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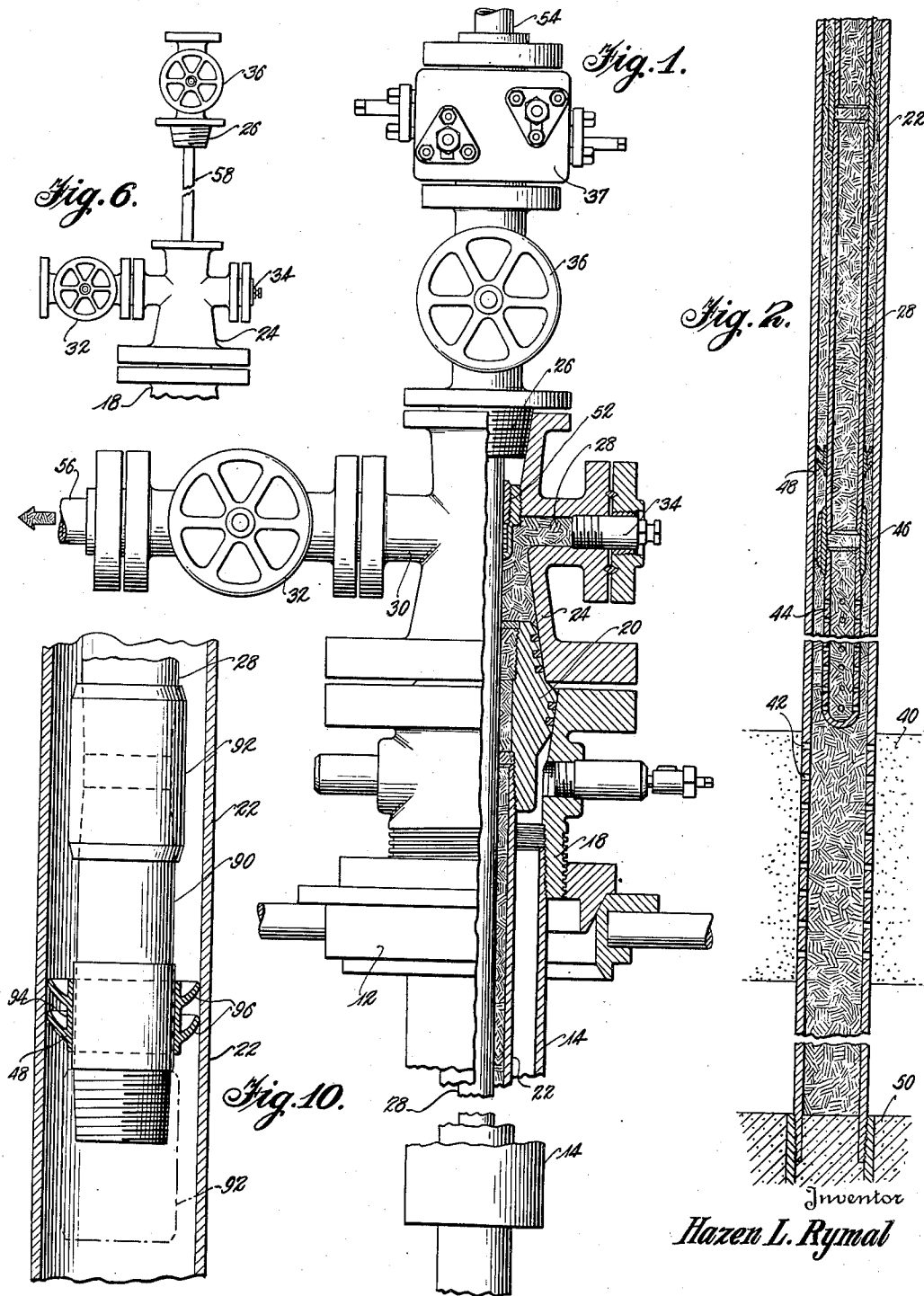
H. L. RYMAL

2,193,144

METHOD AND APPARATUS FOR FORMING MUD SEALS

Filed May 25, 1939

3 Sheets-Sheet 1



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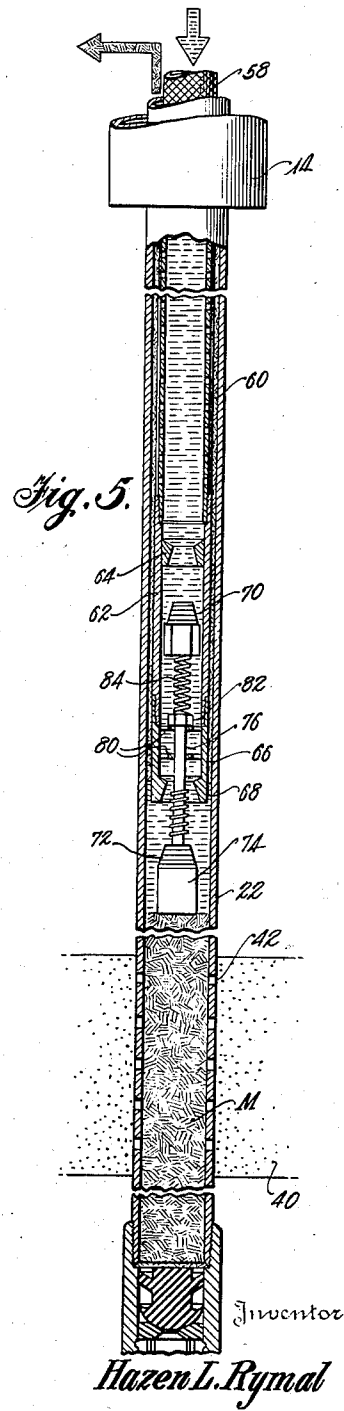
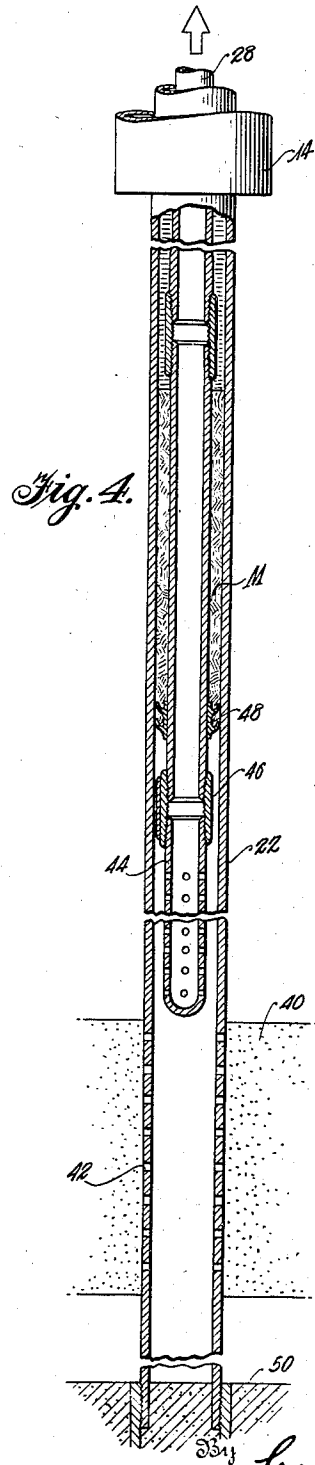
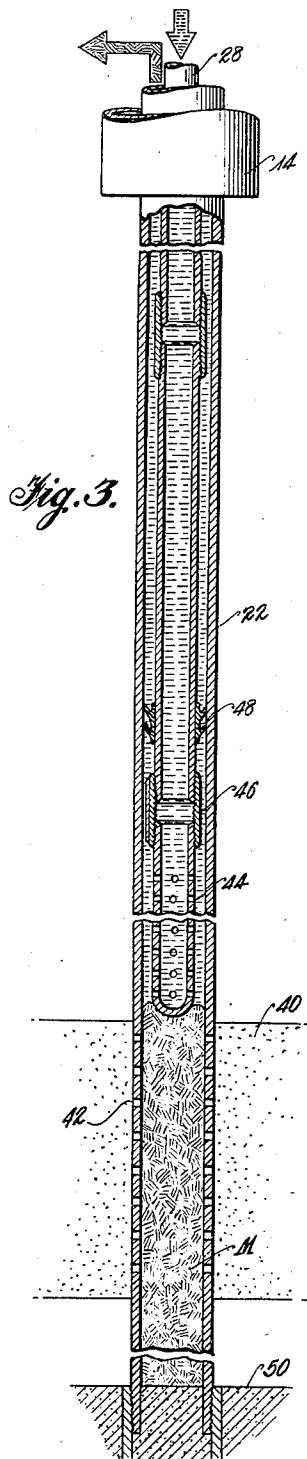
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METHOD AND APPARATUS FOR FORMING MUD SEALS

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3 Sheets-Sheet 2



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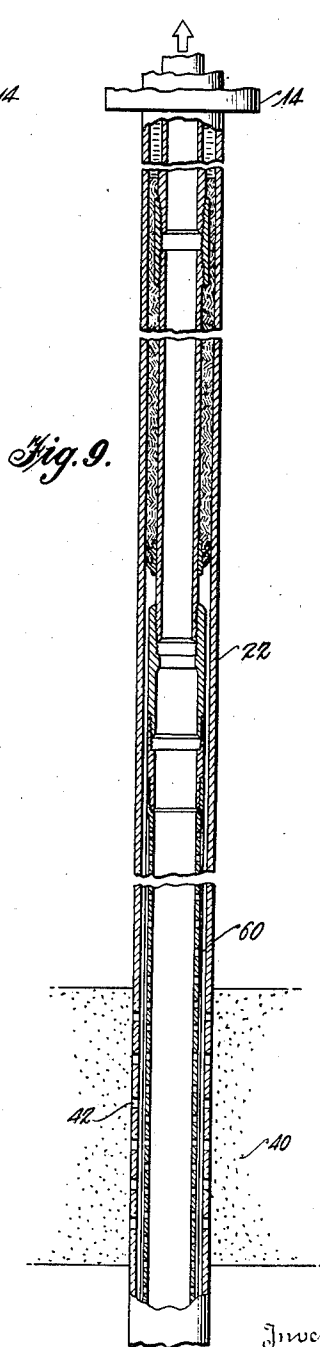
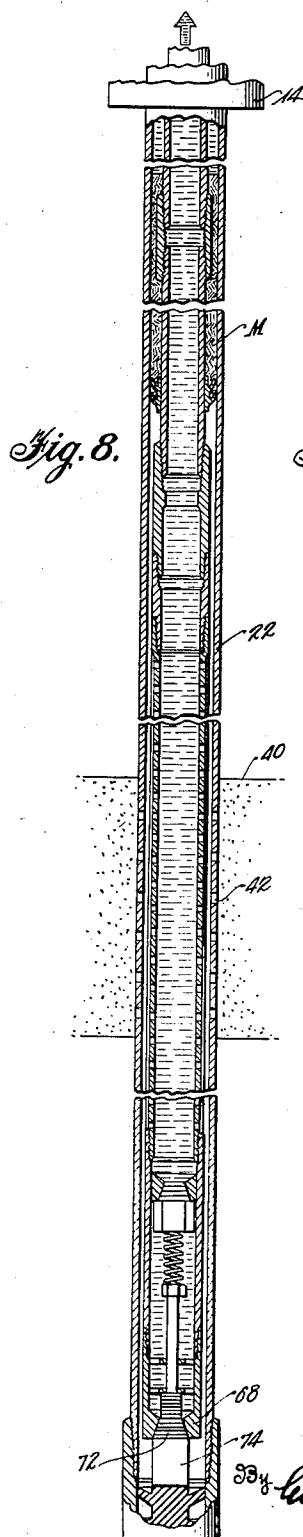
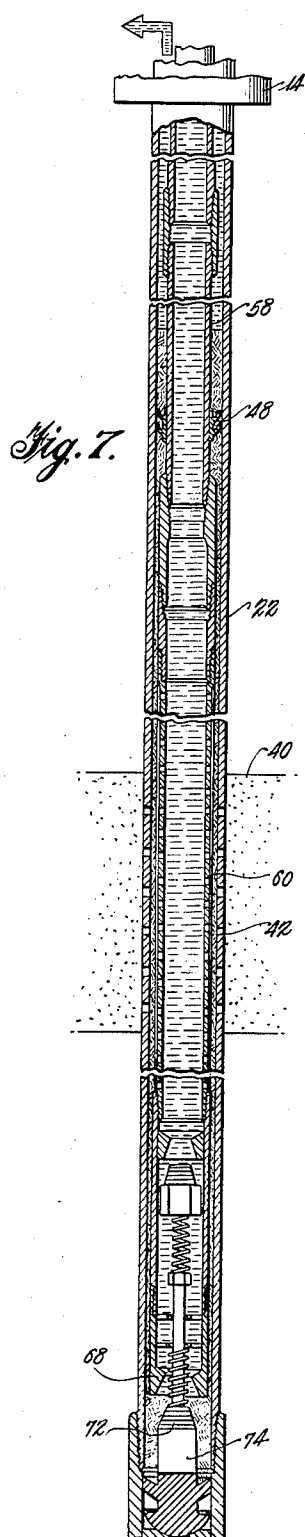
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2,193,144

METHOD AND APPARATUS FOR FORMING MUD SEALS

Filed May 25, 1939

3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,193,144

METHOD AND APPARATUS FOR FORMING
MUD SEALS

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Application May 25, 1939, Serial No. 275,774

19 Claims. (Cl. 166—1)

The present invention relates to methods and apparatus for completing wells wherein a quantity of the oil well mud used during the drilling of the well is maintained in position above the opening from the casing to the producing formation and there permitted to harden or gel, to form a seal between the tubing and the casing.

A principal object of the invention is to conveniently provide such a seal in such manner that when the well is initially produced under natural formation pressure, clear oil will immediately be flowed upwardly through the tubing.

Another object of the invention is to form a seal between the tubing and casing with the ordinary oil well mud used while drilling the well.

Another object of the invention is to form a seal between the tubing and casing, without employing a mechanical packer on the tubing and without the inconvenience of manipulating the tubing as is now necessary to set such a packer.

Various other objects of the invention will be apparent as the specification progresses.

In the drawings, I have shown how the invention is practiced with one particular type of oil well completion equipment. It will be understood, however, that the invention may be practiced with many other of the well known types of apparatus used in completing wells.

In the drawings, which are, therefore, illustrative and in no sense restrictive,

Figure 1 is a side elevational view, partly in section, of the casing head and Christmas tree equipment of a well, which equipment can be used in practicing the invention. This view diagrammatically shows a portion of the well which extends into the ground in section;

Figure 2 is a vertical sectional view through that portion of the well which extends into the ground to the oil producing formation, showing the portion of the well which extends below that portion shown in Figure 1;

Figure 3 is a view similar to Figure 2, showing the well at a further stage of the method;

Figure 4 is a view similar to Figure 2, showing the condition of the well at the termination of the method of this invention, when the well is in condition for production;

Figure 5 is a view similar to Figure 2, showing the first step of the method as practiced with another type of oil well completion apparatus;

Figure 6 is a view similar to Figure 1, showing the condition of the equipment at the casing head when the modified form of the apparatus for

practicing the method is in the position of Figure 5;

Figures 7 and 8 are similar views of the apparatus of Figure 5, showing the well at subsequent stages of the method;

Figure 9 is a view similar to Figure 5, showing the condition of the well at the completion of the modified method, with the well producing through the tubing, and

Figure 10 is an enlarged detail view of the oil well tubing, showing the novel form of packer mounted thereon.

For purposes of illustration, I have shown the present invention associated with oil well completion casing head apparatus of the type disclosed in Patent 2,104,294, Cullen, January 4, 1938. By "casing head" apparatus, I mean that equipment provided on the top of the casing and tubing at the surface of the well.

An understanding of the invention will indicate, however, that it may be conveniently practiced with other forms of casing head equipment.

In Figure 1, an arrangement of casing head equipment convenient for use with relatively deep wells is illustrated. This equipment is mounted upon a foundation ring 12, which is cemented in position at the surface of the well. Extending downwardly into the well from the foundation ring is an outside string of casing 14, which is cemented at its lower end during the drilling of the well.

The first casing head is shown at 18 and it is provided with a central bore terminating at its upper end in a hanger seat in which the casing hanger 20 is hung to form a seal.

The casing hanger 20 is secured to the upper end of a second or inner string of casing 22, which second string of casing is shown in the present illustration as extending down through the producing formation of the well.

The hanger 20 is of a type having an upper tapered sealing surface, now well known in the art, which surface seals with the interior bore of a second casing head 24, this head being usually termed a tubing head. The tubing head also has a bore therethrough, at the upper end of which is provided a seat adapted to receive and seal with the tubing hanger 26, which hanger is secured to the upper end of the tubing 28, the latter extending downwardly through the inner string of casing 22 to a point adjacent the producing formation.

The casing head 18 is provided with the usual side outlets which may be controlled by valves or closed by plugs as shown.

The tubing head 24 likewise is provided with the side outlets 28 and 30, and these outlets may be controlled by a valve 32, as shown in connection with the outlet 30, or closed by a plug 34, as shown with respect to the outlet 28.

The tubing hanger 26 is shown to be of a type having a flange adapted to connect with the flange of the tubing head 24 when the well is completed. However, any type of hanger may be used, and the same may be positioned in its seat and locked, and a Christmas tree flow control valve separate from the hanger may then be secured to the upper end of the tubing head. However, in the present invention, I have shown a well known type of combined hanger and Christmas tree valve, the Christmas tree flow control valve 36 being shown integral with the hanger.

Above the valve 36 is a device 37 known as a composite manifold, which is described in Patent 2,043,428, Cullen, June 9, 1936, which manifold is provided with suitable connections as described in connection with the above mentioned Cullen Patent 2,104,294. This manifold may be considered as a part of the Christmas tree, as it replaces various valves and fittings of more conventional trees.

Referring to Figure 2, the casing 22 is shown extending down into and through the oil producing formation 40, and is open to the producing formation adjacent its lower end. That is to say, the portion 42 of the casing which passes through the producing formation is perforated as shown for flow of oil into the casing in the usual manner. These perforations may be made after the casing is set; for instance, by a gun perforator.

The tubing 28 carries a perforated nipple 44 at its lower end, the nipple being attached to the tubing by means of a collar 46. The perforations in the nipple 44 are provided so that the well may flow into and upwardly through the tubing. However, it will be understood that a simple open ended tubing may be used if desired.

Above the collar 46 and on the exterior of the tubing is mounted a flexible mud support 48. This support is of novel construction, being non-rigid in nature and adapted to be deflected by fluid pressure below the same to permit fluid to pass upwardly through the casing around the outside of the tubing. The construction of the mud support is illustrated in Figure 10 and is hereinafter described.

The provision of the mud support 48 and the practice of the method of the present invention makes possible the forming of a seal between the tubing and the casing by solidified or gelled oil well mud. Heretofore, it has been the practice to complete wells of the type described above without the advantages afforded by such a seal.

In Figure 1, the well is shown equipped with what is known as a full string of casing 22 extending downwardly through the surface string 14 to the bottom of the well, said full string of casing being in communication with the interior of the tubing head 24 below the outlets 28 and 30. This full string of casing is provided with a shoe at its lower end which is cemented in the bottom of the well as shown at 50. It will be understood that fluid flowing upwardly through the casing may discharge outwardly through the tubing head by way of the outlets 28 or 30.

A stuffing box 52 may be provided within the tubing head 24 to form a seal around the tubing above the side outlets 28 and 30, if desired, de-

pending on the manner in which the tubing is installed.

When the tubing is inserted into the innermost string of casing in practicing the present invention, the well is filled with heavy mud as shown in Figures 1 and 2, this mud being used for holding back the formation pressures during the drilling, casing setting and tubing setting operations. Conventional oil well mud is usually made with a clay base and weighted with other substances, such as iron oxide, barites, etc. When a well is filled with this heavy mud fluid, its head is usually sufficient to overcome the natural pressure of the formation penetrated, and thus the well is kept under control.

With the well in the condition of Figure 1, it has been the practice to complete the same for production without forming a seal between the tubing and casing above the casing perforations by connecting the pumps with the tubing above the composite manifold as at 54, opening the valves 36 and 32, and pumping a lighter liquid, such as clear water, downwardly through the tubing to displace the mud in the well. This lighter liquid would flow outwardly through perforations in the nipple 44 at the bottom of the tubing, upwardly through the space between the tubing and the casing 22, and outwardly through the side outlet 30 in the direction of the arrow shown beside the discharge line 56. When the heavy mud had been displaced within the tubing and casing, the natural pressure of the formation would be sufficient to flow the well. It will be understood, however, that when this washing operation was performed, the casing was full of clear water from the tubing head 24 to the bottom end thereof, and when the well started to flow under natural formation pressure upwardly through the tubing, water remaining in the casing would be entrained with the upwardly flowing oil for a period of time, until all of the water within the casing had been removed. The result was that pure oil could not be produced from the well for a considerable period of time after actual completion, for the water or other lighter fluid used to displace the mud, would continue to be carried upwardly through the tubing by the oil in small quantities until all of the water was removed.

The present invention is intended to avoid this disadvantage and permit the well to immediately flow pure oil when the tubing is opened for production after the washing of the well.

Furthermore, with the condition illustrated in Figure 1, and without the provision of the mud support 48 and the method of the present invention, pressure from the formation builds up in the space between the casing and tubing and was exerted against all of the fittings at the top of the casing 22. This high formation pressure was, for instance, exerted on the side outlet valve 32, and on all of the interior surfaces of the tubing head 24. As this formation pressure may be considerable, great care had to be exercised in the maintaining of tight connections at the casing head to withstand this heavy pressure transmitted through the liquid within the casing 22 from the producing formation up to the casing head.

The present invention by providing a seal between the tubing and casing immediately above the producing formation prevents the pressure from being thus transmitted to the casing head.

As stated above, the mud support 48 has continuous, circular, flexible webs of rubber or the

like, as shown in Figure 10, which extend from the outer wall of the tubing upwardly and outwardly into contact with the inner wall of the casing. These webs are flexible enough so that when fluid pressure is applied upwardly from beneath them, the fluid can bend them upwardly and flow upwardly through the casing.

With the well in the condition of Figure 1, the method of the invention is practiced in the manner discussed below. The casing head valve 32 and the Christmas tree valve 36 are opened, and clear water or any other desired fluid lighter than the mud is pumped downwardly through the tubing 28, this fluid passing outwardly through the perforations in the nipple 14 and upwardly through the casing outside of the tubing past the mud support 48. The clear fluid displaces the mud in the casing, which is forced upwardly and permitted to relieve through the side outlet 30 in the casing head and through the discharge line 56. The operation of thus circulating a lighter liquid, called washing, is continued until all of the mud has been displaced and forced from the well, from above the lower end of the tubing. This washing operation clears the perforations in and washes the outside of the nipple 44. The condition of the well after this washing operation is illustrated in Figure 3, wherein the tubing and casing are shown filled with water from a point above the lower end of the tubing, which point is just above the perforated section 42 of the casing, to the surface of the well. This washing operation leaves a remaining body of mud M in the casing below the lower end of the tubing, but the main body of fluid in the well is composed of the relatively light liquid, such as clear water. Therefore, the formation pressure at this time is great enough to overbalance the weight of the column of water, so that when the Christmas tree valve 36 is closed and the casing head valve 32 is opened, oil from the producing formation 40 enters the casing through the perforations 42, and forces the remaining body of mud below the lower end of the tubing upwardly.

The formation pressure is permitted to thus displace the remaining body of mud upwardly in a controlled manner, by employing a well known control device, such as a choke, in the discharge line 56 outside of the valve 32. The choke restricts the outward flow of fluid from the casing under the formation pressure so that the remaining body of mud is elevated relatively slowly. The upward movement of fluid in the casing at this stage of the method is permitted until the remaining body of mud, which was below the lower end of the tubing in Figure 3, has moved upwardly until it is just above the mud support 48, as shown in Figure 4. It will be understood from the above description that the webs of the support 48 yield upwardly to permit the mud to pass by the same. From the quantity of discharge through the outlet line 56 from the casing head, it can be estimated when the remaining body of mud has moved to a point just above the packer 48. The outlet valve 32 is then closed. At this time, there is a body of mud above the support 48 as shown in Figure 4, and above this body of mud there is a column of lighter liquid, such as clear water, extending to the surface of the well within the casing.

When the body of mud has been thus moved upwardly above the support, the well is immediately ready to flow. The Christmas tree flow control valve 36 is opened, and the well is per-

mitted to produce through the tubing under its natural formation pressure. That is, the pressure from the formation 40 forces oil through the perforations 42 in the casing, through the perforated nipple 44 in the lower end of the tubing, and upwardly through the tubing past the flow control valve 36 and through the composite manifold 37, as indicated by the arrow at the top of Figure 4. The composite manifold can be adjusted to flow the oil through any desired lines to tanks, pipe lines, etc. In the case of a normal well, the weight of the column of liquid above the support 48 at the time the flow of the well is initiated through the tubing, is slightly less than the pressure of the formation within the casing 22 below the support 48. As the valve 32 is closed, the pressure of the formation is exerted to force oil upwardly through the tubing. Support 48 serves to separate the mud above the same from the oil below the support which is being forced upwardly through the tubing. Thus no mud is entrained with the oil as the well is initially produced through the tubing. Obviously, with the valve 32 closed at this time, there is a solid column of non-compressible liquid from the mud support 48 upwardly to the tubing head 24. The weight of this column of liquid, as stated before, is slightly less than the formation pressure below the mud support under normal conditions. In the above situation, there is no strain on the relatively delicate webs of the mud support 48 during the flowing of the well through the tubing, and these webs merely serve to separate the oil from the mud and water.

It is a well known fact that oil well mud, when permitted to set, will assume a semi-solid or gelled condition. As the well flows after the opening of the valve 36, as described above, the body of mud above the support 48 remains dormant and gels. In its semi-solid or gelled condition, it forms a seal between the outside of the tubing and the inside of the casing above the support 48. The gelled mud thus forms the seal, the member 48 merely serving to isolate and support the mud while it is solidified, as well as providing some support for the semi-solid body of mud, after it has assumed its gelled condition. As the mud gels, it adheres to both the tubing and casing, forming a tight seal between the same.

As the well continues to flow, and after the mud has gelled, as described above, the formation pressure will eventually drop until it is not as great as that exerted by the head of liquid above the mud seal which in turn is above the support 48.

Notwithstanding this drop in pressure, no mud or water will be entrained with the oil at this stage of production, for the mud seal will continue to support the liquid in the casing above the same, even though the pressure below the support has fallen off until the said head of liquid exceeds it.

The casing head fittings are not subjected throughout the flow life of the well to the high pressure of the formation, as would be the case if the mud seal were not present, as this body of gelled mud adheres to the walls of the tubing and casing, and is sufficiently rigid so that the pressure below the same is not transmitted to the fluid in the casing above the seal. When the seal has been formed as described above, a pressure gauge positioned in an opening in the casing head 24 will indicate zero pressure.

In the above procedure, the well was washed

after the tubing hanger 26 had been landed in the tubing head 24 to permanently seal off the upper end of the well. This procedure was possible using the apparatus described in connection with Figures 1 through 4. It is sometimes necessary or desirable to complete wells with other types of apparatus, and Figures 5 through 9 describe a slightly different method wherein different apparatus is employed.

Referring to Figures 5 and 6, the oil well illustrated is generally the same as that described in connection with Figures 1 through 4, including the casing extending through the producing formation, the casing and tubing heads, Christmas tree and control valve, and casing head outlet valve. However, the lower end of the tubing employed is somewhat different from that illustrated in Figure 1 through 4, being more like the construction illustrated in the aforementioned Cullen Patent 2,104,294. In Figure 5, the lower end of the tubing 58 is provided with a perforated portion 60, this section being threaded into a sleeve 62 which carries an inside valve seat 64. To the lower end of the sleeve 62 is threaded a shoe 66, the lower end of which constitutes an outer valve seat 68.

A pair of valve members 70 and 72 are designed to engage the valve seats 64 and 68, respectively, and close off the lower end of the tubing. When the tubing is being lowered into the well, the valve member 72 extends downwardly below the lower end of the tubing and remains off of its seat, this valve being integral with a heavy block 74. Connected with and extending above the upper end of the block 74 is a valve stem 76, and the stem is guided by spiders 80, which are secured to the interior of the shoe 66. Extending between the head 82 of the valve stem 76 and the lower end of the valve 70 is a spring 84.

The valve construction illustrated above may take various forms and that herein described is used only for purpose of illustration. A single valve only may be used, as in the above mentioned Cullen Patent 2,104,294, or a double valve, as described, may be employed. In fact, the conventional back pressure valve of a tubing, which permits downward flow of fluid, but prevents upward flow of fluid through the tubing, could be employed.

When the tubing is positioned with its lower end above the perforated portion 42 of the casing, and above the producing formation, its upper end extends above the tubing head some distance, as illustrated in Figure 6. The tubing hanger 26 is attached to the upper end of the tubing, as shown in Figure 6, a distance above the tubing head equal to the distance the tubing must be lowered before the well is in condition for flow. With the tubing thus extending upwardly through the casing head, the stuffing box seal 52 (shown in Figure 1) is employed between the outside of the tubing and the inside of the tubing head, to seal off the well above the side outlets 28 and 30.

With the equipment in this condition, the well is washed to remove the mud from above the lower end of the tubing, as described in connection with Figures 2 and 3, by forcing a current of lighter liquid, such as clear water, downwardly through the tubing 58, out through the lower end thereof, and upwardly between the casing and tubing to discharge through the side outlet 30 under control of the valve 32. This washing operation cleans the outside of the perforated

section 60 of the tubing. As previously described, this displaces the long column of mud in the well and substitutes therefor a column of lighter fluid extending from the bottom of the tubing to the casing head. The condition of the well as described above is shown in Figure 5. This washing operation causes the pressure of the producing formation to overbalance the head of liquid in the well, but the well is not yet permitted to flow, as the space between the tubing and casing is closed off by the stuffing box 52 and the valve 32, while flow through the tubing is under control of the valve 36.

Referring to Figure 7, the tubing 58 is equipped with a support 48 of the type previously described, this support being carried by the tubing above its perforated section 60.

When the well has been washed of mud above the lower end of the tubing, as shown in Figure 5, there is a remaining body of mud M in the well below the lower end of the tubing, and the tubing is lowered until the block 74 strikes the bottom of the well, as shown in Figure 7. If desired, the tubing may at this stage be completely lowered until valve member 72 is forced against its seat 68, as shown in Figure 8. This lowering of the tubing displaces a portion of the mud M upwardly above the packer 48. Thereafter, the casing head valve 32 may be opened and the well permitted to relieve from the interior of the casing 22 through the outlet 30 in discharge line 56 in a controlled manner, as previously described, until all of the remaining body of the mud is moved to a position immediately above the support 48, as shown in Figure 8. Thereafter, the tubing is further lowered until the valve member 72 is forced against its seat 68, as shown in Figure 8, at which time the tubing rests on the bottom of the well and the hanger 26 engages its seat in the upper end of the tubing head 24, as shown in Figure 1.

Thereafter, the valve 32 is closed and the valve 36 is opened, and the well will flow clear oil upwardly through the tubing, as shown in Figure 9. Using this modified apparatus, all of the conditions and advantages described in connection with Figures 1 through 4 will be present, and no mud or water will be entrained with the oil which is initially flowed through the tubing. That is, the support 48 will act as a separator, isolating the mud and water above the same, from the oil or gas below. Furthermore, as previously described, the remaining body of mud above the support 48 lies dormant as the well is flowed, and is permitted to become semi-solid, or to gel, forming a seal between the tubing and casing, with all of the results and advantages previously described.

The above description of the method of this invention is given with particular reference to the apparatus shown in the drawings. This apparatus is used only for purposes of illustration, and it will be apparent that the method may be practiced with other well known types of oil well equipment. That is, the method may be practiced using other "casing head" equipment, and when following a different procedure of completion at the bottom of the well. For instance, the present method of forming a seal with mud between the tubing and casing may be practiced in more ordinary procedures of well completion, wherein the last string of casing is set and cemented at a point above the oil sands, the "drilling in" operation performed with the hole full of mud, and a liner or the like thereafter inserted into the

"drilled in" hole, this liner constituting the perforated section of the casing. If such procedure is being practiced on a particular well, the method of the present invention can thereafter be followed when the tubing is inserted with the mud support 48 thereon, by washing the well clear of mud above a certain point, permitting the pressure of the formation to move the remaining mud to position above the support, and then flowing clear oil through the tubing, this being done in the manner heretofore described in connection with the particular type of apparatus illustrated in the drawings.

The specific construction of the flexible support is shown in Figure 10. It is carried by a special short nipple or section of tubing 90, which is threaded into adjacent spaced collars 92. A length of the outside surface of the special nipple 90 is coated with copper, and the flexible support is secured to the outside of the nipple on the copper coating. The support comprises a rubber sleeve 94 having upwardly extending continuous circular flexible webs 96 which rest against the inner wall of the casing 22, as shown. These webs are sufficiently flexible so that fluid under pressure will pass upwardly past the same, but they are strong enough to support the quantity of remaining mud after it has been forced upwardly by formation pressure to a point above the support. That is, while these webs are quite delicate compared with those of ordinary oil well packers, they are quite efficient in performing in the manner previously described. As heretofore discussed, after the body of mud has been moved upwardly above the support, in a normal well, the pressure below the same will be slightly greater than the head of the liquid above the support. As the valve 32 is closed at this stage, pressures on opposite sides of the mud support will be substantially equal so that even though the webs of the support are quite flexible, they will perform their function of isolating the different liquids as previously described.

After a well has been on production, having been completed as previously described, if it becomes necessary for any reason to move the tubing, the semi-solid mud seal above the support can be conveniently removed by starting circulation through the space between the tubing and casing of the well. This circulation can be accomplished by pumping liquid downwardly through the space between the casing and tubing, and will dislodge the solidified material and liquefy the material so that it can be carried away by the circulation. As has been pointed out above, the webs 96 of the mud support are very flexible. While they are designed to extend upwardly, as shown in the drawings, to provide flow of fluid under pressure upwardly past the same, they also can be flexed downwardly by sufficient pressure above them to permit downward flow of liquid past the support. Therefore, if it is desired to remove the mud seal, pressure can be applied within the casing above the mud support, if desired, and fluid can be pumped downwardly past the same, and discharging upwardly through the tubing, to remove and carry away the solidified mud. This mud seal may also be broken down by forcing fluid under pressure downwardly through the tubing and opening the casing head outlet valve to permit the upward flow of fluid between the tubing and casing to dislodge and remove the solidified mud.

To permit the required circulation past the support 48, as described, the webs 96 should be

quite delicate. They may be of a thickness of about one fourth inch where they connect with the sleeve 94, tapering to a thickness of about one eighth inch at their outer ends. When not acted upon by pressure, the upper straight faces of the webs make an angle of about sixty degrees with the vertical, while the lower faces taper slightly with respect to the upper faces so that the webs are of gradually decreasing thickness from their inner to their outer ends. Of course, the dimensions of the support 48 may vary somewhat depending on the size of the tubing and casing with which it is used. However, from the above description it is evident that the support is designed for an entirely different operation than that performed by ordinary packers. While relatively delicate in construction, it serves effectively to separate the liquids in the well as previously described.

It will be apparent that various changes may be made in the apparatus and methods disclosed herein without departing from the invention.

I claim:

1. The method of completing a well having a casing filled with liquid mud and a tubing therein, which includes washing the major portion of the mud from the well and replacing the same with a lighter liquid, while leaving a remaining body of mud below the lighter liquid, supporting said remaining body of mud at a desired position between the casing and tubing, and permitting the same to gel to form a seal between the casing and tubing.

2. The method of completing a well having a casing filled with liquid mud and a tubing therein, which includes washing the major portion of the mud from the well and replacing the same with a lighter liquid, while leaving a remaining body of mud below the lighter liquid, causing the remaining body of mud to move upwardly to a desired position between the casing and tubing, supporting said remaining body of mud at the desired position, and permitting the same to partially solidify to form a seal between the casing and tubing.

3. The method of completing a well having a casing open to the producing formation, and filled with liquid mud, which comprises lowering a flow tubing to a point in the well adjacent the opening to the producing formation, washing mud from the well above the lower end of the tubing and replacing said mud with a lighter liquid, while permitting a body of mud to remain at the bottom of the well adjacent the opening to the producing formation, causing said remaining body of mud to move upwardly between the tubing and casing to a desired position above the opening therefrom to the producing formation, and permitting said body of remaining mud to gel at said desired position forming a seal between the casing and tubing above the opening to the producing formation for use when the well is flowed through the tubing.

4. The method of completing a well having a casing open to the producing formation, and filled with liquid mud, which comprises lowering a flow tubing to a point in the well adjacent the opening to the producing formation, washing mud from the well above the lower end of the tubing and replacing said mud with a lighter liquid, while permitting a body of mud to remain at the bottom of the well adjacent the opening to the producing formation, causing said remaining body of mud to move upwardly between the tubing and casing to a desired position above the

opening therefrom to the producing formation, supporting said body of remaining mud at said desired position and permitting it to gel forming a seal between the casing and tubing above the opening to the producing formation for use when the well is flowed through the tubing.

5. The method of completing a well having a casing open to the producing formation, and filled with liquid mud, which comprises lowering a flow tubing to a point in the well adjacent the opening to the producing formation, washing mud from the well above the lower end of the tubing and replacing said mud with a lighter liquid, thereby causing the formation pressure to overbalance the head of liquid in the well, while permitting a body of mud to remain at the bottom of the well adjacent the opening to the producing formation, causing said remaining body of mud to move upwardly between the tubing and casing to a desired position above the opening therefrom to the producing formation, and permitting said body of remaining mud to partially solidify at said desired position forming a seal between the casing and tubing above the opening to the producing formation for use when the well is flowed through the tubing.

6. The method of completing a well having a casing open to the producing formation, and filled with liquid mud, which comprises lowering a flow tubing to a point in the well adjacent the opening to the producing formation, washing mud from the well above the lower end of the tubing and replacing said mud with a lighter liquid, thereby causing the formation pressure to overbalance the head of liquid in the well, while permitting a body of mud to remain at the bottom of the well adjacent the opening to the producing formation, causing said remaining body of mud to move upwardly under formation pressure to a desired position between the tubing and casing above the opening therein to the producing formation by relieving pressure from the casing at the surface of the well, and supporting said body of remaining mud at said desired position and permitting it to partially solidify forming a seal between the casing and tubing above the opening to the producing formation for use when the well is flowed through the tubing.

7. The method of completing a well having a casing open to the producing formation, and filled with liquid mud, which comprises lowering a flow tubing into the well until its lower end is adjacent to and above the opening to the producing formation, washing mud from the well above the lower end of the tubing with a current of lighter liquid forced downwardly through the tubing and upwardly through the casing, thereby causing the formation pressure to overbalance the head of liquid in the well, while permitting a body of mud to remain at the bottom of the well at the level of the opening to the producing formation, causing said remaining body of mud to move upwardly under formation pressure to a desired position between the tubing and casing above the lower end of the tubing and above the opening from the casing to the producing formation, by relieving pressure from the casing at the surface of the well in a controlled manner, and supporting said body of remaining mud at said desired position and permitting it to partially solidify forming a seal between the casing and tubing above the opening from the casing to the producing formation for use when the well is flowed through the tubing.

8. The method of flowing oil from a well hav-

ing a casing with a perforated section at the oil producing formation and filled with liquid mud, comprising lowering a flow tubing into the casing and establishing above the perforated section of the casing a point above which the mud is to be washed from the well, washing and replacing the mud from the casing above the established point with a lighter liquid forced through the tubing, thereby causing the formation pressure to overbalance the head of liquid in the well, while permitting the body of mud in the casing below the established point to remain in the well, causing said remaining body of mud to move upwardly under the formation pressure to a desired position between the tubing and the casing above the perforated section of the latter by relieving pressure from the casing at the surface of the well, and supporting said body of remaining mud at said desired position and permitting it to partially solidify forming a seal between the tubing and casing above the perforated section of the latter for use when the well is flowed through the tubing.

9. The method of completing a well having a casing open to the producing formation and a casing head with an outlet for release of pressure therefrom, and filled with liquid mud, which comprises lowering a flow tubing into the well until its lower end is adjacent the producing formation, forming a seal between the tubing and casing above the casing head outlet, washing and replacing the mud from the well above the lower end of the tubing with a lighter liquid circulated through the well by way of the tubing and the outlet in the casing head, thereby causing the formation pressure to overbalance the head of liquid in the well, while permitting a body of mud to remain at the bottom of the well adjacent the opening to the producing formation, causing said remaining body of mud to move upwardly under the formation pressure to a desired position between the tubing and the casing above the opening to the producing formation by relieving pressure from the casing through said casing head outlet, and supporting said body of remaining mud at said desired position and closing said casing head outlet, thereby permitting said remaining body of mud to partially solidify forming a seal between the casing and tubing above the opening to the producing formation for use when the well is flowed through the tubing.

10. The method of completing a well having a casing with a perforated section at the producing formation and filled with liquid mud, comprising lowering a flow tubing into the casing until its lower end is adjacent the perforated portion of the casing, washing from and replacing the mud in the casing above the lower end of the tubing with a lighter liquid forced through the tubing, thereby causing the formation pressure to overbalance the head of liquid in the well, while permitting a body of mud to remain in the casing below the lower end of the tubing, closing the tubing, displacing said remaining body of mud upwardly in the casing to position above the lower end of the tubing by relieving pressure from the casing at the surface of the well, thereby causing oil to enter the perforations in the casing under formation pressure to displace said remaining body of mud upwardly, supporting said remaining body of mud at a point above the perforations in the casing, closing off the casing at the surface of the well so that said remaining body of mud may partially solidify, and

flowing the well from the producing formation through the casing perforations and upwardly through the tubing, while said body of partially solidified mud forms a seal between the casing and tubing above the perforations in the casing.

11. The method of completing a well having a casing head with an outlet for release of pressure therefrom, and a casing with a perforated section at the producing formation, and filled with liquid mud, comprising lowering a flow tubing into the casing until its lower end is adjacent to and above the upper end of the perforated section of the casing, washing from and replacing the mud in the casing above the lower end of the tubing with a lighter liquid forced downwardly through the tubing and upwardly through the casing and discharging from the casing head outlet, thereby causing the formation pressure to overbalance the head of liquid in the well, while permitting a body of mud to remain in the casing below the lower end of the tubing, closing the tubing, displacing said remaining body of mud upwardly in the casing to position above the lower end of the tubing by opening the casing head outlet to relieve pressure from the casing, thereby causing oil to enter the perforation in the casing under formation pressure to displace said remaining body of mud upwardly, supporting said remaining body of mud at a point above the perforations in the casing, closing the casing head outlet so that said remaining body of mud may partially solidify, and opening the tubing to permit the oil to flow from the producing formation through the casing perforations and upwardly through the tubing, said body of partially solidified mud forming a seal between the casing and tubing above the perforations in the casing.

12. The method of completing a well having a casing open to the producing formation, and filled with liquid mud, which comprises lowering a flow tubing to a point in the well adjacent the opening to the producing formation, washing mud from the well above the lower end of the tubing and replacing said mud with a lighter liquid, while permitting a body of mud to remain at the bottom of the well adjacent the opening to the producing formation, further lowering the tubing and causing said remaining body of mud to move upwardly between the tubing and casing to a desired position above the opening therefrom to the producing formation, and permitting said body of remaining mud to gel at said desired position forming a seal between the casing and tubing above the opening to the producing formation for use when the well is flowed through the tubing.

13. In oil well completion apparatus, a casing having a perforated section at the oil producing formation, a flow tubing in said casing positioned with its lower end adjacent said perforated section of said casing, and means on said tubing above said perforated section of said casing for supporting a column of mud fluid to permit the same to partially solidify and form a seal between said tubing and said casing, said means being constructed to provide for flow of fluid upwardly past the same between the tubing and casing before said column of mud has partially solidified.

14. A device for supporting a body of oil well mud at a desired elevation in the well between a tubing and a casing, comprising a continuous circular web adapted to be secured at its center to the tubing and to contact the casing at the periphery of the web, said web being

flexible to permit its deflection in one direction for passage of fluid upwardly between the tubing and casing thereby, while being sufficiently rigid against deflection in the opposite direction to separate a body of oil well mud from fluid in the well below the device to permit the mud to gel and form a seal between the tubing and casing.

15. A device for supporting a body of oil well mud at a desired elevation in the well between a tubing and a casing, comprising a continuous upwardly extending circular web adapted to be secured at its center to the tubing and to contact the casing at the periphery of the web, said web being composed of flexible material to permit its deflection upwardly and inwardly toward the tubing for passage of fluid upwardly between the tubing and casing thereby, while being sufficiently rigid against downward deflection to support a body of oil well mud to permit the same to gel and form a seal between the tubing and casing.

16. A device for supporting a body of oil well mud at a desired elevation in the well between a tubing and a casing, comprising a short nipple of pipe adapted to be connected in the tubing, and a flexible continuous circular web secured at its center to said nipple, said web being adapted to contact the casing at the periphery thereof, and being composed of rubber or the like to permit the web to be deflected for passage of fluid upwardly between the tubing and casing thereby, while being sufficiently rigid against downward deflection to support a body of oil well mud to permit the same to gel and form a seal between the tubing and casing.

17. A device for supporting a body of oil well mud at a desired elevation in the well between a tubing and a casing, comprising a short nipple of pipe adapted to be connected in the tubing, a sleeve of rubber or the like secured to the exterior of said nipple, and a plurality of spaced continuous circular upwardly extending webs of rubber or the like, spaced longitudinally of said nipple and integral with said sleeve, said webs being adapted to contact the casing at their peripheries, and being adapted to be deflected inwardly and upwardly toward the tubing for passage of fluid upwardly between the tubing and casing thereby, while being sufficiently rigid against downward deflection to support a body of oil well mud to permit the same to gel and form a seal between the tubing and casing.

18. The method of completing a well having a casing open to the producing formation and filled with liquid mud, and a tubing therein, which includes washing the major portion of the mud from the well and replacing the same with a lighter liquid circulated through the tubing, while leaving a remaining body of mud below the lighter liquid, closing the tubing and elevating the remaining body of mud to a desired position between the casing and tubing by the pressure of formation fluid entering the casing below said mud when the top of the casing is opened, separating said mud from the formation fluid and closing the top of the casing so that said mud may partially solidify to form a seal between the tubing and the casing, and opening the tubing for flow of the formation fluid therethrough.

19. In oil well completion apparatus, a casing having a perforated section open to the oil producing formation, a flow tubing in said casing positioned with its lower end adjacent said per-

forated section, a casing head having means for closing the well against flow of fluid from the casing, means for controlling flow of the well through said tubing, and a separating device having flexible webs of rubber or the like on said tubing above said perforated section of said casing to separate a column of mud fluid above the same from fluid under pressure of the formation below the same, so that said mud may partially solidify and form a seal between said tubing and said casing when the latter is closed

at the casing head, said flexible web being adapted to be deflected to permit flow of fluid upwardly therepast when said casing is open at said casing head and a washing fluid is pumped downwardly through said tubing, and when said tubing is thereafter closed to permit the pressure of fluid from the formation to move a body of mud in the casing to position above said separating device.

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