only when desired;

6. The combined perforating and fracking tool according to any one of claims 1-5, wherein the tool comprises a valve assembly for opening and closing flow of fluid for activation of the punch assembly.

7. The combined perforating and fracking tool according to claim 6, wherein the valve assembly comprises a valve stem operatively connected to a first piston, the valve stem being slidable when fluid entering the tool is at a sufficient pressure to increase the fluid pressure in the first cylinder and cause the first piston to move to an open position and allow the valve stem to uncover a port which allows the fluid to then enter the bore.

8. The combined perforating and fracking tool according to claim 6, wherein the valve assembly comprises a spring-biased ball valve.

9. The combined perforating and fracking tool according to claim 6, wherein the valve assembly comprises a slidable sleeve having a fluid passageway , said slidable sleeve being slidable along a mandrel on the tool at a location on the tool having radial aperture therein, said slidable sleeve on its exterior having a friction member to consistently frictionally engage the casing,

wherein when the tool is lowered to a desired position downhole, upward movement of the tool thereafter and resultant frictional engagement of said friction member with said casing causes relative movement of said slidable sleeve relative to said mandrel and thus

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repositioning of said passageway therein so as to then become in fluid communication with said radial aperture so as to cause such valve assembly to be in an open position and allow supply of fluid to downstream pistons to thereby allow actuation of said punch.

10. The combined perforating and fracking tool according to any one of claims 6 or 7, wherein the valve assembly further comprises a spring member, the spring member operatively engaging the first piston to return the first piston and valve stem to a closed position when fluid pressure is reduced.

11. The combined perforating and fracking tool according to any one of claims 6-10, wherein the valve assembly when in an open position is in fluid connection with a second piston disposed within a second cylinder and fluid is allowed to flow to fill the second cylinder whereby fluid pressure within the second cylinder increases to cause the second piston to move therein.

12. The combined perforating and fracking tool according to claim 11 wherein the second piston is in fluid connection with a third piston disposed within a third cylinder, wherein fluid flowing through the fluidly connected second piston enters the third cylinder through the associated ports to fill the third cylinder whereby fluid pressure within the third cylinder increases to cause the third piston to move therein.

13. The combined perforating and fracking tool according to claim 12, wherein the third piston is a closed member having a pointed downhole end, the pointed end cooperatively engaging with the punch assembly to outwardly extend the punch to perforate the casing.

14. The combined perforating and fracking tool according to claim 13, wherein the punch comprises a pair of pointed perforating members which are forced apart by the pointed end of the third piston to outwardly extend the perforating members.

15. The combined perforating and fracking tool according to claim 14, wherein the pair of pointed perforating members are inwardly biased by a biasing member to inwardly bias the pair of perforating members and cause them to retract within the tool once the casing has been

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perforated and when fluid supply to the third piston has been reduced or halted.

16. The combined perforating and fracking tool according to any one of preceding claims 1-15, wherein the fluid injection port comprises a screen to prevent debris from entering the tool.

17. The combined perforating and fracking tool according to any one of preceding claims 1-16, wherein the at least one sealing member disposed proximate the upper uphole end of the cylinder is biased into sealing contact with the casing when pressurized fluid flows out of the injection port, to thereby prevent flow of fluid between the tool and well casing.

18. The combined perforating and fracking tool according to any one of preceding claims 1-17, wherein the at least one sealing member is frustoconical in shape.

19. The combined perforating and fracking tool according to any one of preceding claims 1-18, wherein a first sealing member is located downhole of the fluid injection port at the uphole end of the series of connected cylinders and a second sealing member is located downhole of the punch assembly disposed at the downhole end of the series of connected cylinders.

20. A combined perforating and fracking tool for perforating a well casing disposed in an underground formation, and for subsequently fracturing the formation while maintaining the tool *in situ*, the tool comprising:

(a) a series of connected cylinders arranged to be disposed in a well casing and adapted at an uphole end to receive fluid, the series of connected cylinders comprising:

a first cylinder comprising a valve assembly for controlling activation of the punch assembly;

a second cylinder comprising an associated piston, the associated piston in fluid connection with the valve assembly such that when the valve assembly is in an open position fluid is allowed to flow through the associated piston and associated ports to fill the second

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cylinder fluid pressure within the second cylinder increases to cause the associated piston to move therein;

(b) a punch assembly disposed at a downhole end of the series of connected cylinders, the punch assembly comprising a pointed punch member for perforating the casing, wherein the punch assembly is actuated by the first and second pistons to outwardly extend the punch member to perforate the casing;

(c) a fluid injection port disposed at the uphole end of the series of connected cylinders to allow fluid to be diverted from the series of connected cylinders and injected into the formation through the perforations created in the well casing; and

(d) at least one sealing member disposed at each end of the series of connected cylinders, each sealing member forming a seal between the casing and the tool such that fluid can be diverted through the fluid injection port for fracturing the formation, and wherein the series of cylinders remains isolated from the injected fluid flowing between the tool and well casing;

wherein fluid flowing through the second cylinder results in a force supplied by the associated piston to actuate the punch assembly.

21. The combined perforating and fracking tool according to claims 20, wherein the tool comprises a valve assembly for opening and closing flow of fluid for activation of the punch assembly.

22. The combined perforating and fracking tool according to claim 21, wherein the valve assembly comprises a valve stem operatively connected to a first piston, the valve stem actuated to an open position when fluid entering the tool is at a sufficient pressure to increase the fluid pressure in the first cylinder and cause the first piston to move therein .

23. The combined perforating and fracking tool according to claim 21, wherein the valve assembly comprises a spring-biased ball valve.

24. The combined perforating and fracking tool according to claim 21, wherein the valve

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assembly comprises a slidable sleeve having a fluid passageway, said slidable sleeve being slidable along a mandrel on the tool at a location on the tool having radial aperture therein, said slidable sleeve on its exterior having a friction member to consistently frictionally engage the casing,

wherein when the tool is lowered to a desired position downhole, upward movement of the tool thereafter and resultant frictional engagement of said friction member with said casing causes relative movement of said slidable sleeve relative to said mandrel and thus repositioning of said passageway therein so as to then become in fluid communication with said radial aperture so as to cause such valve assembly to be in an open position and allow supply of fluid to downstream pistons to thereby allow actuation of said punch.

25. The combined perforating and fracking tool according to claim 22 or 23, wherein the valve assembly further comprises a spring member, the spring member operatively engaging the first piston to return the valve stem valve to a closed position when fluid pressure is reduced.

26. The combined perforating and fracking tool according to claim 20, further comprising:

a third cylinder comprising another piston, the another piston in fluid connection with the associated piston of the second cylinder such that fluid flowing through the fluidly connected associated piston enters the third cylinder through the associated ports to fill the third cylinder whereby fluid pressure within the third cylinder increases to cause the third piston to move therein;

wherein fluid flowing through the second and third cylinders results in a combined increase of hydraulic force generated by the series of corresponding pistons to actuate the punch assembly.

27. The combined perforating and fracking tool according to claim 26, wherein the another piston is a closed member having a pointed downhole end, the pointed end cooperatively engaging with the punch assembly to outwardly extend the punch member to perforate the

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casing.

28. The combined perforating and fracking tool according to claim 20, wherein the punch member comprises a pair of pointed perforating members which are forced apart by the pointed end of the another piston to outwardly extend the perforating members.

29. The combined perforating and fracking tool according to claim 28, wherein the pair of pointed perforating members are connected by a biasing member to inwardly retract the pair of perforating members once the casing has been perforated.

30. The combined perforating and fracking tool according to claim 20, wherein the fluid injection port comprises a screen to prevent debris from entering the tool.

31. The combined perforating and fracking tool according to claim 20, wherein the at least one sealing member disposed at each end of the series of connected cylinders are each biased into sealing contact with the casing when pressurized fluid attempts to enter between the tool and well casing in a region between the upper and lower ends of the tool between the sealing members.

32. The combined perforating and fracking tool according to claim 31, wherein the sealing members at opposite ends of the tool are each frustoconical in shape.

33. The combined perforating and fracking tool according to claim 32, wherein a first sealing member is located downhole of the fluid injection port at the uphole end of the series of connected cylinders and a second sealing member is located downhole of the punch assembly disposed at the downhole end of the series of connected cylinders.

34. A method for perforating a well casing disposed in a formation and for subsequently fracturing the formation while maintaining the tool *in situ*, the method comprising:

(a) supplying fluid to the combined perforating and fracking tool according to any one of claims 1-33 when such tool is disposed within a well casing, activating a valve therein so as to provide fluid flow through the series of connected cylinders and associated pistons

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whereby a combined force is generated by such pistons to actuate the punch assembly to form created perforations in the well casing;

(b) lowering the combined perforating and fracking tool to position the fluid injection port thereon adjacent to the created perforations in the well casing and to position the at least one sealing member downhole of the created perforations in the well casing ; and

(c) pumping fluid through the fluid injection port and created perforations to fracture the formation.

35. The method according to claim 34, wherein the fluid pressure of the fluid supplied to the combined perforating and fracking tool is reduced in step (c) to divert the fluid to flow through the fluid injection port to fracture the formation.

36. The method according to claim 28, wherein the fluid is supplied in step (a) at a hydraulic pressure of at least 6,000 psi.

37. The method according to claim 30, wherein the fluid pressure after step (a) is reduced to below 6,000 psi.

38. The method according to claim 34, wherein a sealing member disposed at each end of the tool forms a seal between the casing and the tool such that fluid can be diverted through the fluid injection port for fracturing the formation, and wherein the tool remains isolated from the injected fluid flowing between the tool and well casing

39. The method according to claim 34, wherein the fluid is fracturing fluid.

40. The method according to claim 39, wherein the fluid comprises proppants.

Fig. 1a

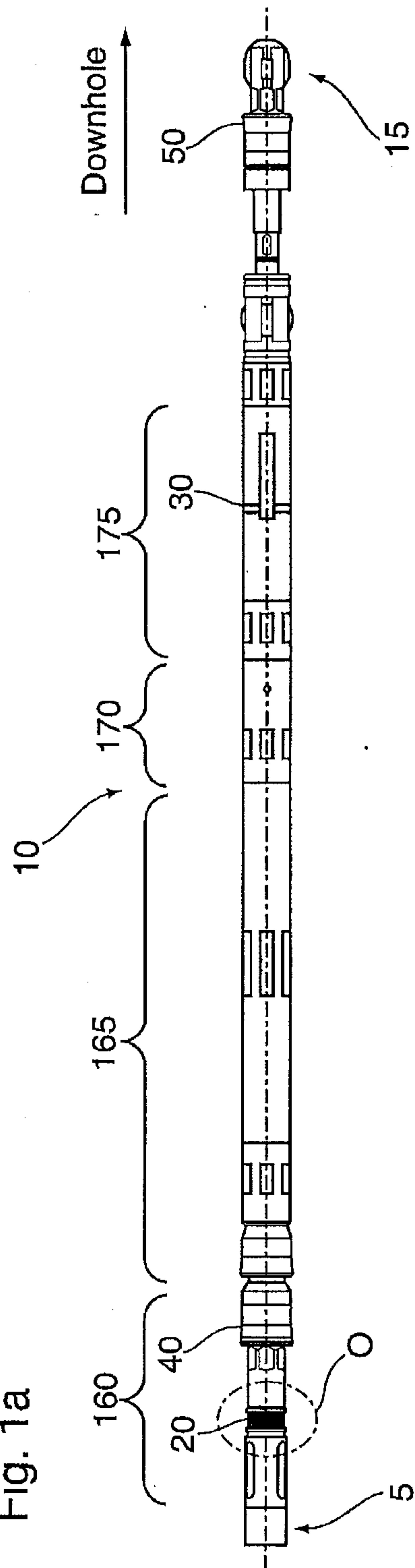


Fig. 1b

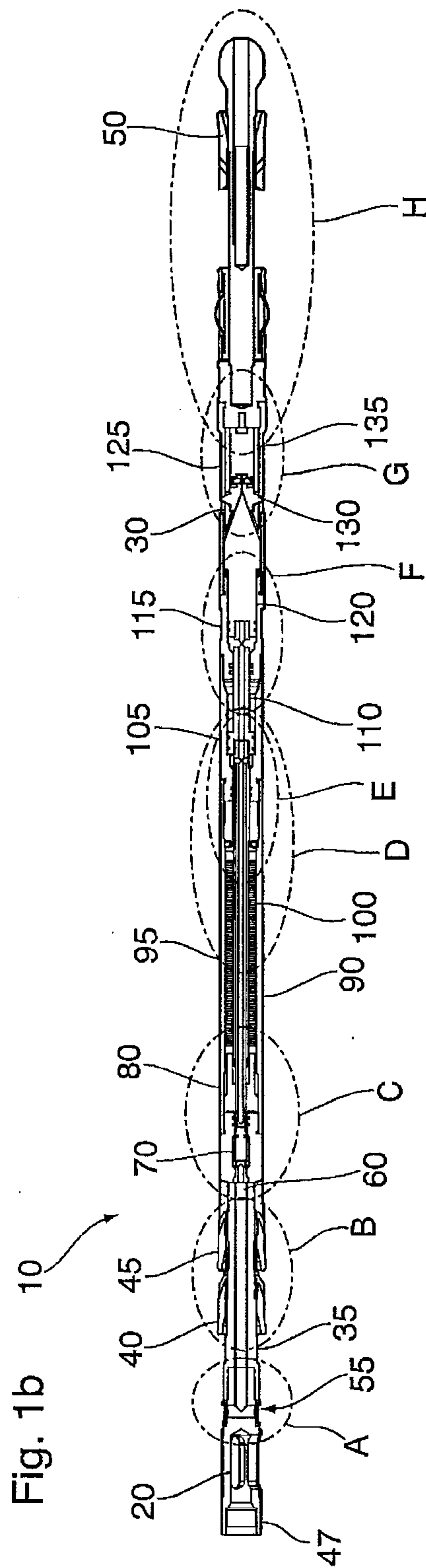


Fig. 2a

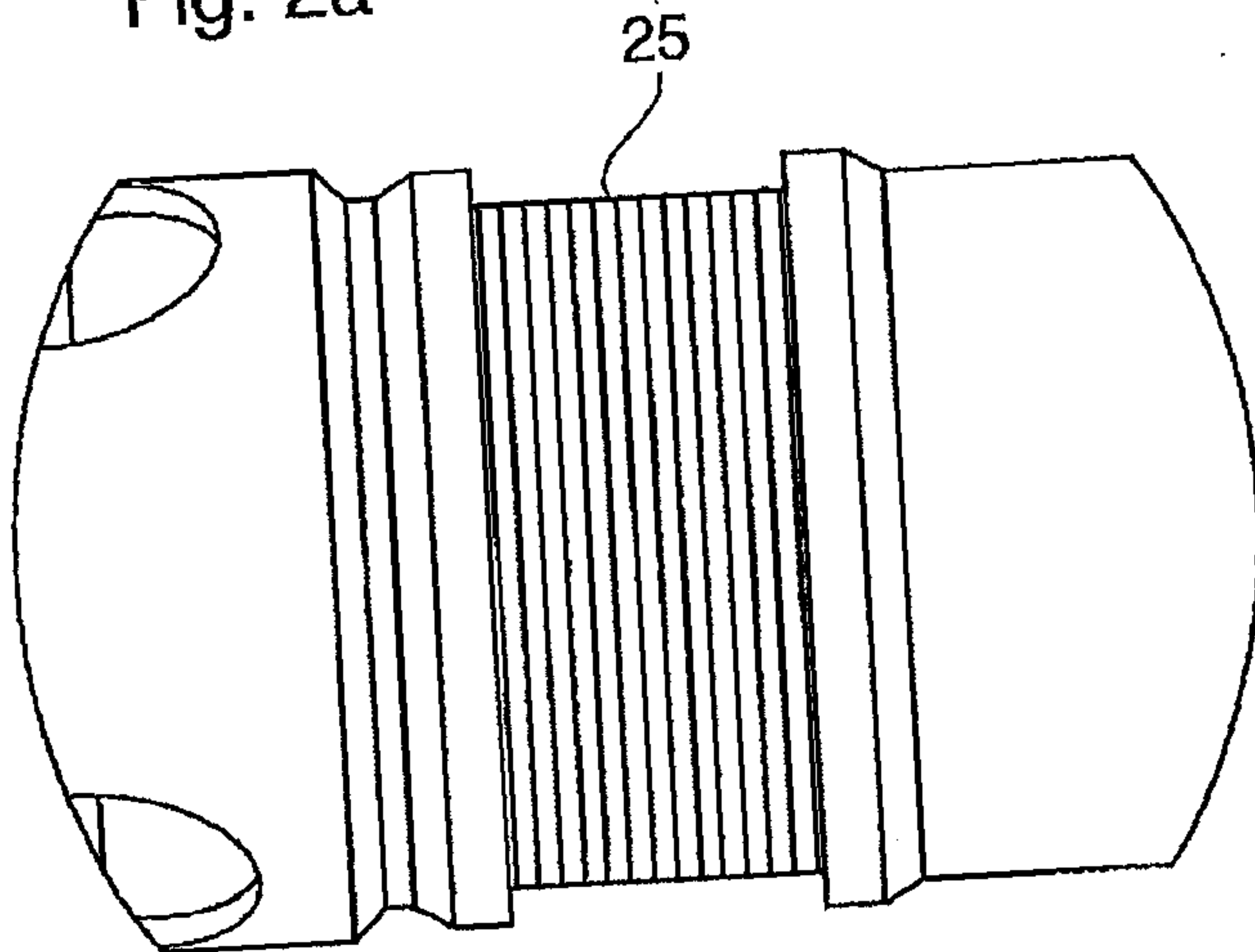


Fig. 2b

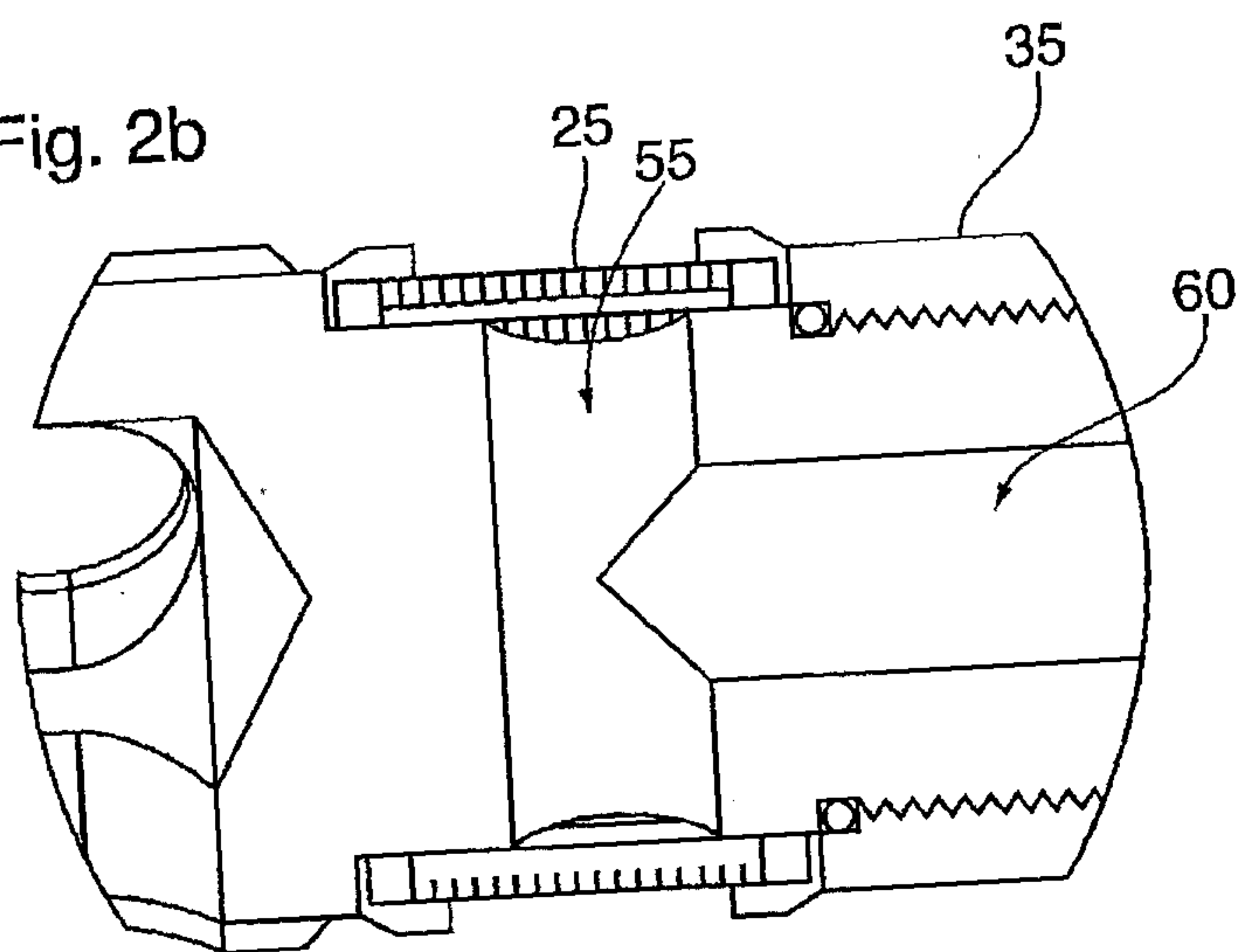


Fig. 3a

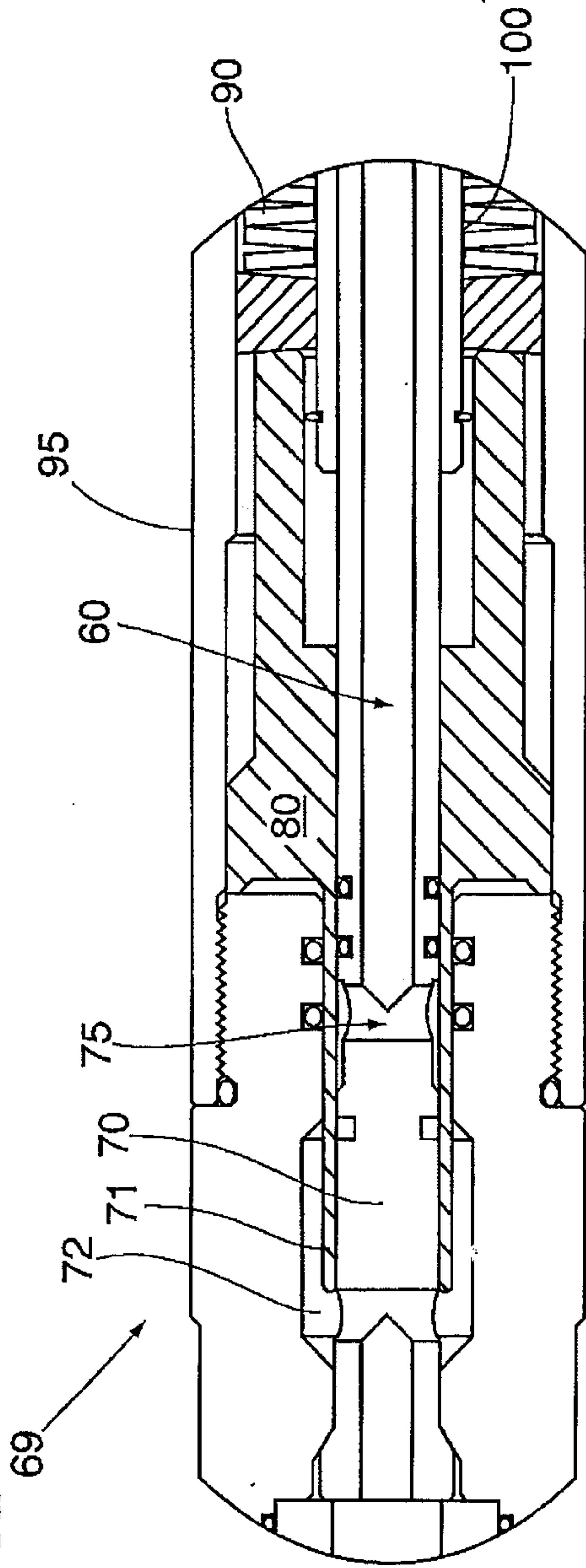


Fig. 3b

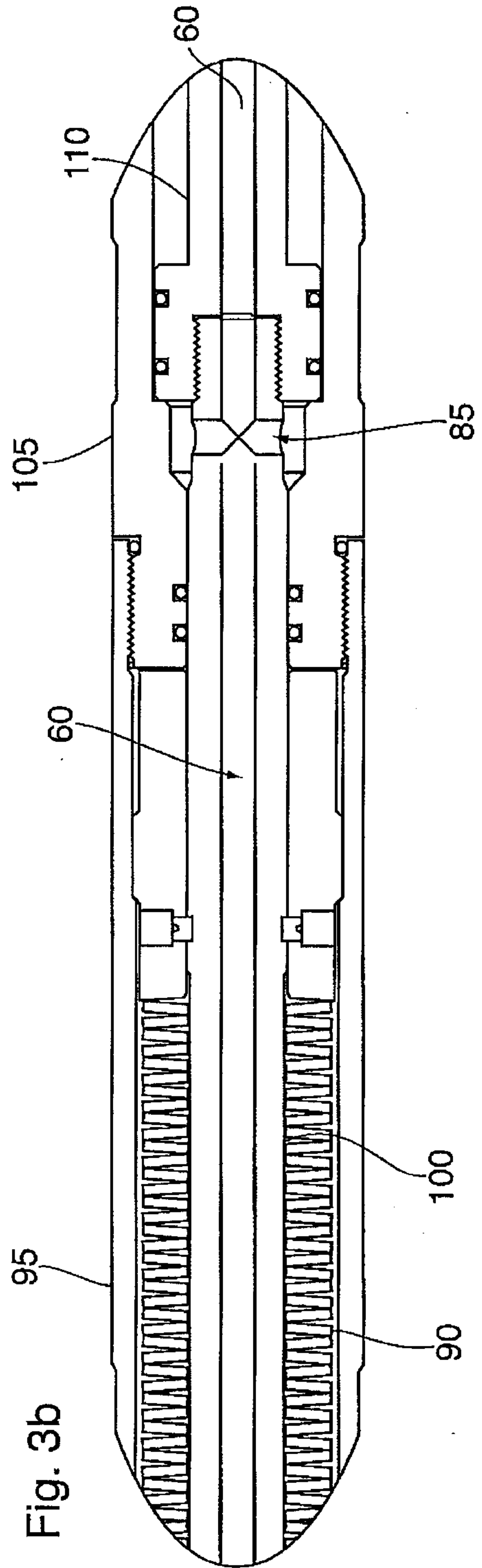


Fig. 4a

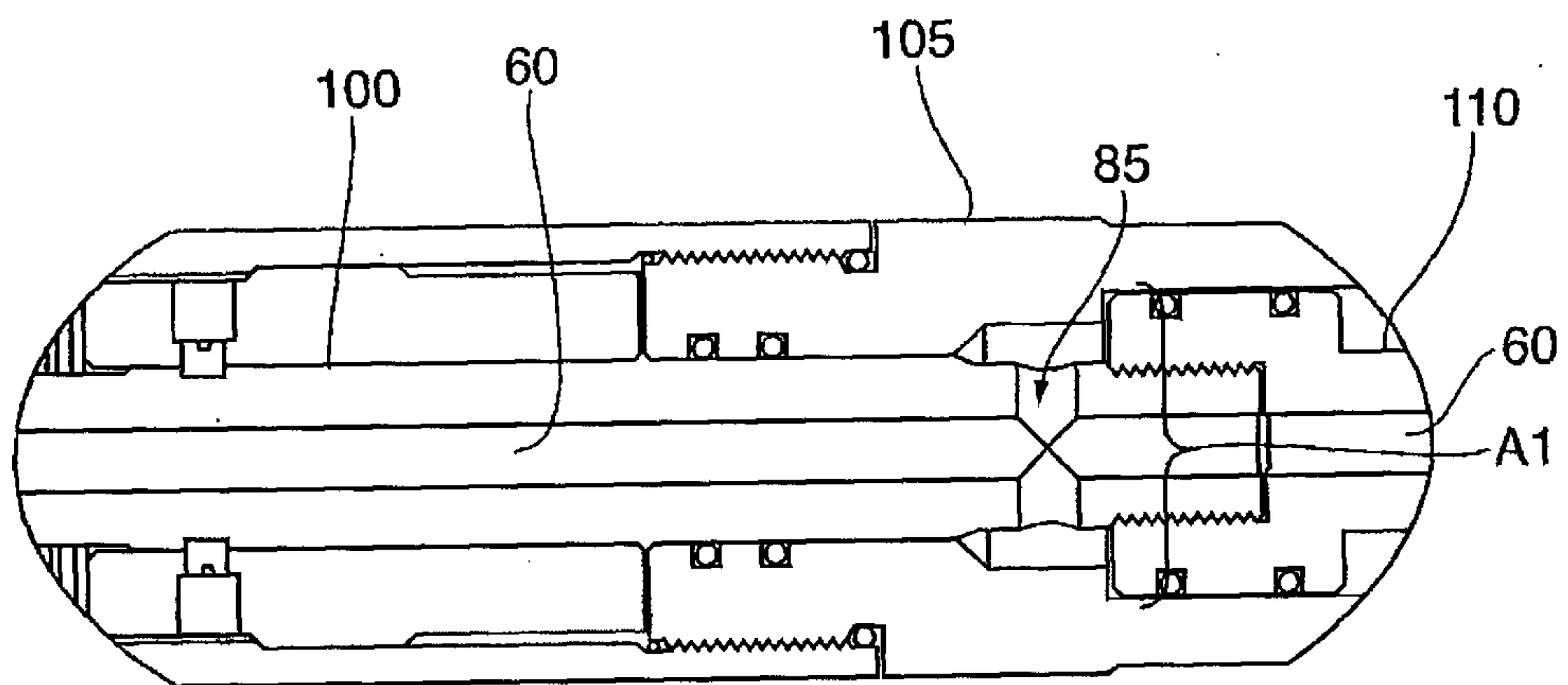


Fig. 4b

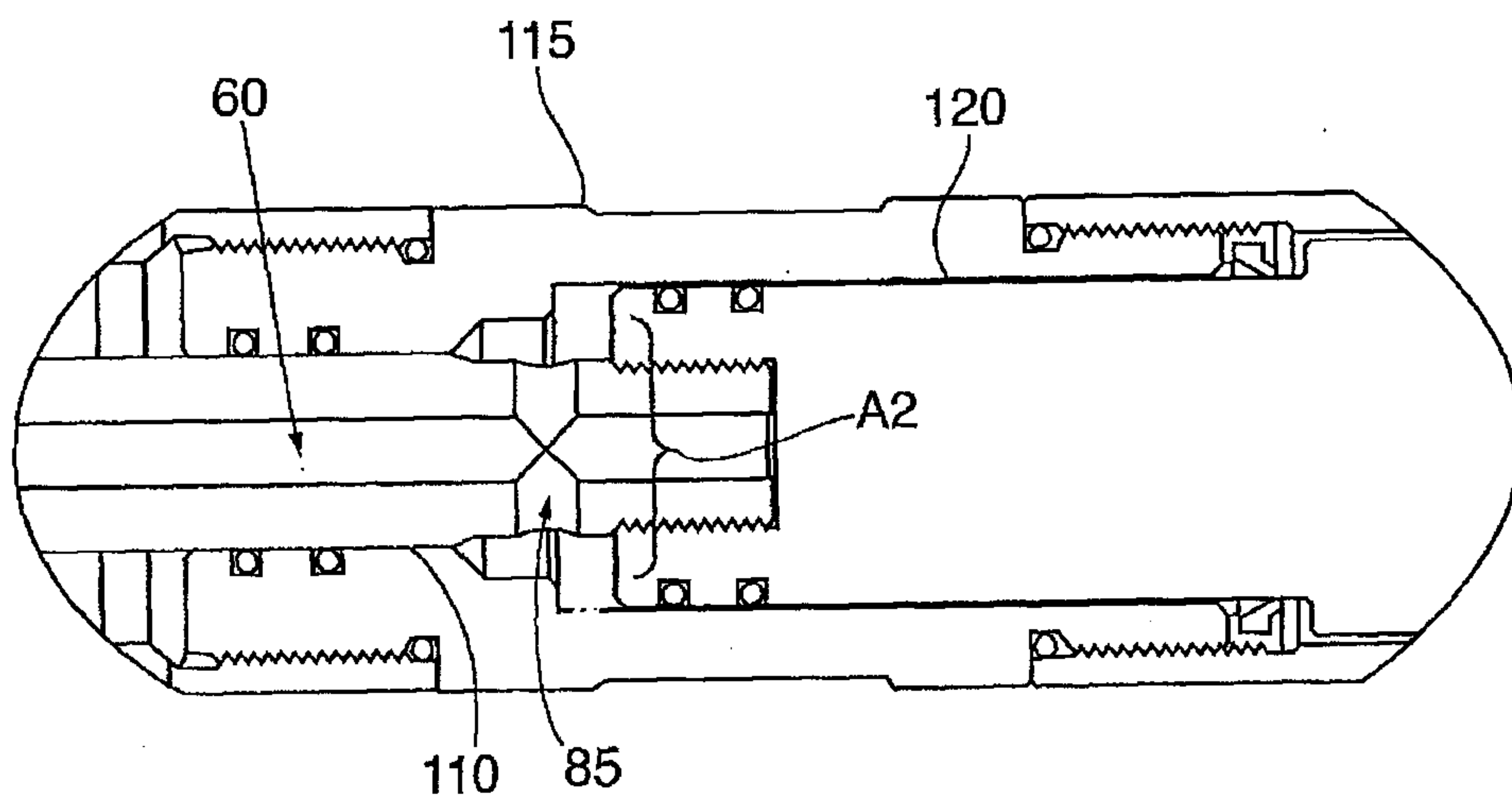


Fig. 5a

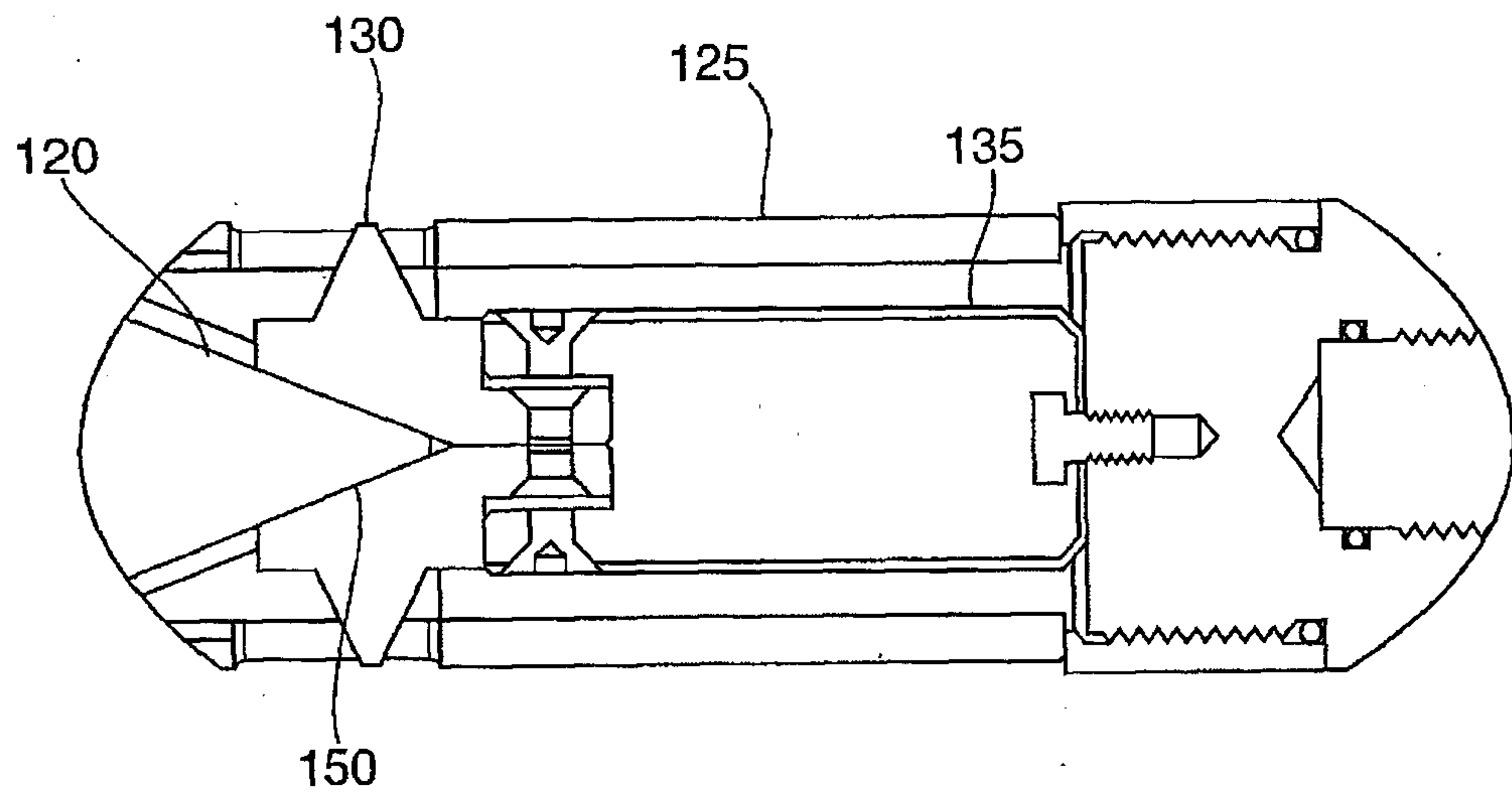
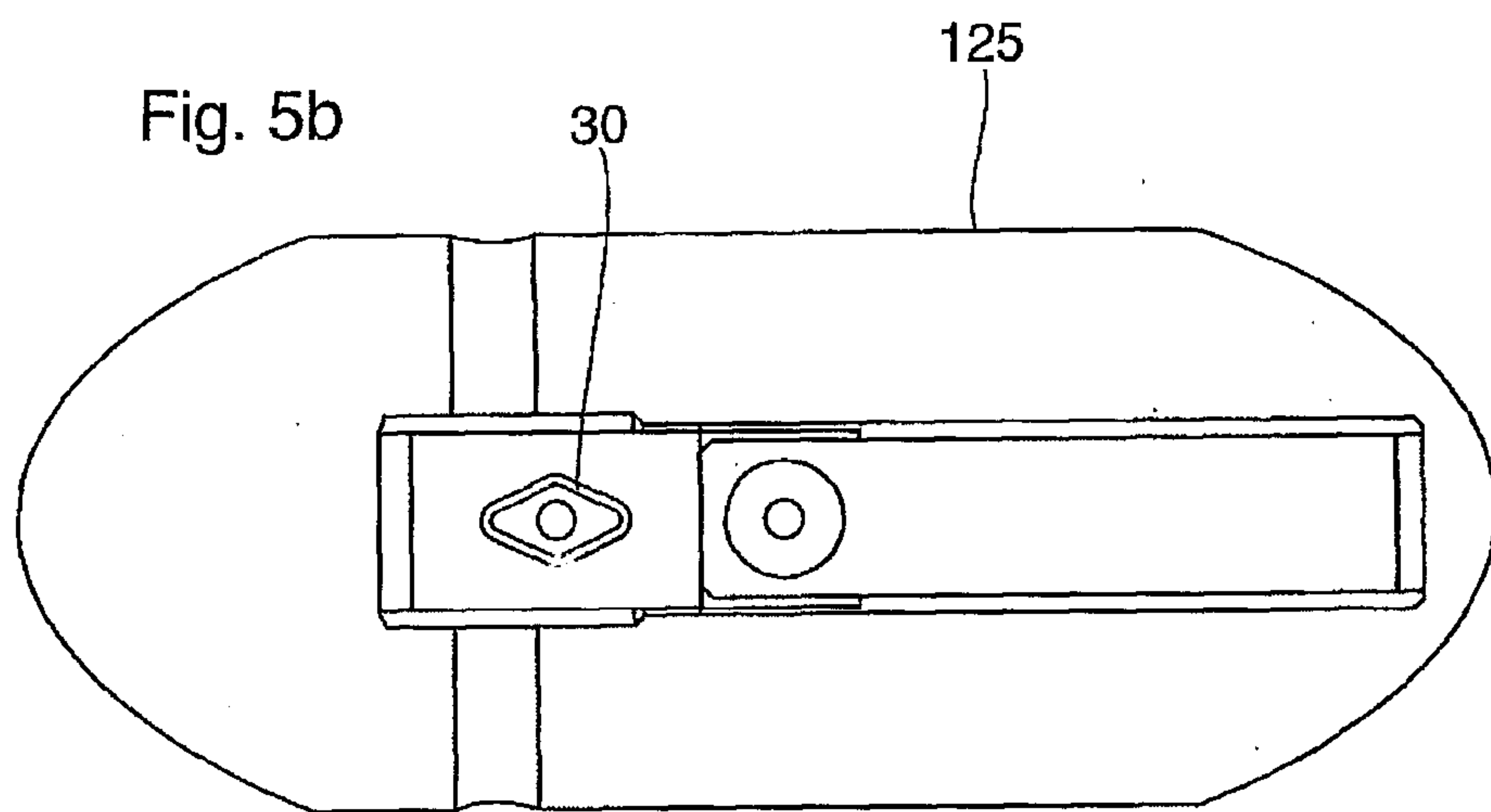


Fig. 5b



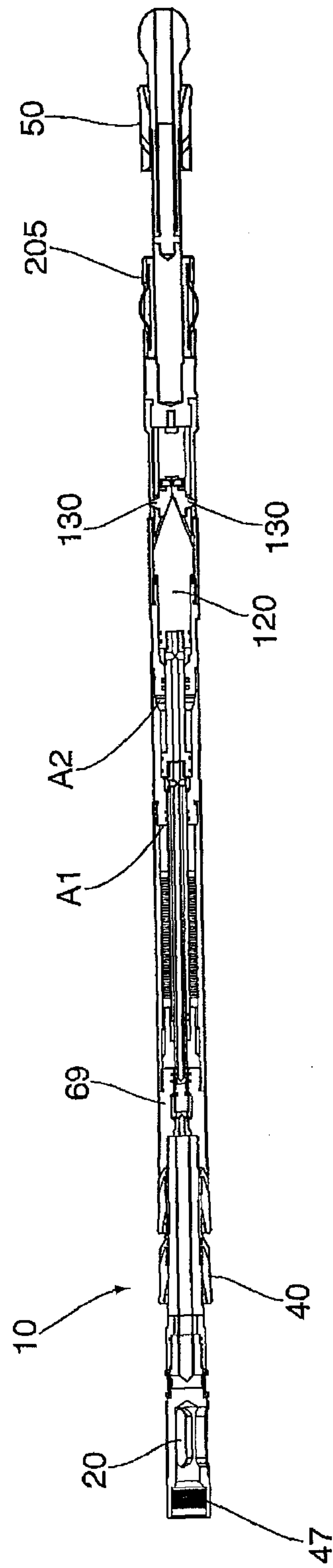


Fig. 6

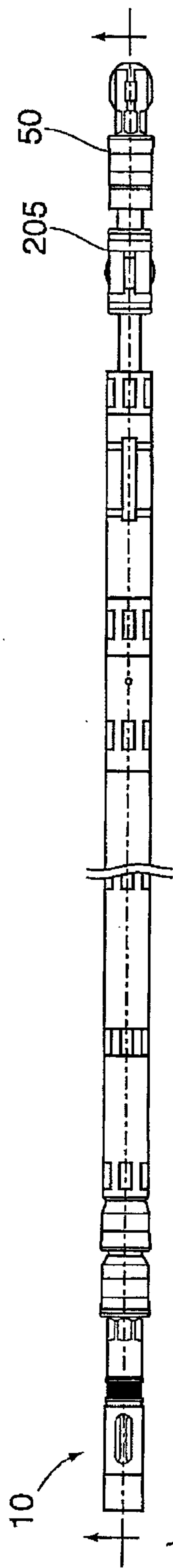


Fig. 7

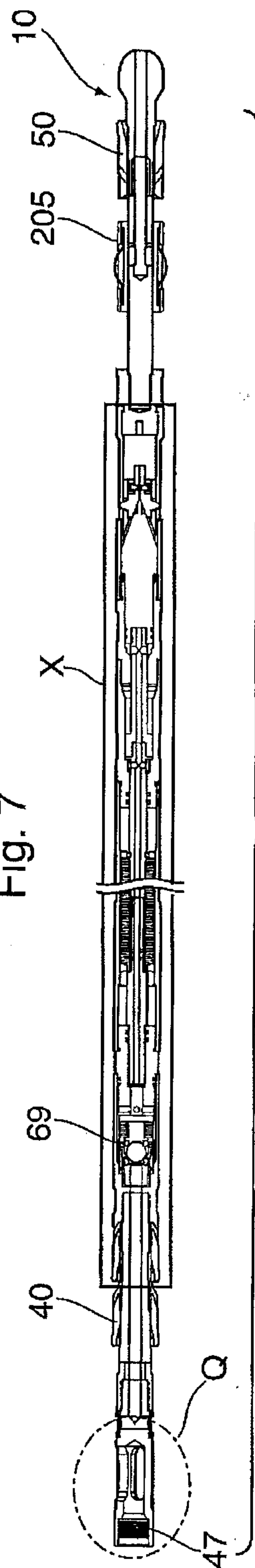


Fig. 8

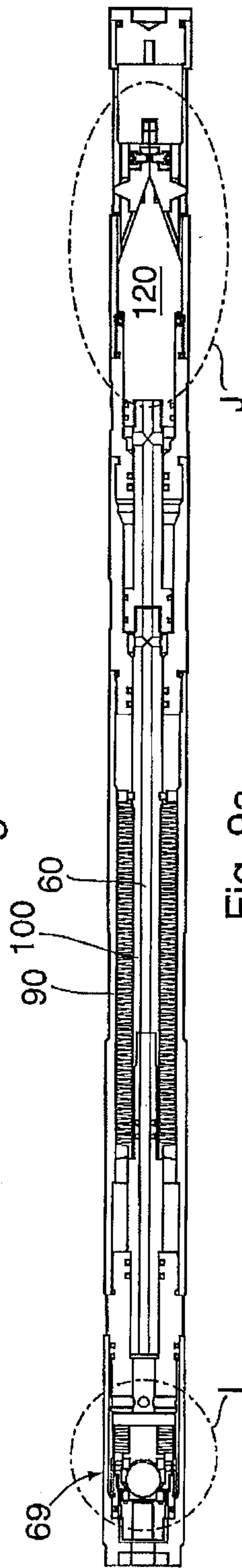


Fig. 9a

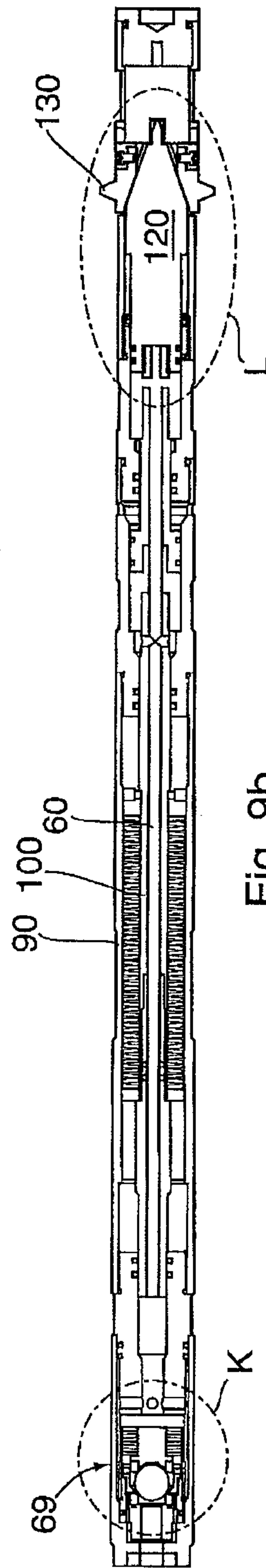


Fig. 9b

Fig. 10

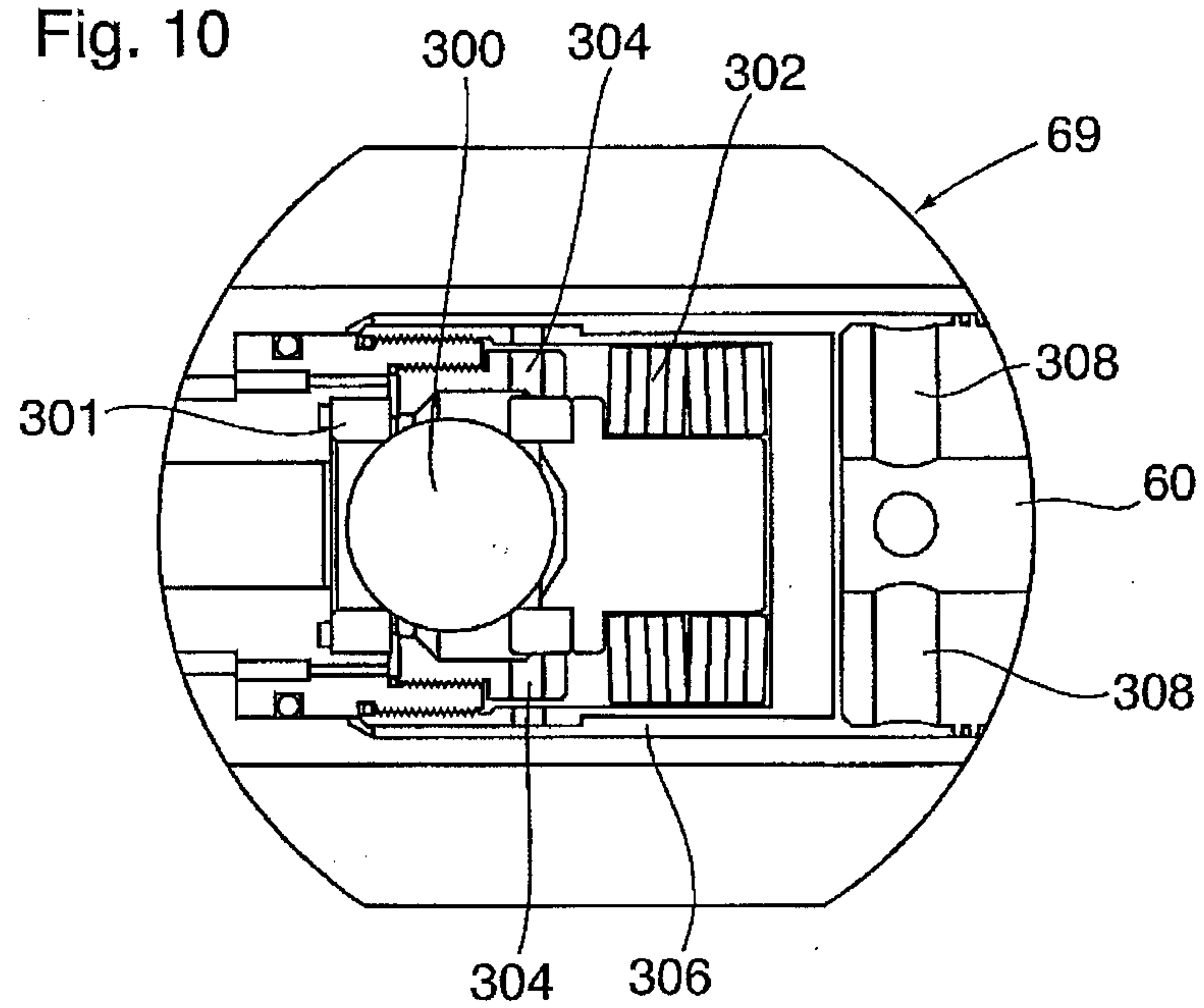
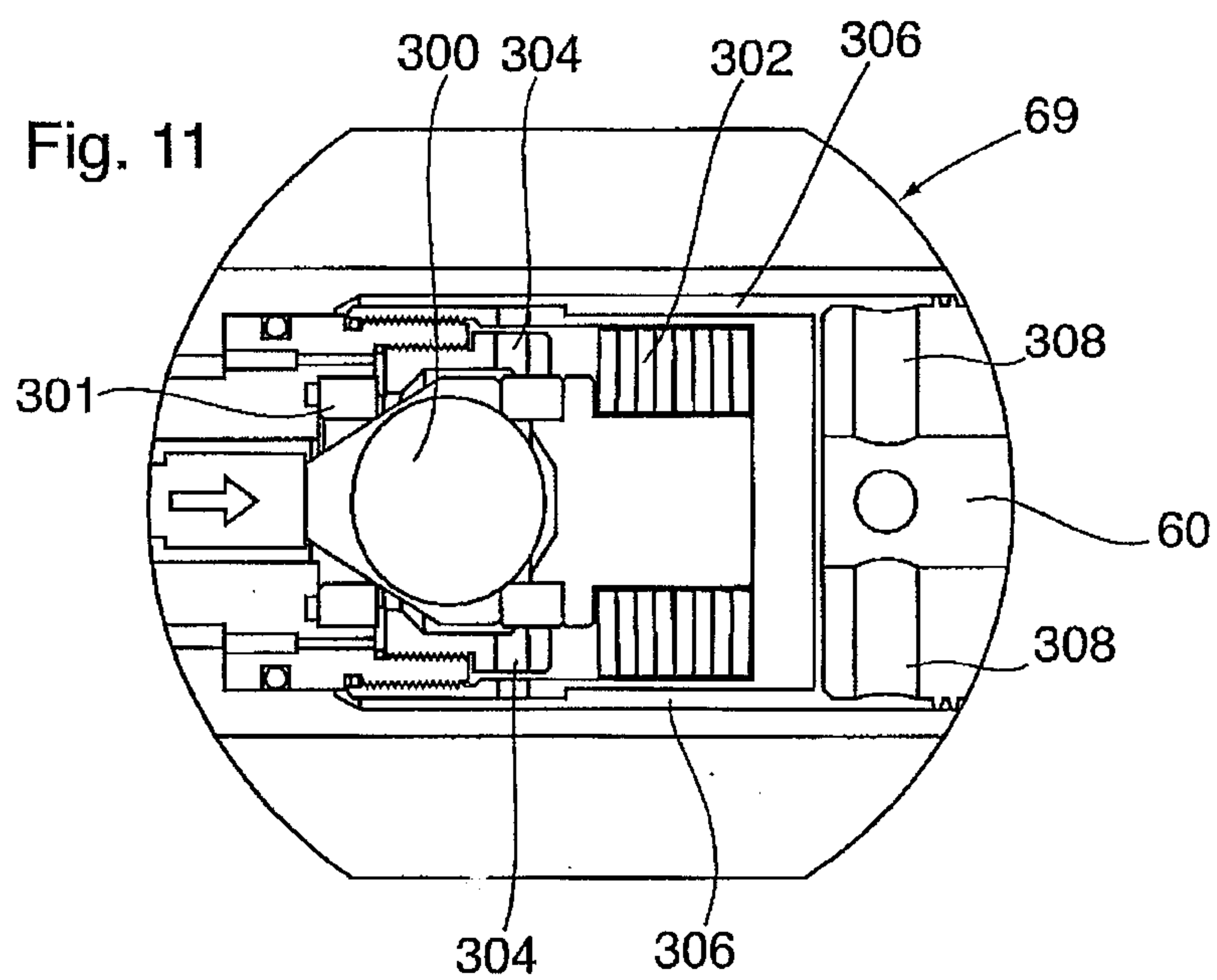


Fig. 11



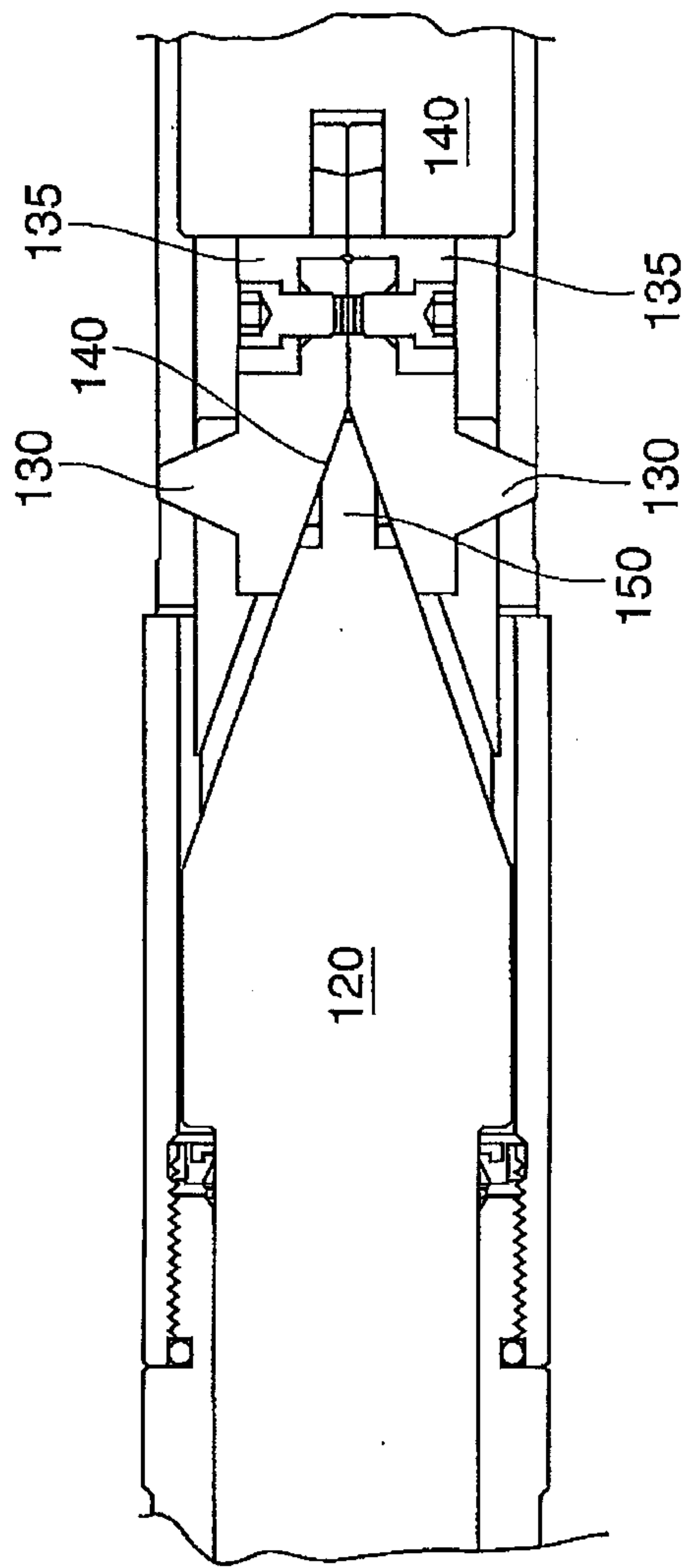


Fig. 12

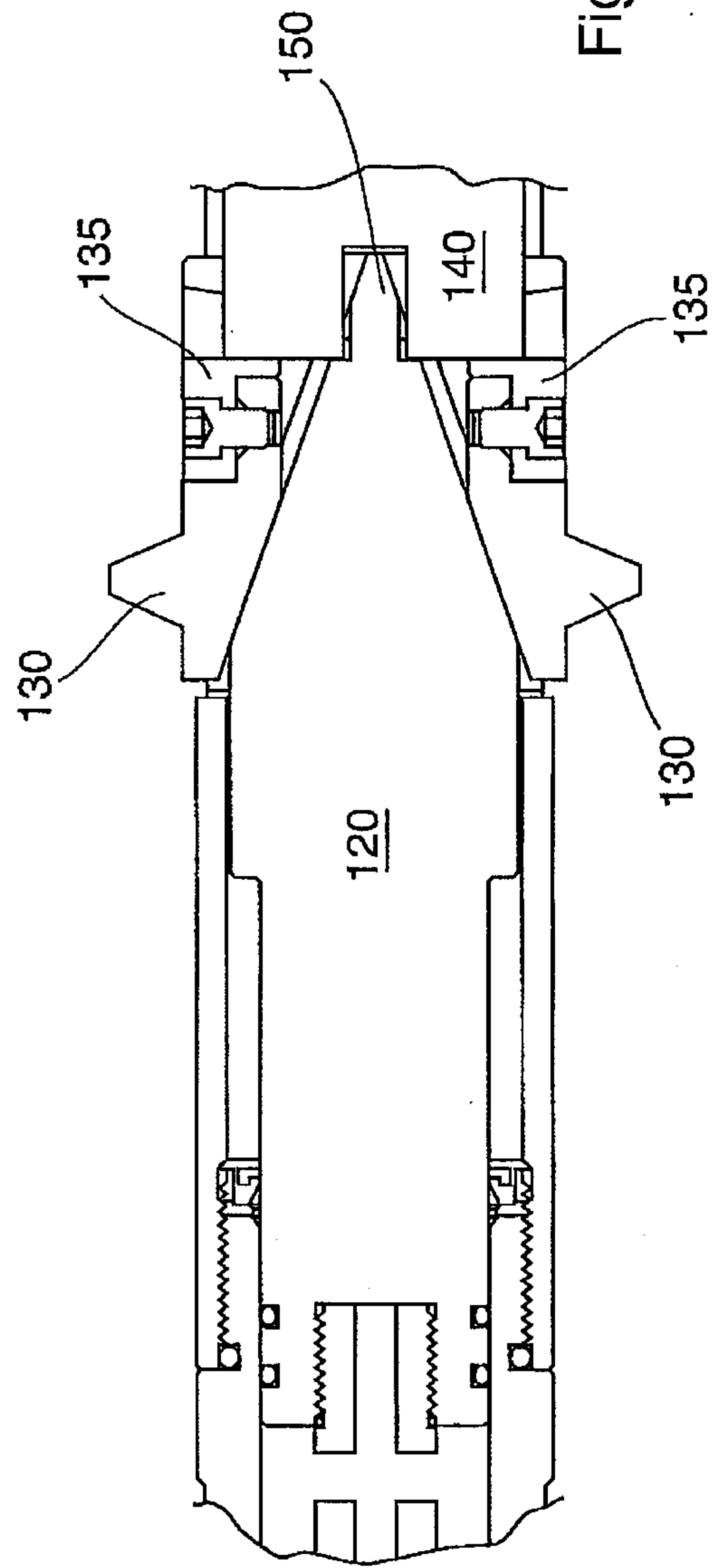
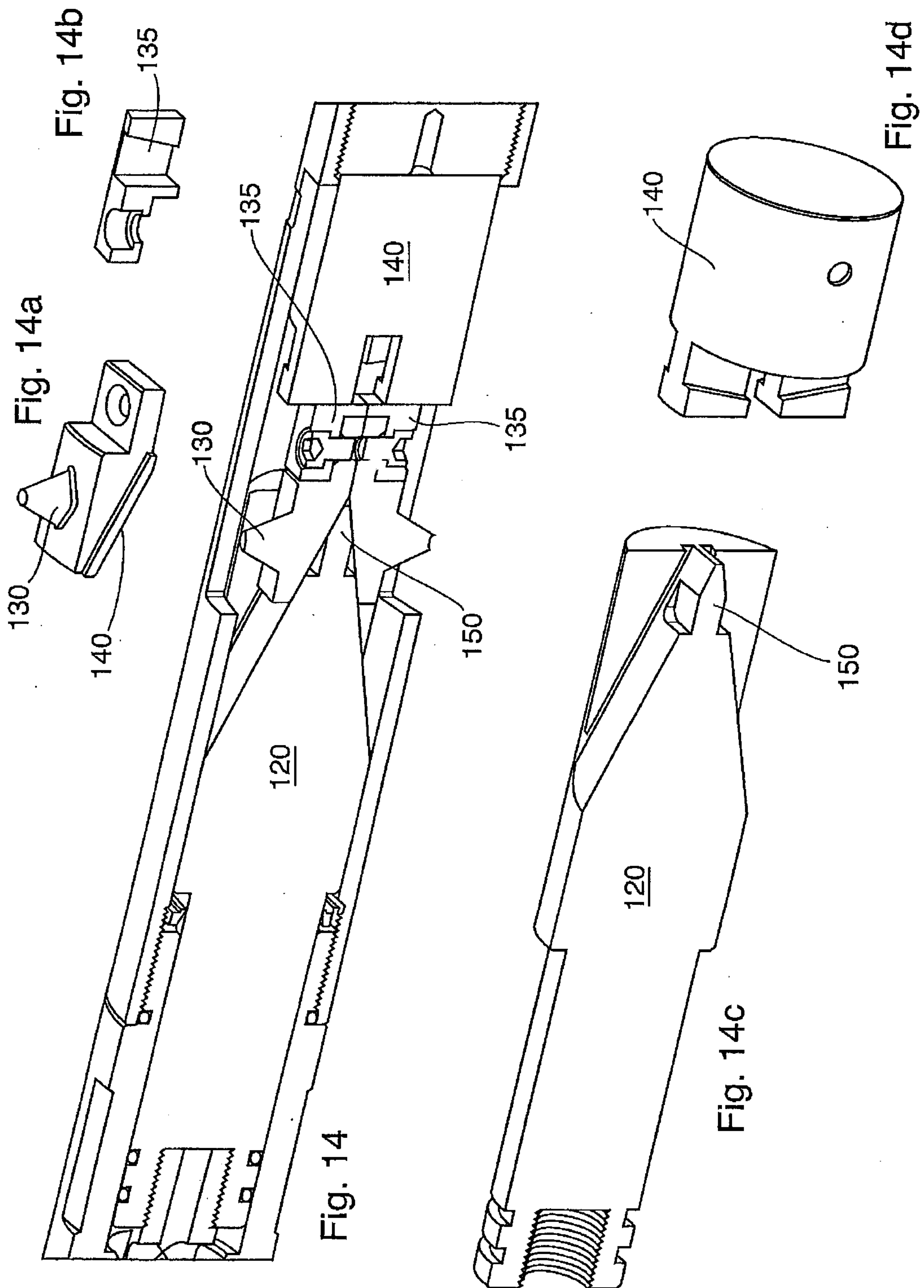


Fig. 13



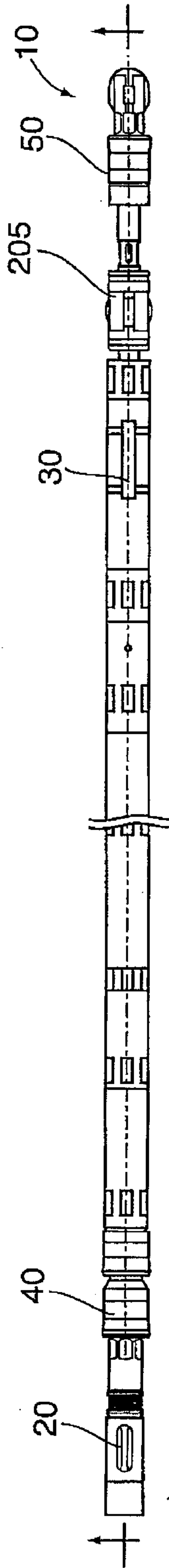


Fig. 15

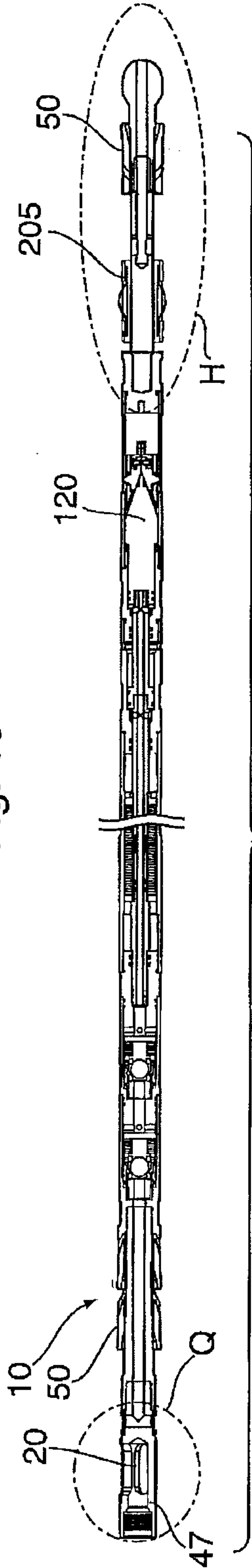


Fig. 16

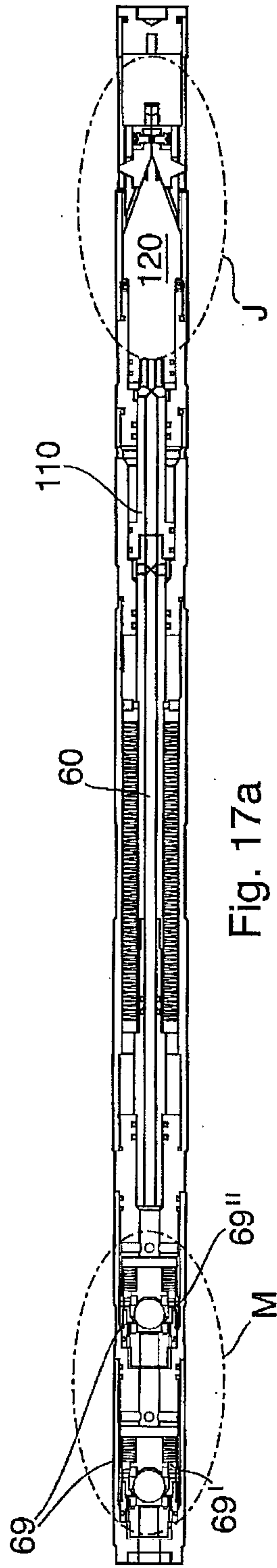


Fig. 17a

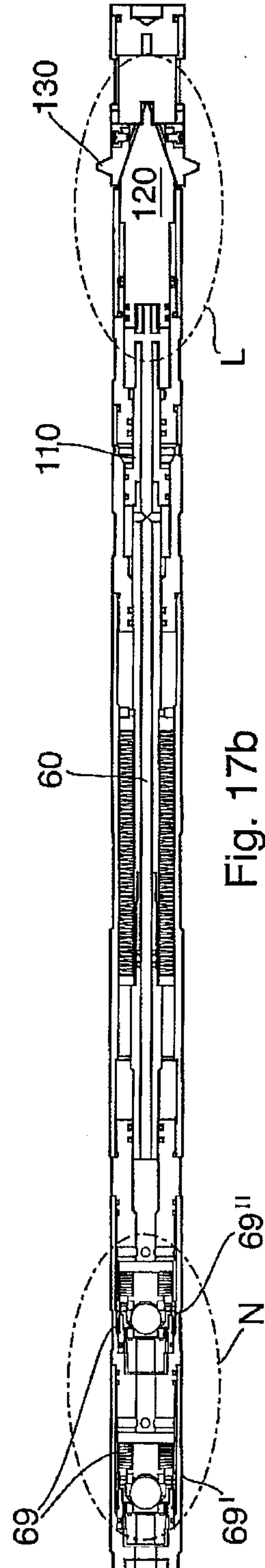


Fig. 17b

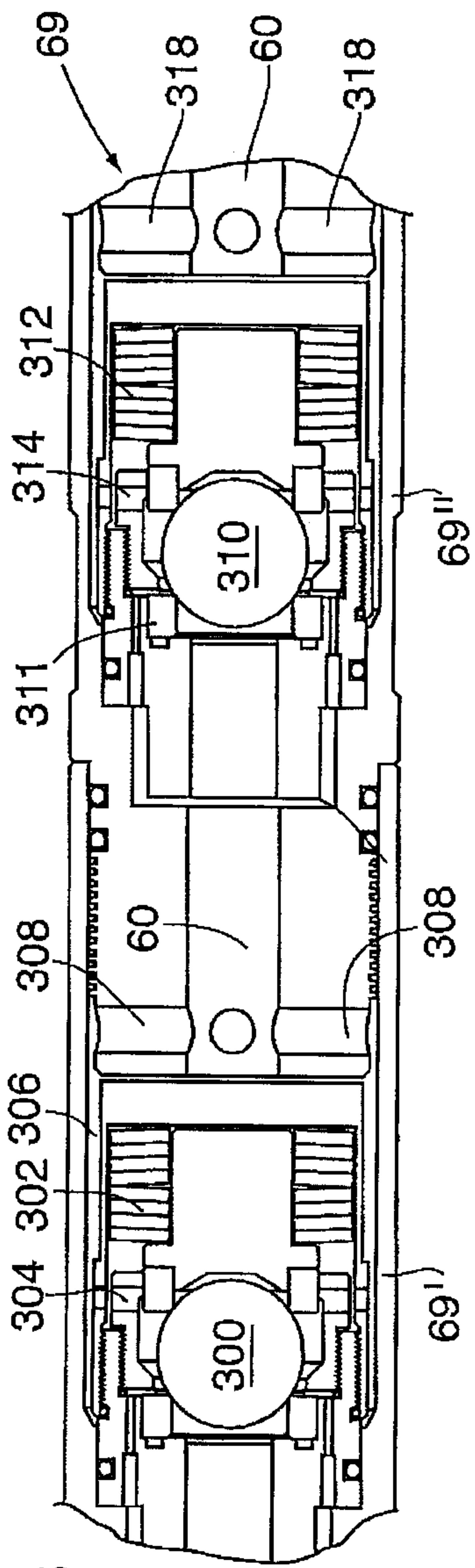


Fig. 18

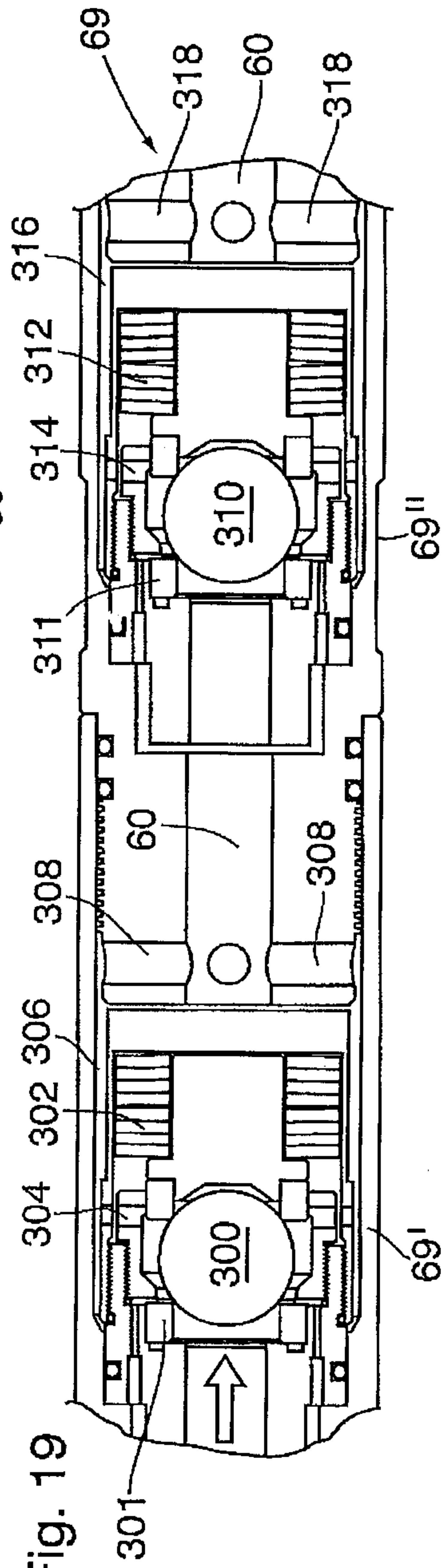


Fig. 19

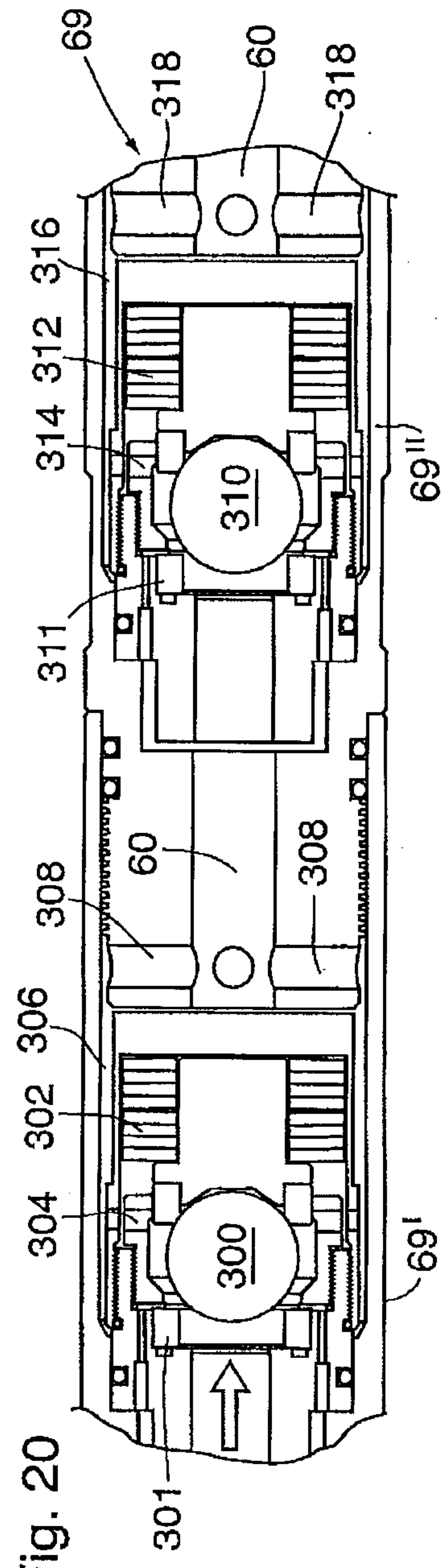
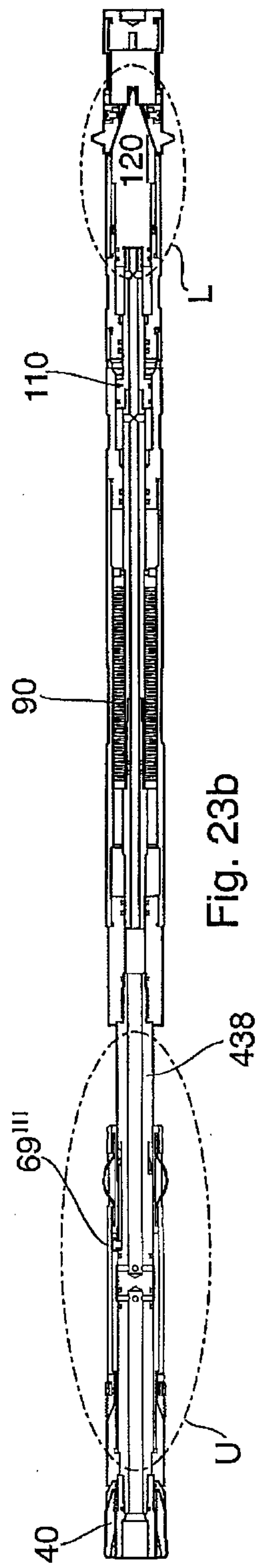
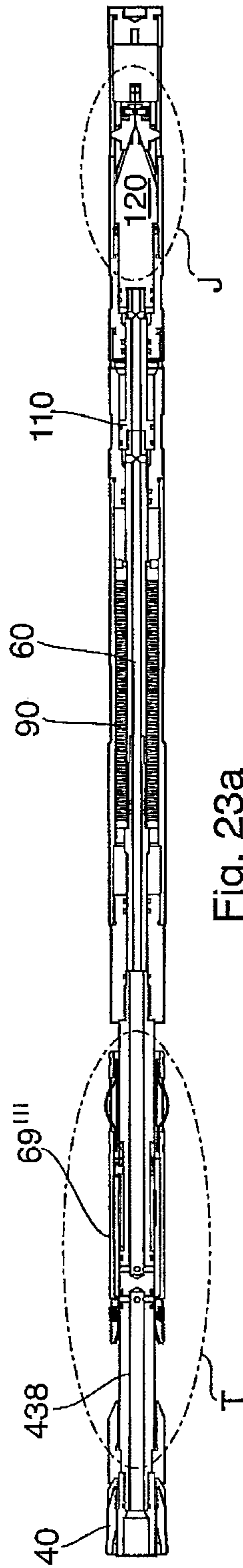
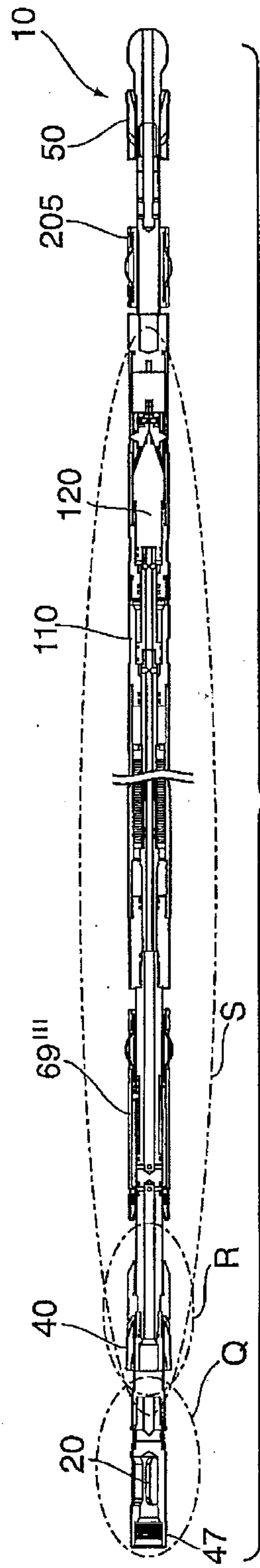
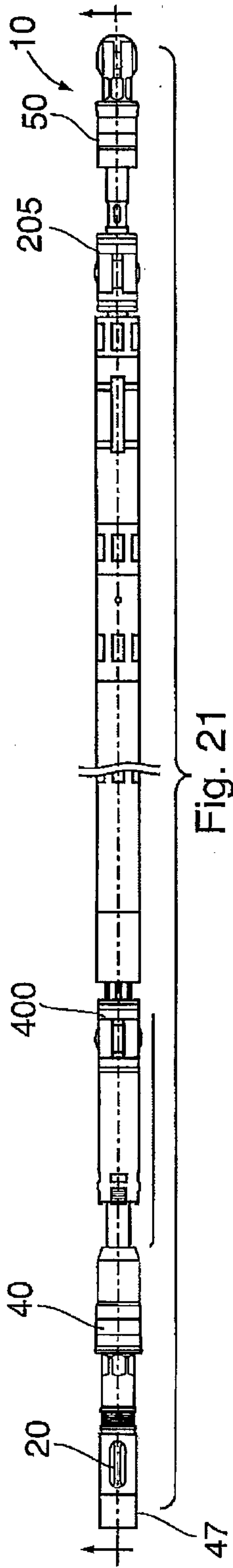
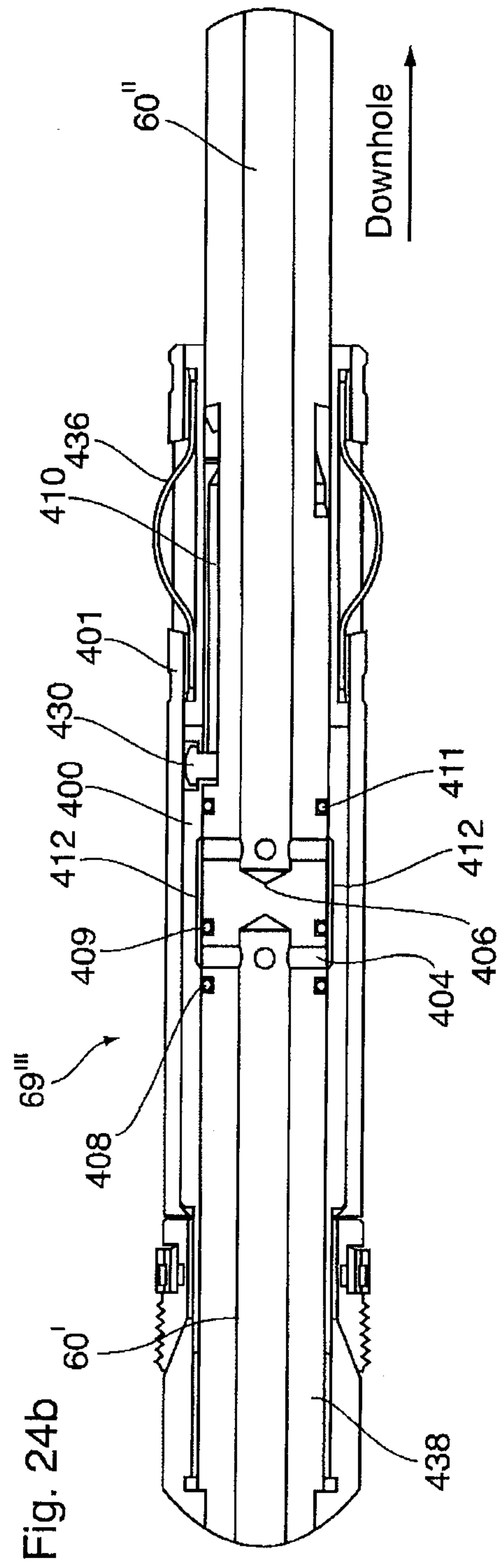
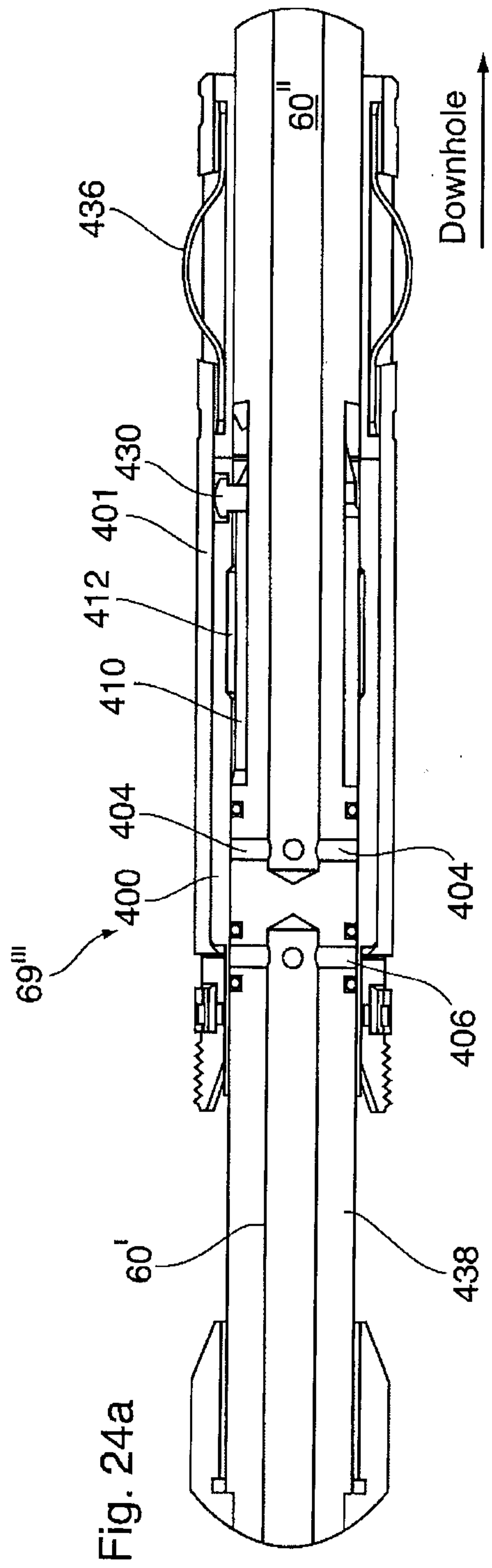


Fig. 20





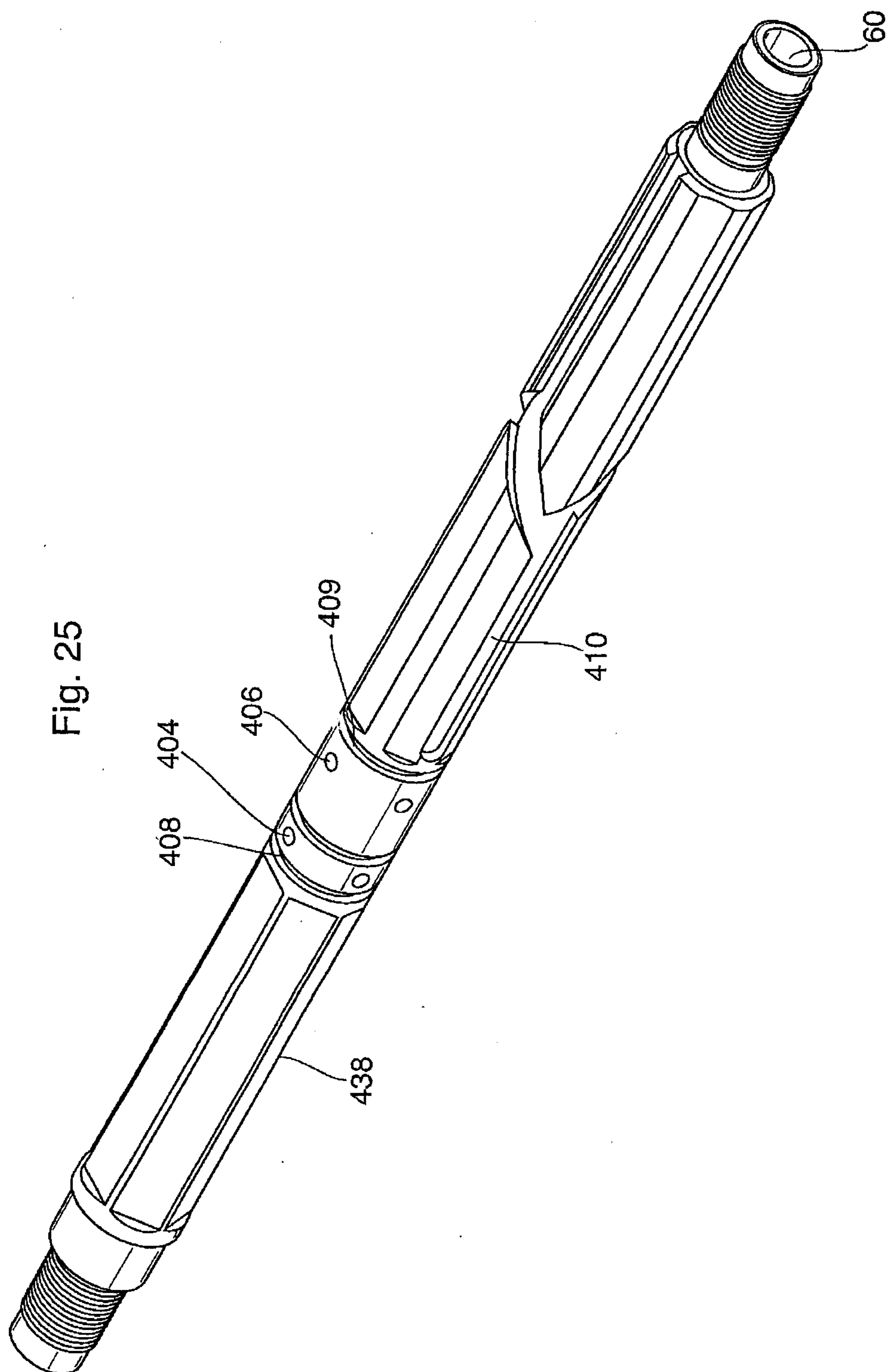


Fig. 26

