April 11, 1967 R. V. CROSS 3,313,346

CONTINUOUS TUBING WELL WORKING SYSTEM

Filed Dec. 24, 1964 6 Sheets-Sheet 1

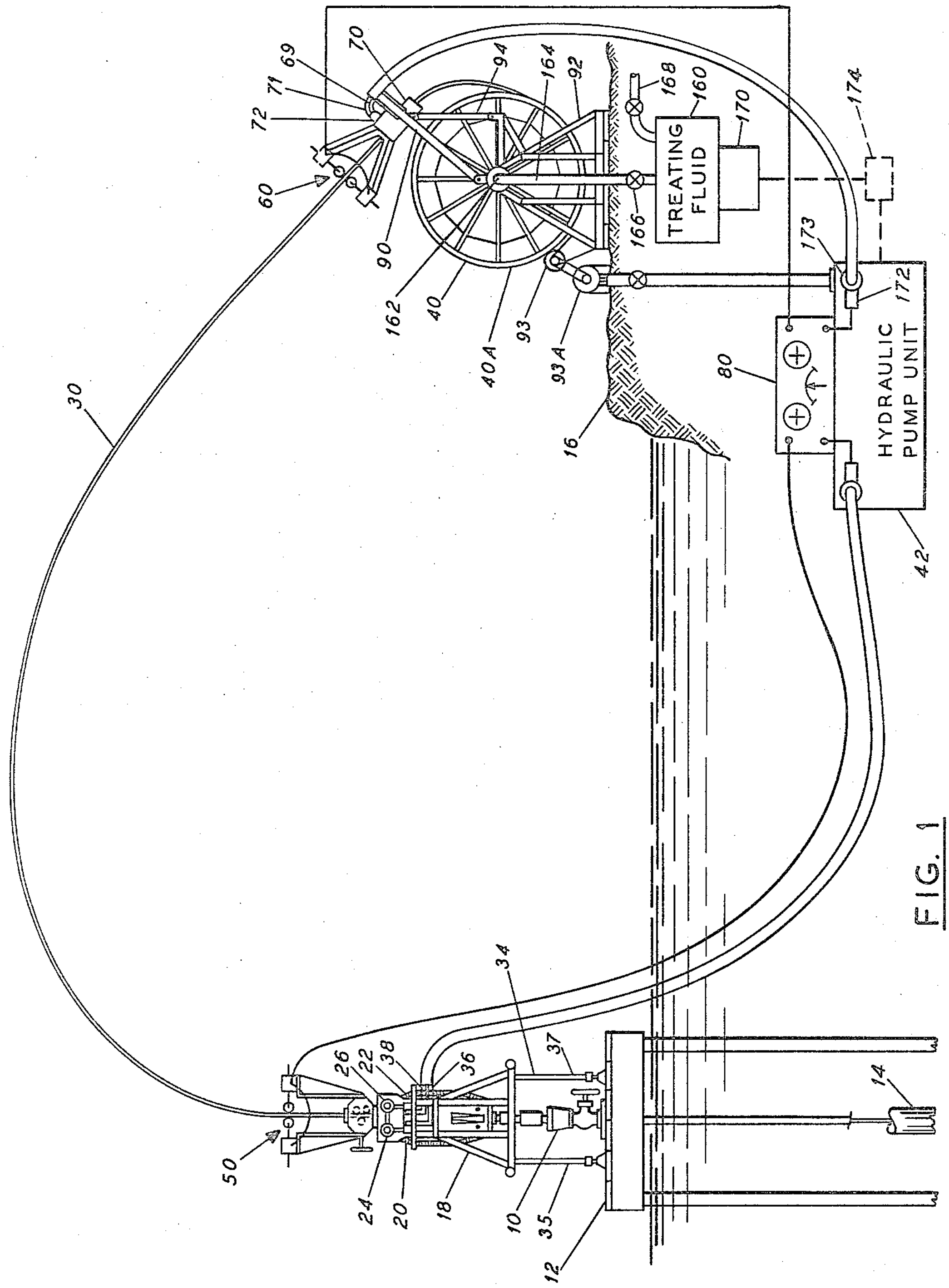

FIG. 1

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CONTINUOUS TUBING WELL WORKING SYSTEM

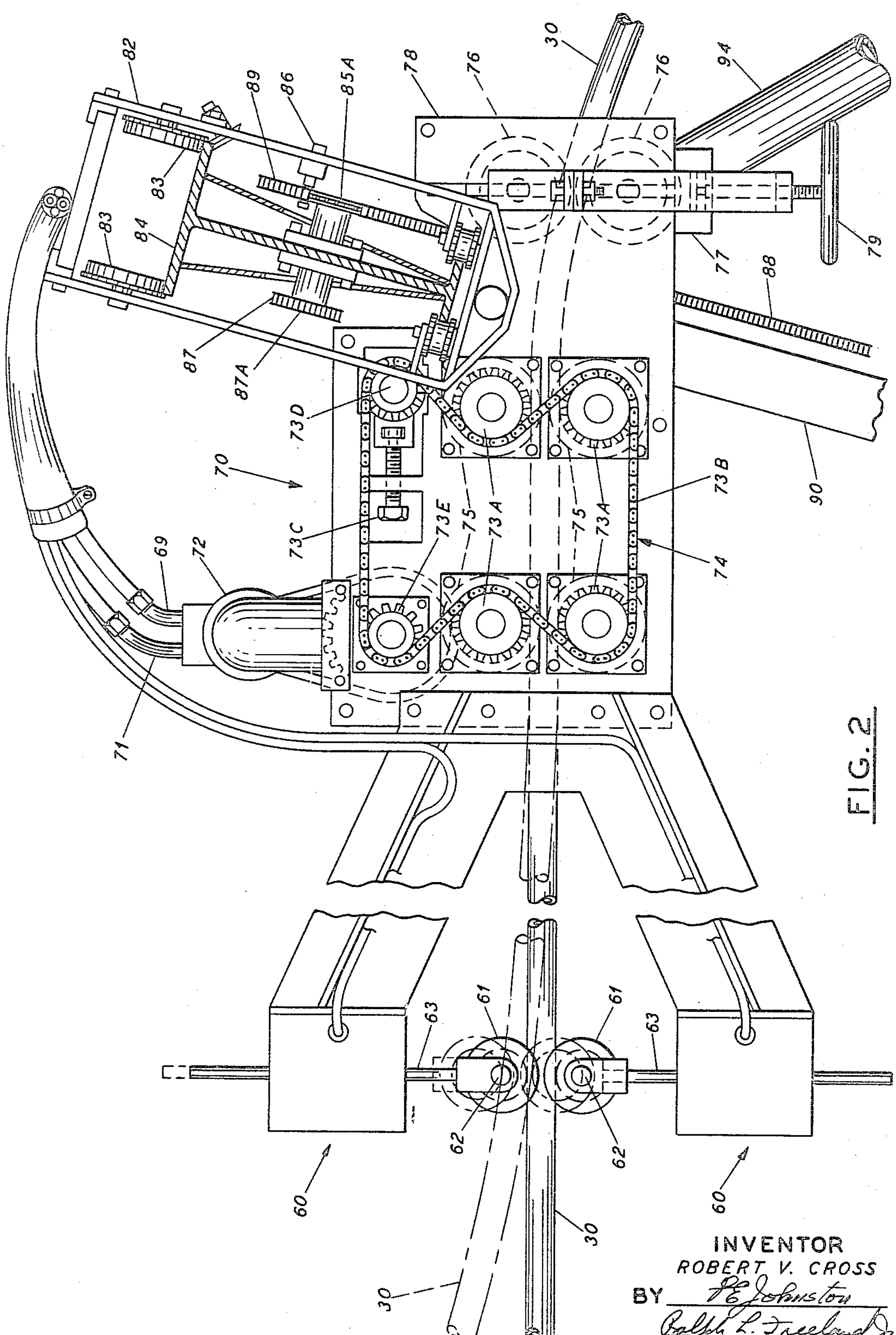

FIG. 2

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CONTINUOUS TUBING WELL WORKING SYSTEM

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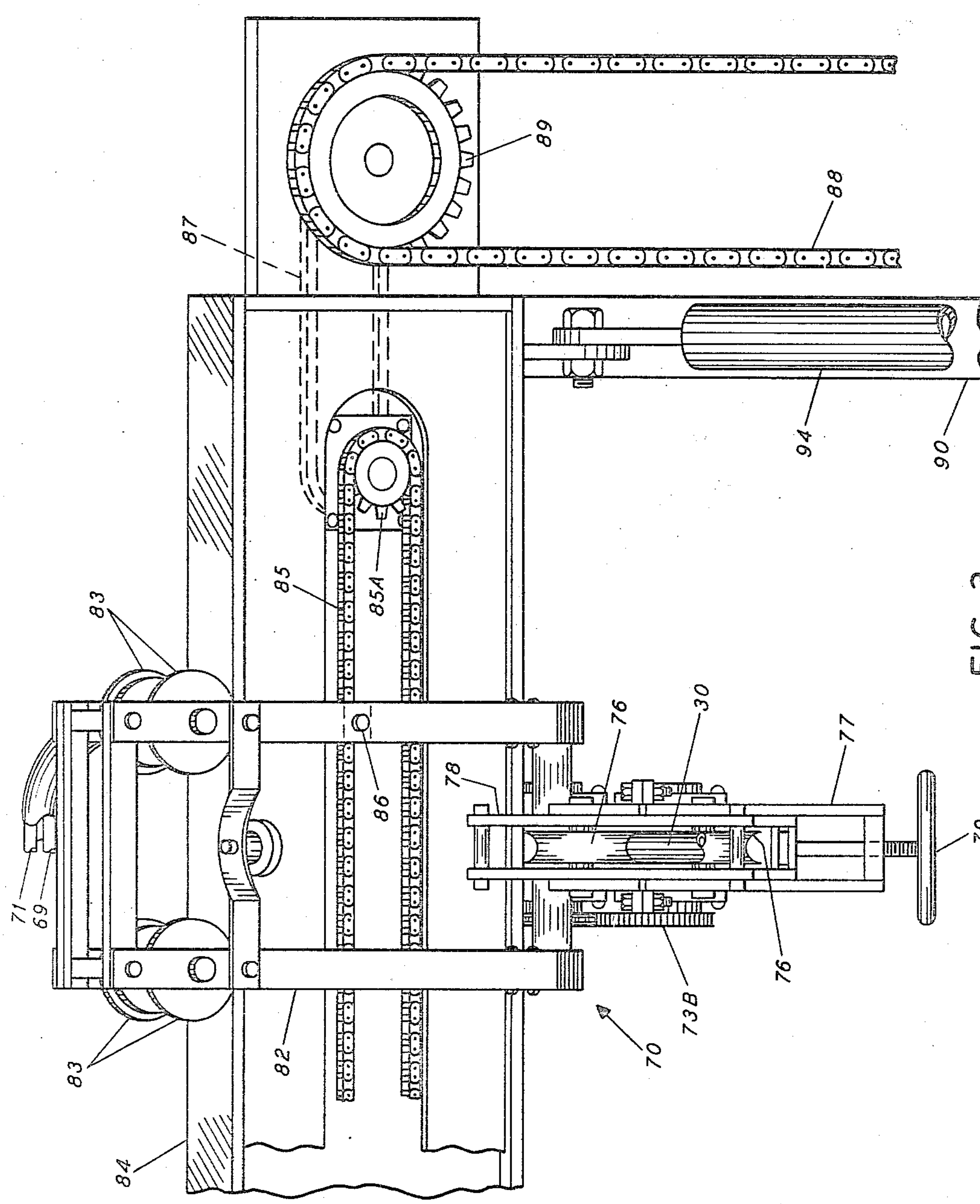

FIG. 3

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April 11, 1967 R. V. CROSS 3,313,346

CONTINUOUS TUBING WELL WORKING SYSTEM

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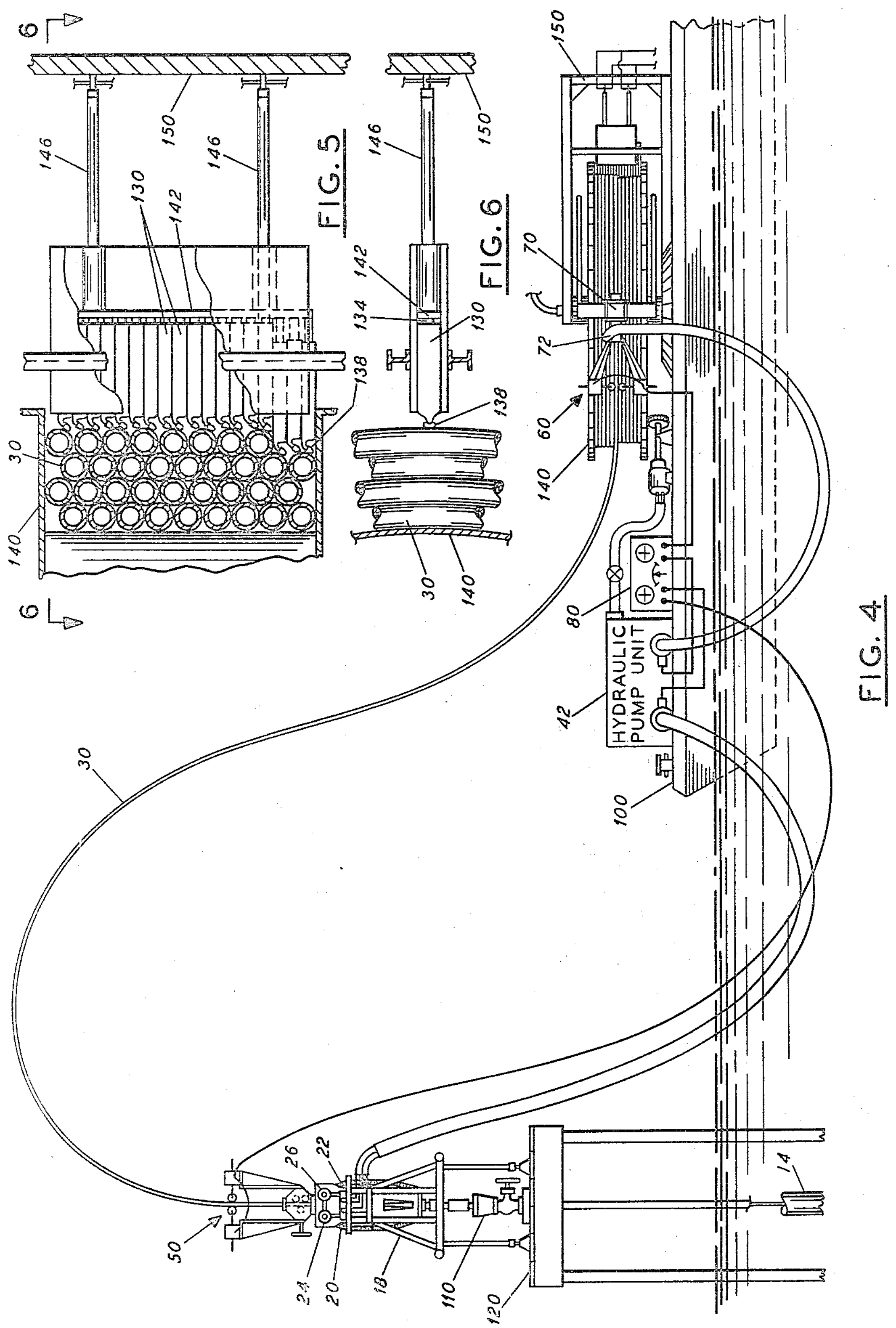

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CONTINUOUS TUBING WELL WORKING SYSTEM

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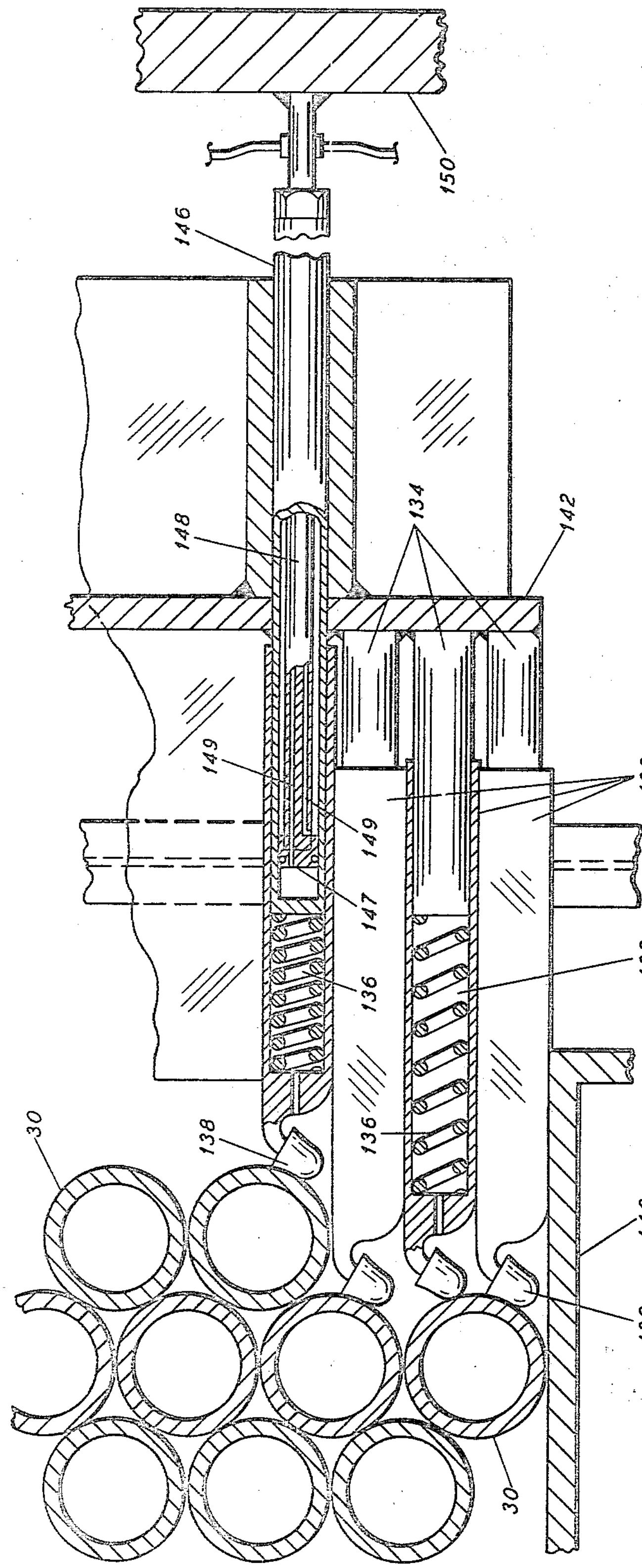

FIG. 7

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CONTINUOUS TUBING WELL WORKING SYSTEM

Filed Dec. 24, 1964 6 Sheets-Sheet 6

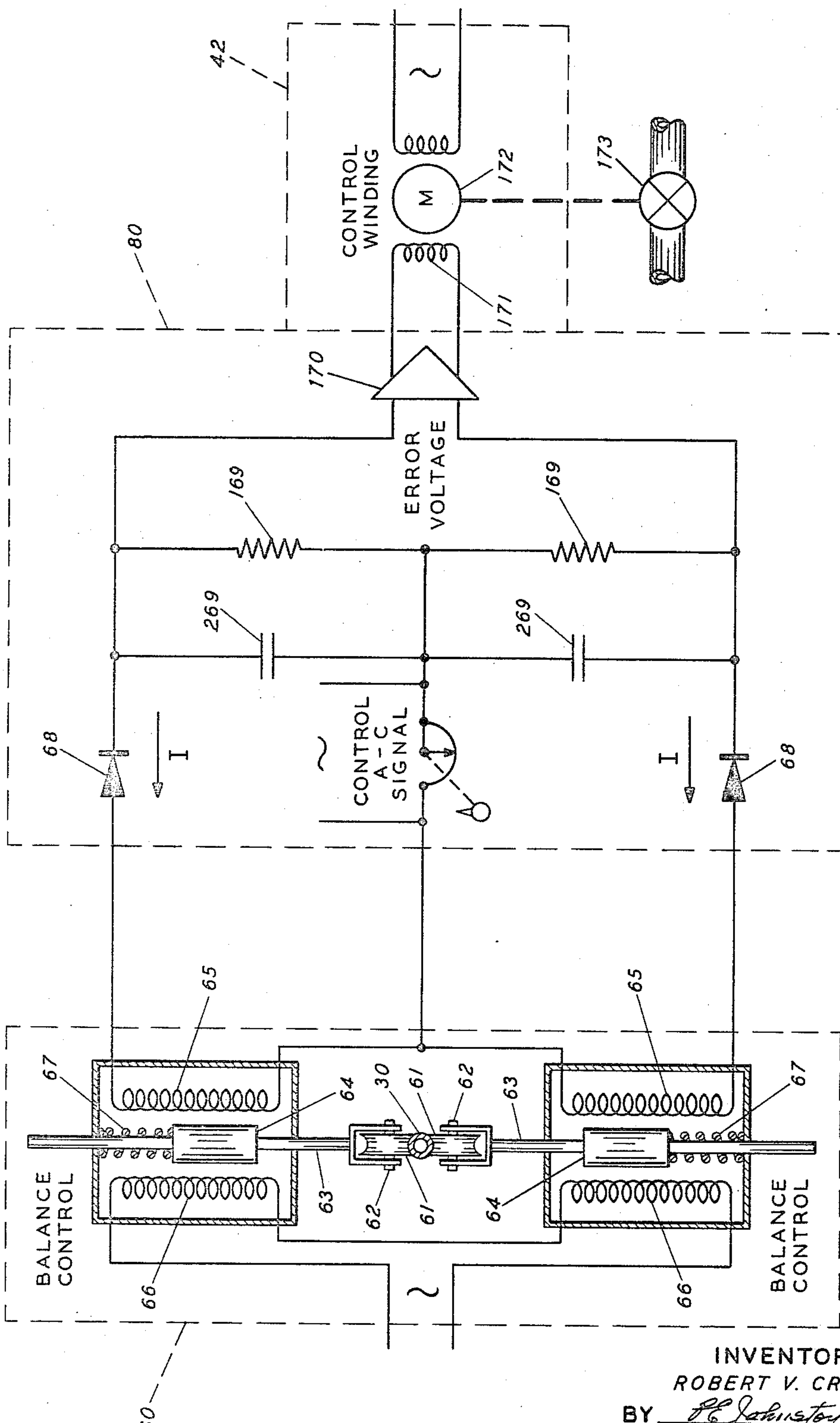

FIG. 8

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3,313,346
CONTINUOUS TUBING WELL WORKING SYSTEM

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Filed Dec. 24, 1964, Ser. No. 420,988
4 Claims. (Cl. 166—.5)

This invention relates to a method of working in wells without the use of a derrick or the like. More particularly, it relates to a method of working in a well using an operating string that is a continuous length of tubing coiled on a reel so that it can be fed into the well by a tubing injector.

It is a particular object of the invention to provide a method of working in an oil well or the like without using a derrick or other conventional hoisting equipment; additionally the method is independent of differences in elevation or proximity between the production platform for the well and the closest available work area on the earth's surface near the platform. In accordance with the invention, a continuous length of tubing is wound on a reel that is located on a work support, such as a barge or a truck, that can place the reel near the production platform. The free end of the tubing extends from the reel, and without intermediate support forms an unrestricted arc to the point where it enters a tubing feed means above the wellhead on the production platform. The tubing is then injected, or lowered, by the feed means into the well at a desired rate. The rate at which tubing is fed off the reel is then controlled to maintain a preselected form of said arc between the reel and the point where the tubing is fed into the well. Control of this arc is then regulated by the rate said tubing is transferred; such regulation is in a direction and to an extent required to maintain said preselected and unrestricted arc between the feed means and the reel within predetermined limits of curvature to avoid kinking, stretching, or loss of control of the portion of tubing forming said arc.

It has been known prior to this invention to wind pipe or tubing as a continuous string on a reel and to support the reel on a movable platform. It is also known to lower into a well production flow line a continuous length of pipe that can be hung to the desired depth in the well and then cut off. Continuous tubing has also been used to support a drilling turbine and bit assembly at the lower end of a drillstring. It has also been proposed to use such a system for washing, acidizing, or other well treatment. However, in previously known systems of this type, it has been necessary to provide guide means to form and maintain the arc between the tubing injector and the supply reel. If the units are separate, the reel must be located with respect to the feed mechanism so that, in effect, there is a direct drive from the reel and through the tubing guide means to the tubing injector. Alternatively, the feed mechanism has been synchronized to the reel drive. This drive connection also requires that the reel and the feed be directly next to each other, preferably mounted on a common base, and hence at the same elevation.

In offshore operations the flow lines are usually connected to the top of the well through a wellhead that is mounted on a production platform. These platforms frequently are crowded with multiple wells on the same platform. It is also common to use a small individual platform for each well. The latter usually has enough space around the well to permit normal gauging and well checking. To service a well in such a location, it is conventional to bring a work barge, including a derrick capable of handling 30 to 60 feet of well pipe at a time, up to the production platform. Because the producing wellhead, sometimes called the Christmas tree, varies in

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height with the type of well, the number of producing intervals in the well, and even pressure conditions of the well, it is desirable that the derrick be adjustable in height and that the production platform be clear of obstructions so that the derrick can be placed over the well. This, of course, requires that the original well platform be built to permit ready access when well servicing is needed. It also requires that allowances be made for other differences in elevation between the work surface and the production platform. Specifically, if wave and tide conditions are not favorable, as in open waters like the Gulf of Mexico or the Pacific Ocean, working in the well can be difficult or impossible. In land-based operations, access to the wellhead is sometimes physically blocked, or the production platform, including its earth base, may not be capable of supporting a workover rig derrick. In these cases, the well usually cannot be entered by conventional pipe handling equipment.

For the foregoing reasons it has been difficult to use known forms of continuous tubing systems since they have required intermediate support that depends upon a close proximity to, and a limited difference in elevations between, the wellhead and the pipe reeling means, or physical access next to the wellhead.

In accordance with this invention, these difficulties have been largely overcome by recognition that the tubing injector means can be isolated from the tubing reel and its support, and differences in elevation or difficult lateral access to the wellhead overcome, by forming the continuous length of pipe into an unrestrained arc extending between the reel and the tubing injector at the wellhead. The rate of unwinding of the tubing from the reel is then controlled independently of the tubing injection rate to maintain said unrestrained arc between reel and tubing injector within predetermined limits of curvature between the wellhead and reel. Such regulation of the rates of feed to maintain said arc thereby avoids kinking or stretching of the tubing and permits service work in wells not otherwise readily accessible.

In accordance with the invention, advantage can be taken of the fact that the stabilization of said unrestrained arc is assisted in extended arc forms by an initial deformation of the pipe from its original round form into a slightly oval shape. By the initial winding and unwinding of the tubing on and off the reel, the cross section of the pipe is made slightly ovate. This form is created by a slight stretch on the pipe's outer radius and slight compression at the inner radius as the pipe is wound as a layer on the reel. The oval form adds lateral stability to the pipe so that the unrestrained arc is more rigid transversely over an extended distance. Thus, independent of relative elevations between the feed point to the tubing injector above the well and the exit point of the pipe deforming element at the tubing reel, the pipe can be maintained in a preselected arc.

A particular advantage of maintaining the arc within predetermined limits is that the feed of the tubing from the reel to the injector is controllable independent of variations in load on the tubing injector while inserting an extensive length, say 15,000 feet of one-inch pipe into a hole against a working pressure of several hundred pounds per square inch. In such a well the tubing must first be forced into the well against well pressure. To do this, a positive downward drive force is applied to the tubing by the injector. After a sufficient length of pipe, say 3,000 or 4,000 feet, has been injected, the weight of the pipe and the pressure will substantially balance. However, upon further injection of pipe, the weight of pipe exceeds the force required to drive it into the well, so the injector, in fact, must act as a brake. When the tubing is withdrawn from the well, these drive and braking operations are reversed. By control responsive to the unrestrained arc of tubing between the tubing injector and pipe supply, in accordance with this invention, we have found it possible to control more accurately the tubing injector and reel feed rates substantially independent of these wide variations in load.

Further objects and advantages of the present invention will become apparent from the following detailed description taken in conjunction with the drawings.

In the drawings:

FIGURE 1 is a schematic representation of an automatic arc control system for a well working rig illustrated as applied to a well having a small production platform and a Christmas tree at a difficult accessible location.

FIGURE 2 is an enlarged side elevation partially in cross section of an arc sensing unit mounted on the tubing bender and level winder shown in FIGURE 1 for continuously feeding drill pipe to and from the tubing reel.

FIGURE 3 is a perspective top plan view of the tubing bender and level winder shown in FIGURE 2.

FIGURE 4 is a schematic representation of an alternate form of well working rig adapted to be transported by barge to an offshore well with the tubing reel mounted for rotation about a vertical axis.

FIGURE 5 is a cross-sectional view of a part of the tubing reel shown in FIGURE 4, partially in vertical cross section, to illustrate means for controlling the levels of pipe winding on the drum.

FIGURE 6 is a partial plan view taken in the direction of arrow 6—6 of FIGURE 5.

FIGURE 7 is an enlarged view in cross section of the bottom portion of FIGURE 5, better showing the operating mechanism for holding tubing layers on the reel.

FIGURE 8 is a circuit diagram of one form of automatic arc control system useful with the systems illustrated in FIGURES 1 and 4 to control power through the hydraulic pumping systems to operate the tubing injector and the reel drive systems.

Referring now to the drawings and particularly to FIGURE 1, a wellhead **10** is illustrated as being positioned on a small production platform **12** over a well **14** drilled in a relatively inaccessible location. Inaccessibility in such a well is illustrated in the following manner. In the Gulf Coast area of the United States, many wells are drilled in the bayou or swamp areas by dredging a canal to the well site. Frequently such a site is accessible only by water, but not by road, so that it is also necessary to bring in equipment to work on the well by barge. FIGURE 1 illustrates such a location where an adjacent work area, indicated by earth bank **16**, is near to, but not directly adjacent, well **14**. Thus, the continuous tubing reel **40** and the associated power supply such as hydraulic pumping unit **42** can be located sufficiently close to platform **12** to permit an unrestricted arc to be formed of pipe **30** over to wellhead **10**. Obviously, intermediate support or drive is quite impractical, because wellhead **10** is located on a small production platform that frequently is only large enough to support the wellhead and flow control, or pumping equipment. It usually includes a few walkways for workmen. Prior to our invention it has been common practice, if space and access were available, to bring a derrick barge up to the platform to work in the well. In the present invention, such a barge is not needed because it is necessary only to mount tubing injector **18**, which can be lifted by a chain hoist or the like, directly over wellhead **10**. Tubing injector **18**, as such, does not form part of the present invention, however, since such units are available commercially. The function of such a unit is to drive tubing **30** into wellhead **10** against load through a pair of endless tracks **20** and **22** driven respectively by hydraulic motors **24** and **26**. Tracks **20** and **22** engage the side of tubing **30** just above wellhead **10** and anchors one end of the unrestricted arc of tubing **30** extending from tubing reel **40**. Sufficient friction is developed between tracks **20** and **22** so that they grip the sides of pipe **30** firmly enough to push the pipe into the top of the wellhead even against well pressure. As explained above, the function of the tubing injector **18** will vary as to whether it is pushing or pulling both on the injection and on retraction of the tubing.

As indicated by framework **34**, tubing injector **18** may be mounted on adjustable legs **35** and **37** supported on work platform **12**. Desirably, the weight and downward thrust of the tubing injector is thus transmitted primarily to platform **12** rather than to wellhead **10** to which the tubing injector is operatively connected. However, in some locations where wellhead **10** may depend for support on the casing in well **14** in a manner known in the art, the weight and downward thrust of injector **18** can be placed directly on wellhead **10** and the supporting casing.

In maintaining the unrestricted arc at the correct degree of curvature bewteen the wellhead **10** and reel **40**, it is desirable to feed pipe **30** into and out of the well at the maximum rate that can be attained. This will, of course, vary with the amount of tubing that is actually in the well. Assuming that 15,000 feet are available on reel **40** for feeding into the well, and that the well is operating at several thousand pounds pressure, it will be apparent that the first few thousand feet must be driven into well **14** by injector **18**. However, when the weight of the drillstring in the wellbore substantially equals the pressure of the well, the load on injector **18** will be substantially balanced. As more pipe is injected, the function of injector **18** is to hold back or brake the load as it is fed into the well. In withdrawing the tubing, the reverse cycle occurs; namely, the greatest force must be exerted as the tubing is being pulled from the bottom point in the well until such time as the well pressure and the weight of the pipe are approximately equal and from there out, the tubing injector acts as a brake.

In the foregoing, it is seen that the rate of injection is difficult to maintain constant because of the wide variations in load on hydraulic drive motors **24** and **26**, connected by a pair of lines **36** and **38** to hydraulic pumping unit **42**. However, with this variation in load, it is important in the operation of the present system to maintain the preselected arc for tubing **30** so that the tubing will function within the desired limits of stress and deformation in the self-sustaining arc between reel **40** and injector **18** without the interposition of guides for this purpose. Further, it is desirable, susbtantially independent of the rates tubing is fed in or out of the wellhead **10** by injector **18**, to control reel **40** and injector **18** so that the selected arc is maintained.

As indicated in FIGURE 1, which illustrates one embodiment of the invention, an arc measuring system, indicated generally as **50**, is positioned above tubing injector **18** so that tubing **30** passes through it closely adjacent to injector **18**. This system will be described more fully below. Its function is to sense at this location, the direction and extent of departure of pipe **30** from the form of the preselected arc. A similar element **60** is positioned to sense the form of the arc of pipe **30** closely adjacent to the pipe bender and level winder **70** above reel **40**. Units **50** and **60**, through regulator **80** on hydraulic pump unit **42**, control, respectively, the rate hydraulic fluid flows to the drive elements of injector **18** and reel **40**. In the present embodiment, the rate of feed from reel **40** is controlled by the drive of hydraulic motor **72** on the tubing bender and level winder **70**. Obviously, once the correct arc is established between reel **40** and the top of injector **18**, it is desirable that the rate of feed by drive of motors **24** and **26** on injector **18** be held substantially equal to the feed rate at which motor **72** winds or unwinds pipe **30** at reel **40**.

The construction of tubing drive unit **70** is best seen in FIGURES 2 and 3. As there indicated, hydraulic motor **72** drives a gear and sprocket arrangement identified generally as **74**. Four drive wheels **75** that frictionally engage pipe **30** are driven by sprocket gears **73A** through chain **73B**. The drive tension on chain **73B** can be manually adjusted by screw **73C** tightening the chain between idler sprocket 73D and drive sprocket 73E. Tubing 30 is formed onto or unwound from reel 40 by drive wheels 75 and forming or clamping wheels 76 which cooperate to bend pipe 30 beyond its elastic limit so that the pipe takes a "set." It is straightened as it leaves reel 40 and is bent into a curved form as it is wound on the reel.

As indicated in FIGURE 2, pipe 30 is bent into the desired curvature as it is wound onto reel 40 by offsetting wheels 76 relative to the pipe's line of travel through drive wheels 75, and is reformed into a substantially straight line as it passes through wheels 75, on payout of the tubing from reel 40. The degree of curvature is, of course, controlled by moving wheel 76 up or down relative to support plates 78 as by turning handwheel 79 to move the bearing support member 77 for wheels 76.

FIGURE 3 best shows the drive for the tubing bender across the drum surface of reel 40 so that each layer of pipe is correctly leveled on the drum. As indicated, support plates 78 which form bearing surfaces for the drive wheels 75 and carry forming wheels 76, are supported on a carriage, indicated generally as 82, that is rollably supported by rollers 83 on transverse beam 84. The entire assembly is supported, as best seen in FIGURE 1, by a pair of arms 90 that are pivotally attached to the supporting base or frame 92 of reel 40. Arms 90 form an angle relative to the vertical, which helps to maintain the desired pipe arc. The lengths of the braces 94, which are connected between the arms 90 and the frame 92, are desirably adjustable to vary the horizontal angle of the arc at the location of the reel.

The winding of pipe 30 onto reel 40 is, of course, synchronized with the rotation of drum 40. The rate of movement of carriage 82 across beam 84 will vary somewhat depending upon the radius of the drum surface of reel 40 and the number of layers of pipe that are then on the drum. It has been found satisfactory in practice to move the carriage manually through a drive mechanism provided by chain 85 secured through pin 86 to carriage 82 and driven by sprocket 85A. A gear reduction provided by sprocket 87A and chain 87 is rotated through chain 88 and sprocket 89. Chain 88 may be manually powered to provide the drive for the system. If desired, chain 88 may, of course, be connected to and variably synchronized with the drive of reel 40, described below. The rotation of reel 40 can also be synchronized to the drive of motor 72 as it pushes the pipe off or on the reel.

In practice, the drive of reel 40 may conveniently be accomplished by a friction drive 93 through the rim 40A of the drum 40 by a motor 93A which preferably, although not necessarily, is hydraulically operated. Motor 93A may be manually controlled independently of the control of motor 72, or it may automatically be synchronized with it as each layer of tubing is wound on or let off the drum. Since the drum of reel 40 is usually on the order of 15–20 feet in diameter, even with relatively large forces being required to bend the pipe and to hold it against movement, the necessary force can be exerted with relative ease at the circumference of the drum.

Referring now to the left hand portion of FIGURE 2, there is illustrated a suitable means for sensing a deviation from the desired predetermined angle with the horizontal of the tubing string 30 adjacent to the exit point from reel 40. When the unsupported arc is established in a desired form for a particular setup of the rig in relation to a well to be worked in, the horizontal angle of the tubing as it leaves the pipe straightener at the drum is one of the parameters of the specific form of the arc.

As shown, sensing unit 60 includes a pair of deflection sensing rollers 61 that are movable transverse to the direction of pipe movement. Sufficient transverse movement is permitted for the rollers so that deviation from the established desired position of tubing 30 for a predetermined arc form may be followed by corresponding movement of both rollers 61. In this embodiment, rollers

61 are rotatably mounted on respective shafts 62 supported in corresponding frames 63 that are in turn mechanically coupled to a respective reactive core member 64, each of which is positioned between a corresponding pair of inductance windings 65 and 66. Each core 64 is spring loaded as by spring 67 to cause the rollers 61 to press against the tubing 30 and follow lateral deviations of it from the preselected angle. The differential motion of core 64 upon movement of the frames 63 of rollers 61 in response to a change in angle of pipe 30 generates a differential electrical signal in the inductance windings.

As best seen in FIGURE 8, movement of core 64 changes current flow in windings 65 and 66 and results in regulation of the speed of rotation of hydraulic drive motor 72 through the regulator 80, FIGURE 1. Windings 66 of the two units are preferably connected to a source of alternating current. The opposite windings 65 are coupled to generate an error voltage dependent upon the direction and extent of the displacement of the reactive core members 64 from a normal operating position relative to the windings. One suitable way of developing the error signal is through a pair of diodes 68 each connected in series with one terminal of windings 65 and to a reference A.C. signal through two parallel circuits each comprising corresponding condensers 269 and resistors 169. The error voltage is then applied to amplifier 170 and the direction and extent of unbalance of the current flow is applied to control winding 171 of motor 172. Motor 172 in turn regulates valve means 173 connected to regulator 80 in a manner known to the art, in a direction and to an extent required to increase or decrease the speed of hydraulic drive motor 72. A followup loop is then completed through the mechanical drive of tubing 30 by motor 72 which increases or decreases the rate at which the tubing is let off or taken up on the drum 40 and thus corrects the deviation from the desired angle that the pipe makes at the sensing unit 60.

A similar curvature or angle sensing unit is supported above the pipe injection unit and is indicated schematically in both FIGURES 1 and 4 as sensing unit 50. Other suitable deflection sensing systems either pneumatic, hydraulic, or electrical can be used to regulate the angular deflection that pipe 30 makes relative to the top of injection unit 18, or the tubing bender and level winder assembly 70 on reel 40.

Referring now to FIGURE 4, a further embodiment of the workover rig is shown that is particularly adapted to use in unprotected offshore locations. This arrangement can also be used in areas where there is limited vertical clearance, since the reel is mounted on its side. In the case of FIGURE 4, barge 100 particularly illustrates the adaptability of the method of the present invention to different environments. As indicated, the platform 120 supporting the wellhead 110 is relatively high and placed well above water level so that in an unprotected offshore location, waves will not wash over it. However, because of this elevation, which varies through tidal and other conditions, it would be difficult to bring a reel mounted on barge 100 to a position close to the wellhead where the tubing could be fed directly into the well from the reel if intermediate tubing supports were required. However, in accordance with the present invention, such close proximity and unvarying relative elevation between reel 140 and wellhead 110 is not required. Through use of an unrestrained arc of tubing in accordance with the method of this invention, and detection of the curvature of the arc as it enters injector 18 above wellhead 110, sensing unit 50 controls the rate at which hydraulic fluid is supplied by pump unit 42 to motors 24 and 26. At the same time, sensing unit 60 is positioned to measure and control the angle of pipe 30 after it leaves the tubing bender and level winder assembly 70 adjacent the reel 140. While the curvature of pipe 30 in going from reel 140 to the top of injector 18 is more complex than in the embodiment shown in FIGURE 1, the unit is capable of maintaining such a pre-established arc within a suitable degree of tolerance and substantially independent of variations in the speed at which the pipe is injected or withdrawn at the wellhead or wound and unwound at the reel.

FIGURES 5, 6 and 7 illustrate an embodiment of one means useful with a reel mounted as in FIGURE 4, to hold pipe **30** in a level course as it is wound on or off the drum. As indicated, when the pipe is being wrapped on or taken off the drum from the bottom toward the top, it is necessary that the remaining levels be held on the drum and properly nested in their proper courses relative to the other layers. For this purpose, and as best seen in FIGURE 7, a plurality of finger members **130** are each formed as a spring loaded cup **132** to telescope over an internal tube **134**. Spring **136** permits longitudinal deflection of the cup **132** as the roller tip **138** of each finger **130** rides on the wrapped turn of tubing **30**. A plurality of horizontally disposed tubes **134** of finger members **130** are assembled in vertical relationship on a support unit **142**. This unit, in turn, may be pressure operated so that the entire assembly of support **142** and the associated finger members **130** are always pushed radially inwardly into engagement with and to support the individual wraps of tubing **30** on drum **140**. As indicated in FIGURES 5–7 and especially FIGURE 7, the support member may be extended by hydraulic pressure by forming shaft **146**, on which support **142** is slidably mounted, as a hydraulic cylinder. Internal piston rod **148**, which is affixed at one end to a relatively stationary support **150**, includes inlet and outlet conduits **149** for hydraulic fluid to actuate cylinder **146** relative to rod **148** and piston head **147**.

As indicated before, the method of the present invention is not limited to the illustrated form of tubing injector unit **18**. Alternatively, a hydraulic ram and piston unit using a pair of slips to successively clamp and unclamp the tubing can be used at the wellhead. In such an arrangement a given length of pipe, say 10 or 15 feet, can be pushed into the well in steps. With such a system, the pipe is grasped, forced in, and then held by a second set of slips while the first set is retracted to engage a successive length of pipe for injection. The holding slips are then released as the ram is operated on the next cycle. In such a system the arc of tubing **30** between the reel **40** and the tubing injector is formed to provide a sufficient length of substantially vertically disposed tubing at the wellhead to accommodate the travel of the slips, and the reel drive can be controlled manually or automatically to maintain the curvature of the arc within safe limits of permissible tubing flexure as the tubing is fed stepwise into the well.

As shown in FIGURE 1, the tubing **30** communicates at the reel **40** with a source **160** of treating fluid. The end of tubing **30** is connected through rotary coupling **162** with a conduit **164** which communicates through valve **166** with the sump **160** which receives the treating fluid through inlet conduit **168**. A pump **170** which is driven from the hydraulic unit **42** through pump controller **174** can be used to force the treating fluid from the sump under controlled pressure into the tubing **30** and thence into the well. The treating fluid may be applied to the well while the tubing is being injected into or withdrawn from it, or the end of the tubing may be placed at a predesignated location within the well to treat or work on a selected formation, or selected portions of casing, production tubing or other apparatus within a completed well.

While only a few illustrative embodiments of the method of the present invention have been described, it will be apparent that numerous modifications and changes can be made in the specific forms of apparatus used to practice it. Specifically, the method of the present invention can be performed by an operator observing an indicator connected to the tubing **30** on the top of the tubing injector unit and observing the angle of the drill pipe as it leaves the tubing bender and level winder at the reel and then, by manually regulating the respective hydraulic supply units, preferably by controls which are placed adjacent to each other at an operator's console, maintain preselected angles at these points to control the unrestricted arc of the pipe extending from reel **40**, as in FIGURE 1, or reel **140** as in FIGURE 4, to the top of injector **18**. By careful control of at least one of the hydraulic pump units, the unrestricted arc can be held within a desired degree of tolerance so that the tubing **30** is not kinked or stretched as it is transferred without intermediate support between the reel and the tubing injector means at the wellhead. Other modifications and changes both in the apparatus and in the system of operating it to perform the method of the present invention will occur to those skilled in the art. All such modifications and changes coming within the scope of the appended claims are intended to be covered thereby.

I claim:

1. The method of working in an offshore well without a derrick or the like positioned above the wellhead and independent of the difference in elevation between the well production platform and the water surface, which comprises the steps of floating a work boat into proximity to a production platform,
   - axially aligning a tubing feed means with a wellhead on said production platform,
   - unwinding a continuous length of tubing from a reel on said work platform,
   - forming said unwound length of tubing into an unrestrained arc extending from the reel into axial alignment with said tubing feed means and said wellhead, independently controlling said tubing feed means to drive said tubing into said wellhead at a desired feed rate, and controlling the unwinding rate of tubing from said reel to maintain said unrestrained arc of said tubing in axial alignment with said wellhead, said control being within predetermined limits so that kinking and stretching of said tubing over said unrestrained arc are avoided during transfer of said tubing between said reel and said tubing feed means at said wellhead.

2. The method of working in a well without use of a derrick or the like positioned above the wellhead and independent of differences in elevation between the production platform for said well and the earth's surface, which comprises the steps of
   - supporting tubing feed means above and in axial alignment with a wellhead on said platform,
   - positioning a movable work support in proximity to said production platform,
   - unwinding a continuous length of coiled tubing from a reel on said work support,
   - deforming said unwound length of tubing into a free length of tubing having substantially less curvature than its coiled form,
   - extending said deformed tubing into a free arc from said reel into axial alignment with said tubing feed means, said arc being unrestrained from said work support to said well platform, and
   - controlling the rate of deformation of said tubing from said reel independently of the rate said tubing is fed into said wellhead by said feed means, said control being in a direction and to an extent required to maintain said unrestrained arc within predetermined limits of curvature so that kinking and stretching of said tubing are avoided between deformation of said tubing as it is unwound from said reel and feeding of said tubing into said wellhead.

3. The method of working in a well without a derrick means positioned above the wellhead and independent of the relative elevation between the support of said wellhead and the support for the well working equipment, which comprises the steps of positioning a work support proximate to said wellhead support,

axially aligning tubing injection means with the opening of said wellhead,

unwinding a continuous length of tubing from a reel on said work support,

forming said unwound length of tubing into a free arc extending from the reel into axial alignment with said tubing injection means over said wellhead, independently running said tubing injection means to drive said tubing into said wellhead at a desired feed rate, and controlling the rate tubing is unwound from said reel to maintain a preselected form of said free arc between said axial alignment with said wellhead and said reel, the limits of departure of said free arc from said preselected form being so that kinking and stretching of said tubing over said free arc are avoided during transfer of said tubing between said reel and the injection means for said tubing above said wellhead.

4. Apparatus for working in an offshore well without use of a derrick positioned above the wellhead and independent of the relative elevation between said wellhead and a work support on the water surface, which comprises:

(a) a movable, floating work platform adapted to be moored in proximity to a production platform for said wellhead,

(b) tubing injector means on said wellhead,

(c) a tubing reel supported on said work platform,

(d) a continuous length of tubing wound on said reel,

(e) means for supplying fluid to said tubing through a rotatable connection at the hub of said reel,

(f) means for bending said tubing mounted adjacent the periphery of said reel,

(g) drive means for said tubing bending means adapted to drive an unwound length of said tubing into an arc extending from said reel into axial alignment with said tubing injector means above said wellhead, and

(h) means for controlling the rate of unwinding of said tubing from said reel independent of the feed rate of said tubing into said wellhead by said tubing injector, said control being in a direction and to an extent required to maintain said arc to a predetermined curvature so that no intermediate support of said tubing is required during said unwinding from said reel and injection of said tubing into said wellhead.

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