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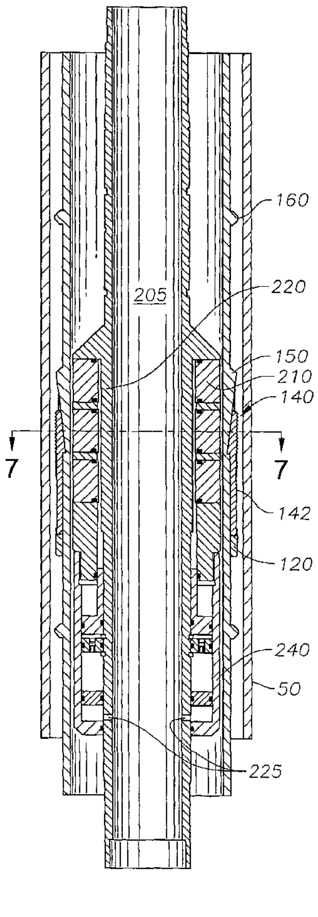
(54) Title: EXPANSION SET LINER HANGER AND METHOD OF SETTING SAME



(57) Abstract: A hydraulic liner hanger (100) is provided. The liner hanger comprises a tubular body (110). A plurality of slips (140) are disposed radially around the outer surface of the body. In one arrangement, each slip has wickers (144) for engaging the inner surface of a surrounding string of casing (50). Each slip is connected to a slip ring (120), the slip ring also being circumferentially disposed around the outer surface of the body. At least some of the slip members are received upon a wedge surface (150), or cone(s). In operation, an expander tool (200) such as a hydraulic setting tool acts upon the liner hanger, causing the slips (140) to be expanded into frictional engagement with the surrounding string of casing (50). The operator is then able to slack off the weight of the liner, allowing multiple slips to engage the casing and to suspend the liner therebelow.

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EXPANSION SET LINER HANGER AND METHOD OF SETTING SAME

The present invention generally relates to completion operations in a wellbore. More particularly, the invention relates to an apparatus for hanging a string of liner from an upper string of casing within a wellbore.

In the drilling of oil and gas wells, a wellbore is formed using a drill bit that is urged downwardly at a lower end of a drill string. After drilling a predetermined depth, the drill string and bit are removed and the wellbore is lined with a string of casing. An annular area is thus formed between the string of casing and the formation. A cementing operation is then conducted in order to fill the annular area with cement. The combination of cement and casing strengthens the wellbore and facilitates the isolation of certain areas of the formation behind the casing for the production or injection of hydrocarbons or other fluids.

It is common to employ more than one string of casing in a wellbore. In this respect, a first string of casing is set in the wellbore when the well is drilled to a first designated depth. The first string of casing is hung from the surface, and then cement is circulated into the annulus behind the casing. The well is then drilled to a second designated depth, and a second string of casing is run into the wellbore. The second string is set at a depth such that the upper portion of the second string of casing overlaps with the lower portion of the upper string of casing. Any string of casing that does not extend back to the surface is referred to as a liner. The second string is then cemented into the wellbore as well. This process may be repeated using additional strings of casing of an ever-decreasing diameter until the wellbore has been formed to the desired total depth.

The process of hanging a liner off of a string of surface casing or other casing string typically involves the use of a liner hanger. In practice, the liner hanger is run into the wellbore above the liner string itself. A connection is made between the liner and the liner hanger, typically via a threaded connection. A setting sleeve, in turn, is affixed above the liner hanger. These tools are made up together at the surface, and are run into the hole at the lower end of a landing string, such as a string of drill pipe. A temporary connection is made between the landing string and the setting sleeve, typically through a float nut. Additional tools may be employed with the running tool, including a slick joint and a wiper plug, depending upon the nature of the completion operation.

Several types of liner hangers are known in the art. In some instances, a mechanical liner hanger is used. A mechanical liner hanger is set typically through the use of rotational and axial motion imparted by rotating and moving the liner string up and/or down. Mechanical liner hangers are most often employed in connection with shallow and non-deviated wells. However, mechanical liner hangers are impractical for deeper wells and for wells which are deviated due to the difficulty in imparting the needed rotation and axial movement.

In the case of deeper wells and highly deviated wells, hydraulic liner hangers are more commonly employed. In order to set a hydraulic liner hanger, a ball is dropped into the wellbore and landed on a seat. The seat is positioned either in the running tool string, on a wiper plug or, in some instances, at a landing collar. Other types of seats are also known. Fluid is then injected into the wellbore under pressure in order to actuate the hydraulic liner hanger.

In known hydraulic liner hangers, fluid under pressure is injected through an inner mandrel of the liner hanger. Fluid passes through one or more ports and into a small annular area defined between the mandrel and a surrounding tubular body called a cylinder. Seals are placed within the annular area above and below the ports in order to confine fluid pressure. The cylinder is configured in such a manner that fluid pressure creates an upward force on the inner surface area of the cylinder between the seals, causing the cylinder to be urged upwardly.

Figure 1 depicts a partial cross-sectional view of a prior art hydraulic liner hanger **10**. Visible in this view is the inner mandrel **12** of the hanger **10**, and the surrounding cylinder body **14**. Above the cylinder **14** is a plurality of radially spaced-apart slip members **18**. Each slip **18** has a base **16** that is connected to the cylinder **14**. In this way, upward movement of the cylinder **14** will in turn drive the respective slips **18** upward.

The slips **18** are disposed upon outwardly angled surface areas called cones **20**. The slips **18** are designed to ride upward upon the cones **20** upon activation of the cylinder **14** through hydraulic pressure. In this respect, hydraulic pressure forces fluid through ports **25** in the mandrel **12**. Fluid is maintained under pressure within the cylinder **14** between upper **24** and lower **26** seals. Because of the configuration of the inner cylinder **14** surface, the injected fluid applies an upward force on the cylinder **14**.

The cylinder **14** is releasably connected to the mandrel **12** by frangible member(s) **28**. Typically, the frangible members **28** are shear screws. Upon a designated axial force caused by fluid acting upon the cylinder **14**, the frangible member(s) **28** are broken, thereby releasing the cylinder **14**. The cylinder **14** then moves upwardly along the outer surface of the liner hanger **10**, forcing the slips **18** to ride upwardly and outwardly along the respective cones **20**.

It can be seen in **Figure 1** that each slip **18** includes a set of teeth. These teeth are typically referred to as "wickers." The wickers provide frictional engagement between the liner hanger **10** and the inner surface of the upper string of casing (not shown in **Figure 1**). The liner, in turn, is threadedly connected to the bottom sub **22** of the liner hanger **10**.

There are disadvantages associated with the use of known hydraulic liner hangers. First, it is evident that the ports **25** and seals **24, 26** between the cylinder **14** and the inner mandrel **12** of the liner hanger **10** are potential leak paths. In this respect, the seals **24, 26** and the surrounding cylinder body **14** are exposed to wellbore pressure and fluids during the life of the well. High downhole temperatures place great demands on the elastomer seals typically used on the cylinder **14**. Failure of the seals **24** or **26** results in costly remedial work to repair the leak.

Associated with this problem is the inherent structural considerations for the cylinder **14**. Hydraulic cylinders **14** are in contact with the wellbore fluids and are thus considered flow-wetted parts. The cylinder **14** is typically constructed of the same material as the liner **22** it is being used with in order to insure compatibility with the fluid. This adds to the cost of the typical liner hanger construction. Further, the high downhole pressures induce high burst and collapse loads on the hydraulic cylinder **14** along with additional stresses on the seals **24, 26** used. Thus, the required cylinder thickness can force compromises in the mandrel **12** thickness that reduces pressure and load capacities. In this respect, there is a limited amount of space between the bore of the inner mandrel **12** and the surrounding ID of the casing string. Increased thickness of the cylinder body **14** means less thickness available for the mandrel **12**.

Hydraulic liner hangers **10** typically have a reduced annular bypass area due to the external hydraulic cylinder **14** used for setting them. The reduction of bypass area increases the surge pressures placed on the formation during run-in. Further, the reduced bypass area restricts the space for annular flow during cementing operations.

Finally, as noted, hydraulic liner hangers **10** typically employ frangible members **28** such as shear screws or rupture discs to prevent premature movement of the hydraulic cylinder **14** during run-in. The frangible member **28** is designed to retain the cylinder **14** in place until a specific internal pressure has been reached. However, if this pressure is prematurely exceeded due to a surge in downhole pressure, the slips could prematurely be released, causing the liner hanger **10** to set improperly within the wellbore. In addition, there is the potential that slip **18** deployment could take place where one or more slip members **18** encounter debris downhole. This again could cause premature setting of a hydraulic liner hanger **10**. Hydraulic liner hangers **10** are typically not considered re-settable. If the hydraulic liner hanger **10** is prematurely activated, the liner **22** will likely not be able to run to the desired setting depth, causing additional drilling and additional length of liner to be used.

As can be seen, there is a need for an improved hydraulic set liner hanger. In this respect, there is a need for a hydraulic set liner hanger which eliminates the use of a cylinder body. Still further, there is a need for a hydraulic set liner hanger which does not employ ports through the wall of the liner hanger body, or seals which could become a source of leaks. There is yet a further need for a hydraulic set liner hanger which can be more easily unset in the event of premature actuation during run-in. Further, a liner hanger that has the above desired features and can be run below a compression set liner top packer. Further still, there is a need for an improved liner hanger which is simpler and more reliable than known hydraulic and mechanical liner hangers.

In accordance with one aspect of the present invention there is provided an expansion set liner hanger for hanging a connected liner from a surrounding casing within a wellbore, the liner hanger comprising a tubular body, and at least one slip disposed outside the outer surface of the tubular body, the at least one slip being movable radially outwardly by a radial force acting on an area of the inner surface of the tubular body and arranged to frictionally engage the surrounding casing so as to gravitationally support the connected liner.

Further aspects and preferred features are set out in claims 2 *et seq*.

The present invention provides an expansion-set liner hanger. In preferred embodiments the liner hanger comprises a tubular body. Disposed circumferentially around the outer surface of the tubular body is a slip ring. The slip ring is movable axially along a portion of the body. Next, the liner hanger includes a plurality of radially spaced-apart slip members. Each slip member has one or more wickers for frictionally engaging a surrounding string of casing. Further, each slip member has a base which is connected to the slip ring. Axial movement of the slip ring upward relative to the body will cause the slips to advance upward along respective cone members. This, in turn, forces the slips to engage the surrounding casing, thereby effectuating a hanging of the liner below. For purposes of this disclosure, the term "casing" includes any tubular member, including a liner, set within a wellbore.

It is noted that the liner hanger does not include a hydraulically actuated cylinder body, nor does it include ports or associated seals. In this respect, actuation of the liner hanger of the present invention is not accomplished by applying hydraulic pressure against a cylinder in order to move the slip ring.

In order to actuate the liner hanger, a hydraulic setting tool is also provided. The setting tool is run into the wellbore on a landing string. The hydraulic setting tool comprises an inner mandrel. The mandrel includes one or more hydraulic ports through which fluid is injected under pressure. Fluid travels through the ports whereupon it contacts the back side of pistons which are disposed outside of the mandrel. At least one set (preferably two sets) of radial pistons are disposed in a radially spaced-apart arrangement around the mandrel. The application of hydraulic pressure behind the pistons causes the pistons to protrude outward from the mandrel.

In operation, the hydraulic setting tool is run into the wellbore along with the running tools. The liner hanger and the running tools, including the hydraulic setting tool, are made up to the liner prior to running the liner. During this assimilation process, the pistons of the hydraulic setting tool are rotationally aligned with the position of selected slips on the liner hanger. Once the liner hanger and running tools are positioned at the appropriate depth within the wellbore, hydraulic pressure is applied to the hydraulic setting tool. As the radial setting pistons are expanded outward, they apply an outward force on the liner hanger body. This forces the mandrel to take on a non-circular shape at the locations of the slips. With sufficient outward force applied against the liner hanger body, the associated slip members engage the surrounding casing.

While the radial pistons of the hydraulic setting tool remain applied against the liner hanger, the weight of the liner is slacked off from the surface. This causes the liner hanger body to be lowered further into the wellbore. Because the slip members have a higher frictional engagement to the inner surface of the casing by the wickers, the mandrel and cones ride downward under the slips. Because the slip ring connects all slips around the body of the liner hanger, all slips stay stationary. In this respect, the cones primarily ride under the slips as opposed to the slips riding upward on the cones. Downward travel of the liner continues until all of the slips are engaged with the casing and the weight of the liner is fully transmitted through the cones/slips.

After the liner hanger has been set, and after associated cementing operations for the liner are concluded, the running tools may be removed from the wellbore. In this respect, the hydraulic setting tool is removed from the wellbore and may be reused for other liner hanging operations.

Some preferred embodiments of the invention will now be described by way of example only and with reference to the accompanying drawings, in which:

Figure 1 presents a cutaway view of a prior art hydraulic liner hanger;

Figure 2 presents a perspective view of a hydraulic liner hanger, showing two slip members, mechanically connected by a slip ring, and associated cones;

Figure 3 is a cross-sectional view of the liner hanger of Figure 2, with the liner hanger body disposed within a string of casing;

Figure 4 presents a perspective view of a hydraulic setting tool as might be used to set a liner hanger, showing one set of radial pistons for expandably setting the hydraulic liner hanger;

Figure 5 is a cross-sectional view of the hydraulic setting tool of Figure 4;

Figure 6 presents a cross-sectional view of a hydraulic setting tool aligned with a hydraulic liner hanger within a string of casing, the liner hanger ready to be actuated by injection of hydraulic pressure into the hydraulic setting tool;

Figure 7 is a cross-sectional view of the liner hanger and hydraulic setting tool of Figure 6, taken across line 7-7 of Figure 6, before expansion of the hydraulic setting tool;

Figure 8 is a cross-sectional view of the liner hanger being actuated through the injection of hydraulic pressure within the hydraulic setting tool, so that the extended radial pistons expand the liner hanger;

Figure 9 is a cross-sectional view, taken across line 9-9 of Figure 8, of the liner hanger being actuated with the hydraulic setting tool, as outward force is applied by the radial pistons against two slips disposed on cones causing the slips to engage the inner surface of the surrounding casing string;

Figure 10 presents a cross-sectional view of the liner hanger as set within a wellbore, after the cones have ridden downward under the slips, causing the slips to be moved radially outward and into frictional engagement with the surrounding casing; visible also in this view is the hydraulic setting tool from which pressure has been relieved, allowing the pistons to return to the mandrel so that the hydraulic setting tool can be retrieved, leaving the liner hanger set;

Figure 11 presents a cross-sectional view of the liner hanger taken across line 11-11 of Figure 10, showing four slips in frictional engagement with a surrounding casing; and

Figure 12 provides a cross-sectional view of the expansion set liner hanger of Figure 10 following removal of the hydraulic setting tool from the wellbore, leaving the liner hanger set along the surrounding casing.

Figure 2 presents a perspective view of a liner hanger **100** in accordance with the present invention. The liner hanger **100** defines an elongated tool designed to be run into a cased wellbore. The liner hanger **100** first comprises a body **110**. The body **110** defines essentially an elongated tubular member having opposite ends. The tubular body **110** is preferably, though not necessarily, circular in cross-section. A bore **105** runs through the length of the body **110** fluidly connecting the opposite ends. The body **110** is designed to be connected at the upper end of a string of liner (not shown). Typically, a threaded connection is utilized (threaded connection not shown).

The opposite ends of the liner hanger body may be conveniently referred to as "top" and "bottom" ends. It should be noted, however, that the use of the terms "top" and "bottom" herein is not meant to imply that the liner hanger of the present invention must be used in a strictly vertical well; rather, use of the terms "top" and "bottom" is simply a convenient way to describe opposite ends of the various elongated parts of the invention. The tool of the present invention may be used in a highly deviated well. Of course, in completing a well, tools are initially run into the wellbore from the rig floor in a vertical alignment.

Disposed around the outside surface of the liner hanger body **110** is one or more tapered surfaces, or cones **150**. In the arrangement shown in **Figure 2**, the cones **150** each define a plate-like member. In **Figure 2**, two cones **150** are visible. However, it is understood that additional cones **150** are present in a radially spaced-apart arrangement. Preferably, four or more cones **150** are employed for the liner hanger **100** of the present invention.

Each cone **150** has a proximal end and a distal end. In the arrangement shown in **Figure 2**, the proximal end is at the bottom of the cone, while the distal end is at the top. The thickness of the cone members **150** increases from the proximal end to the distal end in order to provide a wedge.

Residing on each cone member **150** is a slip **140**. In the run-in position shown in **FIG. 2**, the slips **140** reside essentially on the proximal end of their respective cones **150**. The bottom surface of each slip **140** is configured to slide relative to its respective cone **150**. It is noted that the wedge arrangement of the cones **150** is not directly visible in **Figure 2**; nevertheless, it is understood that a tapered wedge surface is provided under the respective slips **140**.

The top surface, or face, of each slip **140** includes teeth, or "wickers" **144**, designed to engage the inner surface of a surrounding string of casing **50** (not shown). Preferably, the protrusion of the wickers is greater than that of the cones when the slip is at the proximal end of the cone. As will be disclosed below, actuation of the liner hanger tool **100** allows each cone-supported slip **140** to frictionally engage the surrounding casing **50** so as to effectively hang the string of liner (not shown in **FIG. 2**) below the liner hanger **100**. It is understood that the scope of the present invention is not limited to all slips being disposed on cones. In this respect, some of the slips may be placed anywhere on the mandrel **110**.

Each slip **140** includes a base **142** located at the proximal end of each slip **140**. In the arrangement of **FIG. 2**, the base **142** extends below the associated cone member **150**, and is affixed to a slip ring **120**. As shown in **Figure 2**, the slip ring is disposed circumferentially around the outer wall of the body **110** of the liner hanger **100**. The slip ring **120** connects to the base **142** of each slip **140**. In this manner, all slips **140** move simultaneously and with respect to the mating surfaces of the cones **150** or mandrel when the slip ring **120** moves coaxially along the body **110**.

It is understood that the scope of the present invention is not limited to the use of a single cone **150** corresponding to a single slip **140**. In this respect, a larger conical, or "wedge," surface could be employed to accommodate more than one slip **140**. Likewise, a larger slip, such as a single ring having wickers (not shown), could be employed on a wedge surface arrangement.

The liner hanger **100** presented in **Figure 2** includes additional optional features. First, gage ribs **160** are shown on the outer surface of the liner hanger body **110**. In **Figure 2**, a plurality of gage ribs **160** are affixed above and below the slips **140**. The gage ribs **160** serve to centralize the liner hanger **100** within the surrounding casing **50** during run-in and setting. The gage ribs **160** also help to prevent inadvertent catching of the slips **140** as the liner hanger **100** is run into the wellbore. In this respect, the protrusion of each gage rib **160** from the body **110** is greater than that of the wickers **144** on each slip **140**, thus serving to minimize any opportunity for the slips **140** to prematurely engage the casing (shown at **50** in Figure 6).

Also seen in **Figure 2** are optional springs **130**. The springs **130** have a first end attached to a cone **150**, and a second end connected to the slip ring **120**. Preferably, two springs **130** are connected to each cone **150** – one on each side of the base **142** of each slip **140**. The springs **130** are maintained in compression, thereby biasing the slips **140** downward towards the proximal end of the respective cones **150**.

Figure 3 presents a cross sectional view of the liner hanger **100** of **Figure 2**. In this view, the liner hanger **100** is disposed within the casing **50** of a wellbore (not seen). Noted more visibly in the view of **Figure 3** is the inner bore **105** of the liner hanger **100**.

As noted earlier, the liner hanger **100** is typically run into a wellbore above a connected string of liner (not shown). Above the liner hanger **100** is typically a setting sleeve (not shown) or, perhaps, a liner top packer (also not shown). A float nut or other means (not shown) will connect the setting sleeve with a landing string (not shown). In this manner, a connection is made between the landing string and the tools above the liner.

The liner hanger **100** of the present invention is designed to be actuated by expansion. In order to provide actuation, various expander tools may be used. Preferably, the expander tool is a novel hydraulic setting tool **200** as shown in **Figure 4**. A perspective view of the setting tool **200** for setting the liner hanger **100** is seen in the perspective view of **Figure 4**. As seen in **Figure 4**, the hydraulic setting tool **200** generally defines an elongated tubular member. The setting tool **200** first comprises an inner mandrel **220**. The mandrel is seen more clearly running through the setting tool **200** in the cross-sectional view of **Figure 5**. **Figure 5** also more clearly shows a bore **205** running through the mandrel **220**.

The setting tool **200** also includes a surrounding housing **240**. The housing **240** provides a sealed containment around a central portion of the mandrel **220** so as to define an annular region between the mandrel **220** and the housing **240**. At least one port **225** is provided in the wall of the mandrel **220**. The port **225** is also seen more clearly in **Figure 5**. The port **225** serves to provide a direct or indirect hydraulic coupling between the bore **205** and the backs of setting pistons **210**. Direct hydraulic coupling occurs by directly applying fluid pressure through the ports **225** directly to the backs of the pistons **210**. Indirect hydraulic pressure, which is preferred, occurs by applying pressure through a floating piston or booster piston arrangement, as disclosed below. Fluid may be directed into the ports **225** in various ways, such as by dropping a ball (not shown) on a seat below the ports **225**.

Disposed around the mandrel **220** is a plurality of radially arranged setting pistons **210**. The arrangement for the setting tool **200** shown in **Figures 4** and **5** presents a longitudinal array of three setting pistons **210**. However, any number of pistons **210** which are adequate for actuating the liner hanger **100** as will be discussed below, will suffice.

More than one longitudinal row of pistons **210** is preferred. The cross sectional view of **Figure 5** presents two opposing rows of pistons **210** in radially spaced-apart fashion. However, it would be appropriate to use additional rows of setting pistons **210**, such as by matching the number of rows of pistons **210** with the number of corresponding slip members **140** in the liner hanger **100**. In this respect, it will be shown that the purpose of the radial pistons **210** is to expand outwardly so as to cause at least one slip **140** on the liner hanger **100** to be expanded into frictional engagement with the surrounding casing **50**.

A fluid channel **230** may also be provided within the housing **240** or the mandrel **220**. In the arrangement of **Figure 5**, the fluid channel **230** is placed in the wall of the mandrel **220**. The purpose of the fluid channel **230** is to provide a fluid path to the back side of the radially disposed pistons **210**. In this respect, fluid is injected from the surface and through bore **205**. Fluid under pressure travels through the ports **225** and to the back sides of the pistons **210** via fluid channel **230**.

In providing fluid under pressure through the ports **225**, it is understood that a ball (not shown) is typically landed into a downhole seat (also not shown). It is also understood that fluid is maintained behind the setting pistons **210** by the positioning of seals **212** around each piston **210**. Also, it is preferred that each piston **210** be utilized with a biasing member (not shown) which maintains each piston **210** proximate to the mandrel **220** absent an application of fluid pressure.

Figure 6 presents a cross-sectional view of the hydraulic setting tool **200** of **Figure 5**. Also visible is a cross-sectional view of the corresponding liner hanger **100**. Here, the setting tool **200** is disposed within the liner hanger **100**. The setting tool **200** is rotationally positioned so as to actuate the liner hanger **100**. In this respect, the radial pistons **210** are aligned with a corresponding set of cones **150** and slips **140**. In this manner, extrusion of the pistons **210** from the housing **220** will cause the pistons **210** to act upon at least two sets of slips **140**.

Figure 7 is a cross-sectional view of a liner hanger **100** and hydraulic setting tool **200** residing within a surrounding string of casing **50**. Visible in this view are four sets of cones **150** and corresponding slips **140**. The cones **150** are spaced apart at mutual 90 degree intervals. Further, the slips **140** have not been expandably actuated in order to contact the casing **50**.

Turning now to **Figure 8**, a cross-sectional view of the hydraulic setting tool **200** is once again seen. In this view, fluid under pressure has been injected through ports **225** and into the housing **240**. Fluid has contacted the backs of the pistons **210**, forcing them outward from the mandrel **220**. The pistons **210**, in turn, have contacted the inner surface of the body **110** of the liner hanger **100**. Further, the pistons **210** have produced non-circular deformation of the body **110**, causing the slips **140** to engage the inner surface of the surrounding casing **50**.

It can be seen in **Figure 8** that the body **110** is expanded outwardly. Preferably, this expansion is only elastic deformation of the body **110**, and not plastic deformation. In this way, the body **110** is able to essentially rebound to its original circular shape within the wellbore after the liner has been hung. At the same time, the wickers **144** on the slips **140** remain engaged with the surrounding casing **50**. This is accomplished by the operator slacking off on the weight of the liner from the surface while the setting pistons **210** remain in their extended position. This, in turn, will cause the cones **150** to slide under the slips **140**, causing the slips **140** to be advanced upward relative to the cones **150**. As noted earlier, the slips **140** are each connected to a common slip ring **120**. This serves to hold the various slip members **140** in the same axial position as the cones **150** are advanced downward under the respective slips **140**. If plastic deformation does occur, the weight of the connected liner string acting on the cone/slips while slacking off may be used to induce inward radial forces that urge the body to return to its essentially circular cross-section. Pressure is controllably bled off from behind the radial pistons **210** during or after setting the liner hanger **100**.

It is again noted that the configuration of each cone **150** provides for a greater wall thickness at the distal end. This allows each cone **150** to serve as a wedge member. In this manner, advancing a slip **140** along (or relative to) a cone **150** from the proximal end to the distal end has the effect of expanding the radial position of the slip **140** outwardly. This accomplishes a gripping of the casing **50** by the slips **140** residing on the cones **150** as the liner hanger **100** and the liner are lowered within the wellbore.

Figure 9 presents a cross-sectional view of a wellbore having both a liner hanger **100** and a hydraulic setting tool **200** disposed therein. The cross-sectional view of **Figure 9**

is taken across **line 9-9** of **Figure 8**. It can be seen in **Figure 9** that two sets of pistons **210** are expandably acting upon two set of cones **150**/slips **140**. In this manner, frictional engagement between two opposite slips **140** is made with the casing **50**.

After engagement of the slips **140** with the casing **50**, the operator at the surface slacks off the weight of the liner. As noted above, this causes a lowering of the liner hanger body **110** and the attached cones **150**. At the same time, the slips **140** remain stationary. As the cones **150** urge the slips **140** to bite into the casing **50**, the liner hanger **100** assumes the role of providing gravitational support for the suspended liner within the wellbore. The operator at the surface will be able to detect this transfer of support as the gauge measuring the weight of the liner drops.

As a further aid in the expansion of the radial pistons **210** outwardly, and in maintaining expansion of the pistons **210** after fluid pressure is relieved, additional optional features may be incorporated into the hydraulic setting tool **200**. These additional features are best demonstrated in the cross-sectional view of **Figure 5**. First, **Figure 5** depicts a pair of additional pistons incorporated into the housing **240** of the hydraulic setting tool **200**. The first piston is a floating piston **270**; the second piston is a booster piston **250**. A light fluid such as a clean oil is loaded into the housing **240** between the floating piston **270** and the booster piston **250**. In operation, movement of the floating piston **270** towards the radial setting pistons **210** causes a reciprocal movement of the booster piston **250**. At the same time, the booster piston **250** is configured to include a nose portion **255,** which extends into a fluid chamber **235**. The fluid chamber **235**, in turn, is in fluid communication with the fluid channel **230**. In this manner, movement of the booster piston **250** in response to pressure caused by movement of the floating piston **270** applies a multiplied increase in fluid pressure to the fluid channel 230 and against the backs of the setting pistons **210**. This, in turn, allows for a greater degree of pressure to be placed upon the setting pistons **210** in order to force them outwardly from the mandrel **220**, with only a relatively small amount of hydraulic pressure being injected into the bore **205** from the surface.

A fluid medium is also provided within the fluid channel **230** and the fluid chamber **235**. Ideally, the fluid would again be a clean oil which is pre-loaded into the housing **240**. The fluid medium provides the hydraulic pressure needed against the back side of each radial piston **210** when the booster piston **250** is hydraulically actuated into the fluid chamber **235**.

An additional optional feature of the hydraulic setting tool **200** includes the use of a metering device **260**. The metering device **260** is shown in **Figure 5** positioned between the floating piston **270** and the booster piston **250**. In operation, fluid applied from the surface passes into the hydraulic setting tool **200** through ports **225**. Fluid then acts against the floating piston **270**. The floating piston **270**, in turn, pushes fluid pre-loaded into the housing **240** in order to act against the booster piston **250**, as discussed above. This intermediate fluid, e.g., a clean oil, passes through the metering device **260**.

During actuation, the metering device **260** freely permits oil to pass therethrough in order to act against the booster piston **250**. Fluid is then able to flow under the setting pistons **210**, urging them outwardly against the surrounding liner hanger body **110**. However, when fluid pressure from the surface is being relieved while the liner is being lowered from the surface, the metering device **260** serves to impede the free return of oil from the booster piston **250** against the floating piston **270**. This, in turn, allows for a more gradual release of fluid pressure acting behind the radial setting pistons **210** so as to continue to urge the slips **140** outwardly while the liner is being lowered in the wellbore. In other words, an immediate and substantial drop in outward pressure applied through the setting pistons **210** is inhibited.

Figure 10 presents a cross-sectional view of the liner hanger **100** in its set position within a string of casing **50**. In this view it can be seen that the cones **150** have ridden downward under the slips **140**, causing the slips **140** to be moved radially outward. It can also be seen that the slips **140** have moved into frictional engagement with the surrounding casing **50**. Also visible in **Figure 10** is the hydraulic setting tool **200** within the liner hanger **100**. Hydraulic pressure has been relieved from the setting tool

200, allowing the setting pistons **210** of the hydraulic setting tool **200** to return to their dormant positions, i.e., retracted towards the mandrel **220**. In this manner, the hydraulic setting tool can be retrieved, leaving the liner hanger set.

Figure 11 also depicts the slips **140** in frictional engagement with the surrounding casing **50**. **Figure 11** presents a cross-sectional view of the liner hanger **100** of **Figure 10**, with the view taken across **line 11-11** of **Figure 10**. In this arrangement, four slips **140** are shown in frictional engagement with a surrounding casing **50**. However, the setting pistons **210** of the setting tool **200** are no longer extending outwardly in order to contact the inside of the liner hanger body **110**. Nevertheless, because of the operation of the liner hanger **100**, all slips **140** disposed on cones **150** are now together biting into the casing **50** so as to support the fully suspended liner therebelow. More specifically, when one or more slips **140** bites into frictional engagement with the surrounding casing **50**, followed by the lowering of the liner in the wellbore, the wedge surface(s) **150** will then move together under the slips **140**.

Figure 12 provides a cross-sectional view of the expansion set liner hanger **100** of **Figure 10**. In this view, the hydraulic setting tool **200** has been removed from the wellbore, leaving the liner hanger **100** set along the surrounding casing **50**.

From the disclosure of the liner hanger of the present invention above, along with the descriptions of the included drawings, it should be evident to one of ordinary skill in the art that a novel and improved method for setting liner hangers has been provided. It should also be evident that a liner hanger has been provided which is much easier to unset and reuse in the unlikely event of premature setting of the slips **140** within the casing **50**. In this respect, if the operator senses any premature setting of the liner hanger **100** while the liner is being run into the hole, the operator can simply pull back up on the liner string. The springs **130** will act to bring the slip ring **120** downward, thereby pulling the slips **140** away from the distal end of the cones **150**. This, in turn, has the effect of drawing the slips **140** inward and away from the inner surface of the casing **50**.

While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow. For example, the row of slips shown acted upon by the hydraulic setting tool and used to activate the setting of the liner hanger may not be the only row of slips on the liner hanger. There may be one or more rows of additional slips and cones that are connected to the activating slips so that all slips move axially together. These additional slips may be used to carry a portion of, or all of the liner weight when the liner hanger is fully set.

While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

CLAIMS:

1. An expansion set liner hanger for hanging a connected liner from a surrounding casing within a wellbore, the liner hanger comprising:

a tubular body; and

at least one slip disposed outside the outer surface of the tubular body, the at least one slip being movable radially outwardly by a radial force acting on an area of the inner surface of the tubular body, the at least one slip arranged to frictionally engage the surrounding casing so as to gravitationally support the connected liner.

2. A liner hanger as claimed in claim 1, arranged so that the radially outward force deforms the tubular body into a non-circular configuration, thereby causing the at least one slip to be urged into frictional engagement with the surrounding casing.

3. A liner hanger as claimed in claim 1 or 2, further comprising:

a tapered surface disposed on the outer surface of the body, the tapered surface receiving a slip, and the tapered surface having a proximal end having a first wall thickness and a distal end having a second wall thickness, the second wall thickness being greater than the first wall thickness so as to form a wedge.

4. A liner hanger as claimed in claim 3, arranged to be set when, upon movement of the at least one slip radially outward so as to engage the surrounding casing, the liner hanger body is moved downward, causing the distal end of the tapered surface to move relatively toward the corresponding slip.

5. A liner hanger as claimed in claim 4, wherein at least one of the at least one slip member resides essentially on the proximal end of the corresponding tapered surface prior to radially outward movement, but is relatively advanced towards the distal end of the corresponding cones due to radially outward movement as the liner hanger body moves downward.

6. A liner hanger as claimed in any preceding claim, further comprising:

a slip ring disposed circumferentially around the outer surface of the body, the slip ring being connected to the at least one slip.

7. An expansion set liner hanger for hanging a connected liner from a surrounding casing within a wellbore, the liner hanger comprising:

a tubular body;

at least one cone disposed on the outer surface of the body, the or each cone having a proximal end having a first wall thickness and a distal end having a second wall thickness, the second wall thickness being greater than the first wall thickness so as to form a wedge;

at least one slip disposed about the outer surface of the tubular body, the or each slip being disposed upon a corresponding cone at the proximal end of the corresponding cone; and

a slip ring disposed circumferentially around the outer surface of the body, the slip ring being connected to the at least one slip;

wherein at least one of the at least one slip is movable in a radially outward manner in response to an outward force acting on an area of the inner surface of the body, the area of the inner surface of the body generally corresponding to the position of at least one of the at least one slip, the radially outward force deforming the tubular body into a non-circular configuration thereby causing the at least one slip to be urged into frictional engagement with the surrounding casing; and

wherein the liner hanger is set when, upon movement of the slips radially outward so as to engage the surrounding casing, the liner hanger body is moved downward, causing the at least one cone to slide under the corresponding slip.

8. An expansion set liner hanger as claimed in claim 7, wherein:

the at least one cone defines a plurality of cones; and

the at least one slip defines a plurality of slips, each slip being received upon a corresponding cone.

9. An expansion set liner hanger as claimed in claim 8, wherein:

a first select portion of the plurality of slips move in a radially outward manner in response to the outward force; and

a second select portion of the at plurality of slips are in an essentially axially fixed relation to the first select portion of the plurality of slips.

10. A method for setting a liner hanger within a wellbore, the liner hanger being set in order to suspend a connected liner from a surrounding casing, the method comprising the steps of:

running an expansion set liner hanger into a wellbore using a landing string, the expansion set liner hanger comprising:

a tubular body; and

at least one slip member disposed about the outer surface of the tubular body, the at least one slip member being movable in a radially outward manner;

positioning the expansion set liner hanger at a desired level within the wellbore;

applying a radially outward force on an area of the inner surface of the body, the area of the inner surface of the body generally corresponding to the position of the at least one slip member; and

releasing weight of the liner from the landing string.

11. A method as claimed in claim 10, wherein the radially outward force deforms the tubular body into a non-circular configuration, thereby causing the at least one slip member to be urged into frictional engagement with the surrounding casing.

12. A method as claimed in claim 10 or 11, wherein the liner hanger further comprises:

at least one wedge surface disposed on the outer surface of the body, the wedge surface having a proximal end having a first wall thickness and a distal end having a second wall thickness, the second wall thickness being greater than the first wall thickness; and wherein each of the at least one slip member is disposed upon a corresponding wedge surface at the proximal end of the wedge surface.

13. A method as claimed in claim 12, wherein the liner hanger is set when, upon movement of the at least one slip member radially outward so as to engage the surrounding casing, the liner hanger body is moved downward, causing the distal end of the wedge surface to move relatively toward and essentially under the corresponding at least one slip member.

14. A method as claimed in claim 12 or 13, wherein:

the wedge surface defines a plurality of cones; and

the at least one slip defines a plurality of slips, each slip being received upon a corresponding cone.

15. A method as claimed in any of claims 10 to 14, wherein the step of releasing weight of the liner from the landing string allows the liner hanger body to be gravitationally moved to a further level within the wellbore, and causing at least one of the at least one slip member to gravitationally support the connected liner.

16. A method as claimed in any of claims 10 to 15, wherein the liner hanger further comprises:

a slip ring disposed circumferentially around the outer surface of the body, the slip ring being connected to the at least one slip member.

17. A method as claimed in any of claims 10 to 16, wherein the step of applying a radially outward force on an area of the inner surface of the body is accomplished by using a hydraulic expander tool.

18. A method as claimed in claim 17, wherein the hydraulic expander tool comprises:

a mandrel having a bore therein;

a plurality of setting pistons radially spaced apart around the mandrel, the setting pistons being movable from a first position proximal to the mandrel to a second extended position distal to the mandrel by the application of hydraulic pressure; and

at least one through-opening for providing fluid communication between the bore of the mandrel and the setting pistons.

19. A method as claimed in claim 18, further comprising the steps of:

rotationally aligning the radial pistons with at least one corresponding slip member; and

injecting fluid under pressure through the bore of the mandrel such that fluid acts upon the pistons so as to move the radial pistons from their respective first positions to their respective second extended positions.

20. A method as claimed in claim 19, wherein the step of releasing weight of the liner from the landing string is performed while the radial pistons of the hydraulic setting tool are in their second extended positions.

21. A method as claimed in any of claims 18 to 20, wherein the hydraulic expander tool further comprises a fluid channel behind the radial pistons for providing a fluid path for fluid injected through the at least one through-opening to a back side of each radial piston so as to move each radial piston from their respective first positions to their respective second extended positions.

22. A method as claimed in any of claims 18 to 21, wherein the hydraulic expander tool further comprises:

a tubular housing surrounding at least a portion of the mandrel so as to define an annular region around the mandrel;

a float piston within the annular region around the mandrel, the float piston being acted upon by fluid injected under pressure through the at least one through-opening;

a booster piston also residing within the annular region around the mandrel, the booster piston having a nose portion opposite the float piston extending into a fluid chamber;

a first fluid medium within the annular region disposed between the floating piston and the booster piston; and

a second fluid medium within the fluid channel adjacent the nose portion of the booster piston.

23. A method as claimed in claim 22, wherein the first and second fluid media each define a clean oil.

24. A method as claimed in claim 22 or 23, wherein the radial pistons each have a seal for holding the second fluid medium upon the actuation of pressure within the fluid chamber.

25. A method as claimed in any of claims 18 to 24, wherein the radial pistons define at least two rows of three pistons disposed within the housing.

26. A hydraulic expander tool comprising:

a mandrel having a bore therein;

a plurality of setting pistons radially spaced apart around the mandrel, the setting pistons being movable from a first position proximal to the mandrel to a second extended position distal to the mandrel by the application of hydraulic pressure; and

at least one through-opening for providing fluid communication between the bore of the mandrel and the setting pistons.

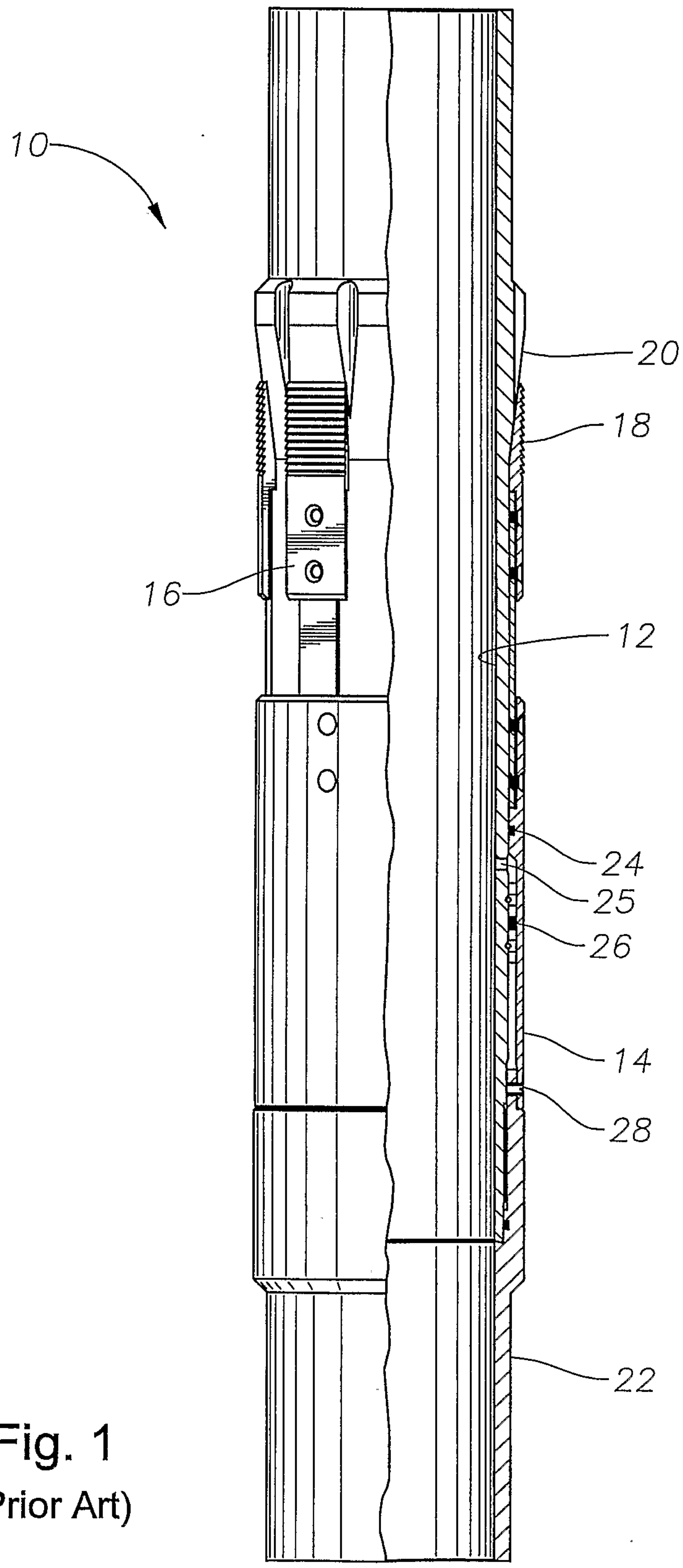

Fig. 1
(Prior Art)

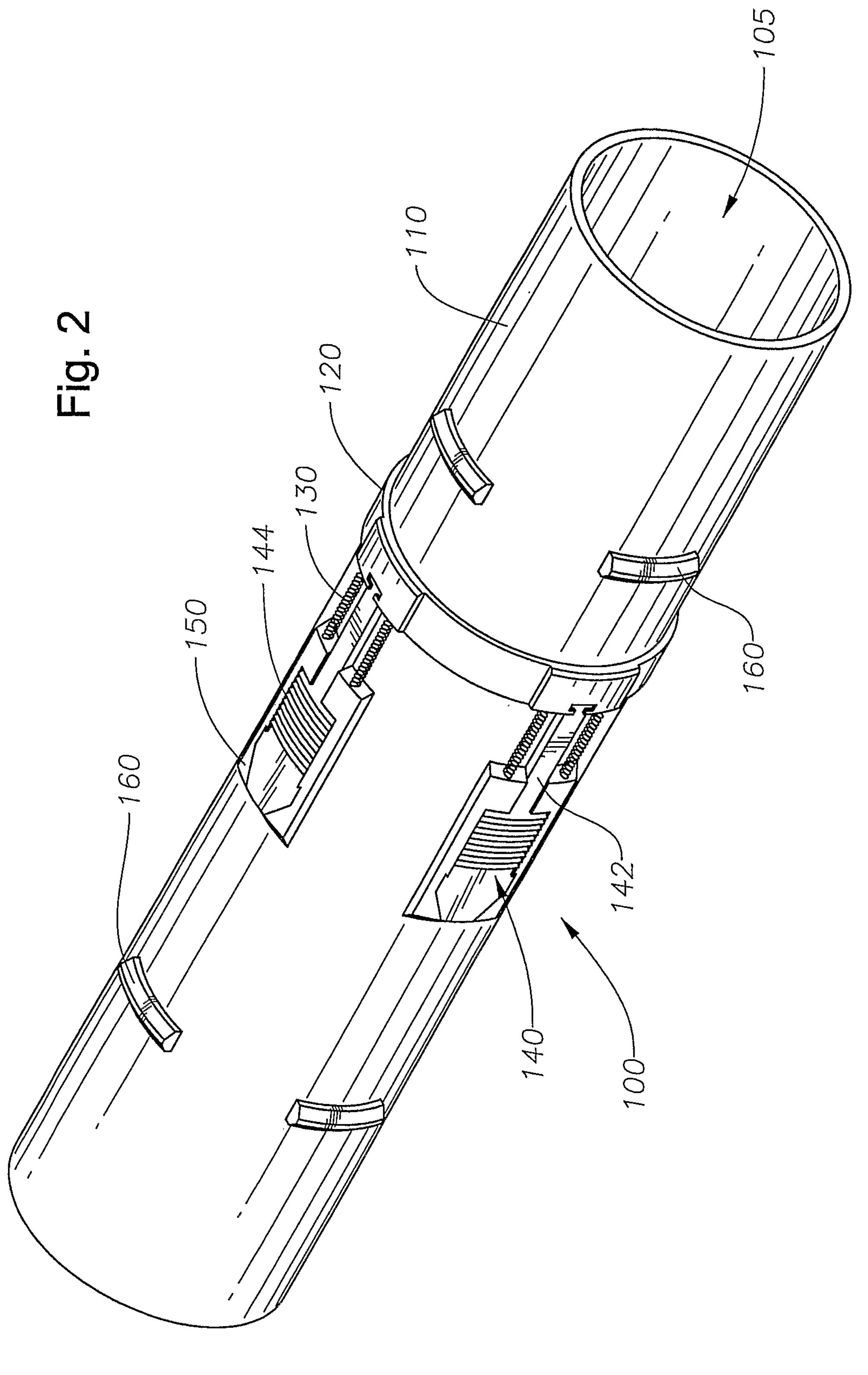

Fig. 2

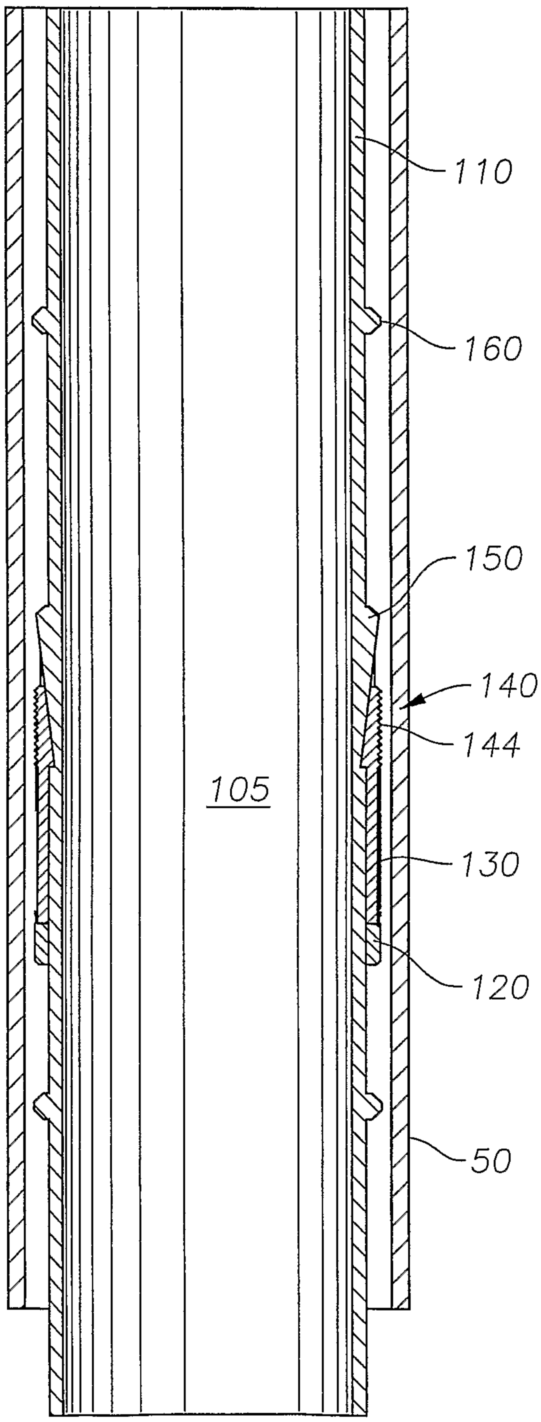
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Fig. 3

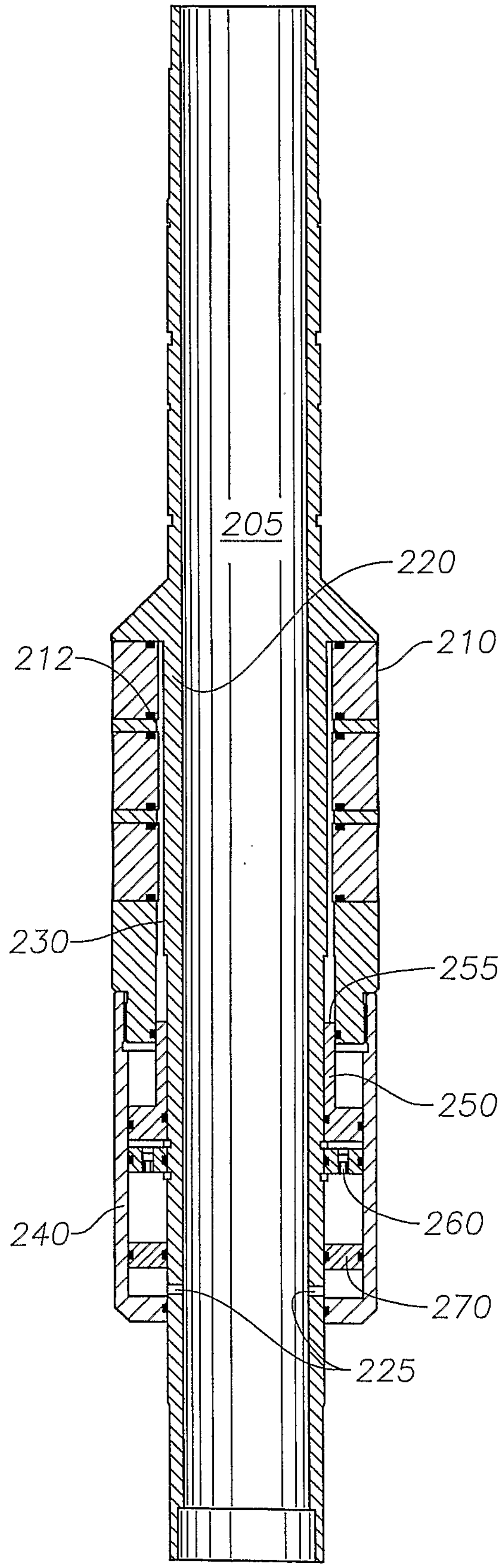
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Fig. 5

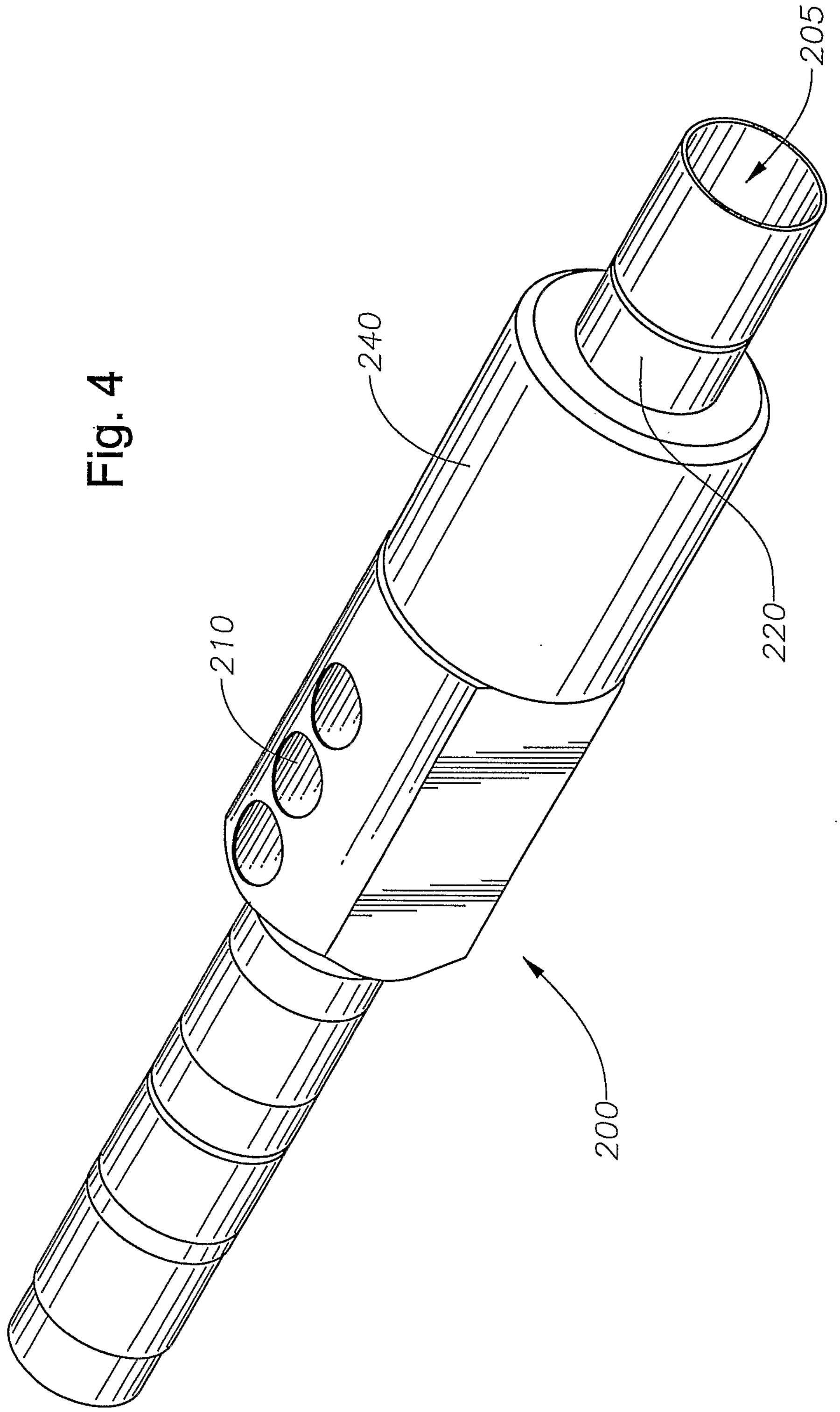

Fig. 4

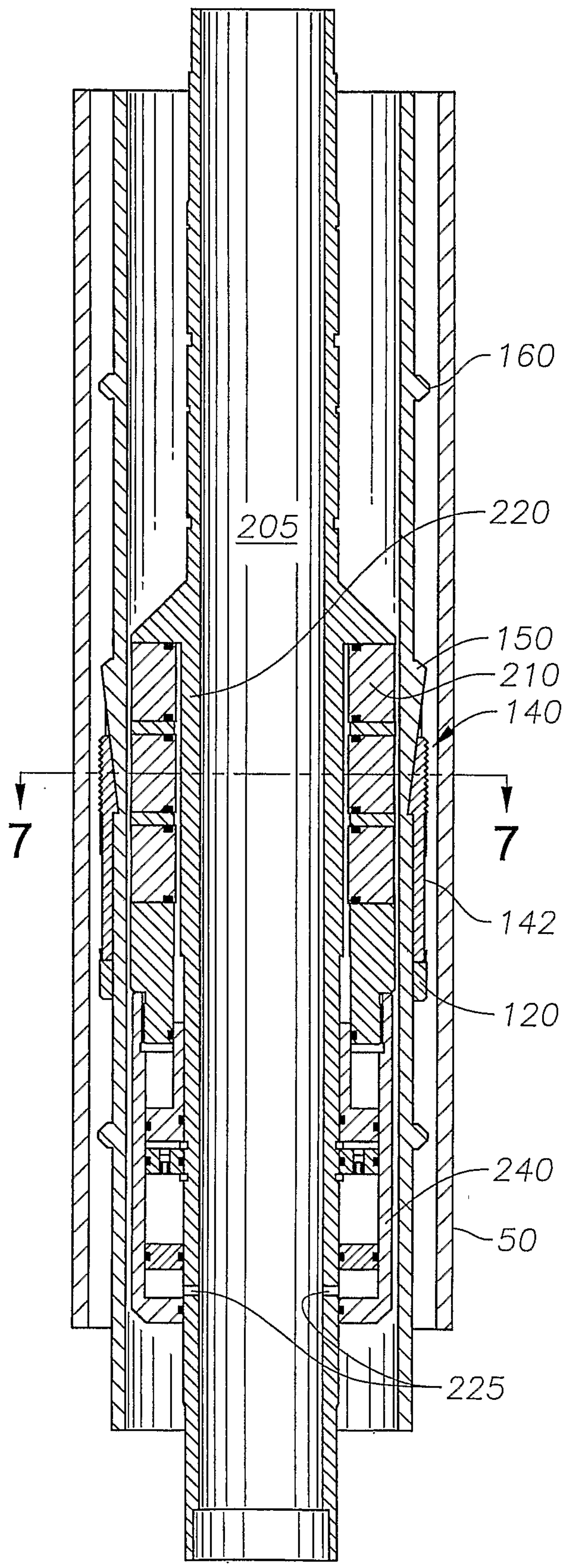

Fig. 6

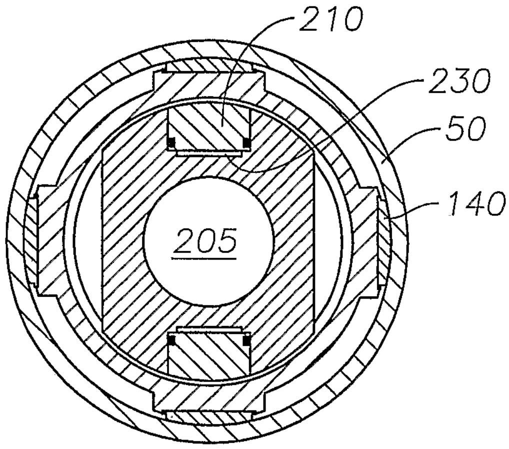

Fig. 11

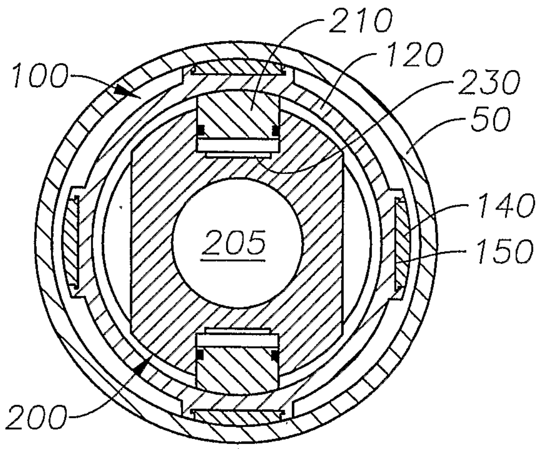

Fig. 9

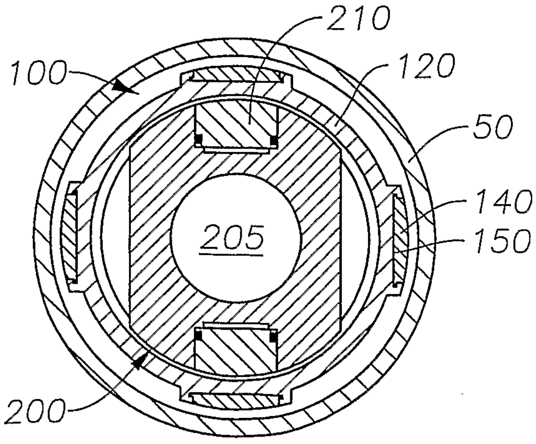

Fig. 7

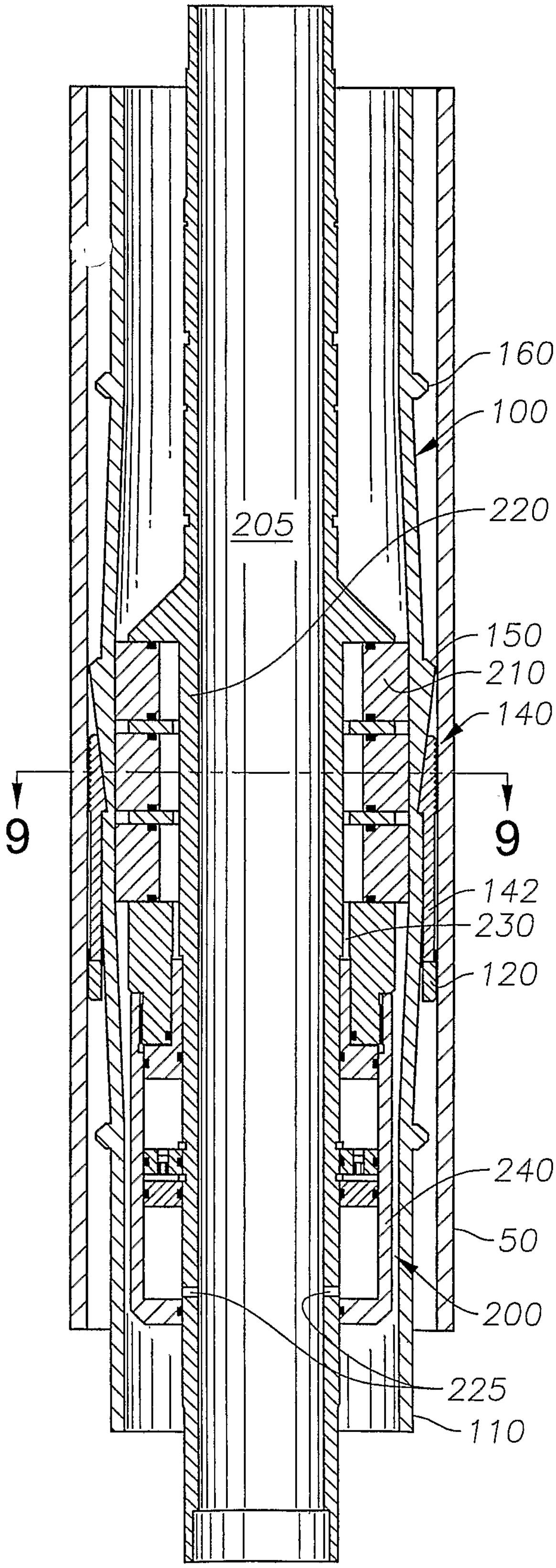
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Fig. 8

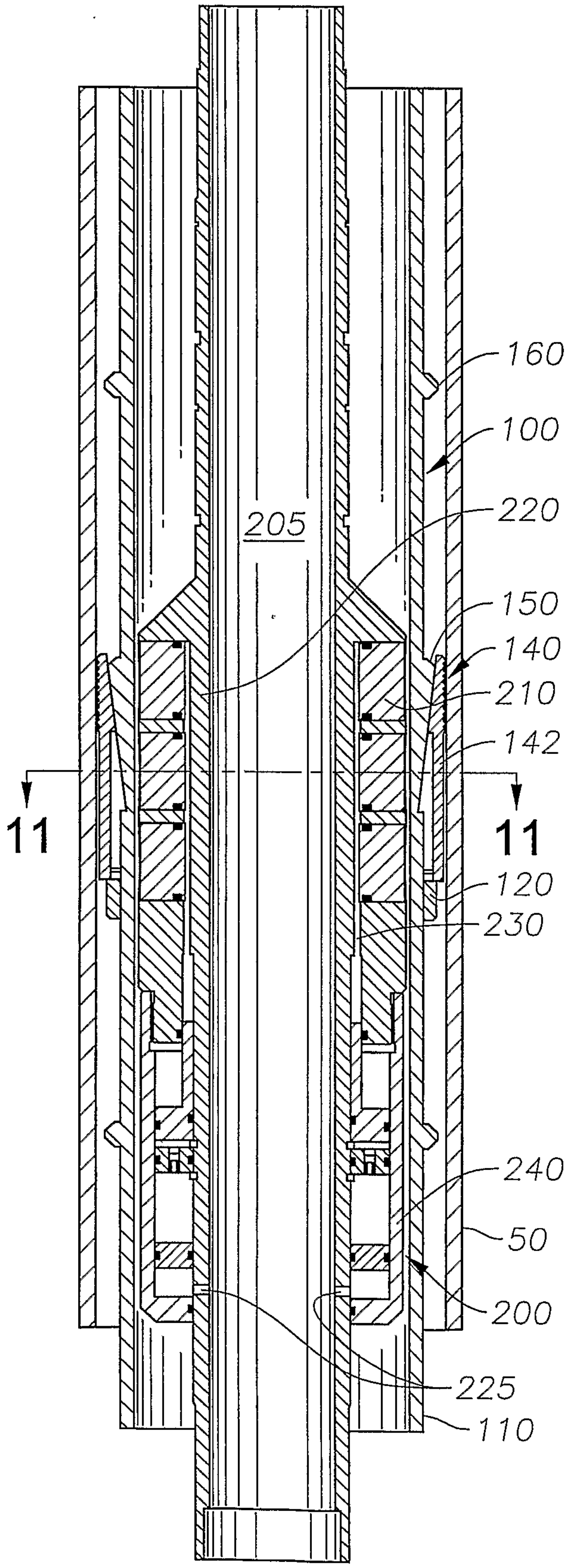
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Fig. 10

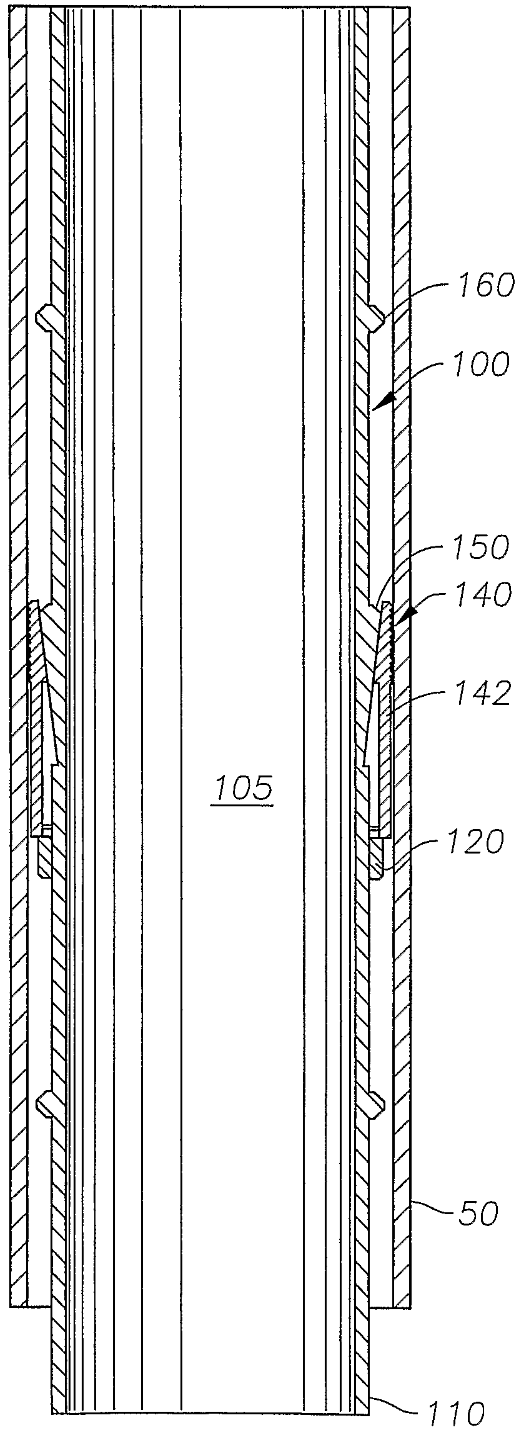

Fig. 12

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 02/05314

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 E21B43/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 497 368 A (BAUGH JOHN L) 5 February 1985 (1985-02-05) column 2, line 18 -column 5, line 5; figure 6	1-5, 10-14
Y	the whole document	6-9

Y	US 4 711 326 A (BAUGH JOHN L ET AL) 8 December 1987 (1987-12-08) column 2, line 53 -column 5, line 9; figure 1	6-9

X	US 5 318 131 A (BAKER SAMUEL F) 7 June 1994 (1994-06-07) column 3, line 63 -column 4, line 2; figure 7	1-5, 10-14
A	the whole document	6-9, 15-26

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 February 2003	28/02/2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Morrish, S

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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X	US 4 523 641 A (MANDERSCHEID PHILLIP H) 18 June 1985 (1985-06-18) column 2, line 47 -column 3, line 64; figure 3 ---	1-5, 10-14
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A	EP 0 368 515 A (CAMERON IRON WORKS INC) 16 May 1990 (1990-05-16) the whole document -----	1,7,10, 26

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Information on patent family members

Inter[redacted]nal Application No
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