June 7, 1960 E. D. HALL 2,939,531

HYDRAULIC METHOD AND APPARATUS FOR FLEXING STUCK PIPE IN WELL BORES

Filed Dec. 12, 1956 3 Sheets-Sheet 1

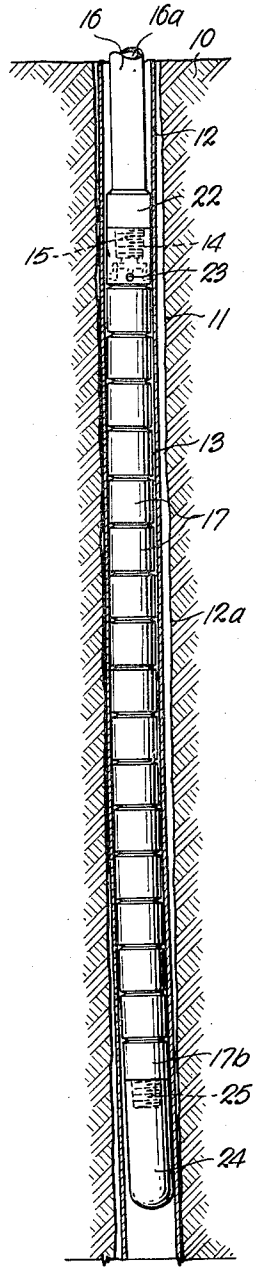


Fig. 1.

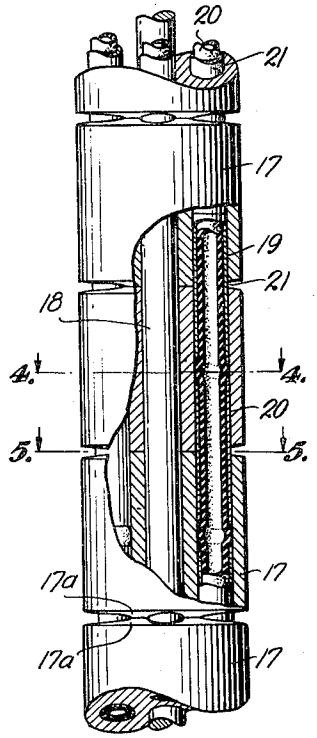


Fig. 2.

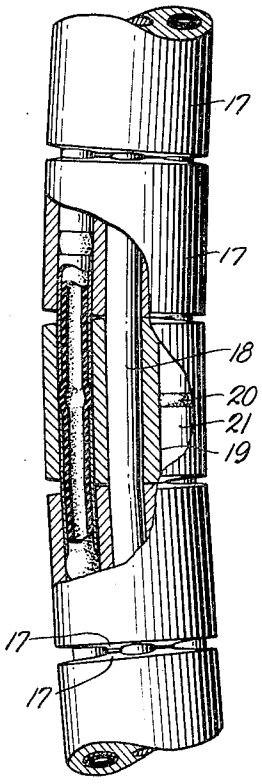


Fig. 3.

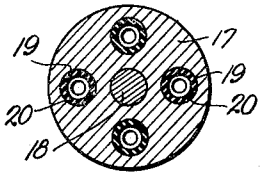


Fig. 4.

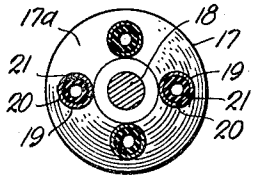


Fig. 5.

INVENTOR.
Elmer D. Hall
BY
Thos E. Scofield
ATTORNEY.

June 7, 1960 E. D. HALL 2,939,531

HYDRAULIC METHOD AND APPARATUS FOR FLEXING STUCK PIPE IN WELL BORES

Filed Dec. 12, 1956 3 Sheets-Sheet 2

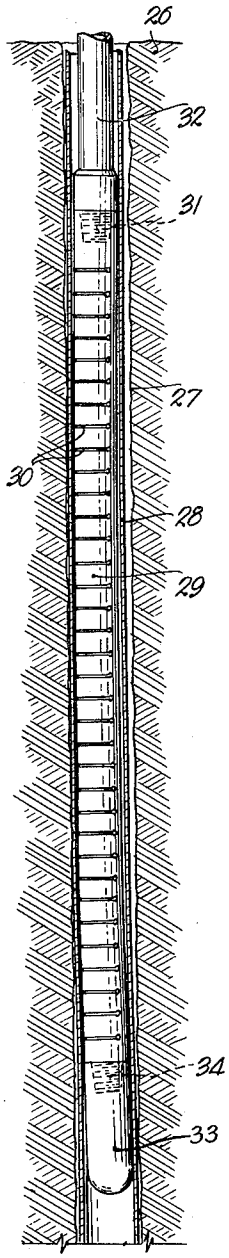


Fig. 6.

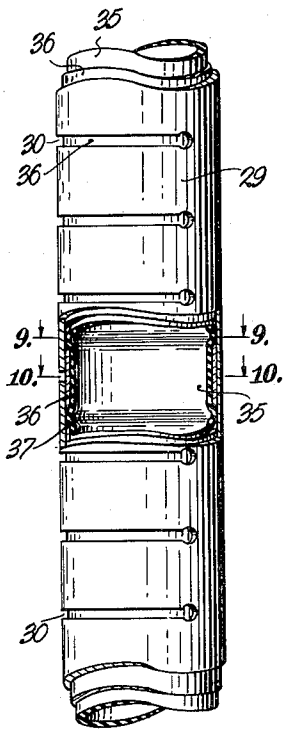


Fig. 7.

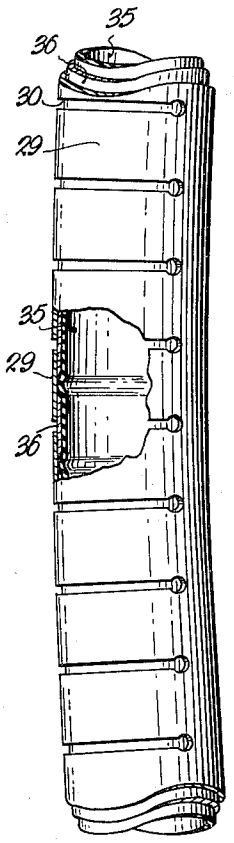


Fig. 8.

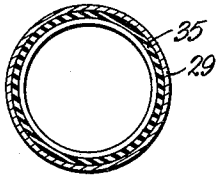


Fig. 9.

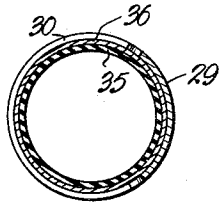


Fig. 10.

INVENTOR.
Elmer D. Hall
BY Thos E. Scofield
ATTORNEY.

June 7, 1960 E. D. HALL 2,939,531

HYDRAULIC METHOD AND APPARATUS FOR FLEXING STUCK PIPE IN WELL BORES

Filed Dec. 12, 1956 3 Sheets-Sheet 3

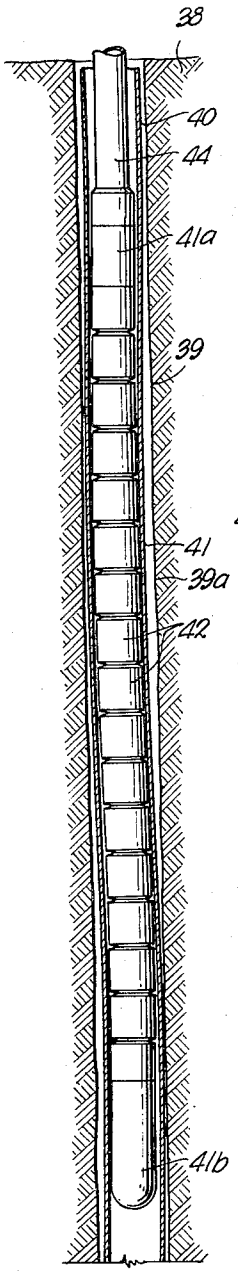


Fig. 11.

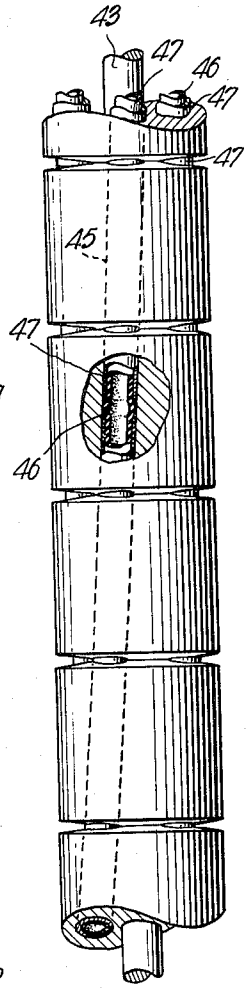


Fig. 12.

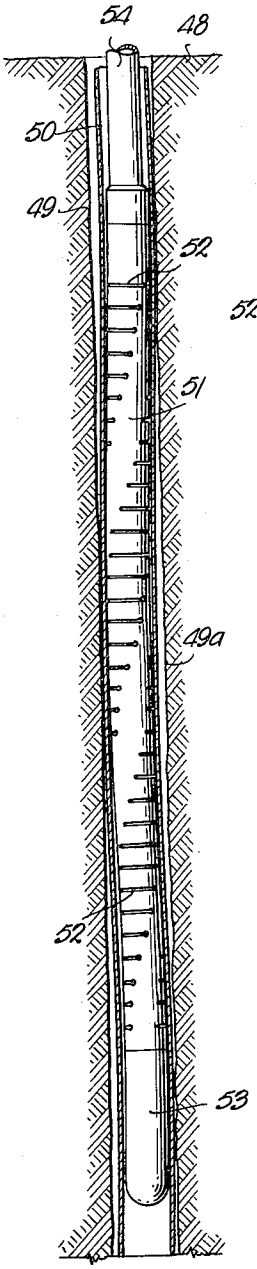


Fig. 13.

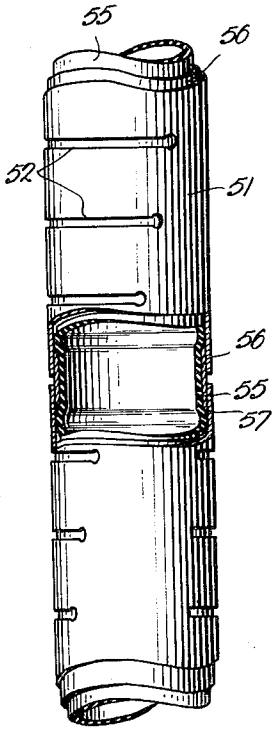


Fig. 14.

INVENTOR.
Elmer D. Hall

BY Thos E Scofield
ATTORNEY.

United States Patent Office 2,939,531 Patented June 7, 1960

2,939,531

HYDRAULIC METHOD AND APPARATUS FOR FLEXING STUCK PIPE IN WELL BORES

Elmer D. Hall, 401 Norton St., Weatherford, Tex.

Filed Dec. 12, 1956, Ser. No. 627,935

9 Claims. (Cl. 166—55)

This invention relates to methods and apparatus for freeing stuck pipe in well bores and refers more particularly to such methods and apparatus wherein a material length is inserted within the pipe to be freed and moved therethrough into the stuck area, force then being applied within the length to flex it in the well bore and the pipe to be freed therewith.

This application is a continuation-in-part of my previous application, Serial No. 601,579, filed August 1, 1956, entitled "Method and Apparatus for Freeing Stuck Pipe."

"Stuck pipe" in this disclosure is to mean any type of pipe which has been lowered into a well bore for the purpose of drilling for, or production of, water, oil, gas, etc., and has become lodged in the well bore in such a manner that it cannot be lowered or withdrawn by present methods of longitudinal tension (pulling on the pipe to its yield point) or compression (applying the weight of the free pipe in the well bore downwardly upon the lodged or stuck pipe). Thus, the term "stuck" will describe pipe lodged in a well bore under the conditions described above.

One of the major concerns in finishing an oil well is sticking of the pipe and actually getting the pipe to the bottom of the hole. It would be extremely desirable to be able to guarantee a job of getting the pipe to the bottom or keeping it free in the well bore if it is to be removed therefrom. Previously, this has not been possible.

A number of conditions can actually happen in a well bore to stick pipe therein. These condtions can be enumerated as follows:

(1) Where loose formations such as sand or shale have settled around the pipe in the annulus between the outside of the pipe and the face of the well bore in a sufficient quantity to cause enough friction that the pipe cannot be moved longitudinally or in rotation.

(2) Where a coupling or any other device that is on the pipe which is of a larger diameter than the pipe becomes lodged in what is referred to in oil well drilling terminology as a "key seat." A key seat is actually an enlargement in one side of the drilled well bore caused by the movement of the pipe, either in rotation or in longitudinal movement, against the inside curve or bend opposite a bend or curve in the well bore. In such a condition, the pipe is held against the inside curve or bend by the tension of pipe hanging below it, causing the pipe to wear away that side of the well bore to the same size of the pipe itself. In other words, a key seat is an attempt by the pipe in tension to straighten out or remove any deviations of the well bore from a straight line. Under these conditions, any object of a larger diameter than the size of the well bore at this "key seat" will tend to become wedged when forced into it. In actual oil well drilling practice, the size of a key seat is determined by the tool joints or couplings on the drill pipe, and it is usually any device that has a larger diameter than the tool joints that may become lodged therein.

(3) Where large objects in the hole, such as boulders, or broken or lost pieces of drilling tools become wedged between the pipe and the well bore, causing the pipe to stick.

(4) Yet another condition in a well bore which may stick pipe is "differential pressure." In "differential pressure" high pressure fluid in the annulus between the casing and the well bore flows into a porous subterranean formation which has a natural pressure far less than that of the annulus fluid. When this condition occurs, the casing cleaves or seizes to the permeable portion of the borehole wall under the influence of the differential pressure. If the casing actually comes into contact with the porous or permeable formation, it acts as a seal over a greater or lesser area thereof and is thus forced against that region by an amount equal to the annulus pressure minus the formation pressure times the actual area of contact between the casing's exterior wall and the wall of the well bore. Thus, for example, if the annulus fluid pressure exceeds the formation pressure by 1800 pounds per square inch, while the area of casing and borehole wall contact is 500 square inches, the casing will be driven against the borehole wall by a total force of 400,000 pounds. It is obvious, that as long as these conditions are maintained, there is little hope of moving the casing further into the bore or removing it therefrom. The reason for this is, in the latter case, that both the casing weight and the shear strength of the contact plane must be overcome.

One of the great problems in oil well drilling is to salvage stuck pipe. Hundreds of millions of dollars of pipe are left in wells every year and only approximately 30% of the total pipe set in wells can be salvaged at present. Up to the present time, it has been possible only to salvage the casing down to the first oil sand in a multiple oil horizon well because the first sand or any permeable area thereabove causes sticking of the pipe by differential pressure.

In my above mentioned previous application, I disclosed various forms of rigid curved or crooked metallic lengths which could be jammed or otherwise forced into stuck pipe to the vicinity of the stuck portion thereof and, once there, either rotated and moved into the stuck area or forced without rotation through the stuck area. This construction involved a rigid metallic length crooked or curved to a greatest diameter beyond that of the pipe to be freed, the length thus distorting the pipe to be freed as it is forced therethrough. While this modification is effective, in some situations, especially where used or weakened pipe is involved, it is not desirable to employ this construction of the pipe freeing apparatus. It has been desirable, therefore, to provide methods and apparatus of flexing the stuck pipe in the vicinity of the stuck area thereof without previously distorting or flexing the pipe in the insertion of the flexing means. The provision of such methods and apparatus is one of the objects of this invention.

Therefore, an object of the invention is to provide method and apparatus for freeing pipe which is struck in a well bore efficiently and dependably.

Another object of the invention is to provide methods and apparatus for freeing pipe stuck in a well bore where the pipe is stuck due to settling of well material, key seat engagement, wedging or differential pressure.

Another object of the invention is to provide methods and apparatus for freeing pipe stuck in a well bore wherein pipe stuck in a plurality of positions in a well bore can be freed and, particularly, pipe stuck against a plurality of permeable sands by differential pressure can be freed.

Another object of the invention is to provide methods and apparatus for freeing pipe stuck in a well bore which will greatly increase the percentage quantity of pipe which

is salvageable from well bores, such salvage saving great quantities of both money and metal.

Another object of the invention is to provide apparatus for flexing the pipe to be freed in the well bore which will flex the pipe in any direction desired sequentially without rotation of the device within the pipe to be freed.

Yet another object of the invention is to provide apparatus for flexing the pipe to be freed in a well bore wherein the means for flexing the device in the pipe to be freed are completely enclosed by the device at all stages in the flexing procedure.

Another object of the invention is to provide methods and apparatus for freeing pipe stuck in boreholes, the method and apparatus being applicable to free cemented pipe where the bond is not complete or the cement has been contaminated, for example, it being common in oil well cement jobs to have several hundred feet of contaminated cement at the top of the cemented portion.

Other and further objects of the invention will appear in the course of the following description thereof.

In the drawings, which form a part of the instant specification and are to be read in conjunction therewith, embodiments of the invention are shown and, in the various views, like numerals are employed to indicate like parts.

Fig. 1 is a cross-sectional view through an earth formation showing a first modification of the inventive apparatus for freeing stuck pipe in a well bore positioned in a casing or pipe in a well bore, the casing just having been flexed in a well bore to free it from its previously stuck position.

Fig. 2 is a detail view of several of the individual sections of the apparatus of Fig. 1 with parts in section and cut away to show the interior construction for flexing the device, the unit shown in the straight position.

Fig. 3 is a detail view of a similar portion of the apparatus of Fig. 1 with parts cut away and in section to show the internal construction of the flexing means, the unit shown in the flexed position.

Fig. 4 is a view taken along the lines **4—4** of Fig. 2 in the direction of the arrows.

Fig. 5 is a view taken along the lines **5—5** of Fig. 2 in the direction of the arrows.

Fig. 6 is a cross-sectional view through an earth formation showing a second modification of the inventive apparatus for freeing stuck pipe in a well bore positioned in a casing or pipe in a well bore, the casing just having been flexed in the well bore to free it from its previously stuck position.

Fig. 7 is a detail view of a portion of the device shown in Fig. 6 with parts cut away and in section to show the internal construction of the flexing means, the portion shown in the straight or unflexed position.

Fig. 8 is a detail view similar to that of Fig. 7 of a portion of the device of Fig. 6 with parts cut away and in section to show the construction of the flexing means, the portion shown in the flexed position.

Fig. 9 is a view taken along the lines **9—9** of Fig. 7 in the direction of the arrows.

Fig. 10 is a view taken along the lines **10—10** of Fig. 7 in the direction of the arrows.

Fig. 11 is a cross-sectional view through an earth formation showing a third modification of the inventive apparatus for freeing stuck pipe in a well bore positioned in a casing therein, the apparatus just having been flexed in the well bore to free the casing from its previously stuck condition.

Fig. 12 is a side elevation of the construction of Fig. 11 with a portion broken away to illustrate the internal construction of the device and parts in dotted lines for the same purpose, the unit shown in the straight position.

Fig. 13 is a cross-sectional view through an earth formation showing a fourth modification of the inventive apparatus for freeing stuck pipe in a well bore positioned in a casing or pipe in the well bore, the apparatus just having been flexed in the well bore to free the casing from its previously stuck condition.

Fig. 14 is a side elevation of the Fig. 13 modification with parts broken away to show the internal construction of the apparatus, the unit shown in the straight position.

Referring to the drawings, and to the modification of the invention shown in Figs. 1–5, earth formation **10** contains well bore **11** extending downwardly therethrough. Casing or pipe **12** has been run in the well bore **11** and has become stuck thereto by one of the previous listed difficulties adjacent the point indicated at **12***a*. The inventive device for freeing casing stuck in the well bore comprises a flexible length generally designated at **13** having means at its upper end therefor for moving it through the pipe to be freed. In the example shown in the drawings, this latter means comprises a threaded upper portion **14** of the device engageable with a threaded portion **15** of a conventional drill stem **16**. The body **13** of the length consists of a multiplicity of sections **17** strung on a relatively flexible, centrally positioned mandrel **18** (Figs. 2–5). The sections **17** are radiused or rounded on both ends thereof as at **17***a* so as to allow flexing or bending of the mandrel **18** carrying sections **17** with a minimum of elongation of the total length **13**. The sections **17**, which are positioned centrally of the ends of the length **13**, are furnished with one or more bores **19** running therethrough substantially parallel to the mandrel **18**. In the example shown in the drawings, four of these bores are formed in the sections positioned equal angular distances apart. Within the bores **19**, stretchable hydraulic tubing **20** of reinforced rubber or like suitable material is enclosed and prevented from extrusion or pinching between the sections **17** by means of the metal sleeves **21** which extend through the gaps between the sections **17**. Sleeves **21** are fixed or welded to one of the sections each penetrates and slidably mounted in the other.

The upper end fitting **22**, besides having the threaded portion **14** therein, has hydraulic fluid feedways **23** therein to feed fluid to the tubings **20** either from tubes extending downwardly in bore **16***a* of the drill stem **16** or the drill stem bore **16***a* itself with a valve means (not shown) controlling the flow between the various bores. At the lower end of the length **13** is preferably rounded end fitting **24** threaded onto threaded extension **25** of the lowest section **17***b*. The bores **19** and tubings **20** are sealed in the lowest section **17***b* to prevent extrusion or release of fluid therefrom. The upper and lower end fittings **22** and **24** retain the sections **17** on the mandrel **18** preferably under mild tension.

When the tubings **20** in the bores **19** are inflated singly, or in pairs on the same side of the length **13**, the stretching of the tubing will cause distortion or flexing of the apparatus as in Fig. 3. It is necessary, of course, that the tubing **20** be of sufficient strength to hold sufficient pressure to distort the casing. The length **13** itself is preferably of an outer diameter only slightly less than the inner diameter of the pipe to be freed whereby any flexion of the length itself will be transmitted to the casing around it and the casing itself will be flexed in the well bore. By increasing and releasing the hydraulic pressure in any one side of the length, the length may be repeatedly flexed in a single direction. By alternately raising and releasing the pressure in opposite sides of the length, the casing may be flexed in opposite directions or at any angles desired. In this manner the casing **12** may be freed within the well bore **11**. The length of the device **13** is preferably less than the length of a conventional length of pipe (thirty feet in oil wells) but this limitation is not necessary. The amount of flexion possible in the device preferably should not exceed the elastic limit of the pipe to be freed. The flexion of the casing is limited by the annular space between the casing and well bore but the strain on

the pipe may be varied by varying the length of the flexing device.

In operation, the device 13 is inserted in the pipe to be freed and run therethrough at the end of drill stem 16. In one variation of the method, the device 13 may be stopped immediately above the stuck section and flexed and then gradually moved into the stuck portion flexing periodically as it is moved. In another variation of the method, the device 13 may be moved right opposite the stuck section and then flexed therein. When the casing or pipe 12 has been freed, the device 13 may be removed on the drill stem 16 and the casing 12 itself removed from the well bore or run lower therein if desired. If, as previously set forth, the length 13 is moved gradually downwardly, continuing flexion, until the area of greatest flexion (centrally) of the device is opposite the cleavage area or stuck portion, the destruction of the cleavage plane of the casing 12 to the formation 10 in a differential pressure sticking will be progressive rather than entire and simultaneous. The length may be moved entirely below the stuck portion while flexing if desired. When the casing 12 is wedged, blocked or in a key seat, it is easy to see that such flexion, if necessary, in all directions, will serve to break up and displace the wedging material to free the pipe. In a differential pressure sticking the passage of the well bore fluids into the permeable zone packs and dehydrates the mud in the well bore against the permeable zone and, once the casing is free, it will not readhere. Additionally, the flexion of the length relative the stuck portion of the casing will mash the heavy, thick mud into the formation pore space and serve to seal off the permeable formation even more and, therefore, the tendency will be for the casing not to restick.

When there are several permeable formations or stuck portions of the casing, the length 13 may be moved first above the first stuck zone, then flexed and moved with periodic flexing into the stuck zone to free it (or run into the zone and flexed). Once that zone has been cleared, the length may then be moved downwardly to a position above the second stuck zone, flexion begun and then the length moved into the zone while flexing. (Or run directly into the zone and flexed.) In this manner, the pipe may be freed from an indefinite number of stuck zones and the running of the casing to the bottom of the hole or its removal from the hole may be guaranteed. Once the stuck areas have been freed, the drill stem 16 and length 13 are withdrawn from the casing. Contaminated or faulty cement jobs will sometimes leave casing or pipe in such a condition of adherence to the well bore that the inventive length may be able to flex or beat several hundred feet of the casing free from the faulty bond to permit the recovering thereof.

It should be understood relative all four modifications of the invention shown in the fourteen figures, that while the cylindrical form (in cross section) is preferred on all of the devices shown in the drawings and described in the specification, any desired form, triangular, square, hexagonal, etc., in cross section may be employed so long as the greatest diameter of the cross-sectional form is not greater than the inside diameter of the pipe to be freed. The usefulness of the cylindrical form lies in its minimizing of friction and localized wear on the pipe as it passes therethrough and is rotated therein.

Referring to Figs. 6–10, therein is shown a second modification of the inventive device for freeing casing in well bores. In Fig. 6, at 26 is shown an earth formation having a well bore 27 extending downwardly therethrough with casing 28 having been run in the well bore. The inventive apparatus for freeing pipe stuck in a well bore comprises in this modification a flexible metal length normally extending relatively straight, the length, as in the previous modification, having an outer diameter sufficiently less than the pipe to be freed to be inserted therein and moved therethrough, means at the upper end of the length for moving it through the pipe to be freed, and means associated with the length whereby to flex it within the pipe to be freed and the pipe to be freed therewith and free the latter in the well bore. The length 29 comprises high strength tubing which is milled or sawed partially through on one side thereof to provide a plurality of hinge kerfs 30. The kerfs 30 being positioned on one side of the tubing serve to weaken that side to flexing stress. The kerfs 30 extend essentially the entire length of the device save for the upper and lower ends thereof, the former having threaded inner portion 31 to engage the drill stem 32 and the latter comprising rounded lower end fitting 33 which engages threaded extension 34 on the lower end of the length 29. Flexible tubing 35 (Figs. 7 and 8) of reinforced rubber or other suitable substance extends essentially the length of the inventive device 29 and may be inflated hydraulically by fluid forced through the drill stem 32. The tubing 35 is sealed at its lower end adjacent the lower fitting 33. Pinching or bursting of the tubing 35 through the kerfs 30 is prevented by the metal liner 36 extending between the tubing 35 and length 29 the length of the latter whose hinge kerfs 37 are midway between those of the outer tubing or casing 29. Hydraulic inflation of the tubing 35 within the weakened casing 29 will cause the latter to distort or flex as shown Fig. 8, this flexion also flexing the casing 28 which it is positioned within. Release of the hydraulic pressure will permit the tubing or casing 29 to resume its normal form. The strength of the tubing must be sufficient to withstand sufficient pressure to deform the length 29 and casing 28.

The operation of this second modification of the invention is the same as that shown in Figs. 1–5 with the exception that the casing 29 must be rotated at the end of drill stem 32 to flex the outer casing 28 in another direction from that originally caused. Thus, once the length 29 is mounted on the drill stem 32, it may be run either to a position above the stuck portion of the pipe or to a position opposite it. If it is run to a position above, the casing 29 may be flexed either in one position or in various angular positions within the casing 28 and moved gradually into the stuck portion of the pipe. In this manner the destruction of the cleavage plane of the casing 28 to the well bore wall will be gradual. Otherwise, the length may be moved right into the stuck portion and flexed and rotated for further flexion as desired. The casing 29 may be moved completely through the stuck portion of the casing in a process of periodic flexion if desired. In a differential pressure sticking, the flexion of the length relative the struck portion of the casing will mash the heavy, thick mud into the formation pore space and serve to seal off the permeable formation, and therefore, the tendency will be for the casing not to restick. The operation relative several permeable formations or stuck portions of the casing is the same as recited relative the Figs. 1–5 modification. As in the Figs. 1–5 modification, the length of the device is not critical but is preferably less than the standard length of a section of pipe to be inserted in the well bore (in oil wells, conventionally 30 feet). If the length is limited in this manner, easier handling and use result.

Referring to the third modification of the invention shown in Figs. 11 and 12, therein is shown a modification of the invention similar to that of Figs. 1–5 with the exception that the bores 19 which contain the tubings 20 of the Figs. 1–5 modification are pitched within the length in the Figs. 11–12 modification whereby to spirally run around the length. By pitching of the bores in the sections of the length, the device can be caused to take a spiral form when pressurized. Alternation of pressure from one tubing bore to the next will, in fact, cause a whipping or snaking motion.

In Fig. 11, earth formation 38 has borehole 39 extending downwardly therethrough. Casing 40 has been run in the well bore 39 and was stuck adjacent 39*a*. Length 41 having a plurality of sections 42 mounted centrally thereof has upper and lower fittings 41*a* and 41*b* at-

tached thereto. The sections 42 are preferably rounded on each end thereof whereby to maintain the device of the same length when the device is flexed. Sections 42 and the upper and lower fittings are mounted on mandrel 43 which extends centrally of the sections. Fittings 41*a* and 41*b* preferably maintain the sections 42 on the mandrel under slight tension. The length 41 is attached at its upper end to drill stem 44. A plurality of bores 45 extend through the sections and contain flexible tubing 46 of reinforced rubber or other suitable material therein. Tubings 46 must be of sufficient strength to withstand any pressures applied hydraulically thereto and are sealed at their lower ends. Hydraulic fluid may be forced into tubings 46 from the bore 44*a* of drill stem 44 or from tubings extending therethrough to the surface (not shown). Metallic sleeves 47 extend between the sections to avoid pinching or extrusion of the tubing between the sections. Sleeves 47 are each fixed in one of the two sections they penetrate and are free in the other. The bores 45 are pitched or angled from the vertical in each section they pass through. Preferably, the bores are pitched so that a given bore 45 extends at least once completely around the mandrel 43 to complete a 360° spiral. The angular deflection of any given bore from its original poistion may be either less or greater than 360°, but the latter is preferred.

In operation, when there is no hydraulic pressure applied to any of the tubings 46, the length 41 hangs straight. It may be inserted in the casing 40 with the rounded lower end 41*b* aiding in insertion. After the length has been inserted into the casing 40, it is run at the end of drill stem 44 either to a position slightly above or a position opposite the stuck portion of the casing 40. If the length 41 is positioned above the stuck portion, the spiral flexion of the length 41 may be begun by raising and releasing the pressure in one or more tubings 46 on a side of the length or the pressure may be alternated back and forth between sides to give the whipping or snaking motion previously noted. If the length was stopped above the stuck area, it may be moved gradually into the stuck area with periodic flexion to gradually destroy the cleavage plane of the casing to the wall or other obstruction. If moved directly opposite the stuck portion, it may be flexed there as desired until the casing is freed. As previously recited relative the other modifications, the length may be moved opposite or relative a plurality of stuck zones to free them in one casing. When the casing is freed, the length may be removed from the well and the casing itself may be either moved to the bottom of the hole or removed as desired. The Fig. 11 illustration shows the pitched bore modification in the spiral flexed position with one side of the bores expanded.

The fourth modification of the invention is shown in Figs. 13–14 and is related to the Figs. 6–10 modification. In Fig. 13, 48 indicates the earth formation, 49 the borehole extending downwardly therethrough and 50 the casing which was previously stuck at an area in the vicinity of 49*a*. Length 51 of high strength tubing has hinge kerfs 52 sawed or milled into the length to weaken areas of the tubing. The kerfs 52 are so positioned on the tubing relative one another that they spiral therearound. This is clearly seen in Fig. 13. Rounded end fitting 53 is threaded onto the lower end of the tubing and seals the lower end thereof. The upper end is threaded to drill stem 54. As seen in Fig. 14, flexible tubing 55, of reinforced rubber or other suitable resilient substance, is enclosed between the tubing and metal liner 56. Liner 56 has spirally positioned hinge kerfs 57 vertically spaced between the kerfs 52 and prevents pinching or bursting of the tubing 55 through the outer kerfs 52. The tubing 55 is sealed at its lower end adjacent or within the bottom fitting 53 and hydraulic fluid may be communicated with the tubing either through the drill stem 54 itself or through a flow line therewithin extending to the surface. Tubing 55 is of a strength to withstand any pressures applied thereto.

The operation of the Figs. 13–14 modification is the same as those previous in that the length 51 may be moved either above or opposite the stuck zone and flexion begun. If the length 51 is above the stuck zone, it is moved into the zone gradually with periodic flexion. The length 51, as in the case of the Figs. 11–12 modification, may be rotated on the drill stem 54 as desired so the form of the spiral will be taken at different angular positions within the casing 50.

It should be noted that in all four modifications or variations of the invention, that, if desired, the length 13, 29, 41 and 51 may be moved to a position adjacent (above or opposite) the stuck zone, then flexed to any desired form, and then, with the tool or length in flexed position, forced downwardly through the casing to be freed into and, if desired, through the stuck portion. In this manner, the flexed length deforms or distorts the casing as it is forced therethrough. The hydraulic devices within the lengths to control their flexion must have sufficient strength to deforn both the length and casing it moves through.

All of the lengths shown in the drawings and described in the specifications preferably have an outside diameter only slightly less than the inside diameter of the pipes to be freed. The mandrel in the lengths of Figs. 1–5 and 11–12 must be of sufficient strength to support the weight of the length and the distortions thereof but must be of sufficient flexibility to deform under application of the hydraulic pressure to the lengths. The sleeve surrounding the hydraulic tubings, to avoid extrusion thereof from the bores carrying the tubing, must be of sufficient strength to withstand any hydraulic pressure applied to the tubing.

From the foregoing it will be seen that this invention is one well adapted to attain all of the ends and objects hereinabove set forth together with other advantages which are obvious and which are inherent to the structures and methods.

It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of the claims.

As many possible embodiments may be made of the invention without departing from the scope thereof, it is to be understood that all matter herein set forth is to be interpreted as illustrative and not in a limiting sense.

Having thus described my invention, I claim:

1. Apparatus for flexing pipe in a well bore comprising a flexible material body normally extending relatively straight, said body of an outer diameter sufficiently less than the pipe to be flexed to be inserted therein and moved therethrough, means for moving said body through the pipe to the portion thereof to be flexed, a mandrel positioned centrally of said body and extending axially the length thereof, said body composed of a plurality of body sections mounted on said mandrel, said body sections each having at least one bore extending therethrough with the bore in one said body section being in axial alignment with the bores in the sections adjacent thereto and running substantially parallel to said mandrel, a stretchable tubing within and extending at least substantially the total length of said bores and sealed at its lower end, separate means in said bores extending between each pair of said sections and positioned circumferential to said tubing for preventing extrusion or pinching of said tubing between said body sections, and means for flowing fluid pressurization medium into said tubing to expand it whereby to flex the body and pipe circumferential thereto.

2. Apparatus as in claim 1 wherein the body sections are radiused at each end thereof so as to allow flexing

of the mandrel with a minimum of elongation of said length.

3. Apparatus as in claim 1 including end fittings on said mandrel to retain the body sections thereon under mild tension.

4. Apparatus as in claim 1 wherein the means in the bores for preventing extrusion or pinching of the tubing comprise reinforcing sleeves extending between successive sections.

5. Apparatus for flexing pipe in a well bore comprising a flexible material body normally extending relatively straight, said body of an outer diameter sufficiently less than the pipe to be flexed to be inserted therein and moved therethrough, means for moving said body through the pipe to the portion thereof to be flexed, a mandred positioned centrally of said body and extending axially the length thereof, said body composed of a plurality of body sections mounted on said mandrel, said body sections each having at least two bores extending therethrough with the bores in one said body section being in axial alignment with the bores in the sections adjacent thereto whereby to provide two series of axially aligned bores, said bores extending substantially parallel to said mandrel, at least two stretchable lengths of tubing, one positioned within and extending at least substantially the total length of each of said axially aligned series of bores and sealed at its lower end, means in each of said bore series extending between each pair of said sections and positioned circumferentially to said tubings for preventing extrusion or pinching of said tubings between said body sections, and means for flowing fluid pressurization medium into each of said tubings whereby to expand them whereby to flex the body and pipe circumferential thereto.

6. Apparatus as in claim 5 wherein said bore series are positioned on opposite sides of the mandrel from one another in said body sections.

7. Apparatus for flexing pipe in a well bore comprising a flexible material body normally extending relatively straight, said body of an outer diameter sufficiently less than the pipe to be flexed to be inserted therein and moved therethrough, means for moving said body through the pipe to the portion thereof to be flexed, a mandrel positioned centrally of said body and extending axially of the length thereof, the body composed of a plurality of body sections mounted on said mandrel, said body sections each having at least one bore extending therethrough, and angled laterally therein relative said mandrel whereby to spiral around said body in axial alignment, stretchable tubing within and extending substantially the total length of said bores and sealed at its lower end, means in said bores circumferential to said tubing between each pair of said body sections for preventing extrusion or pinching of said tubing between said sections, and means for flowing sufficient fluid pressurization medium into said tubing to flex the body and pipe therearound into substantial spiral form.

8. Apparatus for flexing pipe in a well bore comprising a flexible material body normally extending relatively straight, said body of an outer diameter sufficiently less than the pipe to be flexed to be inserted therein and moved therethrough, means for moving said body through the pipe to the portion thereof to be flexed, a mandrel positioned centrally of said body and extending axially of the length thereof, the body composed of a plurality of body sections mounted on said mandrel, said body sections each having at least two bores extending therethrough and angled laterally therein relative said mandrel whereby to provide two axially aligned bore series spiraling around said body, a stretchable tubing within each said bore series extending substantially the total length thereof and sealed at its lower end, means in each said bore series circumferentially to the tubing and between each pair of said body sections for preventing extrusion or pinching of said tubing between said sections, and means for applying sufficient fluid pressurization to each said tubing to flex the body and casing therearound to substantial spiral form.

9. Apparatus as in claim 8 wherein said bore series are diametrically opposed to one another on each side of said mandrel.

References Cited in the file of this patent

UNITED STATES PATENTS

1,837,690	Sunde	Dec. 22, 1931
2,242,279	Young	May 20, 1941
2,340,959	Harth	Feb. 8, 1944
2,382,933	Zublin	Aug. 14, 1945
2,730,176	Herbold	Jan. 10, 1956