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(54) Well casing

(57) The invention relates to a well casing 11 comprising at least two casing lengths 12, 13, 14, 15, 16 with a first casing section 12 having an outside diameter OD₁₂ and an inside diameter ID₁₂ being fitted and cemented in position extending downwardly from the top of the well. The remaining sections are installed subsequently, each subsequent casing section 13, 14, 15, 16 having an outside diameter OD₁₃, OD₁₄, OD₁₅, OD₁₆ and an inside diameter ID₁₃, ID₁₄, ID₁₅, ID₁₆ and the outside diameter OD₁₃, OD₁₄, OD₁₅, OD₁₆ of each section 13, 14, 15, 16 being less than the internal diameter ID₁₂, ID₁₃, ID₁₄, ID₁₅ of the previously installed sections 12, 13, 14, 15 by an amount which is just sufficient for each subsequent sections 13, 14, 15, 16 to pass down through the internal bore of the previously installed section 12, 13, 14, 15. Preferably the average diametrical difference D₁, D₂, D₃, D₄ is less than W mm such that the outside diameter OD₁₂ of the first section 12 can be as small as possible and is at most equivalent to:

$$OD_{12} = (W \times (n-1) + 2 \times T \times n) + ID_{16}$$

where T is the average wall thickness of the casing sections 13, 14, 15, 16; ID₁₆ is the internal diameter of the last section; n is the number of casing sections and W is the average of the diametrical differences. When the well casing is made of continuous coiled tubing W is less than 15 mm and greater than 0.1 mm. When the well casing is made of joined tubing W is less than 25 mm and greater than 1 mm.

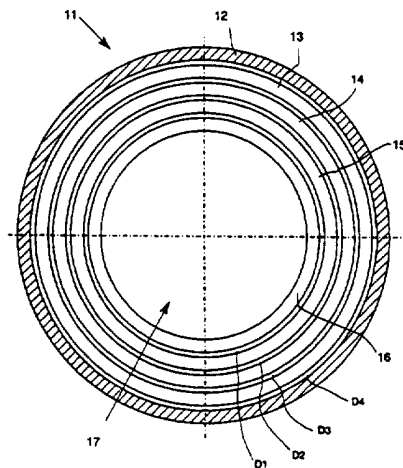


Figure 3

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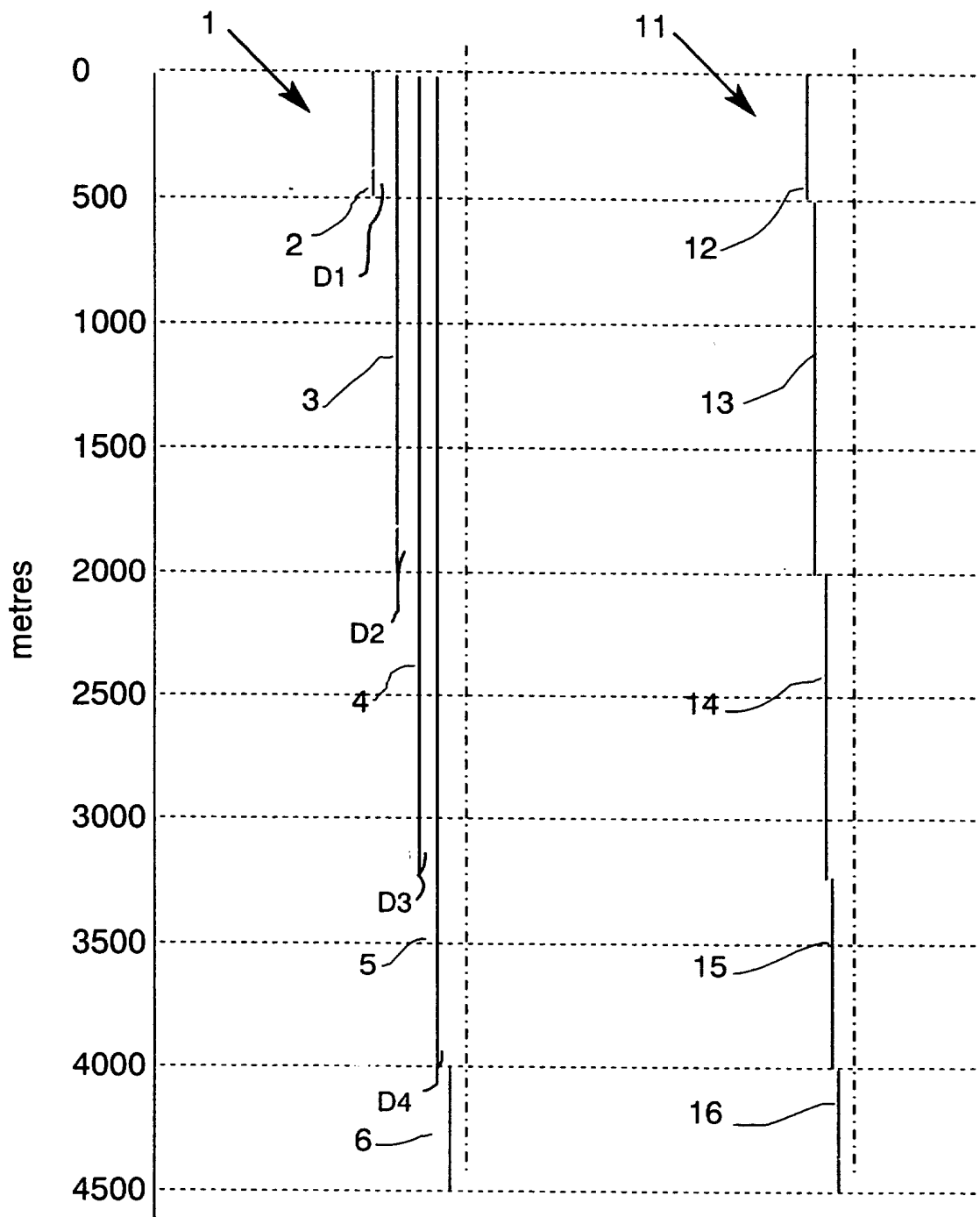


Figure 1

Figure 2

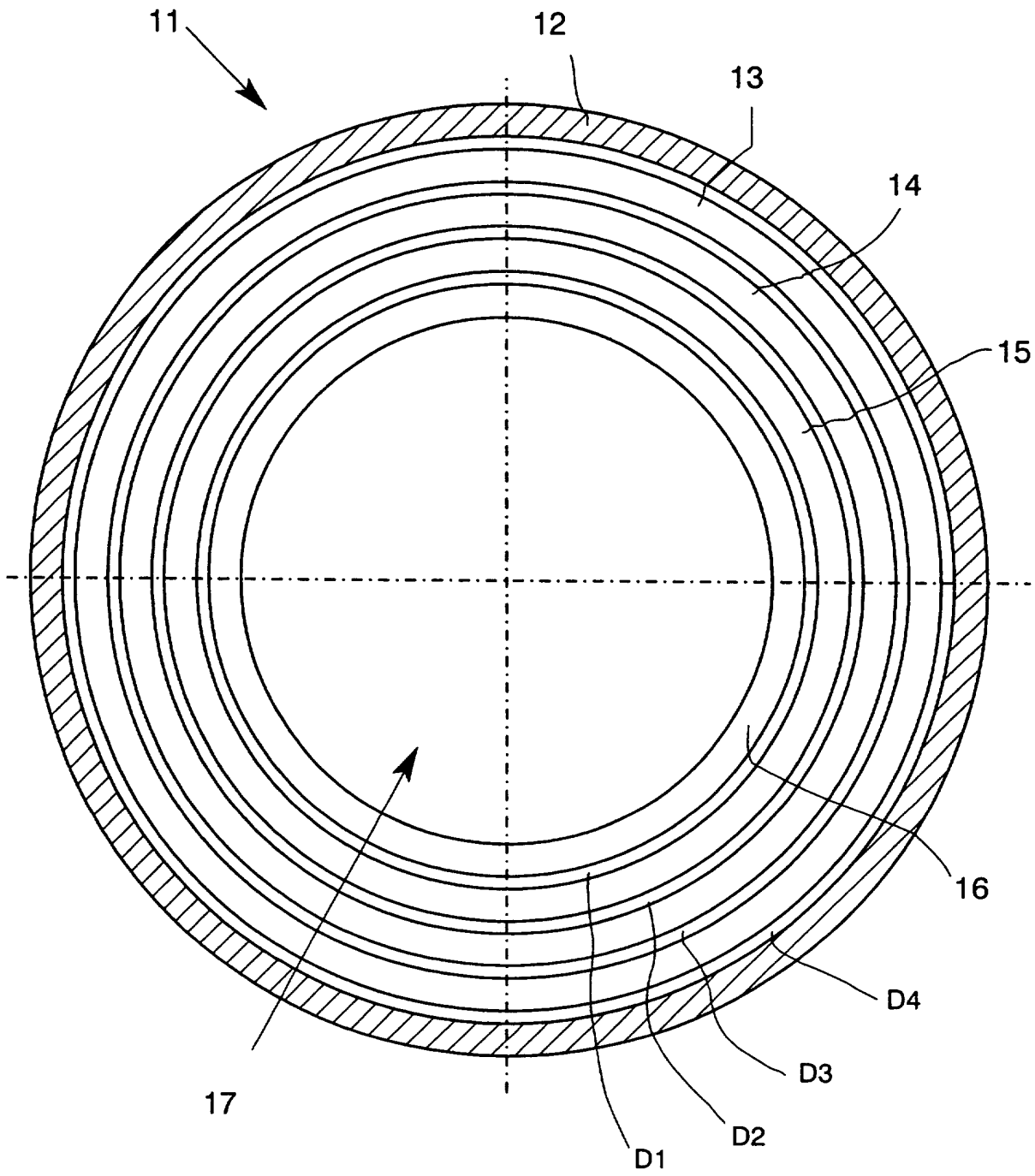


Figure 3

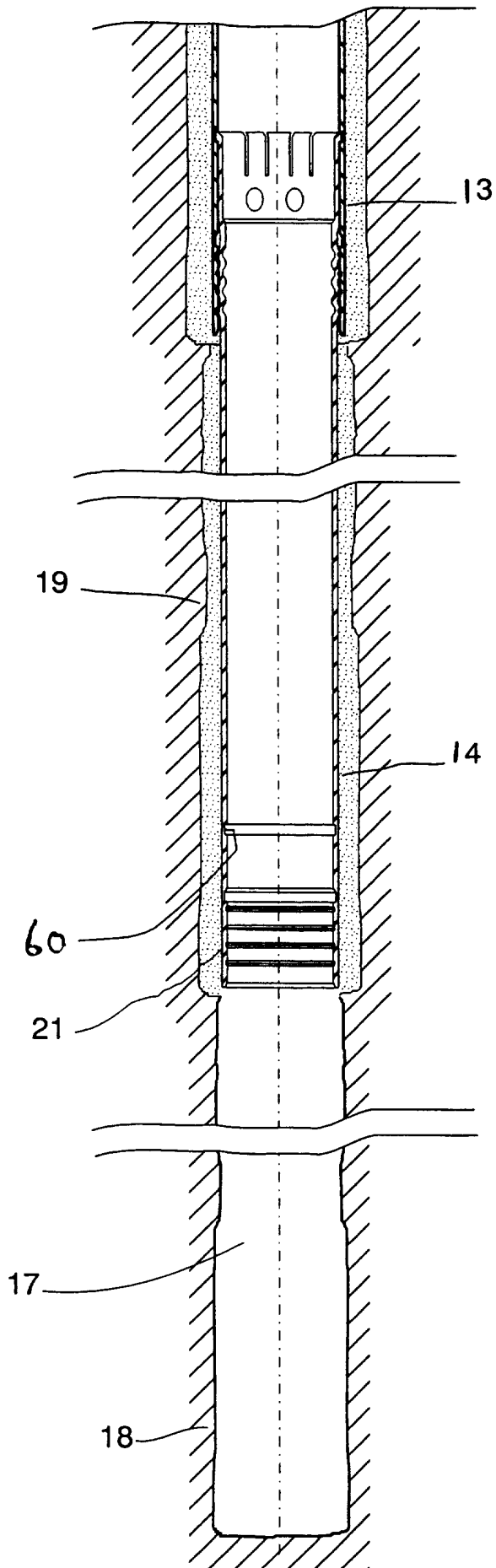


Figure 4

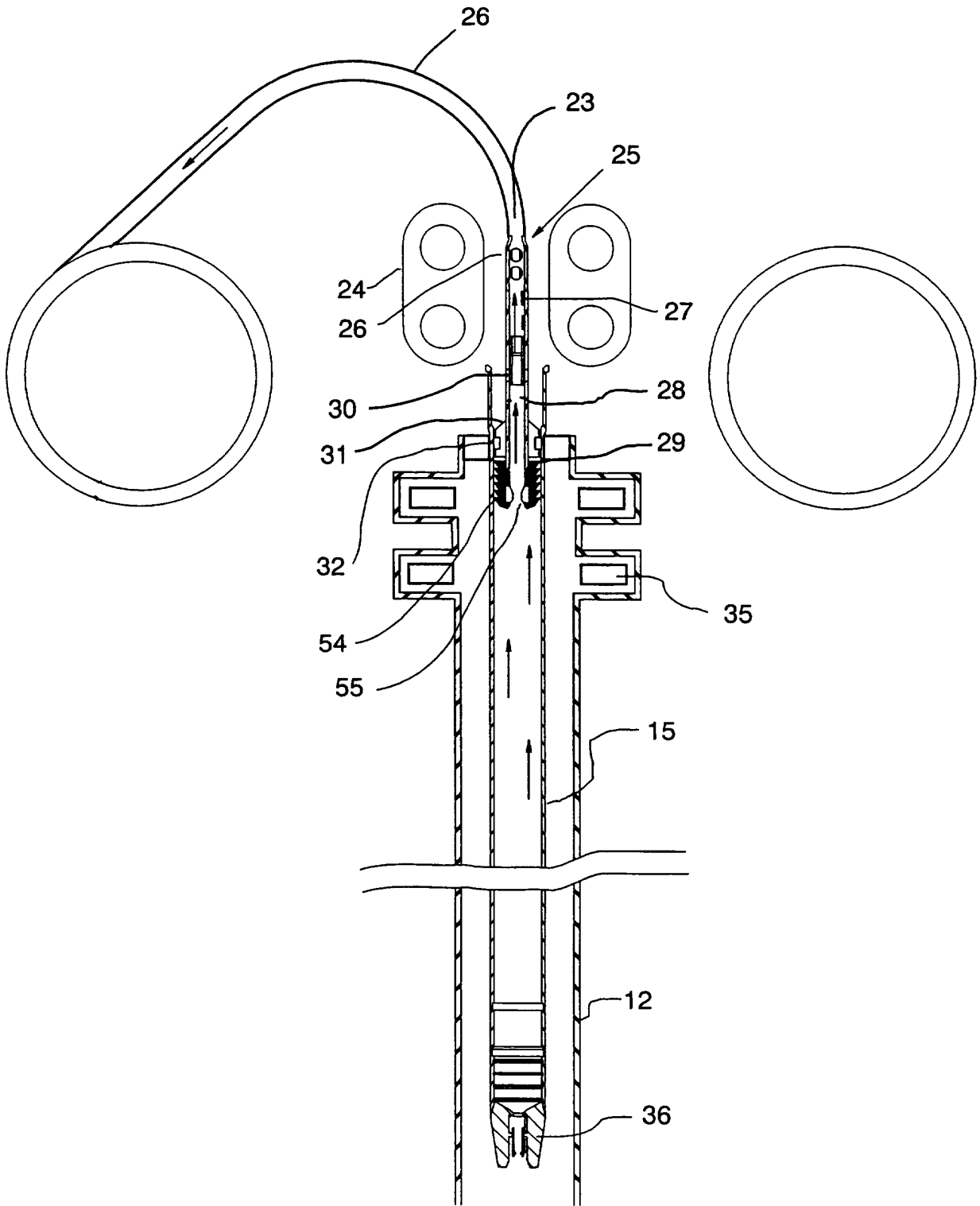


Figure 5

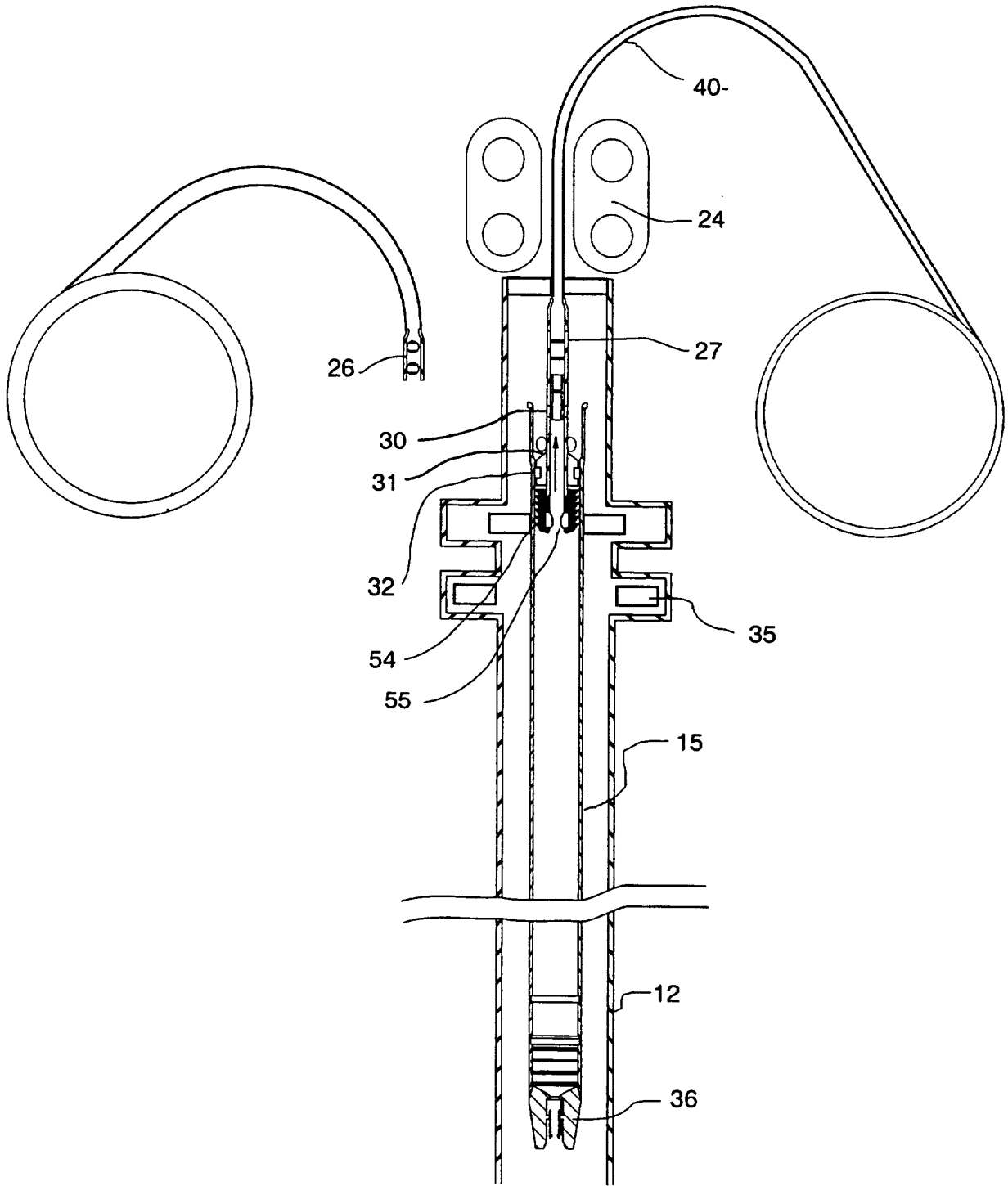


Figure 6

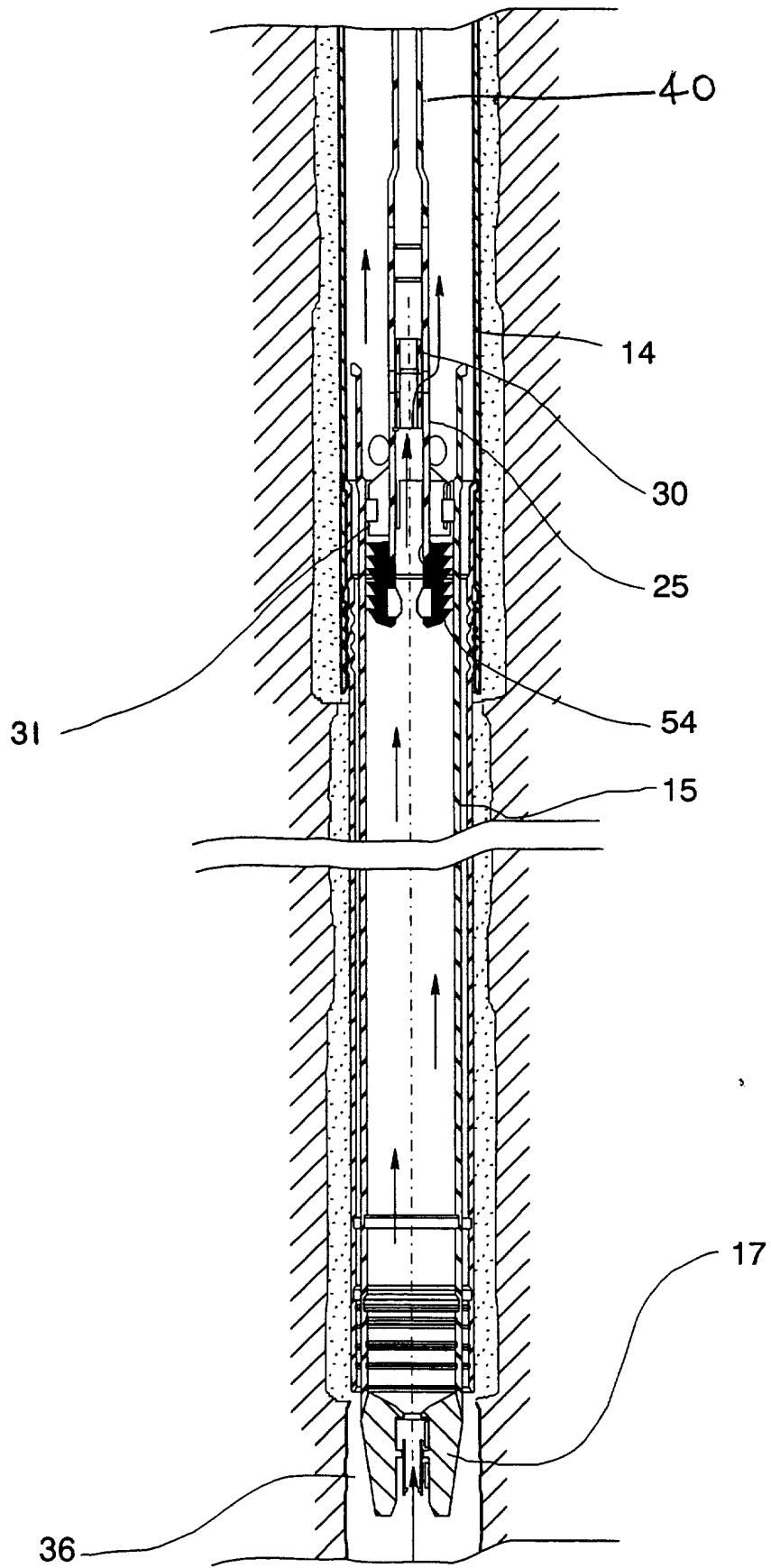


Figure 7

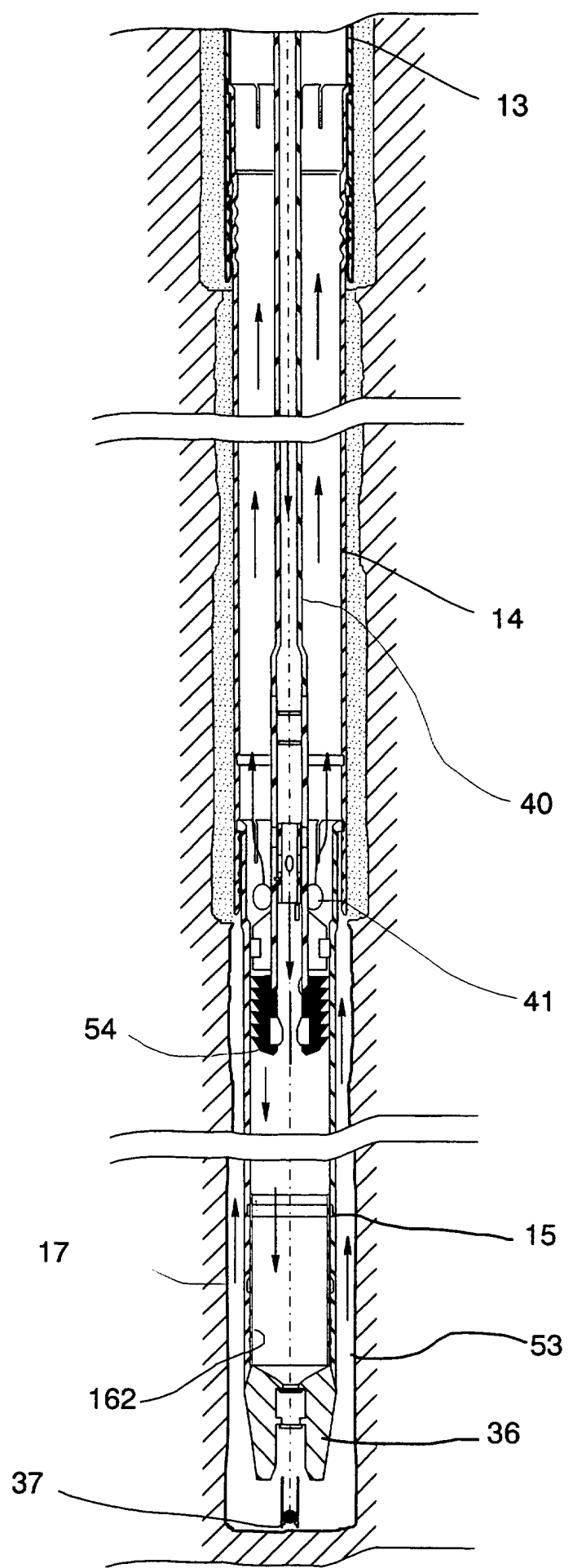


Figure 8

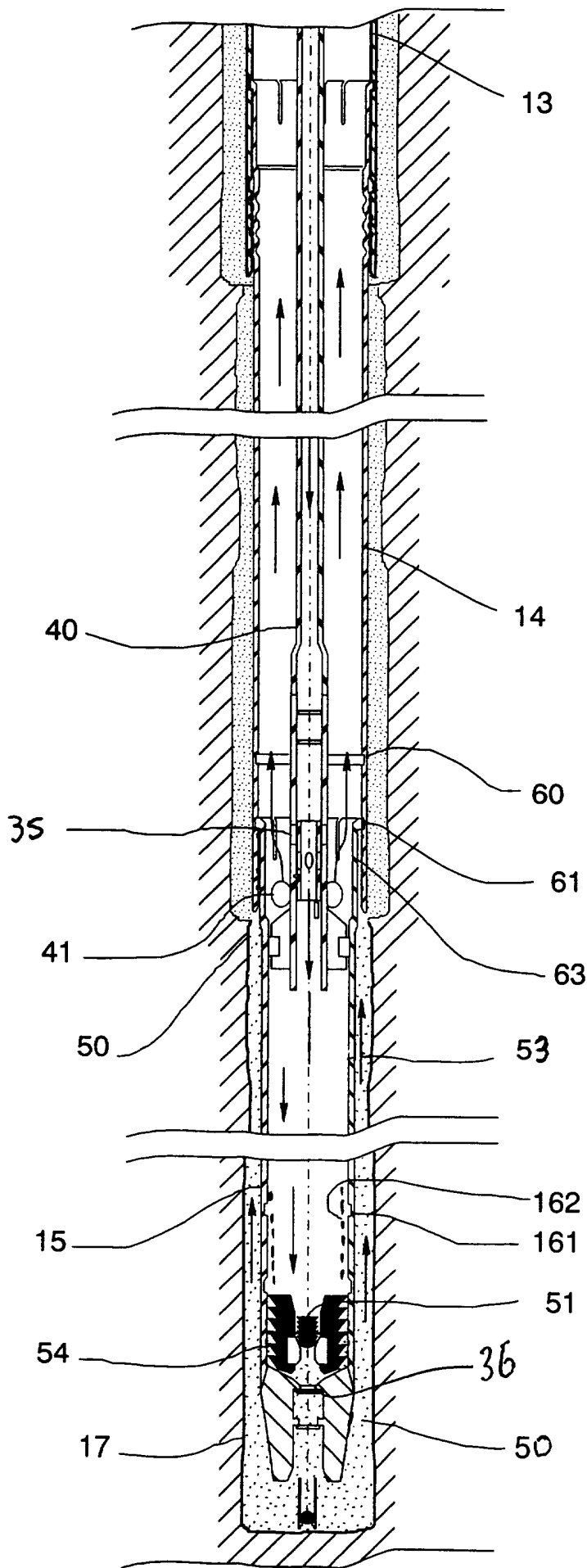


Figure 9

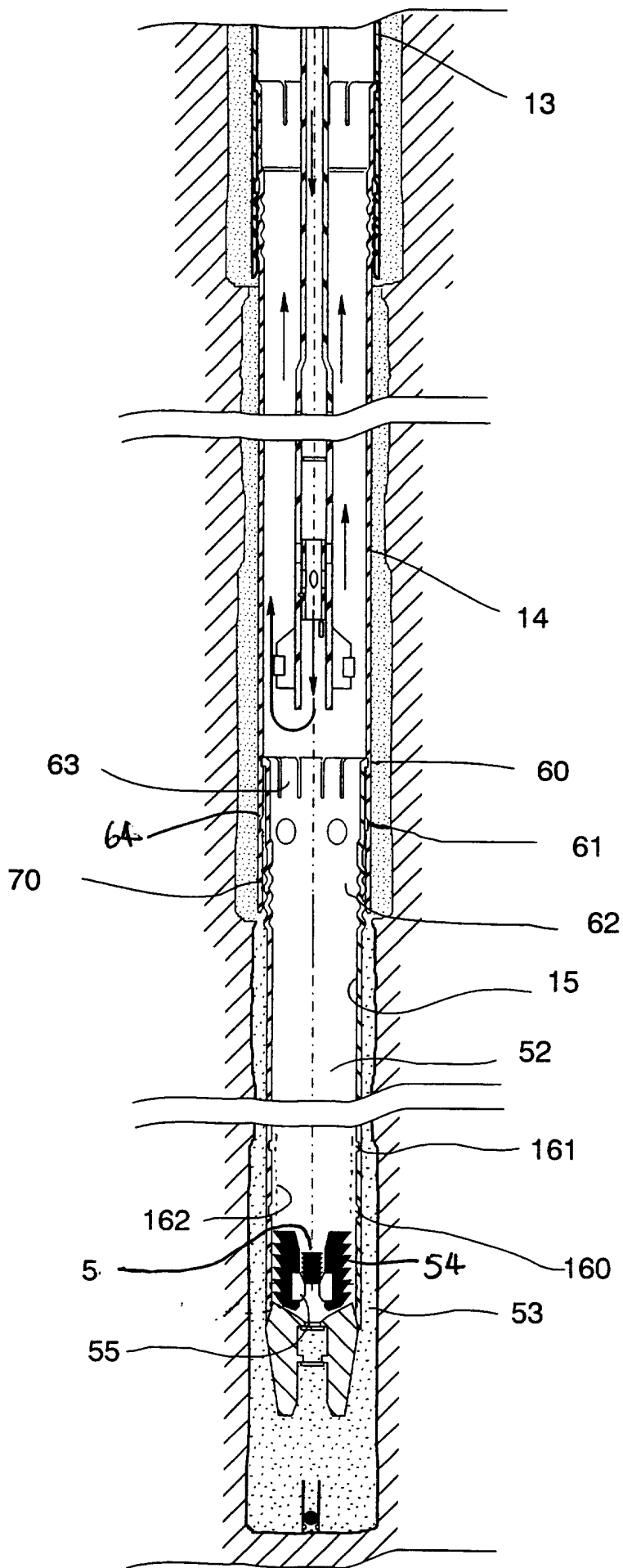


Figure 10

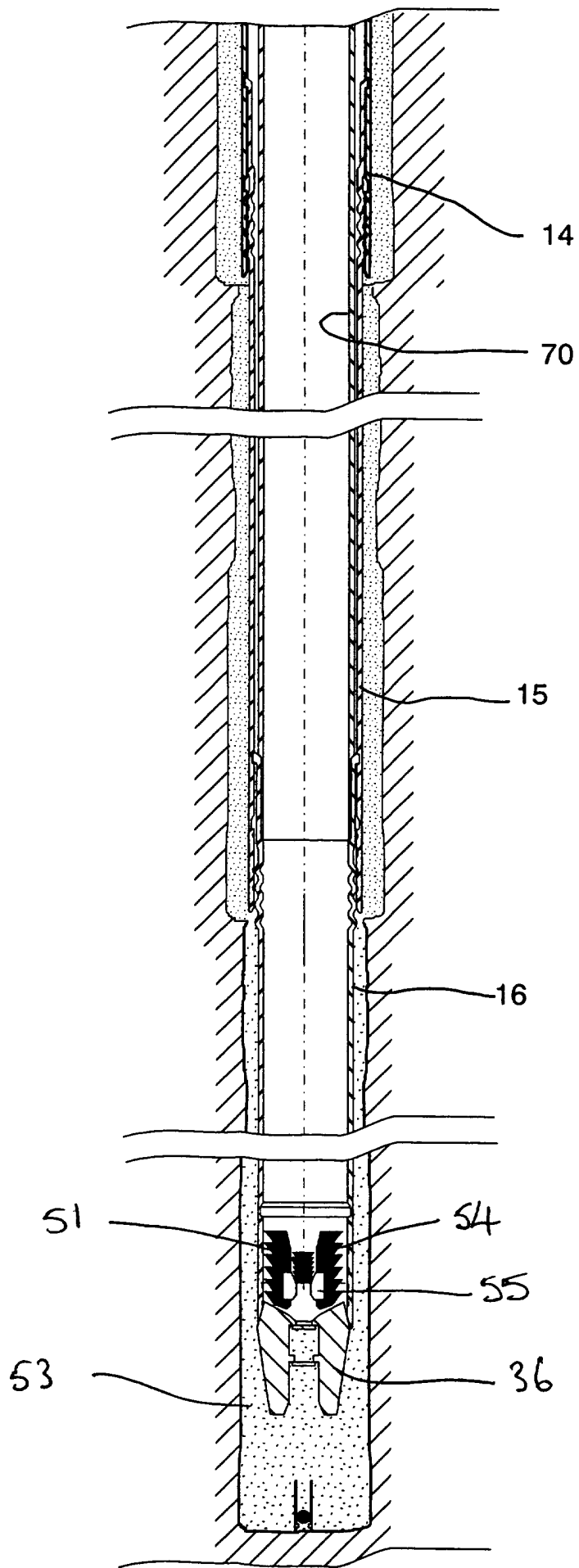


Figure 11

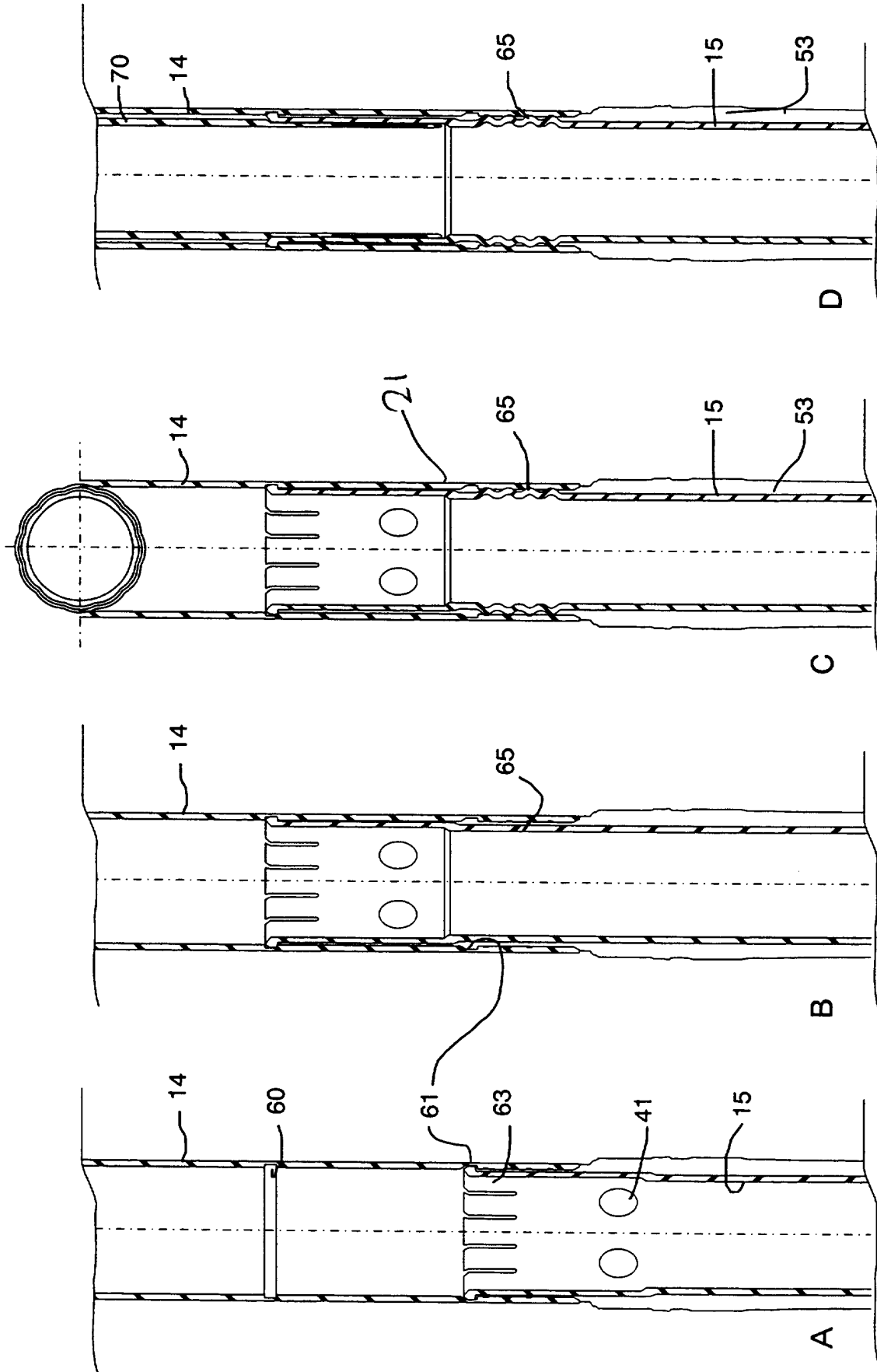


Figure 12

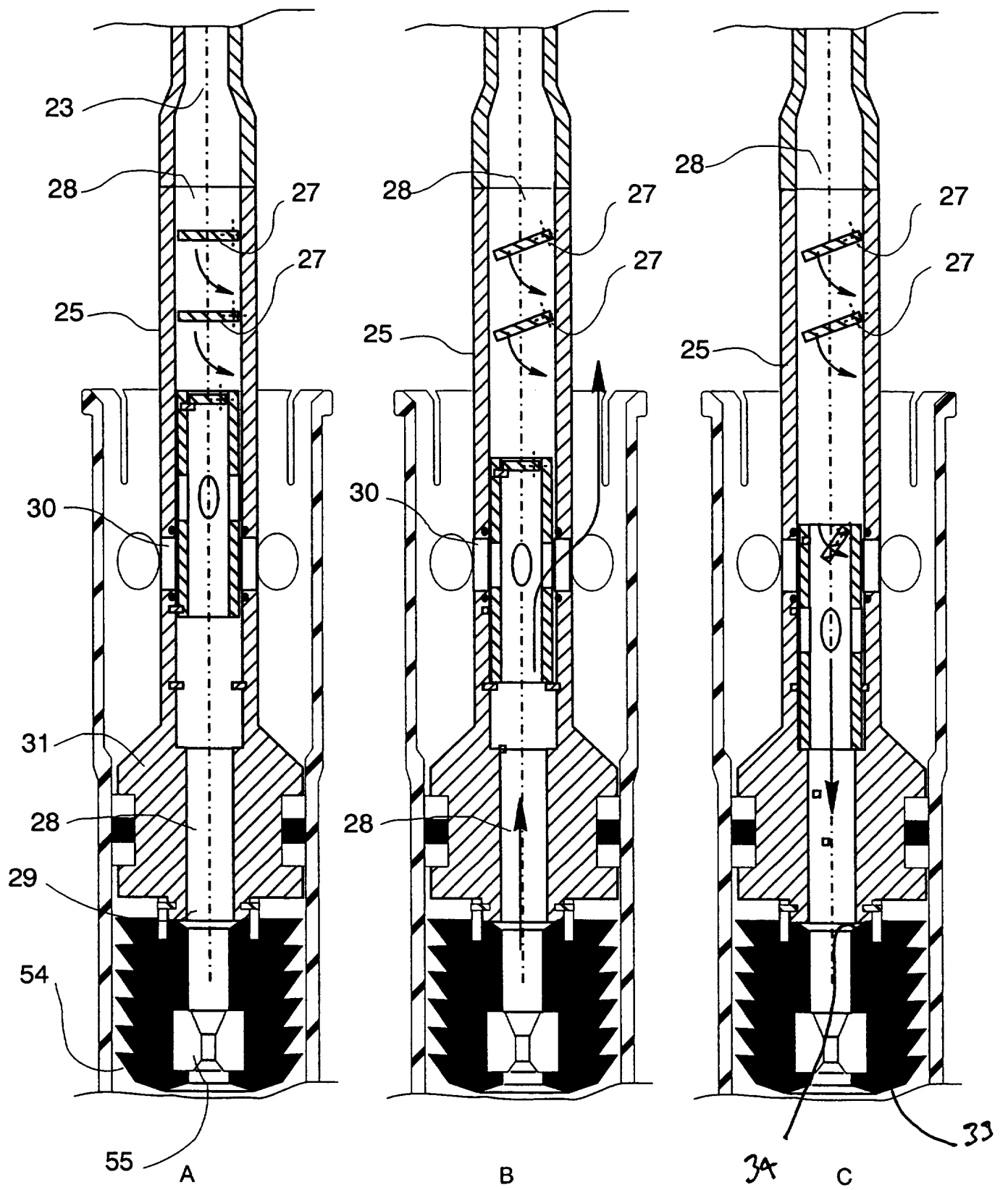


Figure 13

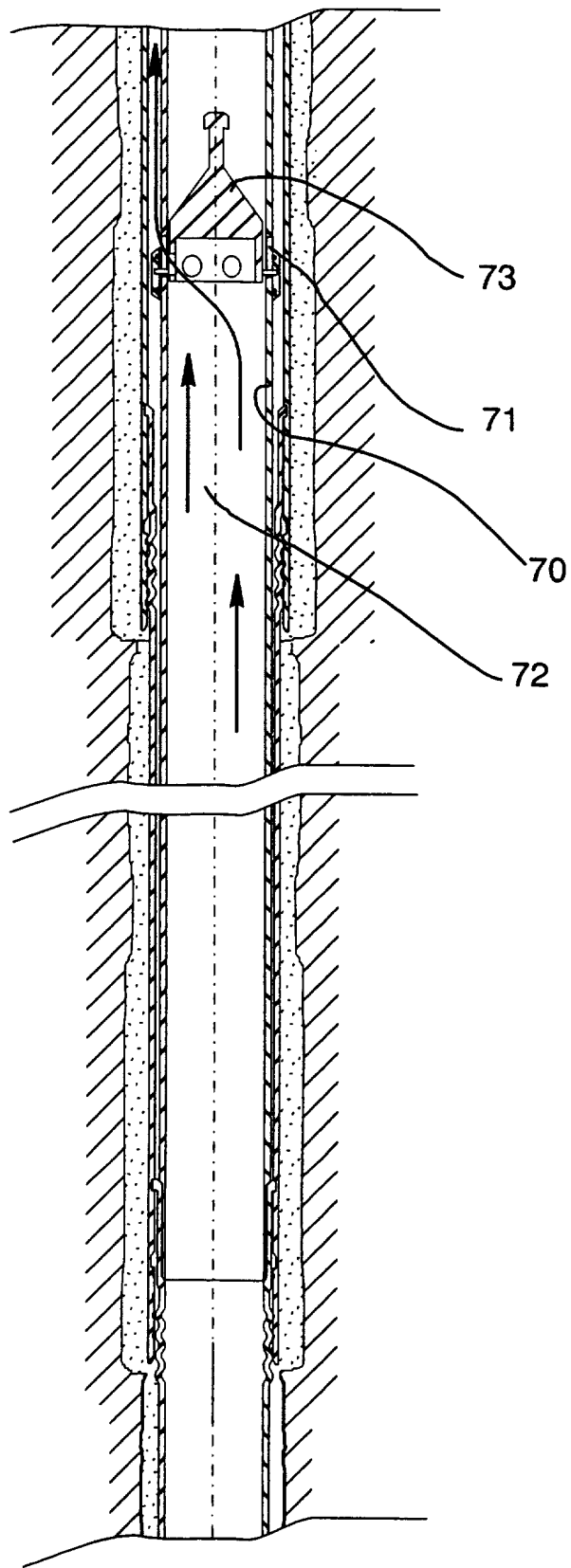


Figure 14

A Casing and Method of Installing the Casing in a Well

The invention relates to a casing and method of installing the casing in a well. Casings are required in wells in order to separate the well from the surrounding formations. Typically the casing is provided in sections which are lowered into the well following the drilling of each corresponding section of the well.

Each casing section is installed inside the previously installed section and consequently its external diameter has to be less than the internal diameter of the installed section. Furthermore it is necessary that this annular gap between the internal diameter of the installed section and the external diameter of the next section is sufficient to accommodate the connecting means between the two sections which includes hanging and packing means as well as the additional diameter of the joints between each length of tubing making up each section. The annular gaps between each subsequent casing section determine the size of the first casing section which is required to be sufficiently large to enable all the required subsequent casing sections to be passed through it and installed in the well. The final casing section is of sufficient diameter to carry out all the desired functions in the production zone of the well which may require over 5 different lengths of casing sections. This results in the first casing section being very large in diameter and therefore expensive and requiring a large diameter hole to be drilled out in order to accommodate it. Further more it is necessary due to the large diameter of the upper sections to extend the smaller diameter lower sections all the way to the surface in order that the required pressure resistance is provided. The objective of the invention therefore is to reduce this required diameter of the sections to considerably reduce the overall costs of the well both in terms of the drilling itself and disposable of the drilled material and in terms of the costs of the large diameter sections.

It has been proposed previously to provide lower diameter sections by reducing the annular space as much as possible, for example in US-A-5307886. The problem with such a narrow annulus and with the method of installation disclosed in this patent and used conventionally is that the well fluids displaced by the introduction and lowering of the subsequent casing section into the well have to pass up the annular space to exit the well at the surface. This presents

considerable disadvantages due to the very high friction pressure which are required to be overcome in order for the well fluids to pass up the narrow annular space. Consequently even with high hydrostatic pressures the installation time is very slow time due to the time taken for the fluids to pass up the annular space. Additionally the circulation of cement is very problematic because it relies on the displacement of the mud fluids in the well which are difficult to effectively displace all of the mud which causes incomplete cementing.

It is therefore the purpose of the present invention to provide an improved casing as well as a method of installation thereof in a well.

According to the invention there is provided a method of providing a casing in a well said casing comprising a series of casing sections the first section being provided from the top of the well and the subsequent casing sections arranged progressively downwards therefrom, wherein each subsequent casing section to be fitted is lowered into the well by means of a lowering tool which is connected at its upper end to suitable lowering means, such as a coiled tubing runner, and is connected at its lower end to the upper end of the said subsequent section to be fitted;
and that the well fluids, which are displaced by the lowering of the combined subsequent casing section, the lowering tool and the lowering means, pass from the lower portion of the well up through the internal bore of the section to be fitted.

The displaced fluids preferably then pass from the internal bore of the casing section being fitted and into the internal bore of the lowering tool and then pass out of the bore of the lowering tool through ports in a side wall thereof into the outside annulus between the lowering tool and existing casing. The ports are controlled by side valves which are held in the in the open position, during the lowering of the casing.

Preferably a lockable non return valve is provided at the lower end of the section to be fitted which when in the locked open position permits the well fluids to flow inside the internal bore of the section to be fitted. When the casing to be fitted has been lowered to its lower position the lockable return valve is unlocked thus operating as a conventional non return valve and

preventing the unwanted flow of fluids up the internal bore of the section to be fitted.

Preferably when the section to be fitted has reached its desired lower position outwardly facing spring biased interlocking means engage into a first lower groove in the internal wall of the existing casing.

Before the next stage the safety non-return valves at the lower end of the casing section being fitted are activated in order to seal the reservoir from the surface. This may be done by dropping a activating ball which is of such a weight and dimension that it releases a catch device which had been holding the non-return safety valve in the open position.

The casing sealing cement is then pumped down through the internal bore of the lowering means through the lowering tool and down through the internal bore of the casing section being fitted, out through the bottom end thereof through the open non-return valve and back up into fill the annular space between the casing section being fitted and the drilled well. The ports in the side walls of the lowering tool are closed for this cement pumping operation. The well fluids are displaced upwards through passage holes in the side walls of the top part of the casing section being fitted, into the annular space between the lowering tool and lowering means and the existing casing section.

Preferably a first wiper plug is pumped down the lowering means to clear the internal bore of the lowering means of any remaining cement. This wiper plug will have a diameter which corresponds to the internal diameter of the lowering means in order that the wiping operation can be effectively carried out. Preferably the first wiper plug then engages with a second wiper plug which is pre-fitted to the lower end of the lowering tool and which has a diameter which corresponds to the internal bore of the casing section being fitted such that continued downwards movement of the first and second wipers together causes the internal bore of the casing being fitted to be wiped of any remaining cement.

The cementing operation is then finally complete. The lowering tool is pulled back up to a small but sufficient extent to permit the spring biased interlocking means to engage in the second groove above the first groove in the internal

wall of the existing casing to secure the section to be fitted more securely to the existing section. The circulation path between the annular space and the internal bore of the section being fitted is closed by closing the through passage holes against the internal wall of the existing casing.

Preferably the lowering tool is raised just above the section to be fitted and well fluids are circulated through the lowering tool to remove any excess cement therein and from the surrounding region. The section to be fitted may then be permanently secured to the existing section by means of pressure forging, such as swaging to provide a sufficiently secure seal. The lowering tool is then released and pulled out of the hole.

Preferably the cement plug and lockable non return valve, which are located in the lower end of the fitted casing section, are removed by a suitable means, such as drilling. The lower end of the fitted section may also preferably comprise first and second grooves which serve to support the subsequent sections through the same fitting procedure.

The section to be lowered in and fitted may be a sand screen or in addition a mono-bore liner or completion barrier.

Preferably the passage hole is provided in the wall of the completion barrier located sufficiently high up the completion barrier to permit the well fluids to pass from the internal bore of the completion barrier to the annular space between the external wall of the completion barrier and the corresponding casing section and upwardly out of the well as the completion barrier is lowered in the well. Following completion of the fitting of the completion barrier the a least one passage hole may be closed by means of a suitable tool.

According to the invention there is also provided a well casing comprising at least two casing lengths with a first casing section having an outside diameter and an inside diameter being fitted and cemented in position extending downwardly from the top of the well, wherein a second casing section having an outside diameter and an inside diameter and the difference $D1$ between the outside diameter of the second section being less than the internal diameter of

the first section being an amount which is just sufficient for the second section to pass down through the internal bore of the first section.

Each subsequent casing section may have an internal diameter and an external diameter and that the differences D2, D3, D4 between the external diameters of each subsequent section and the internal diameters of the previously fitted sections is just sufficient for the subsequent sections to pass through the internal bores of the previously fitted sections.

Preferably each of the differences D1, D2, D3, D4 between the internal diameters of the fitted sections and the outside diameters of the sections to be fitted is less than W mm such that the outside diameter OD12 of the first section can be as small as possible and is at most equivalent to:

$$OD12 = W \times (n - 1) + 2 \times T \times n + ID16,$$

where T is the average wall thickness of the casing sections, ID16 is the internal diameter of the last section and n is the number of casing sections and W is the average diametrical difference.

The well casing is preferably made of continuous coiled tubing and W may be 15 mm and is preferably less than 10 mm and greater than 0.1 mm. W may be less than 5 mm and greater than 0.1 mm. W may be less than 2 mm and greater than 0.1 mm.

The well casing may be made of joined tubing and W is preferably less than 25 mm and greater than 1 mm. W may be less than 15 mm and greater than 1 mm. W may be less than 10 mm and greater than 1 mm.

Each section of well casing comprises outwardly extending rim at its upper end which acts as a spring biased interlock with the existing fitted casings. Each section therefore also preferably has at its lower end a first locating groove for engagement with the corresponding spring biased interlocking means at the upper end of the subsequent casing section. A second locating groove is also provided for engagement with the corresponding spring biased interlocking means.

Each section of the well casing preferably, has at its upper end an undulating profile on its external wall to facilitate the fixing of the subsequent casing section by swaging

The first locating groove preferably comprises a chamfered side.

Preferably each subsequent casing section has at its upper end a flow passage opening to permit flow of well fluids from the outside of the casing section to its internal bore during the lowering procedure.

The well casing may comprise a sand screen and a completion barrier 70.

The completion barrier preferably comprises at least one passage hole in its side wall which is preferably closable

Preferably the passage hole is located above the lower end of the second to last casing section, when the completion barrier is in its fitted position.

The preferred embodiments of the invention will now be described with reference to the following drawings in which:

Fig. 1 is a front elevation of a well casing of the prior art,

Fig. 2 is a front elevation of the well casing according to the invention,

Fig. 3 is a cross section through the casing of the invention viewed well in the uppermost section,

Fig. 4 is a longitudinal section of a well comprising the casing according to the invention showing a first step of the method of the invention,

Fig. 5 is a longitudinal section of a well comprising the casing and apparatus according to the invention showing a second step of the method of the invention,

Fig. 6 is the longitudinal section of fig. 5 showing a third step of the invention,

Fig. 7 is the longitudinal section of fig. 5 showing a further step of the invention,

Fig. 8 is the longitudinal section of fig. 5 showing a further step of the invention,

Fig. 9 is the longitudinal section of fig. 5 showing a further step of the invention,

Fig. 10 is the longitudinal section of fig. 5 showing a further step of the invention,

Fig. 11 is a longitudinal section of the casing of fig. 4 showing a completion barrier,

Figs. 12A, 12B, 12C, 12C, 12D show the stages of connection and fitting a casing to a previously installed casing,

Figs. 13A, 13B, 13C showing an enlarged view of the lowering tool in the different stages of the installation of the casing sections,

Fig. 14 shows an view of the casing of the invention including the tool for fitting the liner barrier.

Referring to the fig. 1 it can be seen that conventionally a well casing comprises a very wide diameter section at the surface which gradually reduce with each subsequent section as the well progresses downwards. This particular well is shown 4500 meters deep. The uppermost casing section 2 is typically 18.875 inches (47.94 cm) in diameter although in some wells this uppermost casing section is as large as 30 inches (76.2 cm). A second casing section 3 extends inside the uppermost casing section 2 from the surface and is 13.375 inches (33.97 cm) in diameter with an annular gap D1 between it and the internal diameter of the first casing section 2. Subsequently a third casing section 4 of approximately 9.625 inches (24.45 cm) is inserted inside the second casing section 3 and extends from the surface with an annular gap D2 from the second casing section 3. A fourth casing section 5 is then inserted

from the surface having a diameter of 7 inches (17.78 cm) with an annular gap D4 from the third casing section. Finally a fifth casing section 6 of 5 inches diameter (12.7 cm) is installed being hung off the previous casing section 5 and leaving an annular gap D4.

In this conventional casing, each casing section is lowered at a sufficient speed to permit a adequately fast construction time for the well because the well fluids can be displaced from the lower parts of the well through the annular gaps D1, D2, D3, D4 to the top of the well as the casing sections are lowered into the well. However the required width of the well has resulted in the use of expensive large diameter casing tubing and also in the removal of considerable amounts of cut rock which has to be disposed of.

Fig. 2 is a casing according to the invention which has a first casing section 12 having a diameter of 6.625 inches (16.83 cm). A second casing 13 is having a diameter of 6 inches (15.24 cm) is installed and hung off the lower end of the first casing section 12 which results in a small annular gap D1. The subsequent sections 14, 15, 16 are 5.375, 4.75 and 4.125 inches in diameter respectively and each is hung-off the lower end of the previously installed section and cemented in the usual way. This results in a much lower annular gap which but also has the consequence that considerably less material has to be drilled out of the well and disposed of and casing sections of considerably lower diameters can be used. This dramatically lowers the cost of the well.

Fig. 3 shows the casing sections 12, 13, 14, 15, 16 according to the invention in cross section and also the small annular gaps between each casing section.

According to the invention a method is also provided of installing the casing sections 12, 13, 14, 15, 16 with small annular gaps there between and which permits the casing sections 12, 13, 14, 15, 16 to be installed in a speedy way which does not cause increases in the construction time of the well.

Referring to fig. 4 a well is shown by way of example with casing sections 13 and 14 already installed and cemented in by cement 19. The well hole is further drilled out below the last casing section 14 and to a greater diameter than the last casing section to form a new drilled section 17 in the new rock 18. This over diameter reaming drilling can be carried out using known drilling

techniques. It will be appreciated that the invention can be applied to any well which is drilled by any known technique.

Referring to fig. 5 the section 15 to be installed is lowered into the well. In the embodiment shown the casing section 15 is provided by a length of continuous coiled tubing. This casing section 15 could just as easily be provided by a suitable length of joined tubing which would be installed into the well in a more conventional manner. In the fig. 5 the casing section 15 has already being installed by the injector 24 and is held in the position shown with the upper most part of the casing section 15 still protruding from the top of the well. During this lowering stage the casing section 15 is then fitted with a hose 26 through which the displaced fluids from the well pass and are disposed of in a usual manner. The casing 15 is then installed in the well with the assistance of the installing means 24 which grips and lowers the casing section 15 thus lowering it into the well as far as the position shown in fig. 5.

The lower end of the casing 15 comprises a lockable non-return valve 36 which normally permits flow downwardly out of the lower end of the casing 15 but prevent flow upwardly into the casing 15 but which may be optionally held in the open position to allow the well fluids to pass up the inside of the casing section 15. The lowering tool 25 comprises gripping seals 31 which grip the casing section 15 as it is lowered into the well. The lowering tool 25 has an internal bore 28 which permits the displaced well fluids to pass up through the lowering tool 25 and out through the coiled tubing hose 26 to be filtered and re-used or disposed of in the usual way.

Referring to fig. 6 when the casing section 15 has been lowered into the well so that its upper end is at the top of the well, the lowering tool 25 is connected to lowering means 40, which is also a coiled tubing, which is again gripped by the installer 24 to lower the casing section 15 further into the well. As the casing section 15 is lowered further into the well the displaced fluids pass out from the internal bore of the lowering tool 25 into the outside annulus between the lowering tool 25 and existing casing 12, 13, 14 through side valves 30 provided in the lowering tool 25 which have now been opened as shown in fig. 7. The flapper valves 27 are now closed to prevent the well fluids travelling up the coiled tubing lowering means 40. At this stage it is easier to dispose of the well fluids if they are displaced through the annulus and also the working

platform and the coiled tubing reel is not exposed to the production reservoir which may be subject to uncertain reservoir pressures. These are best dealt with in the conventional way by allowing the well fluids to be displaced through the annulus between the coiled tubing lowering means 40 and the existing casing 12, 13, 14. The displaced well fluids can continue to flow through the lockable non return valve 36 at the lower end of the casing 15, which is in the locked open position, inside the internal bore of the section being fitted 15 and then through the open radial side valves 30 out of the lowering tool 25 into the annular gap between the lowering means 40 and the installed sections 12, 13, 14.

Referring to fig. 8 the casing section to be fitted 15 has been lowered to its lower required position. The lockable return valve 36 is unlocked thus operating as a conventional non return valve and preventing the unwanted flow of fluids up the internal bore of the casing section 15. The lockable non return valve may be activated in this way by lowering a ball 37 down through the lowering means 40 under pressure. There are many other ways of remotely activating the lockable non return valve which will be apparent to the person skilled in the art.

As the casing section 15 is lowered to its lowermost position spring biased interlocking means 63 at the uppermost end of the section to be fitted 15 to engage into the first groove 61 formed in the internal wall of the existing section 14 thus supporting the section to be fitted 15 for the cement operation. The first groove 61 comprises a bevelled upper most edge 64 to provide a lead into the first groove 61 for the interlocking means 63.

Referring to fig. 9 the cement 50 is ready to be pumped in to fill the annular gap 53 surrounding the casing section 15. The casing sealing cement 50 is pumped down through the internal bore of the lowering means 40 through the lowering tool 25 and down through the internal bore of the section to be fitted 15 out through the bottom end thereof and back up to fill the annular space 53 between the section being fitted 15 and the drilled hole 17. The through side port holes 30 of the lowering tool 25 have now been closed to prevent the cement flowing out radially. The well fluids are displaced upwards in the annular space 53 being pushed up by the incoming cement and pass out of the annular space 53 through passage holes 41 in the side walls of the top part of

the section 15 into the annular space between the lowering tool 25 and lowering means 40 and the existing casing section 14.

A cement plug driver 51 is then released and pumped down the lowering means 40 behind the cement when the required amount of cement has been introduced. The amount of cement required is calculated beforehand to be sufficient to fill the annular gap 53 which additional amount for losses in a way which is well known in the art. The cement plug driver 51 serves to clear any remaining cement from the inside walls of the coiled tubing lowering means 40 and is dimensioned such that it has an outside diameter which corresponds to the internal diameter of the lowering means 40 in such a way that it wipes the internal wall of the lowering means in an effective way.

A cement plug 54 is released from the lowering tool 25, by suitable means such as pressure sensitive shear pins which are activated by the cement plug driver 51 when it reaches the lower end of the lowering tool 25. The cement drive plug acts on a cement plug seat 55. The cement plug 54 ensures that all the cement is removed from the internal bore of the section to be fitted 15 into the annular space 53. The cement plug 54 is dimensioned such that it has an outside diameter which corresponds to the internal diameter of the casing 15 in such a way that the cement plug 54 effectively wipes the internal wall of the casing 15. When the cement plug 54 reaches the non-return valve support 36 at the lower end of the casing 15 it is prevented from further downward movement and the cementing operation is complete.

Referring now to fig. 10 and figs. 12A-12D, the lowering means 40 is then pulled back up by a small but sufficient extent to cause the spring biased interlocking means 63 at the uppermost end of the section to be fitted 15 to engage into the second groove 60. The casing section 15 is thus secured more firmly to the existing section 14 by the engagement of the spring biased interlocking means 63 in the square bevel-less second groove 60. This is compared to the first groove 61 which has the chamfered upper side 64 which also permits the disengagement of the biased interlocking means 63 in the upwards direction.

The circulation path between the annular space 53 and the internal bore of the section to be fitted 15 is then closed by closing the through passage holes 41.

This may be carried out in any suitable way, such as a sliding or rotating collar which may be moved into position to cover the passage holes 41.

As shown in fig. 10 the lowering tool 25 is disconnected from the section to be fitted 15 and is raised just above the casing section 15 and well fluids are circulated through the lowering tool 25 to remove any excess cement therein and from the surrounding region.

The upper end of the newly fitted section 15 is then permanently connected to the lower end of the existing section 14 by suitable deformation operation such a swaging or cold forging. The swaging operation, to form a cold forged seal between the casing section 15 being fitted and the existing casing section 14, may take place as part of the disconnection procedure of the lowering tool from the casing section 15. The swaging operation is carried out by a suitable swaging tool, of the type which are available in the art and which cause deformation of the corresponding ends of the casing to form a permanent seal. The swaging tool is preferably lowered and position on the end of the same lowering means 40.

The cement plug 54 and lockable non return valve 36 which are still located in the lower end of the newly fitted casing section 15 are then removed by a suitable means, such as drilling and the drilling of the next section of the well can commence and/or fitting of the next section of casing 16 can commence. The entire well may already be pre-drilled.

The lower end of the fitted section 15 comprises first and second grooves 160, 161 which serve to support the subsequent section 16 in the same way. The grooves 160, 161 are protected by a removable sleeves 162 in order to stop cement and any other material getting in to the grooves and preventing the subsequent engagement of the spring biased interlocking means of the next casing section. The sleeves 162 may be removed by dissolving or mechanically by a suitable tool in a suitable manner which will be apparent to the skilled person.

The section being fitted could also be a sand screen as well as a casing section such sand screen being necessary to protect the well from areas of formation which generate sand as well as the desired hydrocarbons.

Referring now to fig. 11 to be lowered in and fitted is a mono-bore liner or completion barrier 70. Such a completion barrier 70 will be installed when all the casing section required are installed and the drilling of the well is complete.

The completion barrier may be installed in essentially the same way as the casing sections using the method and lowering tool of the invention. Preferably at least one passage hole 71 is provided in the wall of the completion barrier 70 located sufficiently high up the completion barrier 70 to permit the well fluids to pass from the internal bore 72 of the completion barrier 70 to the annular space between the external wall of the completion barrier 70 and the corresponding casing section 12, 13, 14, 15 and upwardly out of the well 11 as the completion barrier is lowered in the well 11.

The passage holes 71 of the completion barrier 70 are then closed by means of a suitable tool 73 (fig. 14).

Referring now to fig. 3 in conjunction with figs 12A, 12B, 12C and 12D a well casing 11 is shown comprising a number of casing lengths 12, 13, 14, 15, 16 with a first casing section 12 having an outside diameter OD12 of 6.625 inches and an inside diameter ID12 of 6.125 inches being fitted and cemented in position extending downwardly from the top of the well. The second casing section 13 has an outside diameter OD13 of 6 inches and an inside diameter ID13 5.5 inches. The difference D1 between the outside diameter OD13 of the section 13 is less than the internal diameter ID12 of the first section 12 being an amount which is just sufficient for the second to pass down through the internal bore of the first section 12. This difference is 0.25 inches (0.635 cm) in the present exemplary embodiment. However it will be appreciated that the invention can be applied to any annular gap size which is required to accommodate the variances in the ovality and other dimensions in the casing sections of the well. It has been found that differences D1, D2, D3, D4, D5 may be as high as 15 mm and as low as 0.1 mm. The actual difference will be as low as possible to maintain the dimensions of the well as a whole as slim as possible.

Each subsequent casing section 14, 15, 16 has an internal diameter ID14 of 5.25 inches, ID15 of 4.625 inches and ID16 of 3.5 inches respectively and an

external diameter OD14 of 5.375 inches, OD15 of 4.75 inches and OD16 of 4.125 inches respectively. The differences D2, D3, D4 between the external diameters OD14, OD15, OD16 of each subsequent section 14, 15, 16 and the internal diameters ID13, ID14, ID15 of the previously fitted sections 13, 14, 15 will be just sufficient for the subsequent sections 14, 15, 16 to pass through the internal bores of the previously fitted sections 13, 14, 15.

These differences D1, D2, D3, D4 define the annular gap between respective casing sections 12, 13, 14, 15, 16 and according to the invention need not be so large as to permit the flow of fluids there through during the installation of the sections but need only be large enough to allow the sections to pass freely through each other allowing only for the variations of ovality and wall thicknesses according to the tolerances of manufacture of the sections. When planning and designing the well it is necessary to start with the dimensions of the last casing section since this has to be of a certain minimum size to permit the normal operations to take place at the lowermost point of the well. The required sizes of the other sections are calculated upwardly therefrom and will depend on the expected condition of the rock and location of reservoirs etc. The size of the first section will therefore be eventually calculated and for very deep or long wells will have to have a very large diameter. It is beneficial to reduce this diameter as much as possible. According to the invention this is possible by reducing the annular spaces D1, D2, D3, D4 between the sections to a minimum.

Thus the differences D1, D2, D3, D4 will determine the ultimate required size of the first section.

These differences D1, D2, D3, D4 between the internal diameters ID12, ID13, ID14, ID15 of the fitted sections 12, 13, 14, 15 and the outside diameters OD13, OD14, OD15, OD16 of the sections to be fitted 13, 14, 15, 16 may be defined as W (inches or mm) such that the internal diameter ID12 of the first section 12 can be as small as possible and is at most equivalent to:

$$ID12 = W \times n + T \times n + ID16,$$

where T is the average wall thickness of the casing sections 13, 14, 15, 16, ID16 is the internal diameter of the last section and n is the number of casing sections.

It has been found that when the casing is made of continuous coiled tubing then W may be less than 15 mm and greater than 0.1 mm depending on the quality of manufacture and length of the section of casing concerned.

It is also preferable and possible in certain circumstances when the well casing is made of continuous coiled tubing that W is less than 10 mm and greater than 0.1 mm. It has also be found that when the well casing is made of continuous coiled tubing and of good quality manufacture with fine tolerance limits on ovality and straightness along its length and if the length of tubing is less than approximately 2000 metres then W may be less than 5 mm and greater than 0.1 mm.

When the well casing is made of joined tubing an additional factor has to be considered and that is the width of the joints between each section. Clearly this will put the greatest limit on the amount to which the value W can be reduced. However it has been determined by the inventor that W may be less than 25 mm and greater than 1 mm and even at the higher end of this range vary useful reductions in the overall diameter of the well and the consequent reductions in material costs and disposal costs as well as well construction time costs can be achieved.

Preferably and also possible is that when the well casing is made of joined tubing W is less than 15 mm and greater than 1 mm.

It has also been found to be possible for certain types of wells depending on the operating demands of the well notably pressure that certain special slimmer joints can be used such that the well casing is made of joined tubing with the value W less than 10 mm and greater than 1 mm.

Referring to figures 12A, 12B, 12C and 12D an enlarged view of the upper end of the casing section being fitted 15 and the lower end of the existing casing 14 is shown. In fig. 12B the lower casing section 15 is lifted up and the spring biased interlocking means s63 engaging in the second groove 60. As shown

in fig. 12C it is now desired to permanently join the lower casing section 15 to the upper casing section 14. This is carried out in this embodiment by swaging by applying pressure by means of an expanding swaging tool which is known to persons skilled in the art to cause the respective undulated part 65 of the lower end 21 of the existing casing section 14 to be permanently deformed together with the corresponding part of the upper end of the fitted casing section 15.

It will be noted that only the apparatus essential to the understanding of the invention itself is shown and described. The use of other equipment and procedures which are known in the art will be necessary and recommended for example, depending on the conditions of the well and its location. A blow-out preventer 35, for example is shown, which would be apparent to the person skilled in the art.

The completely, fitted casing section is shown in fig. 12D.

Referring now to figs. 13A, 13B and 13C the lowering tool 25 of the invention is shown in more detail. The lowering tool 25 comprises a generally elongate shape and having an internal bore 28 with an upper opening 23 and a lower opening 29 and comprising gripping seals 31 for connecting to and supporting the item to be lowered into the well. The item may be a casing section or a sand screen or a completion barrier or any similar component. The lowering tool 25 also comprises a radial closeable opening 30 which when in the open state permits flow in the generally radial direction of fluids from the internal bore 28 of the tool 25 to the outside of the tool.

The lowering tool 25 is connected at its open upper end to a tubular lowering means 40 which is preferably continuous coiled tubing.

The lowering tool 25 also comprises valve means 27, such as flapper valves, arranged above the radial closeable opening 30 which can be operated to permit flow in the axial direction from the coiled tubing lowering means 40 down through the lowering tool 25 into the well.

The lowering tool 25 comprises at its lowermost end an annular cement plug 54 which includes a plug seat 54 arranged internally thereof.

When the lowering tool is lowering an item down into the well the radial valve 30 is in the open position as shown in fig 13B to allow the flow of well fluids up the internal bore 28 of the tool 25 and out of the radial holes 30. Fluids are prevented from flowing up the coiled tubing lowering means by the non return flapper valves 27. When the item is lowered in position the lowering tool 25 may be used to circulate the cement as shown in fig. 13C. In this position the radial valve 30 is closed to prevent flow from the internal bore 28 to the outside of the tool 25 and the flapper valves 27 permit fluids such as cement to be pumped down through the tool into the well 11.

The gripping seal 31 arranged at the lower end of the lowering tool is selectively engageable to grip and lower the casing section 15, or whatever the item to be lowered is and also to adjust it, for example to raise it backwards to engage the interlocking means 63 in the second groove 60 in the embodiment described above. It is also releasable from the item being lowered when the operation is complete.

CLAIMS

1. A well casing 11 comprising at least two casing lengths 12, 13, 14, 15, 16 with a first casing section 12 having an outside diameter OD12 and an inside diameter ID12 being fitted and cemented in position extending downwardly from the top of the well, characterised in that the remaining sections are installed subsequently each subsequent casing section 13, 14, 15, 16 having an outside diameter OD13, OD14, OD15, OD16 and an inside diameter ID13, ID14, ID15, ID16 and the diametrical difference D1, D2, D3, D4, D5 between the outside diameter OD13, OD14, OD15, OD16 of the sections 13, 14, 15, 16 being less than the internal diameter ID12, ID13, ID14, ID15 of the corresponding fitted sections 12, 13, 14, 15 being an amount which is just sufficient for the subsequent sections 13, 14, 15, 16 to pass down through the internal bore of the corresponding fitted section 12, 13, 14, 15 and the average diametrical difference is less than W mm such that the outside diameter OD12 of the first section 12 can be as small as possible and is at most equivalent to:

$$OD12 = (W \times (n-1) + 2 \times T \times n) + ID16,$$

where T is the average wall thickness of the casing sections 13, 14, 15, 16, ID16 is the internal diameter of the last section, n is the number of casing sections and W is the average of the diametrical differences .

2. A well casing according to claim 1, characterised in that the well casing is made of continuous coiled tubing and W is less than 15 mm and greater than 0.1 mm.

3. A well casing according to claim 2, characterised in that the well casing is made of continuous coiled tubing and W is less than 10 mm and greater than 0.1 mm.

4. A well casing according to claim 3, characterised in that the well casing is made of continuous coiled tubing and W is less than 5 mm and greater than 0.1 mm.

4. A well casing according to claim 1, characterised in that the well casing is made of joined tubing and W is less than 25 mm and greater than 1 mm.
5. A well casing according to claim 4, characterised in that the well casing is made of joined tubing and W is less than 15 mm and greater than 1 mm.
6. A well casing according to 5, characterised in that the well casing is made of joined tubing and W is less than 10 mm and greater than 1 mm.
7. A well casing 11 according to any one of claims 1 to 6, characterised in that each section 12, 13, 14, 15, has at its upper end an undulating profile on its external to facilitate the fixing of the subsequent casing section 13,14,15,16 by swaging.
8. A well casing 11 according to any one of claims 1 to 7, characterised in that each section 12, 13, 14, 15, has at its lower end a first locating groove 61 for engagement with a corresponding spring biased interlocking means 63 at the upper end of the subsequent casing section 13, 14, 15, 16.
9. A well casing 11 according to any one of claims 1 to 8, characterised in that each section 12, 13, 14, 15, has at its lower end a second locating groove 60 for engagement with a corresponding spring biased interlocking means 63 at the upper end of the subsequent casing section 13, 14, 15, 16.
10. A well casing 11 according to claim 9, characterised in that the second locating groove 60 is deeper than the first locating groove 61.
11. A well casing 11 according to claim 9, characterised in that the first locating groove 61 comprises a chamfered side.
12. A well casing 11 according to any one of the preceding claims 1 to 11, characterised in that each subsequent casing section 13, 14, 15, 16 has at its upper end a flow passage opening 41 to permit flow of well fluids from the outside of the casing section 13, 14, 15, 16 to its internal bore during the lowering procedure.

13. A well casing according to any one of the preceding claims 1 to 12, characterised in that the casing comprises a sand screen.

14. A well casing according to any one of the preceding claims 1 to 13, characterised in that the casing comprises a completion barrier 70.

15. A well casing according to claim 14, characterised in that the completion barrier 70 comprises at least one passage hole 71 in its side wall.

16. A well casing according to claim 15, characterised in that the passage hole 71 is closable.

17. A well casing according to claim 15, characterised in that the passage hole 71 is located at least above the lower end of the second to last casing section 15, when the completion barrier 70 is in its fitted position.

18. A method of providing a casing as described in claim 1 in a well 11 said casing comprising a series of casing sections 12, 13, 14, 15, 16 the first section 12 of which is provided from the top of the well and the subsequent sections 13, 14, 15, 16 arranged progressively downwards therefrom, the subsequent section to be fitted 13, 14, 15, 16 being lowered into the well by a suitable lowering means 40, such as a coiled tubing runner, and that the well fluids which are displaced by the lowering of the subsequent section 13, 14, 15, 16 and the lowering means 40, passes from the lower portion of the well up through the internal bore of the section to be fitted 13, 14, 15, 16, characterised in that the displaced fluids pass out from the internal bore of the lowering means 40 into the outside annulus between the lowering means 40 and existing casing 12, 13, 14, 15 through radial closable openings or side valves 35.

19. A method according to claim 18, characterised in that a lockable non return valve 36 is provided at the lower end of the section to be fitted 13, 14, 15, 16 which normally permits flow downwardly out of the casing 15 and prevents flow upwardly into the casing 15 but which may be optionally arranged in a locked open position to permit the well fluids to flow inside the internal bore of the section to be fitted 13, 14, 15, 16.

20. A method according to claim 19, characterised in that when the casing to be fitted 13, 14, 15, 16 has been lowered to its lower position the lockable return valve 36 is unlocked thus operating as a conventional non return valve and preventing the unwanted flow of fluids up the internal bore of the section to be fitted 13, 14, 15, 16.

21. A method according to claim 18, characterised in that when the section to be fitted 13, 14, 15, 16 has reached its desired lower position an interlocking means 63 provided on the upper end of the casing being fitted 13, 14, 15, 16 engages into a first groove 61 in the internal wall of the existing casing 12, 13, 14, 15.

22. A method according to claim 18, characterised in that when the section to be fitted 13, 14, 15, 16 has reached its desired lower position the ports 35 are closed and sealing cement 50 is pumped down through the internal bore of the lowering means 40 through the lowering tool 25 and down through the internal bore of the of the section to be fitted 13, 14, 15, 16 out through the bottom end thereof and back up into fill the annular space 53 between the section to be fitted 13, 14, 15, 16 and the open hole, and the well fluids being displaced upwards through passage holes 41 in the sides walls of the top part of the section to fitted 13, 14, 15, 16, into the annular space between the lowering means 40 and the existing casing section 12, 13, 14, 15.

23. A method according to claim 22, characterised in that a cement plug 54 is released from the lowering tool 25 to ensure that all the cement is removed from the internal bore of the section to be fitted 13, 14, 15, 16 into the annular space 53.

24. A method according to claim 23, characterised in that a cement plug driver 51 is introduced into the lowering means 40 and engages the cement plug 54.

25. A method according to claim 24, characterised in that the cement plug 54 is released from the lowering tool 25 by means shear pins which are sheared by pressure behind the cement plug driver 51.

26. A method according to claim 22, characterised in that the lowering means 40 is pulled back up to a small but sufficient extent to cause the spring biased interlocking means 63 at the uppermost end of the section to be fitted 13, 14, 15, 16 to engage into a second groove 60 to secure the section to be fitted 13, 14, 15, 16 more securely to the existing section 12, 13, 14, 15 so that the passage holes 41 are raised above the open hole.

27. A method according to claim 22, characterised in that when the cementing operation is complete the circulation path between the annular space 53 and the internal bore of the section to be fitted 13, 14, 15, 16 is closed by closing the through passage holes 41.

28. A method according to claim 21, characterised in that the first groove 61 has an chamfered upper side to permit the disengagement of the biased interlocking means 63.

29. A method according to claim 27, characterised in that the lowering tool 25 is removed from the section to be fitted 13, 14, 15, 16.

30. A method according to claim 27, characterised in that the lowering tool 25 is raised just above the section to be fitted 13, 14, 15, 16 and well fluids are circulated through the lowering tool 25 to remove any excess cement therein and from the surrounding region.

31. A method according to claim 27, characterised in that the section to be fitted 13, 14, 15, 16 is permanently secured to the existing section 12, 13, 14, 15 by means of pressure forging, such as swaging, providing a permanent seal between the respective sections and closing passage holes 41.

32. A method according to claim 31, characterised in that the cement plug and lockable non return valve, which are located in the lower end of the fitted section 13, 14, 15, 16, are removed by a suitable means, such as drilling.

32. A method according to claim 18, characterised in that the section being fitted is a mono-bore liner or completion barrier 70 and at least one passage hole 71 is provided in the wall of the completion barrier 70 located sufficiently high up the completion barrier 70 to permit the well fluids to pass from the

internal bore 72 of the completion barrier 70 to the annular space between the external wall of the completion barrier 70 and the corresponding casing section 12, 13, 14 and upwardly out of the well 11 as the completion barrier is lowered in the well 11.

33. A method according to claim 32, characterised in that following completion of the fitting of the completion barrier 70 the a least one passage hole 71 is closed by means of a suitable tool 73.



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Claims searched: 1 to 33

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Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:
UK Cl (Ed.O): E1F (FAC; FJB; FKG)
Int Cl (Ed.6): E21B
Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	US 3948321 (Owen et al)	1

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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