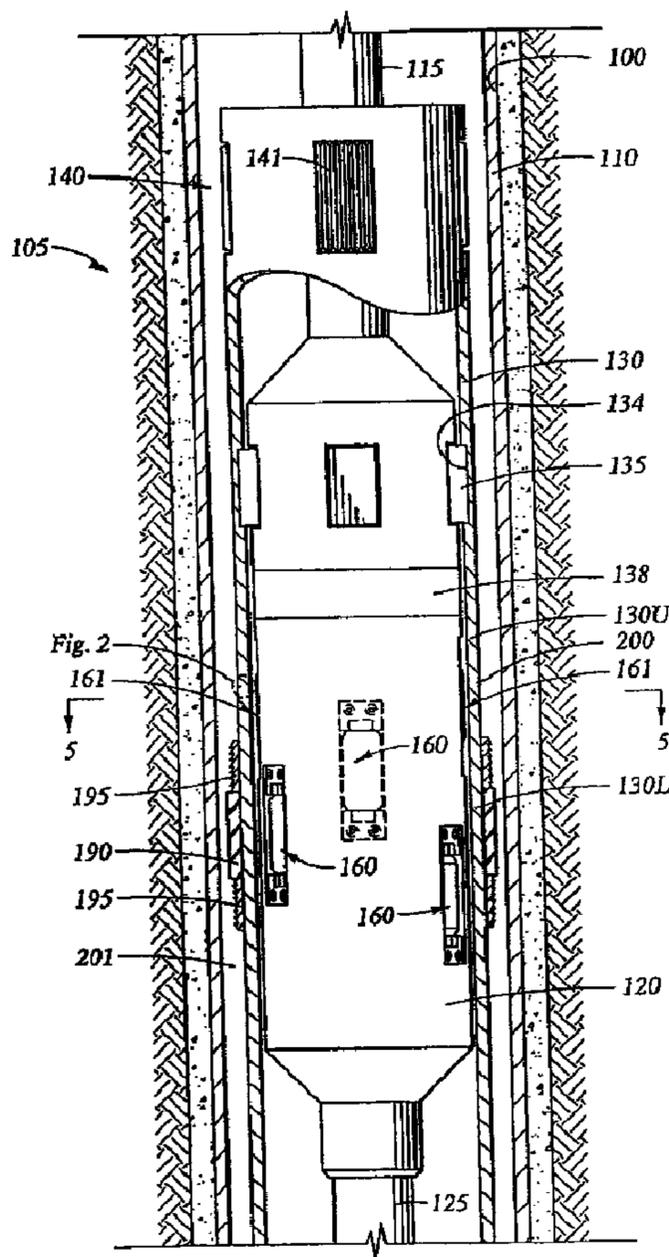




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(54) Titre : PROCÉDE ET APPAREIL POUR ETENDRE ET SEPARER DES TUBULAIRES DANS UN Puits  
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(57) Abrégé/Abstract:

An apparatus and method for expanding a lower string of casing into frictional contact with an upper string of casing, and thereby hanging the lower string of casing onto the upper string of casing is provided. The apparatus substantially defines a lower string of



(57) **Abrégé(suite)/Abstract(continued):**

casing having a scribe placed into the top end thereof. The lower string of casing is run into the wellbore, and positioned so that the top end overlaps with the bottom end of an upper string of casing already cemented into the wellbore. The top end of the lower casing string is expanded below the depth of the scribe into frictional contact with the upper string of casing. At the same time, or shortly thereafter, the top end of the upper string of casing is expanded. As the portion of the lower casing string having the scribe is expanded, the casing severs into upper and lower portions.

## Abstract

An apparatus and method for expanding a lower string of casing into frictional contact with an upper string of casing, and thereby hanging the lower string of casing onto the upper string of casing is provided. The apparatus substantially defines a lower string of casing having a scribe placed into the top end thereof. The lower string of casing is run into the wellbore, and positioned so that the top end overlaps with the bottom end of an upper string of casing already cemented into the wellbore. The top end of the lower casing string is expanded below the depth of the scribe into frictional contact with the upper string of casing. At the same time, or shortly thereafter, the top end of the upper string of casing is expanded. As the portion of the lower casing string having the scribe is expanded, the casing severs into upper and lower portions.

## **METHOD AND APPARATUS FOR EXPANDING AND SEPARATING TUBULARS IN A WELLBORE**

This is a divisional application of Canadian Patent Application Serial No. 2,462,115 filed on September 26, 2002.

The present invention relates to methods and apparatus for wellbore completions. More particularly, the invention relates to completing a wellbore by expanding tubulars therein. More particularly still, the invention relates to completing a wellbore by separating an upper portion of a tubular from a lower portion after the lower portion of the tubular has been expanded into frictional engagement with another tubular therearound, or into contact with a surrounding wellbore formation.

It should be understood that the expression "the invention" and the like encompasses the subject-matter of both the parent and the divisional applications.

Hydrocarbon and other wells are completed by forming a borehole in the earth and then lining the borehole with steel pipe or casing to form a wellbore. After a section of wellbore is formed by drilling, a section of casing is lowered into the wellbore and temporarily hung therein from the surface of the well. Using apparatus known in the art, the casing is cemented into the wellbore by circulating cement into the annular area defined between the outer wall of the casing and the borehole. 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 of hydrocarbons.

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. In this respect, 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, or liner, is run into the well. The second string is set at a depth such that the upper portion of the second string of casing overlaps the lower portion of the first string of casing. The second liner string is then fixed or "hung off of the existing casing

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by the use of slips which utilize slip members and cones to wedgingly fix the new string of liner in the wellbore. The second casing string is then cemented. This process is typically repeated with additional casing strings until the well has been drilled to total depth. In this manner, wells are typically formed with two or more strings of casing of an ever decreasing diameter.

Apparatus and methods are emerging that permit tubulars to be expanded *in situ*. The apparatus typically includes expander tools which are fluid powered and are run into a wellbore on a working string. The hydraulic expander tools include radially expandable members which, through fluid pressure, are urged outward radially from the body of the expander tool and into contact with a tubular therearound. As sufficient pressure is generated on a piston surface behind these expansion members, the tubular being acted upon by the expansion tool is expanded past its point of plastic deformation. In this manner, the inner and outer diameter of the tubular is increased in the wellbore. By rotating the expander tool in the wellbore and/or moving the expander tool axially in the wellbore with the expansion member actuated, a tubular can be expanded along a predetermined length in a wellbore.

There are advantages to expanding a tubular within a wellbore. For example, expanding a second tubular into contact with a first tubular therearound eliminates the need for a conventional slip assembly. With the elimination of the slip assembly, the annular space required to house the slip assembly between the two tubulars can be reduced.

In one example of utilizing an expansion tool and expansion technology, a liner can be hung off of an existing string of casing without the use of a conventional slip assembly. A new section of liner is run into the wellbore using a run-in string. As the assembly reaches that depth in the wellbore where the liner is to be hung, the new liner is cemented in place. Before the cement sets, an expander tool is actuated and the liner is expanded into contact with the existing casing therearound. By rotating the expander tool in place, the new lower string of casing can be fixed onto the previous upper string of casing, and the annular area between the two tubulars is sealed.

There are problems associated with the installation of a second string of casing in a wellbore using an expander tool. Because the weight of the casing must be borne by the run-in string during cementing and expansion, there is necessarily a portion of surplus casing remaining above the expanded portion. In order to properly complete the well, that section of surplus unexpanded casing must be removed in order to provide a clear path through the wellbore in the area of transition between the first and second casing strings.

Known methods for severing a string of casing in a wellbore present various drawbacks. For example, a severing tool may be run into the wellbore that includes cutters which extend into contact with the tubular to be severed. The cutters typically pivot away from a body of the cutter. Thereafter, through rotation the cutters eventually sever the tubular. This approach requires a separate trip into the wellbore, and the severing tool can become binded and may otherwise malfunction. The severing tool can also interfere with the upper string of casing. Another approach to severing a tubular in a wellbore includes either explosives or chemicals. These approaches likewise require a separate trip into the wellbore, and involve the expense and inconvenience of transporting and using additional chemicals during well completion. These methods also create a risk of interfering with the upper string of casing. Another possible approach is to use a separate fluid powered tool, like an expansion tool wherein one of the expansion members is equipped with some type of rotary cutter. This approach, however, requires yet another specialized tool and manipulation of the run-in string in the wellbore in order to place the cutting tool adjacent that part of the tubular to be severed. The approach presents the technical problem of operating two expansion tools selectively with a single tubular string.

There is a need, therefore, for an improved apparatus and method for severing an upper portion of a string of casing after the casing has been set in a wellbore by expansion means. There is a further need for an improved method and apparatus for severing a tubular in a wellbore. There is yet a further need for a method and apparatus to quickly and simply sever a tubular in a wellbore without a separate trip into the wellbore and without endangering the integrity of the upper string of casing.

Apparatus aspects corresponding to method aspects disclosed herein are also provided, and vice versa.

According to an embodiment, there is provided a method comprising:

- positioning a first tubular within a wellbore;
- placing a scribe within the top portion of a second tubular;

running the second tubular to a selected depth within the wellbore such that the top portion of the second tubular overlaps with a bottom portion of the first tubular;

expanding the top portion of the second tubular at the depth of said scribe so that the outer surface of the expanded top portion of the second tubular is in frictional contact with the inner surface of the bottom portion of the first tubular, and thereby severing the top portion of the second tubular into an upper and lower portion; and

removing said severed upper portion of said top portion of the second tubular from the wellbore.

According to an embodiment, an expansion assembly is run into a wellbore on a run-in string. The expansion assembly comprises a lower string of casing to be hung in the wellbore, and an expander tool disposed at an upper end thereof. The expander tool preferably includes a plurality of expansion members which are radially disposed around a body of the tool in a spiraling arrangement. In addition, the lower string of casing includes a scribe placed in the lower string of casing at the point of desired severance. The scribe creates a point of structural weakness within the wall of the casing so that it fails upon expansion.

The expander tool is run into the wellbore to a predetermined depth where the lower string of casing is to be hung. In this respect, a top portion of the lower string of casing, including the scribe, is positioned to overlap a bottom portion of an upper string of casing already set in the wellbore. In this manner, the scribe in the lower string of casing is positioned downhole at the depth where the two strings of casing overlap. Cement is injected through the run-in string and circulated into the annular area between the lower string of casing and the formation. Cement is further circulated into the annulus where the lower and upper strings of casing overlap. Before the cement cures, the expansion members at a lower portion of the expansion tool are actuated so as to expand the lower string of casing into the existing upper string at a point below the scribe. As the uppermost expansion members extend radially outward into contact with the casing, including those at the depth of the scribe, the scribe causes the casing to be severed. Thereafter, with the lower string of casing expanded into frictional and sealing relationship with the existing upper casing string, the expansion tool and run-in string, are pulled from the wellbore.

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According to an aspect of the present invention there is provided a method for expanding and separating a tubular in a wellbore, the method comprising:

- positioning a first tubular within a wellbore;
- providing a second tubular having a preferred line of fracture within a top portion thereof;
- running the second tubular to a selected depth within the wellbore such that the top portion of the second tubular overlaps with a portion of the first tubular;
- expanding at least a portion of the top portion of the second tubular at and/or below the preferred line of fracture so that the outer surface of the expanded portion of the second tubular is in frictional contact with the inner surface of said portion of the first tubular, and thereby severing the top portion of the second tubular into an upper and lower portion; and
- removing said severed upper portion of said top portion of the second tubular from the wellbore.

According to another aspect of the present invention there is provided a method of expanding a second tubular into a first tubular within a wellbore, comprising:

- lowering the second tubular to a selected depth within the wellbore so that a portion of the second tubular overlaps with a portion of the first tubular, a portion of a surface of the second tubular having a scribe therein;
- expanding the portion of the second tubular so that an outer surface of the second tubular is in frictional contact with an inner surface of the first tubular at the overlap, thereby severing the second tubular into an upper and lower portion at the scribe; and
- removing the severed upper portion of the second tubular from the wellbore.

According to a further aspect of the invention there is provided an apparatus for expanding and separating a tubular in a wellbore, the tubular having an inscribed portion, the apparatus comprising:

- an expander tool disposed within the inscribed tubular and connected thereto, the expander tool having first extendable roller members for causing the tubular to fail at the inscribed portion and second extendable roller members,

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wherein the tubular is disposed within a wellbore and expandable into frictional contact with the wellbore by the second extendable roller members, the second extendable roller members extendable prior to the first extendable roller members.

According to a further aspect of the present invention there is provided a tubular for insertion into a wellbore, the tubular having a preferred line of fracture within a top portion thereof so as to permit severing of the top portion into an upper and a lower portion by expansion of at least a portion of the top portion at and/or below the preferred line of fracture.

According to a further aspect of the invention there is provided a system for completing a wellbore comprising the tubular as described hereinabove and an expander tool.

According to a further aspect of the invention there is provided a method for expanding a second tubular into a first tubular, the first tubular and second tubular each having a top portion and a bottom portion, comprising the steps of:

- positioning the first tubular within a wellbore;
- placing a scribe within the top portion of the second tubular;
- running the second tubular to a selected depth within the wellbore such that the top portion of the second tubular overlaps with the bottom portion of the first tubular;
- expanding the top portion of the second tubular at the depth of said scribe so that the outer surface of the expanded top portion of the second tubular is in frictional contact with the inner surface of the bottom portion of the first tubular, and thereby severing the top portion of the second tubular into an upper and lower portion; and
- removing said severed upper portion of said top portion of the second tubular from the wellbore.

According to a further aspect of the present invention there is provided an apparatus for expanding and separating a tubular in a wellbore, the tubular having an inscribed portion, the apparatus comprising:

- an expander tool disposed within the inscribed tubular and connected thereto, the expander tool having at least one first extendable roller member for causing the tubular to fail at the inscribed portion and at least one second extendable roller member,

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wherein the tubular is disposed within a wellbore and expandable into frictional contact with the wellbore by the at least one second extendable roller member, the at least one second extendable roller member extendable prior to the at least one first extendable roller member.

According to an aspect of the present invention there is provided an expander tool for expanding a tubular, the tool comprising:

a body having a bore longitudinally formed therein;

at least one first roller member radially extendable from the body into contact with a surrounding inside surface of the tubular; and

at least one second roller member constructed and arranged to extend from the body after the at least one first roller member has been extended therefrom.

According to another aspect of the present invention there is provided an expander tool for expanding a tubular, comprising:

a body having a longitudinal bore therein; and

at least two expansion members radially extendable from the body into contact with a surrounding inside surface of the tubular, wherein the at least two expansion members are radially extendable at different times.

According to a further aspect of the present invention there is provided a method of expanding a tubular, comprising:

providing an expander tool within a tubular, the expander tool comprising at least two expansion members radially extendable from a body having a longitudinal bore therethrough;

radially extending one of the at least two expansion members into contact with an inside surface of the tubular; and

thereafter radially extending another of the at least two expansion members into contact with the inside surface of the tubular.

According to a further aspect of the present invention there is provided a method of expanding a tubular, comprising:

running an expansion assembly that is supporting a tubular into a wellbore;

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actuating the expansion assembly to expand a first portion of the tubular while preventing expansion of a second portion of the tubular; and

actuating the expansion assembly to expand the second portion of the tubular, thereby severing the second portion of the tubular from the first portion of the tubular.

According to a further aspect of the present invention there is provided a method of expanding a tubular, comprising:

running a tubular that is supported by an expansion assembly having a first member and a second member into a wellbore;

actuating the first member to expand a first portion of the tubular while preventing actuation of the second member; and

actuating the second member to expand a second portion of the tubular.

According to a further aspect of the present invention there is provided an apparatus for expanding a tubular, comprising:

a body having a bore disposed through the body;

a first member that is radially extendable from the body; and

a second member that is radially extendable from the body and is configured to extend from the body after extension of the first member.

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 is a partial section view of a wellbore illustrating the assembly according to an embodiment of the present invention in a run-in position.

Figure 2 is an enlarged sectional view of a wall in the lower string of casing more fully showing one embodiment of a scribe of the present invention.

Figure 3 is an exploded view of an expander tool as might be used in the methods of the present invention.

Figure 4 is a perspective view showing a shearable connection for an expansion member.

Figures 5A - 5D are section views taken along a line 5-5 of Figure 1 and illustrating the position of expansion members during progressive operation of the expansion tool.

Figure 6 is a partial section view of the apparatus in a wellbore illustrating a portion of the lower string of casing, including slip and sealing members, having been expanded into the upper string of casing therearound.

Figure 7 is a partial section view of the apparatus illustrating the lower string of casing expanded into frictional and sealing engagement with the upper string of casing. Figure 7 further depicts the lower string of casing having been severed into an upper portion and a lower portion due to expansion.

Figure 8 is a partial section view of the wellbore illustrating a section of the lower casing string expanded into the upper casing string after the expansion tool and run-in string have been removed.

Figure 9 is a cross-sectional view of an expander tool residing within a wellbore. Above the expander tool is a torque anchor for preventing rotational movement of the lower string of casing during initial expansion thereof. Expansion of the casing has not yet begun.

Figure 10 is a cross-sectional view of an expander tool of FIG. 9. In this view, the torque anchor and expander tool have been actuated, and expansion of the lower casing string has begun.

**Figure 1** is a section view of a wellbore **100** illustrating an apparatus **105** for use in the methods of the present invention. The apparatus **105** defines a string of casing **130**, and an expander tool **120** for expanding the string of casing **130**. By actuation of the expander tool **120** against the inner surface of the string of casing **130**, the string of casing **130** is expanded into a second, upper string of casing **110** which has already been set in the wellbore **100**. In this manner, the top portion of the lower string of casing **130U** is placed in frictional engagement with the bottom portion of the upper string of casing **110**.

In accordance with the present invention, a scribe **200** is placed into the surface of the lower string of casing **130**. An enlarged view of the scribe **200** in one embodiment is shown in **Figure 2**. As will be disclosed in greater detail, the scribe **200** creates an area of structural weakness within the lower casing string **130**. When the lower string of casing **130** is expanded at the depth of the scribe **200**, the lower string of casing **130** is severed into upper **130U** and lower **130L** portions. The upper portion **130U** of the lower casing string **130** can then be easily removed from the wellbore **100**. Thus, the scribe may serve as a release mechanism for the lower casing string **130**.

At the stage of completion shown in **Figure 1**, the wellbore **100** has been lined with the upper string of casing **110**. A working string **115** is also shown in **FIG. 1**. Attached to a lower end of the run-in string **115** is an expander tool **120**. Also attached to the working string **115** is the lower string of casing **130**. In the embodiment of **FIG. 1**, the lower string of casing **130** is supported during run-in by a series of dogs **135** disposed radially about the expander tool **120**. The dogs **135** are landed in a circumferential profile **134** within the upper string of casing **130**.

A sealing ring **190** is disposed on the outer surface of the lower string of casing **130**. In the preferred embodiment, the sealing ring **190** is an elastomeric member circumferentially fitted onto the outer surface of the casing **130**. However, non-elastomeric materials may also be

used. The sealing ring **190** is designed to seal an annular area **201** formed between the outer surface of the lower string of casing **130** and the inner surface of the upper string of casing **110** upon expansion of the lower string **130** into the upper string **110**.

Also positioned on the outer surface of the lower string of casing **130** is at least one slip member **195**. In the preferred embodiment of the apparatus **105**, the slip member **195** defines a pair of rings having grip surfaces formed thereon for engaging the inner surface of the upper string of casing **110** when the lower string of casing **130** is expanded. In the embodiment shown in **FIG. 1**, one slip ring **195** is disposed above the sealing ring **190**, and one slip ring **195** is disposed below the sealing ring **190**. In **Figure 1**, the grip surface includes teeth formed on each slip ring **195**. However, the slips could be of any shape and the grip surfaces could include any number of geometric shapes, including button-like inserts (not shown) made of high carbon material.

Fluid is circulated from the surface and into the wellbore **100** through the working string **115**. A bore **168**, shown in **Figure 3**, runs through the expander tool **120**, placing the working string **115** and the expander tool **120** in fluid communication. A fluid outlet **125** is provided at the lower end of the expander tool **120**. In the preferred embodiment, shown in **FIG. 1**, a tubular member serves as the fluid outlet **125**. The fluid outlet **125** serves as a fluid conduit for cement to be circulated into the wellbore **100** in accordance with the method of the present invention.

In the embodiment shown in **Figure 1**, the expander tool **120** includes a swivel **138**. The swivel **138** allows the expander tool **120** to be rotated by the working tubular **115** while the supporting dogs **135** remain stationary.

**Figure 3** is an exploded view of the expander tool **120** itself. The expander tool **120** consists of a cylindrical body **150** having a plurality of windows **155** formed therearound. Within each window **155** is an expansion assembly **160** which includes a roller **165** disposed on an axle **170** which is supported at each end by a piston **175**. The piston **175** is retained in the body **150** by a pair of retention members **172** that are held in place by screws **174**. The assembly **160** includes a piston surface **180** formed opposite the piston **175** which is acted upon by pressurized fluid in the bore **168** of the expander tool **120**. The pressurized fluid

causes the expansion assembly **160** to extend radially outward and into contact with the inner surface of the lower string of casing **130**. With a predetermined amount of fluid pressure acting on the piston surface **180** of piston **175**, the lower string of casing **130** is expanded past its elastic limits.

The expander tool **120** illustrated in **FIGS. 1** and **3** includes expansion assemblies **160** that are disposed around the perimeter of the expander tool body **150** in a spiraling fashion. Located at an upper position on the expander tool **120** are two opposed expansion assemblies **160** located  $180^\circ$  apart. The expander tool **120** is constructed and arranged whereby the uppermost expansion members **161** are actuated after the other assemblies **160**.

In one embodiment, the uppermost expansion members **161** are retained in their retracted position by at least one shear pin **162** which fails with the application of a predetermined radial force. In **Figure 4** the shearable connection is illustrated as two pin members **162** extending from a retention member **172** to a piston **175**. When a predetermined force is applied between the pistons **175** of the uppermost expansion members **161** and the retaining pins **162**, the pins **162** fail and the piston **175** moves radially outward. In this manner, actuation of the uppermost members **161** can be delayed until all of the lower expansion assemblies **160** have already been actuated.

**Figures 5A – 5D** are section views of the expander tool **120** taken along lines 5-5 of **Figure 1**. The purpose of **Figures 5A - 5D** is to illustrate the relative position of the various expansion assemblies **160** and **161** during operation of the expander tool **120** in a wellbore **100**. **Figure 5A** illustrates the expander tool **120** in the run-in position with all of the radially outward extending expansion assemblies **160**, **161** in a retracted position within the body **150** of the expander tool **120**. In this position, the expander tool **120** can be run into a wellbore **100** without creating a profile any larger than the outside diameter of the expansion tool body **150**. **Figure 5B** illustrates the expander tool **120** with all but the upper-most expansion assemblies **160** and **161** actuated. Because the expansion assemblies **160** are spirally disposed around the body **150** at different depths, in **Figure 5B** the expander tool **120** would have expanded a portion of the lower string of casing **130** axially as well as radially. In addition to the expansion of the lower string of casing **130** due to the location of the expansion assemblies **160**, the expander tool **120** and working string **115** can be rotated

relative to the lower string of casing **130** to form a circumferential area of expanded liner **130L**. Rotation is possible due to a swivel **138** located above the expander tool **120** which permits rotation of the expander tool **120** while ensuring the weight of the casing **130** is borne by the dogs **135**.

**Figure 6** presents a partial section view of the apparatus **105** after expanding a portion of the lower string of casing **130L** into the upper string of casing **110**. Expansion assemblies **160** have been actuated in order to act against the inner surface of the lower string of casing **130L**. Thus, **Figure 6** corresponds to **Figure 5B**. Visible also in **Figure 6** is sealing ring **190** in contact with the inside wall of the casing **110**. Slips **195** are also in contact with the upper string of casing **110**.

**Figure 5C** is a top section view of a top expansion member **160** in its recessed state. Present in this view is a piston **175** residing within the body **150** of the expander tool **120**. Also present is the shearable connection, i.e., shear pins **162** of **FIG. 4**.

Referring to **Figure 5D**, this figure illustrates the expander tool **120** with all of the expansion assemblies **160** and **161** actuated, including the uppermost expansion members **161**. As previously stated, the uppermost expansion members **161** are constructed and arranged to become actuated only after the lower assemblies **160** have been actuated.

**Figure 7** depicts a wellbore **100** having an expander tool **120** and lower string of casing **130** according to an embodiment of the present invention disposed therein. In this view, all of the expansion assemblies **160**, **161**, including the uppermost expansion members **161**, have been actuated. Thus, **Figure 7** corresponds to the step presented in **Figure 5D**.

Referring again to **Figure 1**, formed on the surface of the lower string of casing **130L** adjacent the uppermost expansion member **161** is a scribe **200**. The scribe **200** creates an area of structural weakness within the lower casing string **130**. When the lower string of casing **130** is expanded at the depth of the scribe **200**, the lower string of casing **130** breaks cleanly into upper **130U** and lower **130L** portions. The upper portion **130U** of the lower casing string **130** can then be easily removed from the wellbore **100**.

The inventors have determined that a scribe **200** in the wall of a string of casing **130** or other tubular will allow the casing **130** to break cleanly when radial outward pressure is placed at the point of the scribe **200**. The depth of the cut **200** needed to cause the break is dependent upon a variety of factors, including the tensile strength of the tubular, the overall deflection of the material as it is expanded, the profile of the cut, and the weight of the tubular being hung. Thus, the scope of the present invention is not limited by the depth of the particular cut or cuts **200** being applied, so long as the scribe **200** is shallow enough that the tensile strength of the tubular **130** supports the weight below the scribe **200** during run-in. The preferred embodiment, shown in **Figure 2**, employs a single scribe **200** having a V-shaped profile so as to impart a high stress concentration onto the casing wall.

In the preferred embodiment, the scribe **200** is formed on the outer surface of the lower string of casing **130**. Further, the scribe **200** is preferably placed around the casing **130** circumferentially. Because the lower string of casing **130** and the expander tool **120** are run into the wellbore **100** together, and because no axial movement of the expander tool **120** in relation to the casing **130** is necessary, the position of the upper expansion members **161** with respect to the scribe **200** can be predetermined and set at the surface of the well or during assembly of the apparatus **105**.

**Figure 7**, again, shows the expander tool **120** with all of the expansion assemblies **160** and **161** actuated, including the uppermost expansion members **161**. In **Figure 7**, the scribe **200** has caused a clean horizontal break around a perimeter of the lower string of casing **130** such that a lower portion of the casing **130L** has separated from an upper portion **130U** thereof. In addition to the expansion assemblies **160** and **161** having been actuated radially outward, the swivel **138** permitted the run-in string **115** and expansion tool **120** to be rotated within the wellbore **100** independent of the casing **130**, ensuring that the casing **130** is expanded in a circumferential manner. This, in turn, results in an effective hanging and sealing of the lower string of casing **130** upon the upper string of casing **110** within the wellbore **100**. Thus, the apparatus **105** enables a lower string of casing **130** to be hung onto an upper string of casing **110** by expanding the lower string **130** into the upper string **110**.

**Figure 8** illustrates the lower string of casing **130** set in the wellbore **100** with the run-in string **115** and expander tool **120** removed. In this view, expansion of the lower string of

casing **130** has occurred. The slip rings **195** and the seal ring **190** are engaged to the inner surface of the upper string of casing **110**. Further, the annulus **201** between the lower string of casing **130** and the upper string of casing has been filled with cement, excepting that portion of the annulus which has been removed by expansion of the lower string of casing **130**.

In operation, the method and apparatus of the present invention can be utilized as follows: a wellbore **100** having a cemented casing **110** therein is drilled to a new depth. Thereafter, the drill string and drill bit are removed and the apparatus **105** is run into the wellbore **100**. The apparatus **105** includes a new string of inscribed casing **130** supported by an expander tool **120** and a run-in string **115**. As the apparatus **105** reaches a predetermined depth in the wellbore **100**, the casing **130** can be cemented in place by injecting cement through the run-in string **115**, the expander tool **120** and the tubular member **125**. Cement is then circulated into the annulus **201** between the two strings of casing **110** and **130**.

With the cement injected into the annulus **201** between the two strings of casing **110** and **130**, but prior to curing of the cement, the expander tool **120** is actuated with fluid pressure delivered from the run-in string **115**. Preferably, the expansion assemblies **160** (other than the upper-most expansion members **161**) of the expander tool **120** extend radially outward into contact with the lower string of casing **130** to plastically deform the lower string of casing **130** into frictional contact with the upper string of casing **110** therearound. The expander tool **120** is then rotated in the wellbore **100** independent of the casing **130**. In this manner, a portion of the lower string of casing **130L** below the scribe **200** is expanded circumferentially into contact with the upper string of casing **110**.

After all of the expansion assemblies **160** other than the uppermost expansion members **161** have been actuated, the uppermost expansion members **161** are actuated. Additional fluid pressure from the surface applied into the bore **168** of the expander tool **120** will cause a temporary connection **162** holding the upper expansion members **161** within the body **150** of the expander tool **120** to fail. This, in turn, will cause the pistons **175** of the upper expansion members **161** to move from a first recessed position within the body **150** of the expander tool **120** to a second extended position. Rollers **165** of the uppermost expansion members **161** then act against the inner surface of the lower string of casing **130L** at the depth of the scribe

**200**, causing an additional portion of the lower string of casing **130** to be expanded against the upper string of casing **110**.

As the uppermost expansion members **161** contact the lower string of casing **130**, a scribe **200** formed on the outer surface of the lower string of casing **130** causes the casing **130** to break into upper **130U** and lower **130L** portions. Because the lower portion of the casing **130L** has been completely expanded into contact with the upper string of casing **110**, the lower portion of the lower string of casing **130L** is successfully hung in the wellbore **100**. The apparatus **105**, including the expander tool **120**, the working string **115** and the upper portion of the top end of the lower string of casing **130U** can then be removed, leaving a sealed overlap between the lower string of casing **130** and the upper string of casing **110**, as illustrated in **Figure 8**.

**Figures 5A-5D** depict a series of expansions in sequential stages. The above discussion outlines one embodiment of the method of the present invention for expanding and separating tubulars in a wellbore through sequential stages. However, it is within the scope of the present invention to conduct the expansion in a single stage. In this respect, the method of the present invention encompasses the expansion of rollers **165** at all rows at the same time. Further, the present invention encompasses the use of a rotary expander tool **120** of any configuration, including one in which only one row of roller assemblies **160** is utilized. With this arrangement, the rollers **165** would need to be positioned at the depth of the scribe **200** for expansion. Alternatively, the additional step of raising the expander tool **120** across the depth of the scribe **200** would be taken. Vertically translating the expander tool **120** could be accomplished by raising the working string **115** or by utilizing an actuation apparatus downhole (not shown) which would translate the expander tool **120** without raising the drill string **115**.

It is also within the scope of the present invention to utilize a swaged cone (not shown) in order to expand a tubular in accordance with the present invention. A swaged conical expander tool expands by being pushed or otherwise translated through a section of tubular to be expanded. Thus, the present invention is not limited by the type of expander tool employed.

As a further aid in the expansion of the lower casing string **130**, a torque anchor may optionally be utilized. The torque anchor serves to prevent rotation of the lower string of casing **130** during the expansion process. Those of ordinary skill in the art may perceive that the radially outward force applied by the rollers **165**, when combined with rotation of the expander tool **120**, could cause some rotation of the casing **130**.

In one embodiment, the torque anchor **140** defines a set of slip members **141** disposed radially around the lower string of casing **130**. In the embodiment of **Figure 1**, the slip members **141** define at least two radially extendable pads with surfaces having gripping formations like teeth formed thereon to prevent rotational movement. In **FIG. 1**, the anchor **140** is in its recessed position, meaning that the pads **141** are substantially within the plane of the lower casing string **130**. The pads **141** are not in contact with the upper casing string **110** so as to facilitate the run-in of the apparatus **105**. The pads **141** are selectively actuated either hydraulically or mechanically or both as is known in the art.

In the views of **FIG. 6 and FIG. 7**, the anchor **140** is in its extended position. This means that the pads **141** have been actuated to engage the inner surface of the upper string of casing **110**. This position allows the lower string of casing **130** to be fixed in place while the lower string of casing **130** is expanded into the wellbore **100**.

An alternative embodiment for a torque anchor **250** is presented in **Figure 9**. In this embodiment, the torque anchor **250** defines a body having sets of wheels **254U** and **254L** radially disposed around its perimeter. The wheels **254U** and **254L** reside within wheel housings **253**, and are oriented to permit axial (vertical) movement, but not radial movement, of the torque anchor **250**. Sharp edges (not shown) along the wheels **254U** and **254L** aid in inhibiting radial movement of the torque anchor **250**. In the preferred embodiment, four sets of wheels **254U** and **254L** are employed to act against the upper casing **110** and the lower casing **130**, respectively.

The torque anchor **250** is run into the wellbore **100** on the working string **115** along with the expander tool **120** and the lower casing string **130**. The run-in position of the torque anchor **250** is shown in **Figure 9**. In this position, the wheel housings **253** are maintained essentially within the torque anchor body **250**. Once the lower string of casing **130** has been

lowered to the appropriate depth within the wellbore **100**, the torque anchor **250** is activated. Fluid pressure provided from the surface through the working tubular **115** acts against the wheel housings **253** to force the wheels **254C** and **254L** outward from the torque anchor body **250**. Wheels **254C** act against the inner surface of the upper casing string **130**, while wheels **254L** act against the inner surface of the lower casing string **130**. This activated position is depicted in **Figure 10**.

A rotating sleeve **251** resides longitudinally within the torque anchor **250**. The sleeve **251** rotates independent of the torque anchor body **250**. Rotation is imparted by the working tubular **115**. In turn, the sleeve provides the rotational force to rotate the expander **120**.

After the lower casing string **130L** has been expanded into frictional contact with the inner wall of the upper casing string **110**, the expander tool **120** is deactivated. In this regard, fluid pressure supplied to the pistons **175** is reduced or released, allowing the pistons **175** to return to the recesses **155** within the central body **150** of the tool **120**. The expander tool **120** can then be withdrawn from the wellbore **100** by pulling the run-in tubular **115**.

Although the invention has been described in terms of preferred embodiments as set forth above, it should be understood that these embodiments are illustrative only and that the claims are not limited to those embodiments. Those skilled in the art will be able to make modifications and alternatives in view of the disclosure which are contemplated as falling within the scope of the appended claims. In this respect, it is within the scope of the present inventions to expand a tubular having a scribe into the formation itself, rather than into a separate string of casing. In this embodiment, the formation becomes the surrounding tubular. Thus, the present invention has applicability in an open hole environment.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. An expander tool for expanding a tubular, the tool comprising:  
a body having a bore longitudinally formed therein;  
at least one first roller member radially extendable from the body into contact with a surrounding inside surface of the tubular; and  
at least one second roller member constructed and arranged to extend from the body after the at least one first roller member has been extended therefrom.
2. The expander tool of claim 1, wherein the at least one first roller member and the at least one second roller member are arranged to extend due to fluid pressure applied from the bore to a piston surface formed on a roller housing.
3. The expander tool of claim 1 or 2, wherein, in use, the first roller member is situated lower than the second roller member.
4. The expander tool of any one of claims 1 to 3, further comprising a torque anchor.
5. The expander tool of any one of claims 1 to 4, wherein the at least one first roller member is radially extendable to expand the tubular.
6. The expander tool of claim 2, wherein the fluid pressure required to radially extend the at least one second roller member is greater than the fluid pressure required to extend the at least one first roller member.
7. The expander tool of claim 2, wherein a first fluid pressure is arranged to be applied from the bore to extend the at least one first roller member and a second, increased fluid pressure is arranged to be applied from the bore to extend the at least one second roller member.

8. The expander tool of any one of claims 1 to 7, wherein a temporary connection prevents the at least one second roller member from extending from the body prior to the at least one first roller member.
9. The expander tool of claim 8, wherein the at least one second roller member is extendable from the body upon application of a predetermined radial force applied from the bore to disconnect the temporary connection.
10. The expander tool of claim 9, wherein the predetermined radial force is fluid pressure.
11. The expander tool of claim 10, wherein the temporary connection is a shearable member.
12. The expander tool of any one of claims 1 to 11, wherein a plurality of first roller members are spirally disposed around the body at varying axial locations.
13. The expander tool of claim 2, wherein the fluid pressure is arranged to cause the piston surface to move from within the body to a radially extended position outside the body.
14. An expander tool for expanding a tubular, comprising:
  - a body having a longitudinal bore therein; and
  - at least two expansion members radially extendable from the body into contact with a surrounding inside surface of the tubular, wherein the at least two expansion members are radially extendable at different times.
15. The expander tool of claim 14, wherein the at least two expansion members are arranged to expand the tubular at different locations.
16. The expander tool of claim 14, wherein the at least two expansion members are axially spaced.

17. The expander tool of claim 16, wherein the at least two expansion members are arranged to expand the tubular at axially spaced locations.
18. The expander tool of claim 16, wherein one of the at least two expansion members is arranged to expand the tubular at a first location before the other one of the at least two expansion members is arranged to expand the tubular at a second location axially spaced from the first location.
19. The expander tool of claim 16, wherein the at least two expansion members are arranged to expand a circumferential area of the tubular by rotation of the at least two expansion members.
20. The expander tool of any one of claims 16 to 19, wherein the body is supported by a work string.
21. The expander tool of claim 20, wherein the longitudinal bore of the body is in fluid communication with the work string.
22. The expander tool of any one of claims 16 to 21, wherein each of the at least two expansion members are in fluid communication with the longitudinal bore of the body.
23. The expander tool of any one of claims 16 to 22, wherein the tubular is supported by the body of the expander tool.
24. The expander tool of any one of claims 16 to 23, further comprising a plurality of dogs radially disposed about the body of the expander tool, wherein the plurality of dogs are adapted to engage an inside surface of the tubular to support the tubular.
25. The expander tool of claim 24, wherein the plurality of dogs are radially disposed about the body of the expander tool in a circumferential profile.

26. The expander tool of claim 24, further comprising a swivel, wherein the swivel allows a portion of the body of the expander tool to rotate while the plurality of dogs remain stationary.
27. The expander tool of any one of claims 16 to 26, wherein each of the at least two expansion members comprise:  
a roller;  
a radially movable piston coupled to the roller, wherein the piston is in fluid communication with the longitudinal bore; and  
a connection member, wherein the connection member temporarily prevents radial movement of the piston.
28. The expander tool of claim 27, wherein the connection member of one of the at least two expansion members is arranged to prevent radial movement of the piston longer than the connection member of the other one of the at least two expansion members.
29. The expander tool of claim 27, wherein the connection member is a shearable pin.
30. The expander tool of any one of claims 1 to 29, wherein the at least two expansion members are spirally disposed about the body.
31. A method of expanding a tubular, comprising:  
providing an expander tool within a tubular, the expander tool comprising at least two expansion members radially extendable from a body having a longitudinal bore therethrough;  
radially extending one of the at least two expansion members into contact with an inside surface of the tubular; and  
thereafter radially extending another of the at least two expansion members into contact with the inside surface of the tubular.
32. The method of claim 31, wherein the expansion tool comprises a plurality of expansion members, each expansion member radially extending from the body at a different time.

33. The method of claim 31 or 32, wherein the at least two expansion members radially extend in response to pressurized fluid within the bore.
34. The method of claim 31, wherein the step of radially extending one of the at least two expansion members into contact with an inside surface of the tubular comprises radially extending one of the at least two expansion members into contact with an inside surface of the tubular to expand a first area of the tubular; and  
wherein, the step of thereafter radially extending another of the at least two expansion members into contact with the inside surface of the tubular comprises thereafter radially extending another of the at least two expansion members into contact with the inside surface of the tubular to expand a second area of the tubular, wherein the first and second areas are axially spaced from one another.
35. The method of claim 34, wherein the at least two expansion members radially extend in response to pressurized fluid within the longitudinal bore.
36. The method of claim 34 or 35, further comprising providing a first fluid pressure to extend one of the at least two expansion members, and providing a second fluid pressure to extend the other one of the at least two expansion members, wherein the second fluid pressure is greater than the first fluid pressure.
37. The method of any one of claims 34 to 36, further comprising rotating the at least two expansion members to form an expanded circumferential area of the tubular.
38. The method of claim 37, further comprising supporting the tubular with the body of the expander tool while rotating the at least two expansion members.
39. A method of expanding a tubular, comprising:  
running an expansion assembly that is supporting a tubular into a wellbore;  
actuating the expansion assembly to expand a first portion of the tubular while preventing expansion of a second portion of the tubular; and  
actuating the expansion assembly to expand the second portion of the tubular,

thereby severing the second portion of the tubular from the first portion of the tubular.

40. The method of claim 39, further comprising rotating the expansion assembly to circumferentially expand the first portion of the tubular.

41. The method of claim 40, further comprising rotating the expansion assembly to circumferentially expand the second portion of the tubular.

42. The method of claim 41, further comprising preventing rotation of the tubular relative to the wellbore when rotating the expansion assembly.

43. The method of claim 42, further comprising removing the second portion of the tubular and the expansion assembly from the wellbore.

44. The method of any one of claims 39 to 43, wherein actuating the expansion assembly to expand the second portion of the tubular includes shearing a shearable member of the expansion assembly.

45. The method of claim 44, wherein the expansion assembly includes a first radially extendable member configured to expand the first portion of the tubular and a second radially extendable member configured to expand the second portion of the tubular.

46. The method of claim 45, further comprising preventing the second radially extendable member from expanding the second portion of the tubular with the shearable member while expanding the first portion of the tubular with the first radially extendable member.

47. The method of claim 46, further comprising shearing the shearable member with the second radially extendable member and expanding the second portion of the tubular with the second radially extendable member.

48. A method of expanding a tubular, comprising:

running a tubular that is supported by an expansion assembly having a first member and a second member into a wellbore;

actuating the first member to expand a first portion of the tubular while preventing actuation of the second member; and

actuating the second member to expand a second portion of the tubular.

49. The method of claim 48, further comprising severing the second portion of the tubular from the first portion of the tubular during expansion of the second portion of the tubular.

50. The method of claim 48 or 49, further comprising rotating the expansion assembly to circumferentially expand the first and second portions of the tubular.

51. The method of any one of claims 48 to 50, wherein preventing actuation of the second member includes preventing extension of the second member with a shearable member while expanding the first portion of the tubular with the first member.

52. The method of claim 51, wherein actuating the second member to expand the second portion of the tubular includes shearing the shearable member using the second member.

53. An apparatus for expanding a tubular, comprising:

a body having a bore disposed through the body;

a first member that is radially extendable from the body; and

a second member that is radially extendable from the body and is configured to extend from the body after extension of the first member.

54. The apparatus of claim 53, wherein the second member is located above the first member.

55. The apparatus of claim 54, wherein the first and second members are in fluid communication with the bore.

56. The apparatus of claim 55, further comprising a shearable member coupled to the body and configured to temporarily prevent extension of the second member while the first member is extended.

57. The apparatus of claim 56, wherein the first and second members comprise rollers.

58. The apparatus of claim 57, wherein the first and second members are longitudinally offset.

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Fig. 1

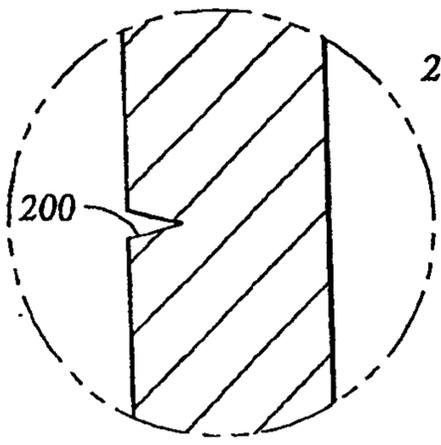
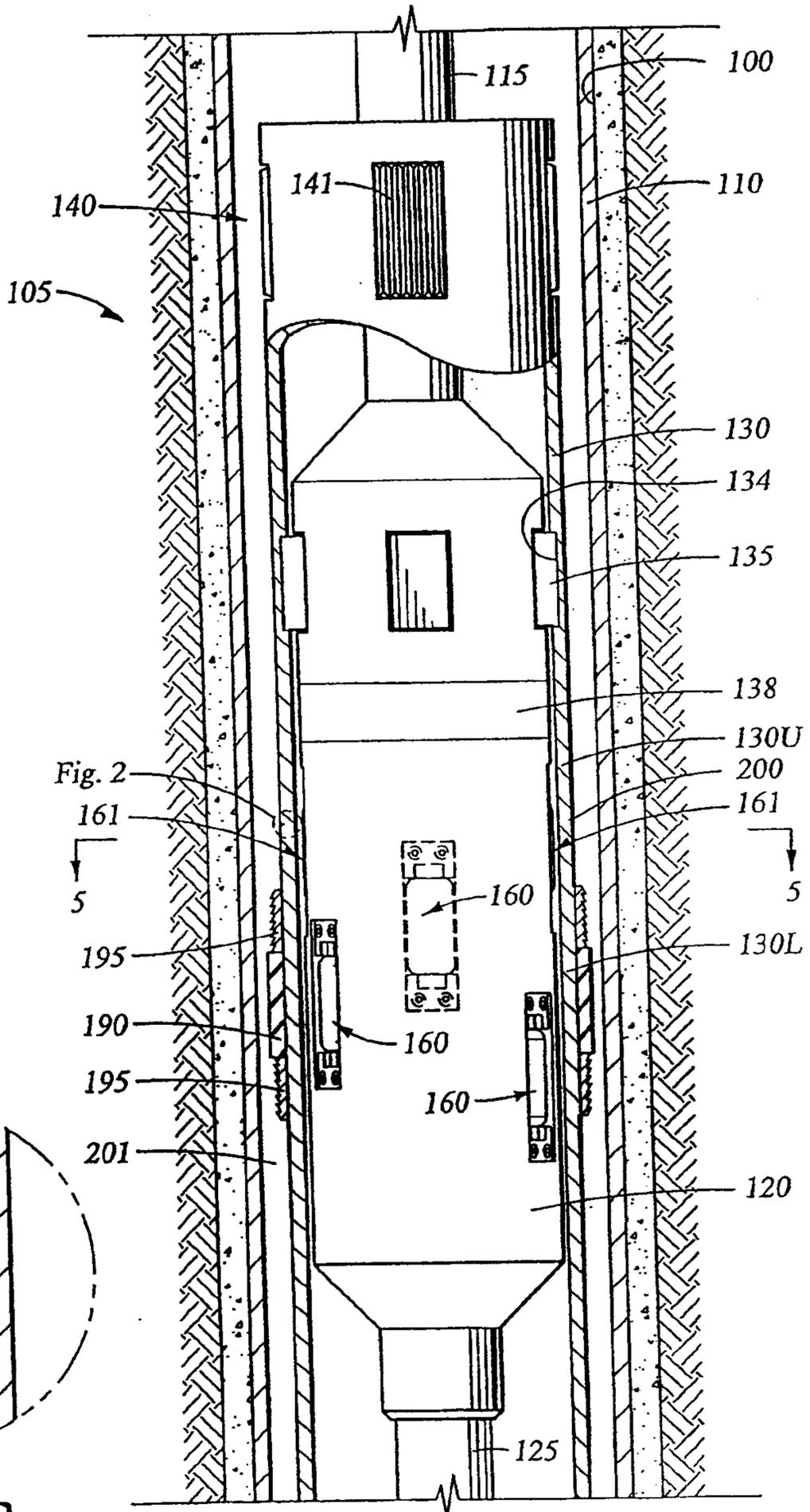


Fig. 2

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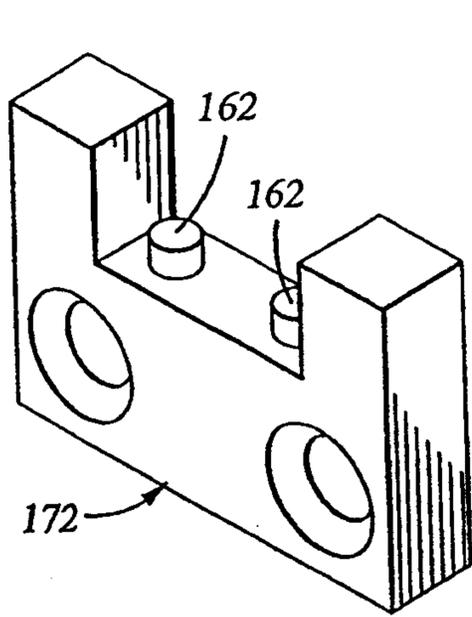


Fig. 4

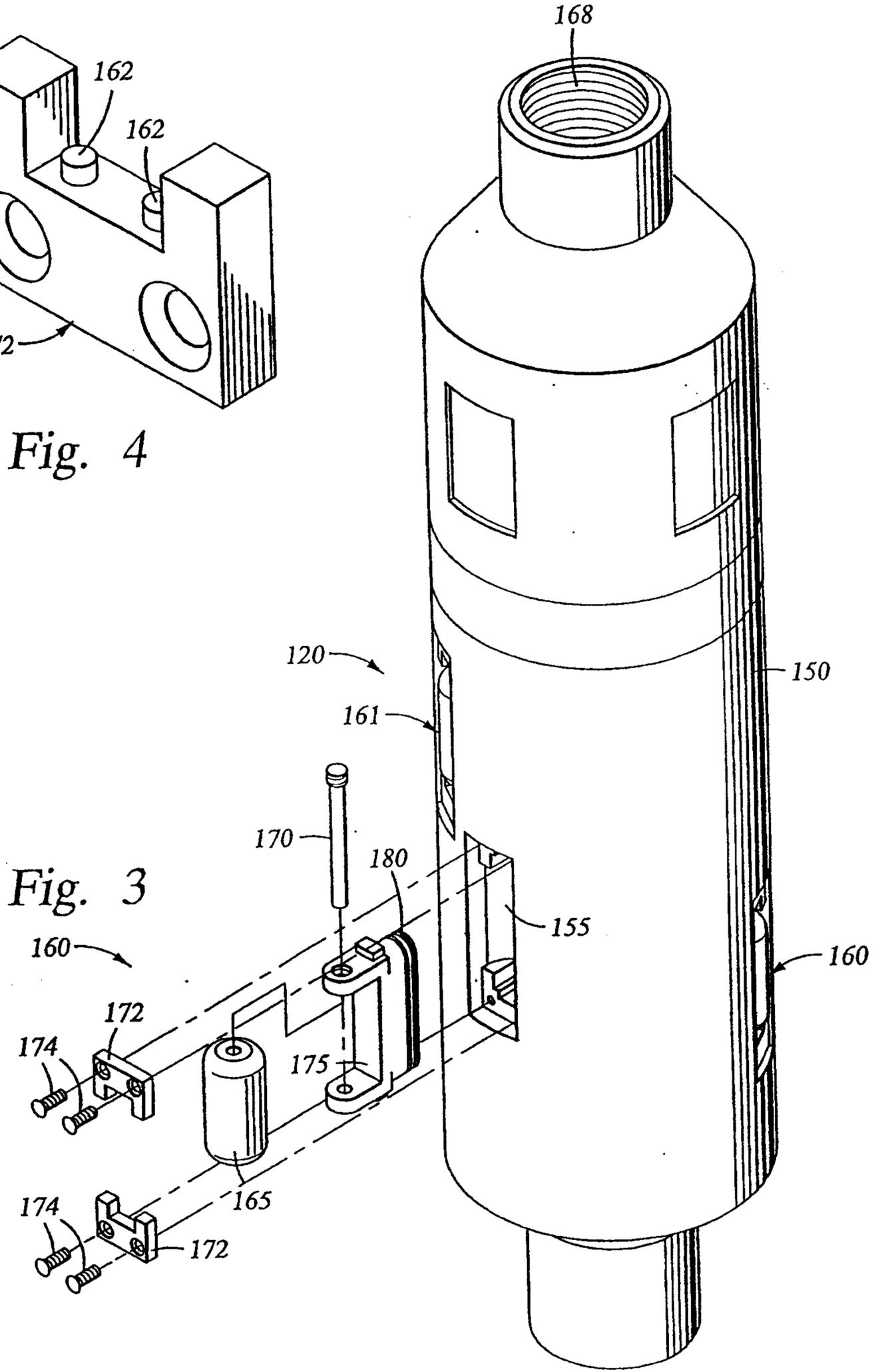


Fig. 3

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Fig. 5A

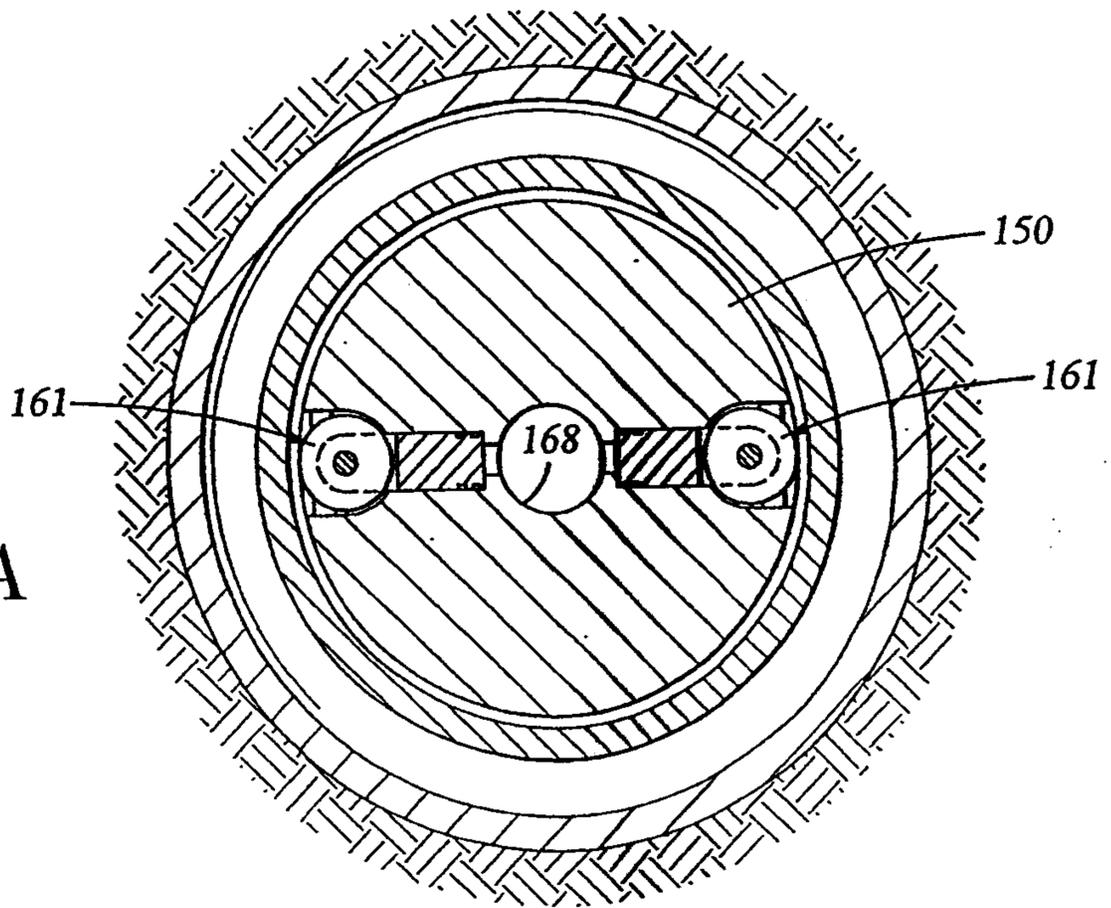
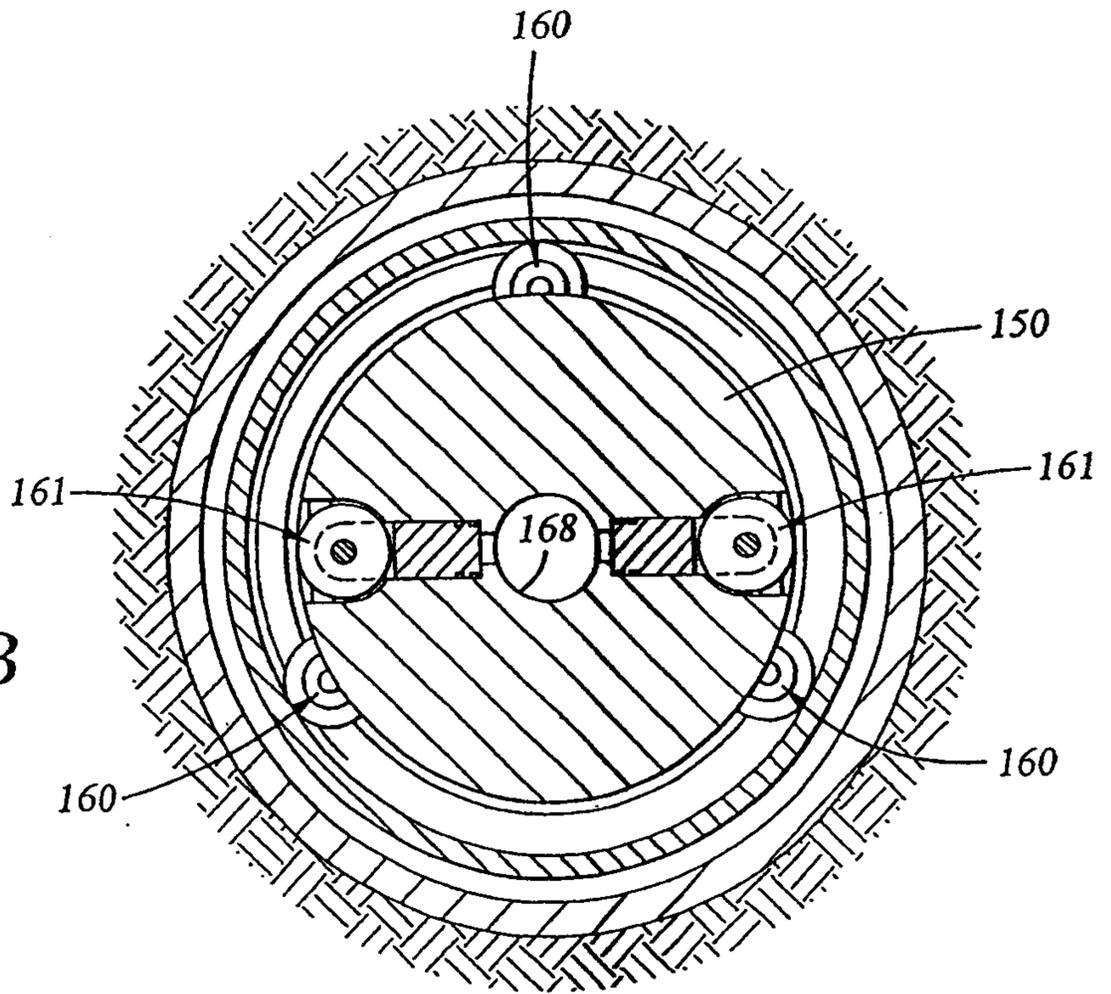


Fig. 5B



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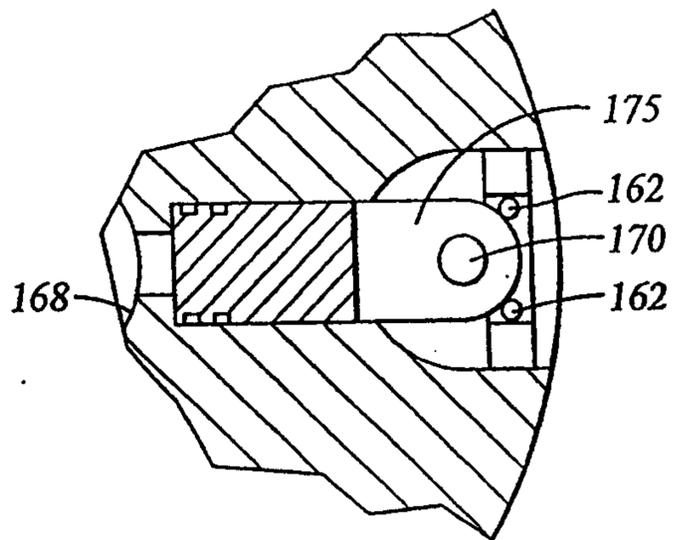


Fig. 5C

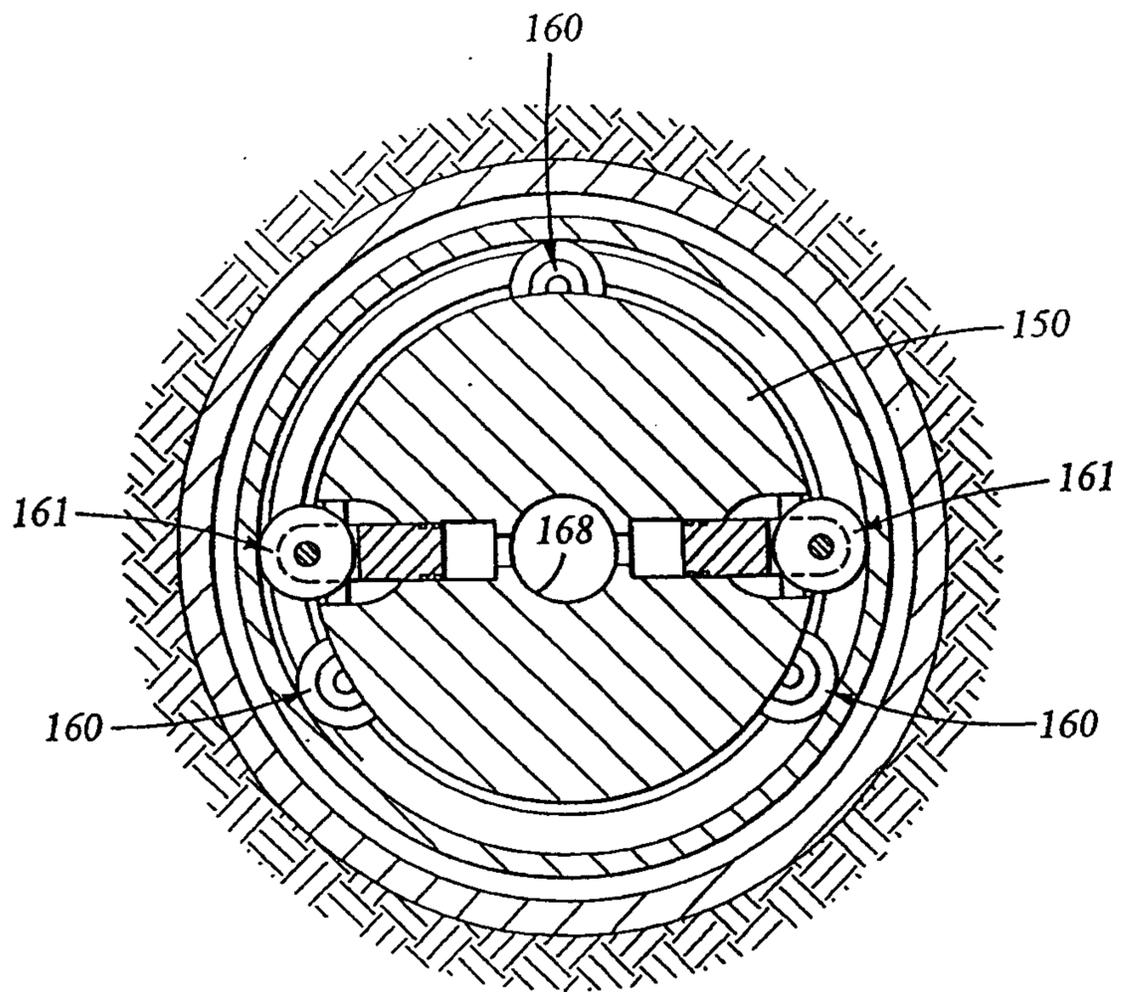


Fig. 5D

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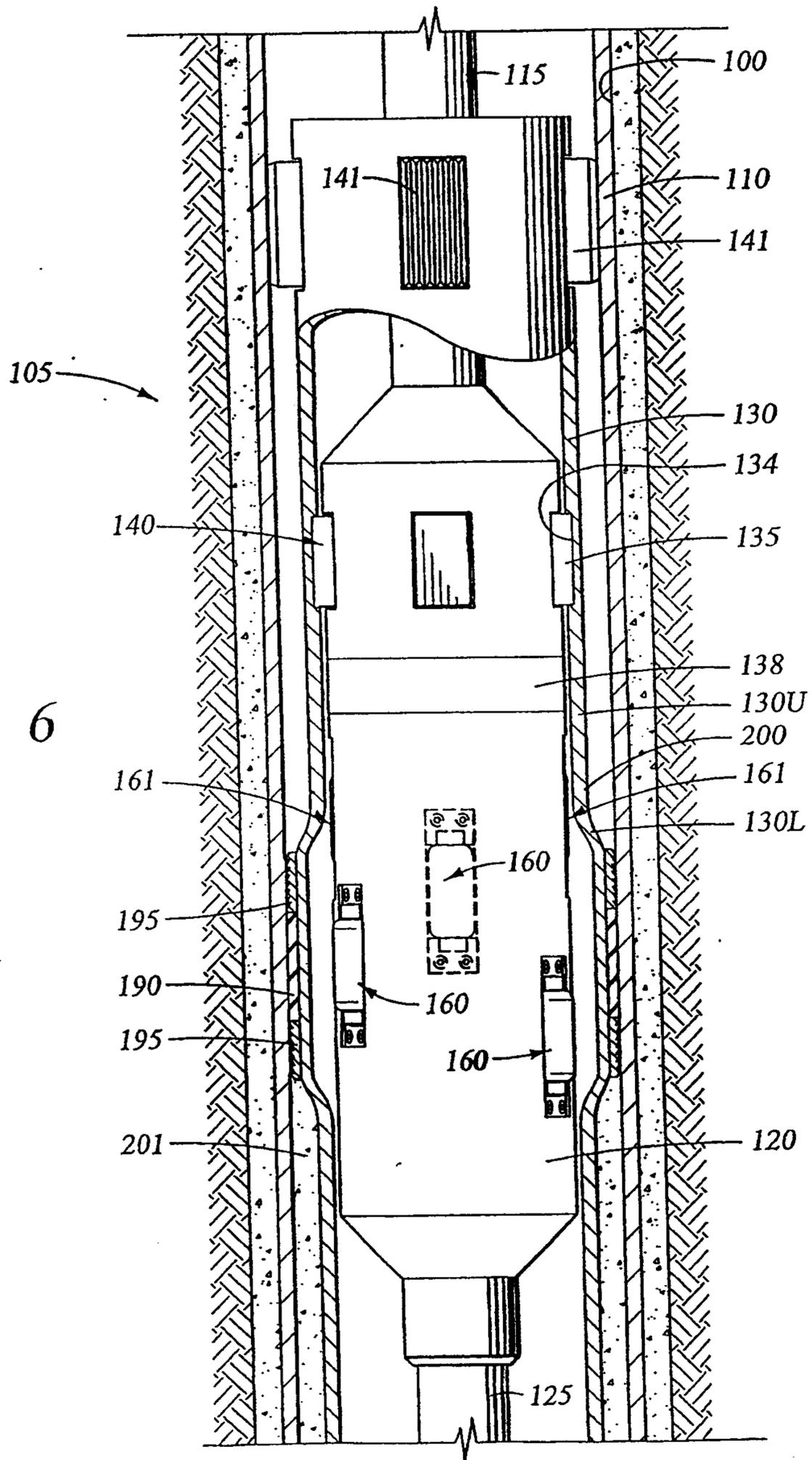


Fig. 6

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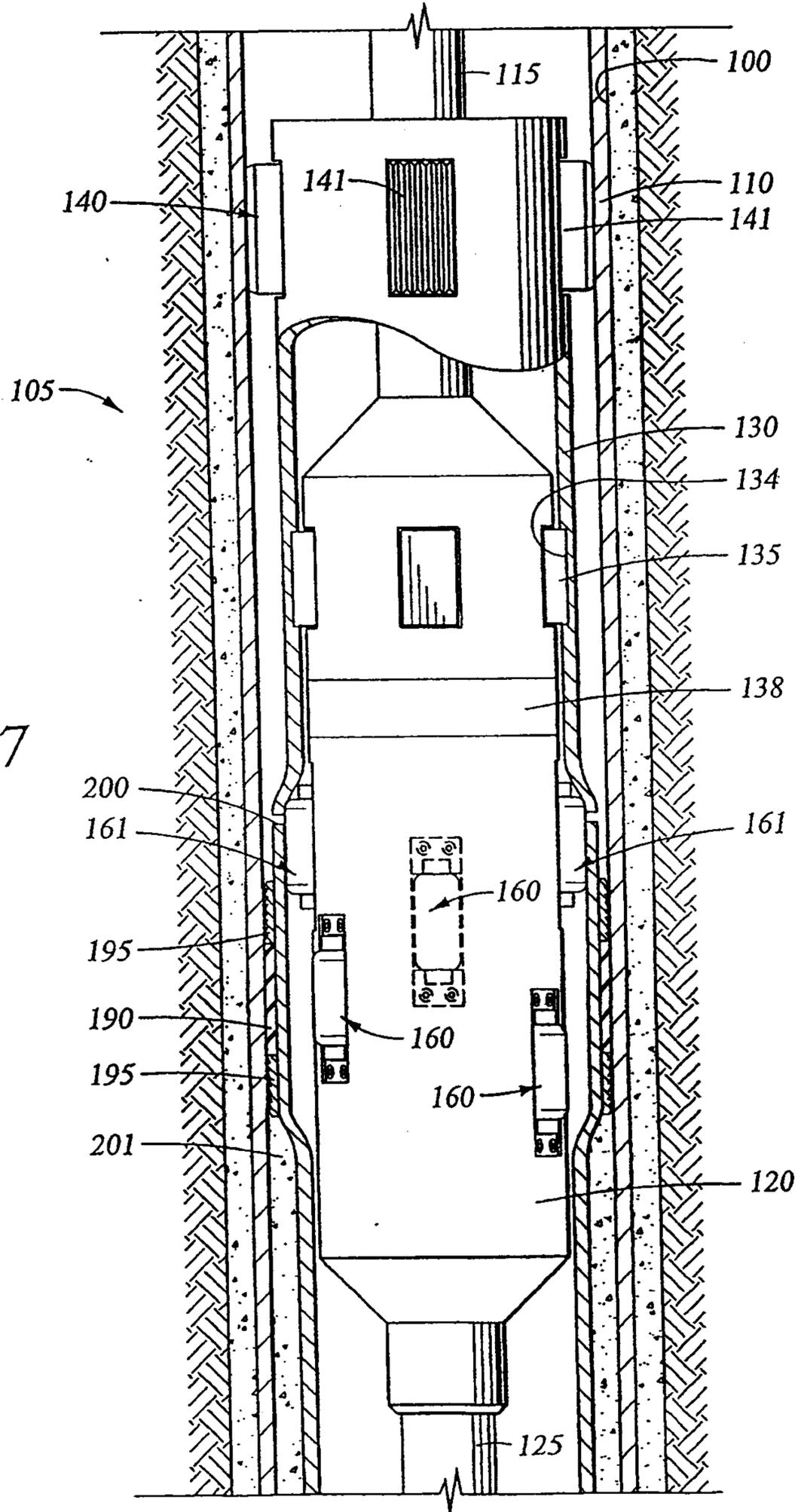
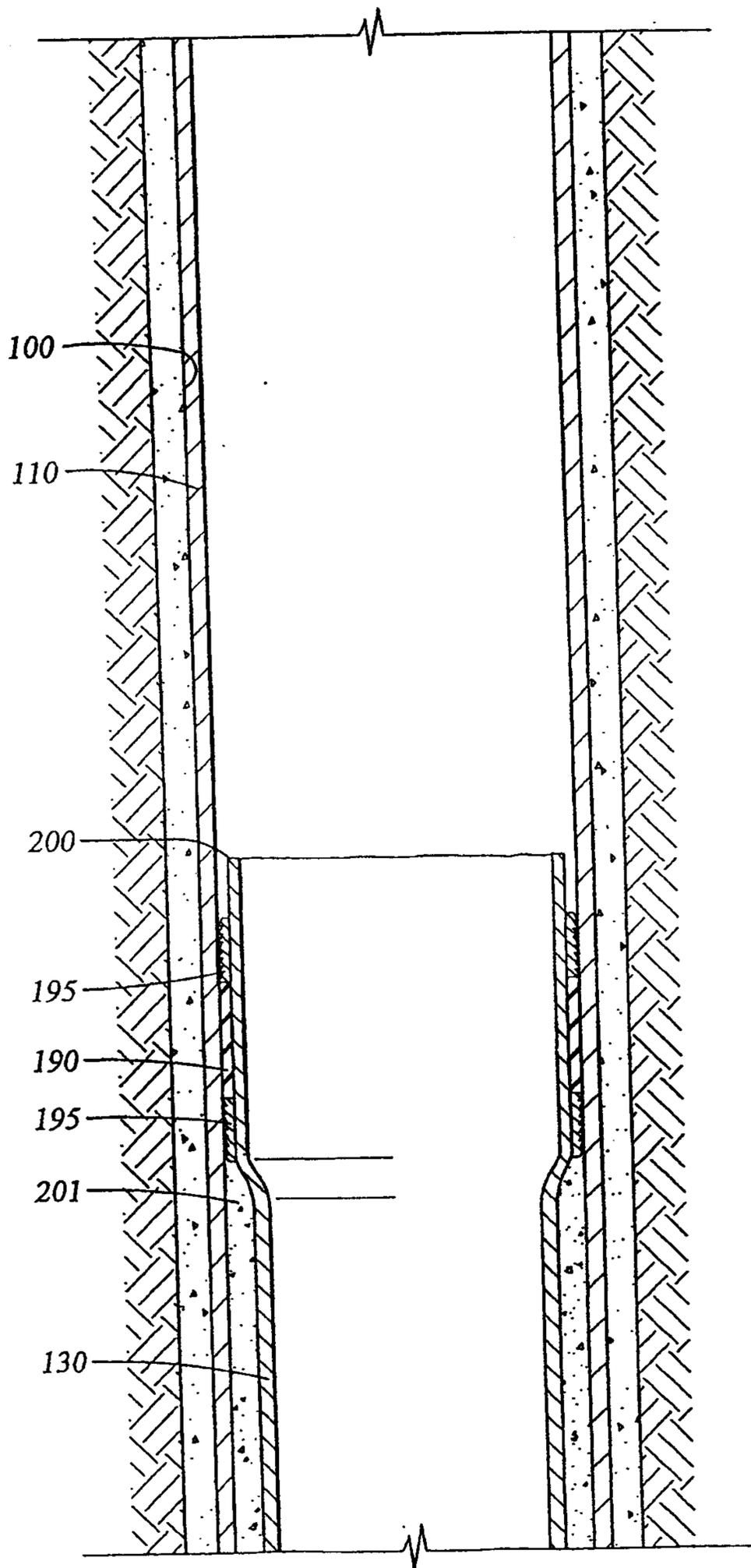


Fig. 7

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Fig. 8



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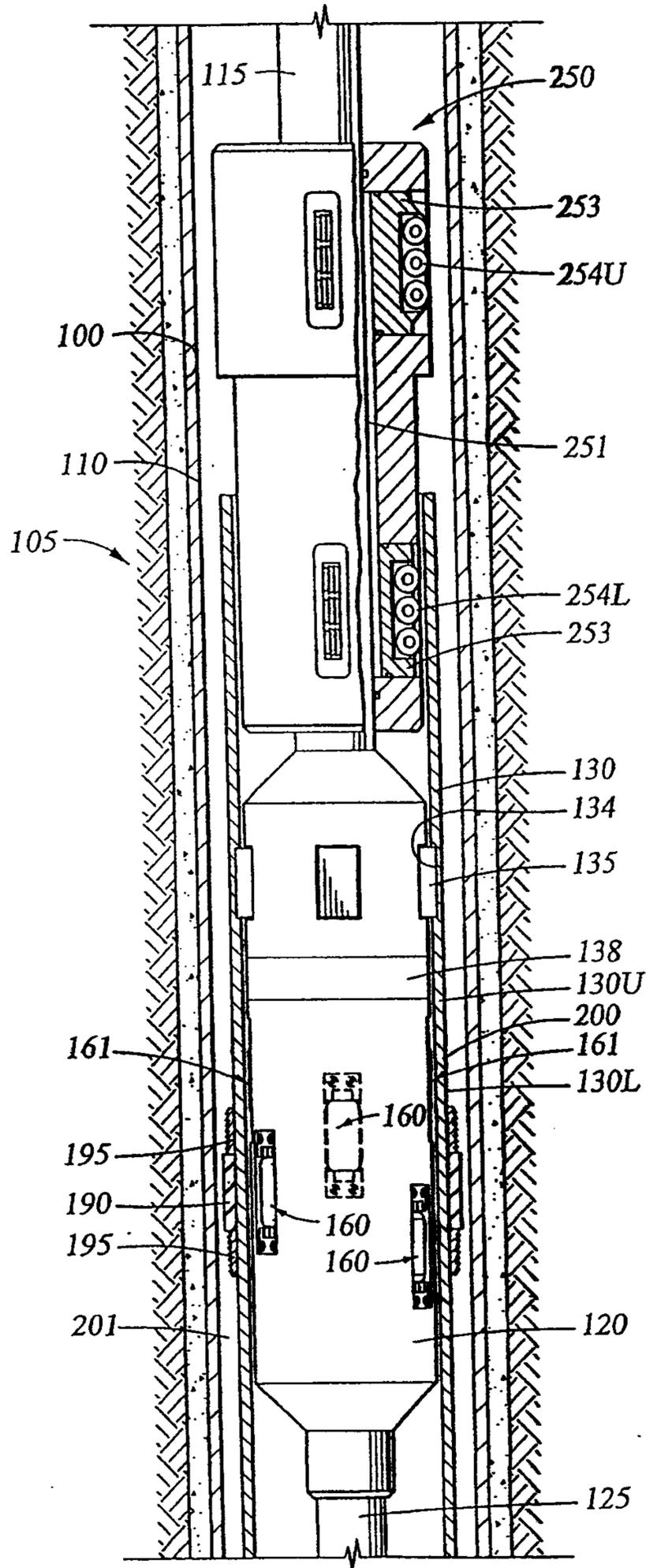


Fig. 9

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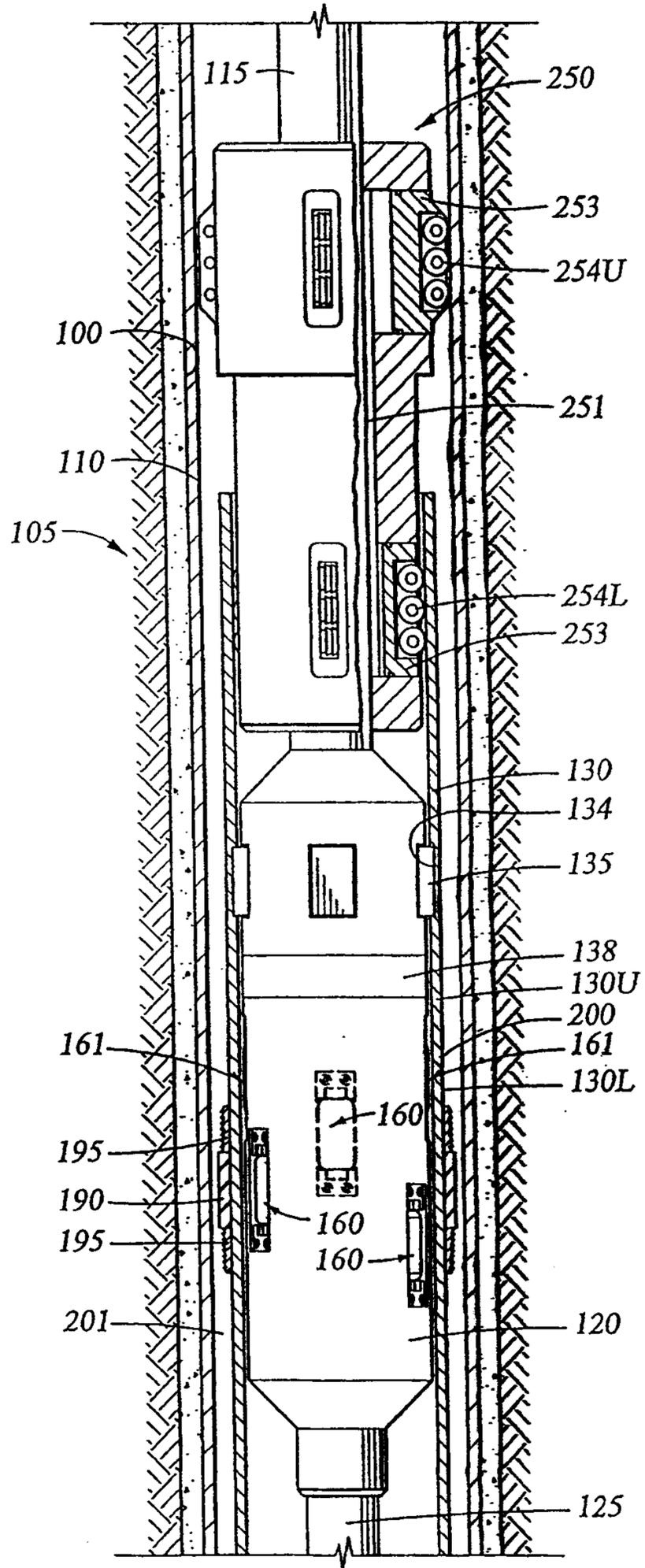


Fig. 10

