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**EUROPEAN PATENT APPLICATION**

⑳ Application number: 83304298.9

⑤① Int. Cl.<sup>3</sup>: **E 21 B 7/08**

㉔ Date of filing: 25.07.83

③① Priority: 26.07.82 US 401613  
02.03.83 US 471437  
02.03.83 US 471430

④③ Date of publication of application: 08.02.84  
Bulletin 84/6

⑧④ Designated Contracting States: AT BE CH DE FR GB IT  
LI LU NL SE

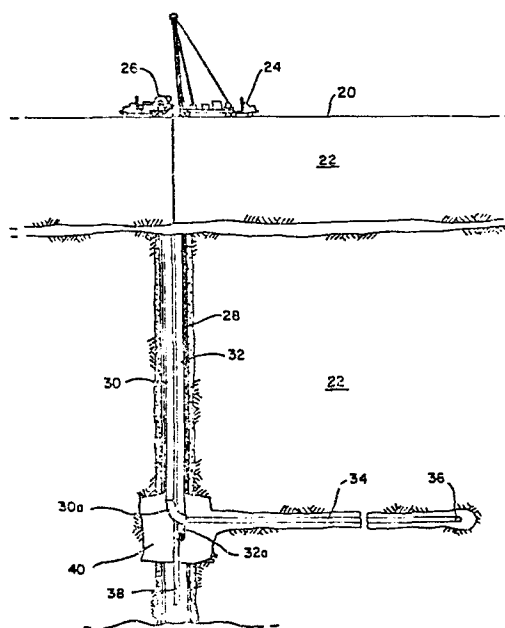
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⑤④ **Earth drilling apparatus and method.**

⑤⑦ Apparatus for forming a bore hole in an underground formation including a guide pipe (30, 32) with a fluid seal and a tube (34) sealed with the seal and terminating in a drillhead (36) with at least one fluid exit port. The tube moves out the exit end of the guide pipe into the formation under hydraulic pressure applied against the drillhead. Preferably, the bottom of the guide tube includes a whipstock (30a, 32a) to turn the drillhead, preferably from a vertical to a horizontal direction, to form a radial. The whipstock may be stationary or may be extendible.



-1-

## EARTH DRILLING APPARATUS AND METHOD

The present invention is directed primarily to a system for the formation of a bore hole for use in the recovery or enhancement of recovery of oil from an oil-bearing formation, or for the recovery of mineral deposits or the like, or for drilling through an underground formation for some other purpose. The system includes an assembly with piston means in a guide means. The piston means consists of a body formed by a drilling tube which is open at its rearward end and includes a drillhead of the hydraulic jet type at its forward end, the drillhead being provided with multiple fluid exit ports. The guide means is a tube or pipe in fluid communication with the interior of the drilling pipe. There is sealing means between the drilling tube and guide pipe so that pressurized fluid flowing through the guide tube and drilling tube applies force to cause the piston means to move in a forward direction through tube bending means and into the underground formation.

In a preferred embodiment, tube bending means referred to as a whipstock, is attached to the guide pipe to cause the piston body or drilling tube to turn from the

vertical to the generally horizontal direction in a short radius of the order of 6 to 12 inches for steel drilling tubes that may, for example, be of the order of  $1\frac{1}{4}$  to  $1\frac{1}{2}$  inches OD, with a wall thickness of from 0.080-0.125  
5 inches. Such a normally rigid metal piston body, due to the hoop stress caused by internal high pressure drilling fluid and the bending stress during movement through the whipstock, causes plastic deformation in the metal during the turn without collapse or breaking of the tube.  
10 Thereafter straightening means causes the tube to reassume a substantially straight condition.

The whipstock may be stationary or retractible. A retractible whipstock consists of two connected assemblies which when extended from a retracted position  
15 within the structure, form an arcuate tube bending guideway. When hydraulic pressure is applied to the guide pipe, it applies force to the drilling tube to propel it downwardly through the guide pipe and through the guideway, thereby causing the tube to be bent to  
20 project the drilling head laterally against the formation. Each of the assemblies of the whipstock has a series of rollers or sheaves rotatably carried by the same to form a segment of the arcuate guideway. The bending means also includes means for straightening the  
25 tubing as it exits from the guideway.

Two or more such assemblies may be provided in a well to provide two or more laterally extending bores for the injection of a hot fluid, such as steam, to heat oil in the formation and cause it to flow to a nearby production  
30 well or to a production pump in the same well casing.

Objects of the invention include the providing of a system and method that is capable of forming radially

extending bores (radials) in a relatively short radius turn, and which is efficient and economical compared to prior systems and methods.

It is a particular object to form multiple radials in a 5 single pre-existing well casing.

It is a further object to provide a multiple radial system in a combined injection production well.

It is a further object to provide a system of the foregoing type capable of drilling into unconsolidated 10 formation without the necessity of using a rotating drillhead.

Further objects and features of the invention will be apparent from the following description taken in conjunction with the appendant drawings.

15 Figure 1 is a side elevational view, partially in section, illustrating a drill string assembly with conventional surface apparatus, and an expanded, partially broken away well casing and radials formed in accordance with the invention.

20 Figure 2 is a schematic view, partially in section, of the assembly of the present invention moving horizontally through a whipstock and turning to a vertical direction.

Figures 3 and 4 are side and end views, respectively, 25 of a drillhead and piston body.

Figure 5 is a sectional view illustrating the drillhead and a single opening, while Figure 6 is a cross-sectional view taken along the line 6-6 of the same opening as in Figure 5, illustrating the oblique-oblique orientation of  
5 one of a number of multiple ports in a drillhead embodiment.

Figure 7 is a cross-sectional view of a casing including four radials and corresponding whipstocks, together with a central production string.

10 Figure 8 is a cross-sectional view of the system of Figure 7 taken along the line 8-8.

Figure 9 is a detail in side elevation showing another embodiment of tube bending means.

Figure 10 is a view looking toward the exit end of the  
15 guide way of the bending and straightening means of Figure 9.

Figure 11 is a detail in side elevation showing another embodiment of tube bending and straightening means.

Figure 12 is a detail looking toward the exit end of the  
20 guide way of Figure 11.

Figure 13 is a detail in side elevation and in section showing means for establishing a sealed connection for introducing steam into the drilling tube.

Figure 14 is like Figure 13 but shows a connection after  
25 it is established for introducing steam.

Figure 15 is a schematic view in side elevation, illustrating the apparatus disposed within an earth well, with the drilling tube extended in a lateral bore.

Figure 16 is a detail in side elevation, illustrating the  
5 tube bending means of Figure 14 and its mounting.

Figure 17 is a detail in section elevation, illustrating the bending means in side elevation and extended.

Figure 18 is a view looking toward the right hand side of Figure 17.

10 Figure 19 is a detail in section showing another embodiment of the invention in side elevation.

Figure 20 is a view looking toward the right hand side of Figure 19.

Figure 21 is a detail in section showing sealing means  
15 between the well piping and the drilling tube.

Figure 22 is a side elevation, partly in section, showing another embodiment in which the guide means is in three sections.

Figure 23 is an elevation looking toward the right hand  
20 side of Figure 21.

Figure 24 is a side elevation like Figure 22, but showing the bending means extended.

Figure 25 is an enlarged detail in section showing adjustable means for straightening the drilling tube.

In one major use of the present invention, a system is provided for forming one or more radial pipes or tubes in radial bores extending from a pre-existing cased well. A major use for such a radial pipe is to inject  
5 a hot fluid such as steam or solvents into the surrounding formation to render high-viscosity oil in the underground formation more flowable. An important application is to heat oil left in the ground by a production well system which has ceased producing  
10 economically.

Referring to Figure 1, the ground level 20 above the underground mineral bearing formation 22 is illustrated on which a production rig is disposed to the right and coiled tubing rig 26 is disposed to the left. The  
15 function of a production rig 24 is to screw together sections of one or more guide tubes or pipes 30 and 32 at the site in a conventional manner. Piston body or drilling tube 34 is formed of a metal tube of the solid wall type which may for example have an outer diameter  
20 (OD) of approximately 1.25 in., and is coiled on spool 26 and passed downwardly into the guide tube. When a sufficient length of the piston body or drilling tube 34 is in the guide pipe to reach the desired ultimate radial length, the drilling tube is severed and lowered  
25 down the guide pipe.

The lower portion of the drawing illustrates a pre-existing cemented-in well casing 28 in which are contained two different axially disposed guide pipe means, including axially disposed guide tubes or pipes

30 and 32, terminating in whipstocks 30a and 32a, respectively, each whipstock having curved barrels or guideways. Piston means are disposed in each guide pipe, each piston means including an elongate piston body in the form of a drilling tube, the tube terminating in drillhead means. The piston body is formed of a relatively rigid metal material such as steel, and so has the advantage of moving in a substantially straight path through the formation. As 10 illustrated, only piston body or drilling tube 34, traveling in guide pipe 30, is visible with drillhead means 36 at the forward end thereof. A suitable guide pipe is about 2 in. OD in about 30 ft. sections.

The piston body or drilling tube 34 can be turned by 15 bending and, upon turning through whipstock 30a and drilling into the formation, becomes a radial or lateral tube or duct suitable for the injection of a hot fluid such as steam into the formation to heat up the viscous oil for removal. In the alternative, heat from the hot 20 fluid causes the oil to flow back towards a casing containing a production pump as well as the radial, as better illustrated in Figures 7 and 8 described below.

In the illustrated embodiment, a fluid downcomer 38 (e.g. 1.25 in. OD) projects centrally of guide tubes 30 25 and 32 and is suitable for the injection of a foamed or foamable fluid or high viscosity fluid to assist the lifting of cuttings formed during operation of the drillhead 36, or during subsequent deposition of cement. Such cuttings flow back along the tube 34 and are lifted 30 by foam to flow upwardly through axial spaces within the well casing 28. Tube 38 may also be used to conduct and

deposit cement into chamber 40 to fix the position of the radials and whipstocks upon completion of vertical bore hole drilling.

In a typical operation, well casing 28 may be present from a pre-established injection well. A typical size in some areas of the United States for such casing is 5-1/2 in. in outer diameter, although larger casings may be used. Normally, the casing has been milled and the formation underreamed in a conventional manner to form a cavity 40 within which the whipstock 30a is disposed. In one alternative, an abrasive such as silica may be added to the drilling fluid supplied to drillhead 36 or a separate drilling device, and directed against an existing well casing wall or cement formation to bore an opening through the casing or formation so that the drilling tube 34 and head 36 can move through the wall or formation to form a radial.

The general principle of forming a radial according to the invention is now disclosed, although the detailed structure of the parts will be described more fully below in conjunction with the drawings. Briefly, the piston body or tube 34 is adapted to move within the guide pipe and provides an interior fluid passageway with an outward, open rearward end and drillhead means at its forward end. Single or multiple fluid exit ports are provided in the drillhead means for the passage of drilling fluid from the piston body fluid passageway into the adjacent formation. The interior of the guide pipe means is in fluid communication with the rearward end of the piston body interior passageway. Sealing means provides a seal between the piston means and the guide

tube. High pressure fluid flowing through the piston body fluid passageway applies pressure against the back of the drillhead means to cause the piston to move in a forward direction. When the piston body or tube reaches  
5 the whipstock, combined stresses, including the hoop stress (or radial stress) caused by the high pressure fluid within the piston body, together with the bending stress in the whipstock, causes the piston body or tube, which is a normally rigid metal, to be stressed and  
10 deformed plastically in a physical metallurgical sense and to bend and turn into a radial, preferably horizontal, direction so as to be movable into the formation. The high pressure liquid issuing from the drillhead penetrates the formation and forms cuttings,  
15 which are slurrified and passed backwardly along the outside periphery of the piston body into cavity 40, wherein foam or other lifting fluid, which is passed downwardly through downcomer 38, may be added to lift the slurry up to the surface of the formation through the  
20 axial space within the casing not otherwise occupied by the guide tubes. In an alternative, not shown, no fluid downcomer is required and the fluid is directed into the surrounding formation under such force that the formation fracs or fractures, causing fissures into which the  
25 formed slurry can flow, whereby little, if any, cuttings are moved rearwardly along the radial and so lifting of such cuttings is not required.

A significant advantage of this system is that it is capable of drilling radial bores with a non-rotating  
30 drillhead, and that the bore hole is cased while drilling.

Referring to Figure 2, a system is illustrated for vertical hydraulic jet drilling. It utilizes the piston-guide pipe assembly of Figure 1, in which the piston tube turns from a horizontal direction on the surface to a vertical direction by passage through a whipstock on the surface. This permits the guide pipe to extend along the ground rather than being supported vertically. The underground formation 42 includes an upper cavity 44 to facilitate drilling. Guide tube or pipe 46 is supported at ground level by conventional means. The rearward end of guide pipe 46 is illustrated as projecting into a housing 48, which includes a source of high pressure drilling fluid, not shown, and also means for introducing the piston means comprising piston or drilling tube 50 terminating in drillhead 52. A drilling fluid seal 54 is provided which may be of chevron type as illustrated. The forward end of guide pipe 46 is formed into a curved whipstock 46d attached by coupling 46c to the main body of the guide pipe. Whipstock 46d includes a curved barrel adapted to bend or turn the piston body 90° from a generally horizontal to a generally vertical direction.

In operation, piston or drilling tube 50 is urged forwardly away from the high pressure pump in housing 48 to the left as shown in the drawing, past seal 54, by the drilling fluid pressure applying force against the fluid pressure area of the rearward side of the drillhead. When the piston tube is forced through the whipstock 46d, bending forces are applied to cause the tube to conform generally to the curve of the whipstock, whereby the tube is caused to turn downwardly into the formation. A straightener portion 46e is provided at

the forward end of whipstock 46d. It is inclined towards the vertical (e.g. at 5 to 10 degrees) in the same general direction as the forward movement of the tube. In this manner, the contact of the tube with the pipe  
5 straightener at point A causes the pipe to straighten into a generally vertical direction, rather than to continue its curve and curl backwardly into a spiral path. Drilling fluid is directed outwardly through one or more ports 52a of the drillhead 52 into the formation  
10 to provide a slurry through which the drillhead readily moves under the force applied by the pressurized fluid.

The piston body or tube may be formed of steel or other metal of sufficient rigidity to travel in a straight line through the formation, but is capable of the above  
15 plastic deformation. For example, a suitable wall thickness for this purpose is 0.080 - 0.125 in. of 36,000-70,000 psi or more yield steel for tubes ranging from 1½ to 1½ inches OD.

The principle of operation of the guide pipe-piston  
20 assembly is more clearly illustrated in the embodiment of Figure 2. That is, a fluid seal 54 between the stationary guide pipe and movable piston means is provided so that the high pressure fluid emerging from housing 48 (e.g. at 1,000 to 10,000 psi or higher)  
25 applies a high pressure force against drillhead 52 to cause it to move forwardly at a relatively high speed. The pressurized drilling fluid presses against seal 54 and the portion of the guide pipe upstream from that seal which is in fluid communication with the entire  
30 length of the tube 50, to assure that the major force is directed against the rearward side of the drillhead to

cause it to project forwardly. Although a minor portion of the pressure is lost due to the drilling fluid emerging through port or ports 52, the major portion of that force carries the drillhead and drilling tube 5 forwardly.

Downstream of seal 54, significant internal radial pressure (hoop pressure) causes the normally rigid piston body tube (e.g. formed of 0.80 - 0.125 in. wall thickness for steel tubing ranging from 1½ to 1½ inch 10 OD) to be highly stressed. This stress, together with the bending stresses created when the piston tube passes through the whipstock, causes the tube to be plastically deformed and turned or bent in a relatively short radius from a horizontal to a vertical direction.

15 With the system of Figure 2 vertical drilling is created without radials being formed. Since the pressure behind the seal 54 must be maintained for the above-described mode of propulsion and simultaneously jet cutting (hereinafter the piston effect), it is apparent 20 that the length of the piston body downstream of the seal can be no greater than the initial length of the guide pipe upstream of the seal. One of the major advantages of the illustrated system is that no pre-existing casing is required, and it is unnecessary to drill a 25 pre-existing hole for the guide tube.

Referring to Figures 3 and 4, one embodiment of the drillhead of the present invention is illustrated. Drillhead 56 is mounted to the forward end of the piston body tube 58, suitably by welding. As illus- 30 trated, the forward end of the drillhead is generally

rounded, hemispherical in shape. Spaced generally forward directed ports 56a are illustrated. In addition, elliptical ports 56b may be provided for directing drilling fluid in a generally rearward direction to  
5 assist the fluidizing of cuttings surrounding the piston body as it passes through the formation, to lubricate the cuttings and prevent binding with the formation and to assist movement of the formed cuttings in a rearward direction. Alternatively, all ports or a single port may  
10 be directed forward to maximize cutting.

Referring to Figures 5 and 6, the nose of the drillhead of Figures 3 and 4 is illustrated in which one or more of ports 56a are illustrated in an oblique-oblique direction. That is, such port is disposed in a direction  
15 which is oblique in two different planes to the axis of the drillhead. In this manner, the jets cut the kerf or slot walls which would otherwise be formed forward of the drillhead by ports oblique in one direction only and cause possible drillhead resistance. By disposing the  
20 ports obliquely at least 10-30° off the axis in at least two different directions, the fluid jet shears the formation in such a manner that the drillhead functions progressively to shear off the kerfs in the cut formation as the drillhead passes.

25 Referring to Figures 7 and 8, a combination injection well and production well is illustrated. There, a pre-existing well casing 90 is provided, and four guide tubes 92, 94, 96 and 98 ending in whipstocks 92a, 94a, 96a and 98a, respectively, are placed circumferentially  
30 within the guide tube. Whipstocks 92a and 96a project parallel to each other in opposite directions.

Similarly, whipstocks 94a and 98a project parallel to each other in opposite directions and perpendicular to the directions of whipstocks 92a and 96a. Piston bodies 100, 102, 104 and 106 are directed downwardly through 5 guide tubes 92, 94, 96 and 98, respectively, and turn through their respective whipstocks to form horizontal or radial portion 100a, 102a, 104a and 106a, respectively. Thus radials project every 90 degrees in a horizontal direction into the formation.

- 10 Centrally of the well casing 90 is a production tubing or pipe 110 of a conventional size and shape, including a conventional sucker rod pump assembly with a sucker rod 112 and a piston valve schematically illustrated at 114 in Figure 8. At the bottom of the tubing 110 is a 15 conventional slotted cylindrical portion 110a, which is permeable to oil flow but which filters out particulate matter, much as a wire-wrapped screen sand filter.

In essence, the embodiment of Figures 7 and 8 comprises a combination injection production system. That is, after 20 the radials (100a, 102a, 104a, 106a) are in place and the bottom of production tubing 110 is in place in a sump at the bottom of casing 90, a hot fluid such as steam may be flowed through the radials and out the drillhead to heat the adjacent oil bearing formation to allow the oil to 25 flow downwardly and laterally and into the sump, generally designated by the number 116. There, the oil is pumped to the surface in a conventional manner by a sucker rod pump assembly. Heat energy is used effectively since some of the heat from the downwardly flowing 30 steam is utilized to maintain the upwardly flowing oil at a temperature such that the oil is maintained fluid as delivered to the top of the well.

Referring again to Figure 8, the system may be used for "steam soaking" in the following manner. After formation of the radials 102a, 104a, and 106a, they may be cut from their corresponding whipstocks, and the whipstocks  
5 withdrawn to the surface for possible reuse. Then steam is passed down well casing 90 to permeate into the formation. A pump is placed in the sump as illustrated, and the oil, which has been heated by the steam to flow into the sump, is pumped to the surface.

- 10 It is possible that the force applied to the drillhead is sufficient to cause the piston body to move at a rate faster than the jets can effectively fluidize the formation which the drillhead contacts. Means may be provided in the form of a restraint line for controlling  
15 the maximum rate of movement of the piston body. Such a line may also serve to monitor the speed with which the drillhead progresses into the formation.

- A system of the foregoing type may be utilized for the injection of a hot fluid or steam through the radials  
20 which are formed in the system for heating the underground formation for production at either the same casing as the one from which the radials project, or at a remote casing.

- When drilling is complete, the system is sealed as  
25 illustrated in Figures 13 and 14 hereinafter or by some other means. For example, the system may be sealed by passing cement into the area surrounding the piston body through the fluids downcomer or guide tube. If the openings in the drillhead are of insufficient size to  
30 pass the necessary volumes of steam or other fluid, an

-16-

abrasive may be included in the drilling fluid to erode out the openings to the desired size for fluid injection, or the openings may be enlarged by the action of a suitable solvent. The drillhead may be completely severed using an explosive charge.

Two additional embodiments of tube bending means are illustrated in Figures 9-12. In both instances the dimensions and configurations are such that the well must be of sufficient diameter to permit their introduction. In Figure 9 a housing 151 encloses a portion of tube bending means 152. The bending means consists of a body which is rigid, and is formed by the spaced side plates 154 that are secured together by connecting walls. Two series of sheaves 156 and 157 are journaled between the side walls 154, and are positioned to form the curved guide way 158. This guide way is dimensioned to be compatible with movement of the drilling tube through the same, the arrangement being such that when the drilling head and tube are forced through the guide way by hydraulic pressure, the tube is at all times in contact with a plurality of sheaves, and is bent to the desired radius. Tube straightening means 159 is disposed at the exit end of the guide way, and consists of a cruciform-like body 161, which is attached to the side plates 154. The body carries four sheaves, namely the upper and lower sheaves 162, and the opposed side sheaves 163. These sheaves are so formed that their peripheral surfaces embrace substantially the entire circumference of the drilling tube.

It may be explained that when the drilling tube is caused to pass through the guide way 158 the bending is

-17-

accompanied by some change in its cross-sectional configuration. More specifically as the tube reaches the end of the guide way it has a cross-section configuration which is oval rather than circular. It has been found that straightening of such a tube is sometimes more effective if it includes some reforming of the tube to circular configuration. To accomplish this the sheaves 163 are so formed that they apply force to the exiting drilling tube to somewhat reform the same to circular configuration while simultaneously applying unbending force. In connection with the straightening action the sheaves 162 and 163 also cooperate with the adjacent ones of sheaves 156 and 157.

In another embodiment the cruciform type of straightening means shown in Figures 9 and 10 are not used. Thus as shown in Figures 11 and 12 the straightening means in such event can employ only the two upper and lower sheaves 162.

Figures 13 and 14 illustrate means for introducing drilling fluids such as steam into the drilling head after formation of the bore hole. This may be necessary if the sliding seal suitable for the driving piston effect is not sufficiently tight to fully contain steam injection into the piston body for heating the underground formation. This is the purpose of the steam seal now described. The figures show a guide pipe 166 together with a threaded coupling 167 between sections of the guide pipe. The drilling tube 168 is shown passing through the seal 164. The upper end of the drilling tube 168 is provided with the threaded portion 171. The lower end of the upper section of the guide pipe 166, is also

-18-

provided with the internally threaded portion 172. The threads of the coupling 167 are made the same as the threads of the collar 171 and portion 172. More specifically the threads for coupling the two sections of the guide pipe may be left-handed, and the threads of 171 and 172 are also made left-handed. Assuming that hydraulic pressure has been applied to the guide pipe to force the drilling tube 168 and its attached drilling head laterally into the mineral bearing formation and it is now desired to introduce steam or other treatment fluid into the drilling tube, the coupling 167 is disengaged by clockwise turning the upper part of the guide pipe 166, after which it is lifted and turned counterclockwise to engage the threaded portions 171 and 172. This provides a sealed metal to metal coupling. The parts are then in the condition shown in Figure 14. Steam or other treatment fluid can now be introduced through the guide pipe and through the drilling tube 168, and from thence into the mineral bearing formation.

Figures 13 and 14 also show an annular portion 173 at the inlet to the portion 171, which is formed to provide a downwardly convergent entrant opening. This improves the flow characteristics of the arrangement in that it provides a transition from the larger internal diameter of pipe 166 to the smaller internal diameter of tube 168. Portion 173 is dimensioned to form a stop when the threaded portions 171 and 172 are engaged.

Figure 15 schematically shows an earth well 210 which extends down to the mineral bearing formation 211. In this instance the well is shown provided with a casing 212, which may extend down to a cavity 213 that is

adjacent the formation 211. The piping extending into the well consists in this instance of a pipe string 214 within which a drilling tube 215 is normally disposed. As shown in Figure 21, a seal 216 is mounted within the pipe string 214, and forms a seal between the pipe string and the drilling tube 215. The upper open end of the drill pipe 215 is above the seal 216, when the drilling tube is fully extended as shown in Figure 15. Before the drilling tube is extended it is within the pipe string 214, with its drilling head 217 located below the seal 216. The structure 221 serves to carry the pipe bending means 222. While the seal 216 may be incorporated in a coupling between sections of the pipe string 214, it is preferably incorporated in the coupling adjacent the upper end of the bending means 222. Pipe 249 is a fluid downcomer.

Figure 15 also schematically shows a production rig 224 of the mobile type, and a reel carrying truck 225 which may carry a supply of the drilling tubing 215.

One embodiment of an extensible whipstock or bending means is shown in Figures 16-18. It consists of the structure 221, which carries the bending assemblies 226 and 227. Structure 221 can be in the form of a pipe section having one side cut away as indicated at 228. Assembly 226 consists of a rigid mounting made of rigid side plates 229 attached to a back plate (not shown), and a top plate 231. This assembly is secured to the structure 221 as indicated at 232. The assembly 227 similarly includes a rigid mounting formed by the connected side plates 233, which have a pivotal connection 234 with the lower end of the assembly 226. The

-20-

upper assembly 226 carries two series of rollers or sheaves 236 and 237. They are disposed to form a guideway 238, dimensioned to receive the drilling tube 215. The lower assembly 227 is similarly provided with two series of rollers or sheaves 239 and 240. They are positioned to form the guideway 242.

The bending means described above is extended to the position shown in Figure 17, by swinging the lower assembly outwardly and upwardly. The guideway formed by each assembly becomes a segment of the entire guideway formed when the lower assembly is swung to the position in Figure 17.

Suitable power means is provided for moving the lower assembly 227 to the extended position shown in Figure 17. This may consist of a hydraulic actuator 244 of the cylinder-piston type, having its operating rod pivotally connected at 246 with the side walls 233 of the assembly 227. When hydraulic liquid under pressure is applied to the operator 244, it moves the lower assembly 227 from the position shown in Figure 15, to that shown in Figure 16. Continued application of hydraulic pressure to the actuator 244, or hydraulic loading, serves to retain the assembly in the position shown in Figure 17, during passage of a drilling tube through the same, and during subsequent drilling operations. Assuming that the operator is of the single acting type, the control valve for admitting or venting hydraulic fluid may be closed after actuation to lock the assembly 226 in extended position. Figure 14 shows a tube 247 extending to the top of the well for the hydraulic operation of the operator 244.

-21-

When it is desired to salvage the bending means, following application of steam or other treatment fluid through the radially extending drilling tube, the pipe string 214, together with the housing 221, can be pulled upwardly to force retraction of assembly 227 and crushing and breaking off of the extended position of the drill tube. In the event the operator 244 is of the double acting type, it can be used as power means to retract assembly 227 with crushing or buckling of the drilling 10 tube. Tubing 215 may be severed explosively or otherwise prior to whipstock collapse.

As shown in Figure 17 the series of rollers or sheaves carried by the assemblies 226 and 227 provide a continuous curved guideway through which the drilling tube is 15 caused to pass, to apply the desired bend. The sheaves of each assembly may engage either the inner or outer walls of the bent tube. It is assumed that the tube bend usually will be through 90°, although this may vary depending upon particular requirements. By way of 20 example the present invention makes it possible to employ bending radii of the order of 6 to 12 inches, for steel pipe ranging from 1½ to 1½ inches, and a wall thickness of the order of 0.080 to 0.125 inches. The metal of the tubing may, for example, have a yield point ranging from 25 36,000 to 70,000 pounds or more per square inch.

One would normally expect the tubing to buckle or break upon bending to such relatively short radii. However, the fact that the tubing does not buckle or break is attributed in part to the presence of a liquid at 30 relatively high pressure within the tube, while the tube is in transit through the bending means. This imposes hoop stress in the metal walls in conjunction with stresses applied during bending.

-22-

Again referring to Figure 17, it will be noted that the sheaves 239a, 239b, 239c and 239d, and the opposed sheaves 240a, 240b and 240d, are arranged to form a straight guideway. The purpose of these sheaves is to form straightening means whereby the drilling tube leaving these sheaves is relatively straight. The sheaves 239d and 240d are large in diameter and have peripheral grooves such that they embrace substantially the entire circumference of the tube. Thus this arrangement serves to apply straightening forces to the tubing as it exits from the guideway. In addition to straightening the tube by applying unbending forces, sheaves 239d and 240d may have reforming forces to reform the tube from oval to more circular configuration.

For the purpose of strengthening the structure 221 against side thrust, its upper end is shown attached to the template extension 221a, which may be a pipe section which extends for a substantial distance into the well casing 212.

The manner in which the extendible whipstock is used in practice, is as follows. Assuming that the well has been drilled by conventional means, and that a cavity 213 has been formed adjacent to the mineral bearing formation 211, sections of the drill string 214 are assembled with the lowermost coupling attached to the member 251 of the tube bending means. An adequate length of the drilling tube is provided with the hydraulic jet-type drilling head 217 attached to its one end. This may then be assembled within the drill string with the drillhead at or slightly below the seal 216. An adequate length of

-23-

drilling tube is one which has a length sufficient to extend laterally for the required distance, plus a further length sufficient to ensure that the upper open end of the tube is well above the seal 216, when the tube 5 is extended as shown in Figure 15. The assembly of the drill string 214, together with the attached housing 221 and bending means 222, is now lowered into the well, at which time the bending means is in retracted condition. When the bending means has reached a level corresponding 10 to the mineral bearing formation, the upper end of the pipe 214 is connected to a source of hydraulic liquid (i.e., water) at a relatively high available pressure, which may range, for example, from 1,000 to 10,000 psi or more. In an alternative and preferred method, the drill 15 string, including the whipstock but not the drillhead and drill tube, is first lowered to the desired final location. Then the drillhead and drill tube are lowered. Assuming now that one desires to make a lateral bore into the mineral bearing formation, bending means 222 is 20 extended as shown in Figure 15, by applying hydraulic pressure to the operator 244, and then high pressure hydraulic liquid is introduced into the upper end of the pipe string 214. The hydraulic liquid flows into and through the drilling tube 215, and by virtue of the fluid 25 pressure areas afforded by the drilling tube together with the drillhead 217, the tube is driven downwardly through the seal 216, the bending means 222, and then laterally against the formation in accordance with the principles set out above. The jet drilling head 217 30 penetrates the formation to form a laterally extending bore as shown, for example, in Figure 15. At the conclusion of this operation, and assuming that the mineral bearing formation is to be treated with steam or

-24-

other fluids, application of hydraulic pressure to pipe string 214 is discontinued, a steam seal is formed, and this string connected at the surface of the well with a source of the treating fluid. Thus the apparatus may  
5 then serve over an extended period of time as means for introducing treating fluid well into the mineral bearing formation.

The embodiment illustrated in Figures 19 and 20 has another form of tube straightening means. In place of  
10 the tube straightening rollers or sheaves 239d and 240d there is a cruciform-type of straightening means 251. It consists of a body 252 which serves to mount the opposed sheaves 253 and 254, together with the laterally disposed sheaves 256 and 257. The grooves in the  
15 peripheries of these sheaves are proportional whereby they embrace substantially the entire circumference of the tube. It has been found that although the drilling tube is not collapsed during bending, there is a plastic deformation of the metal walls, whereby when the tube  
20 exits from the guideway, its configuration in cross-section is slightly oval, rather than circular. The rollers 256 and 257 may be set whereby when the tube passes between them, side pressure is applied to the tube side walls to somewhat reform the cross-sectional con-  
25 figuration to near circular. It has been found that this aides straightening of the tube, whereby, together with the action of sheaves 239a-239c and 240a, 240b, that portion of the tube extending from the straightening means to the formation, is sufficiently straight to  
30 transmit the desired thrust of the drilling head into the formation, without further straightening.

The embodiment of Figures 22-25 is also provided with a plurality of sheaves that form the arcuate guideway of the bending means. However the bending means is formed by three assemblies, instead of the two assemblies of  
5 Figures 16 and 17. Also an adjustable straightening means is provided. The housing 261 may be similar to the housing 221 of Figure 16. The tube bending means consists of the three assemblies 262, 263 and 264, each of which forms a segment of the arcuate guideway. Assembly  
10 262 consists of the rigid side walls 266 that are rigidly secured together in spaced relationship, and are fixed to the upper portion of housing 261. The edges of the sidewalls are shown connected by closure or cover plates 266a and 266b. Assembly 263 likewise consists of spaced  
15 connected walls 267, the upper ends of which have pivotal connection 268 with the side walls 266 of assembly 262. Walls 267 are also shown connected by closure or cover plates 267a and 267b. Assembly 264 also consists of spaced connected walls 269 that have pivotal connection  
20 271 with the lower ends of the walls 267, and which have closure or cover plates 269a and 269b.

Figures 22 and 23 show the assemblies 263 and 264 retracted within the housing structure 261. The power means for extending the assemblies to the position shown in  
25 Figure 22 may consist of a hydraulic operator 272 that is pivotally anchored at 273 to the housing 261 and has its operating rod 274 pivotally connected at 276 to the side walls of assembly 264. The side walls of assemblies 262 and 263 have their adjacent ends 276 and 277 formed  
30 whereby they come into abutting engagement when the bending means is fully extended. The opposed ends 278 and 279 of the side walls of assemblies 263 and 264 are similarly formed. In place of the power operator,

-26-

assembly 264 may be connected to a pull cable extending to the top of the well.

When operator 272 is actuated by hydraulic pressure, the assemblies 262, 263 and 264 are extended to the limiting position shown in Figure 22, with the ends 276 and 277, and 278 and 279 in abutting engagement.

Each of the assemblies 262, 263 and 264 have a plurality of rotatable sheaves that are disposed in such a manner as to form, when the assemblies are extended, a continuous tube bending guideway which progressively bends the drilling tube as the tube is driven through the same. The complete guideway is arcuate, with the assemblies 262, 263 and 264 forming segments of the arc. The sheaves for assembly 262 are designated 281 and 282, for assembly 263 they are designated 283 and 284, and designated 286 and 287 for assembly 264. The sheaves 286a, 286b, 286c, 286d and 286e, and 287a, 287c and 287e cooperate to straighten the drill tube before it exits from the assembly 264. Preferably sheave 287c is adjustable to adjust the straightening force that it applies. Thus, in Figure 25, it is shown rotatably carried by the structure 288, which in turn is pivotally connected to the pin or shaft 289 that is carried by the side walls of assembly 264. The positioning of sheave 287c can be adjusted relative to sheaves 286b, 286c and 286d by adjustment of the screw 291. To enhance the straightening action, the sheaves 286b, 286c and 286d are shown disposed with their line of centers arched upwardly (Figures 23 and 24). The sheave 287e is not essential for straightening action and may be omitted. The adjustment feature of sheave 287c is also applicable to the embodiments of Figures 9, 11, and 16.

As in Figures 16 and 17 the sheaves 286e and 287e are of such size and with grooves such that they substantially embrace the circumference of the drilling tube. They may somewhat reform the tube to more nearly circular form.

5 The embodiment of Figure 22-25 when extended functions in substantially the same manner as the embodiments of Figures 16-20. However, when retracted, it is more compact since the assemblies 262, 263 and 264 have a straight configuration. Also when operator 272 is  
10 energized to extend the assemblies, assembly 264 is first to be swung outwardly because of the locations of the pivotal connections 271 and 272, and is followed by the assembly 263.

When the drilling tube is being driven through the  
15 bending means and into the adjacent formation, it is desirable to introduce water into the assemblies 262, 263 and 264. Thus a small duct 293 is indicated in Figure 24 which diverts some water from above the seal 292 to the assembly 262. It may discharge into assembly  
20 262 or it may connect with ducts 294, 295 and 296 in the side walls of the assemblies. The latter ducts are so located that they are in communication when the assemblies are extended. Duct 296 may discharge sprays of water through the nozzles 297. Introduction of water  
25 tends to flush out and prevent clogging of the guideway or jamming of the sheaves due to entrance of foreign material (e.g. sand or small rocks).

The closures or cover plates for the assemblies 262, 263 and 264 may be used to keep out rocks or other  
30 debris. In some instances they may be perforated.

CLAIMS:

1. An apparatus for forming a bore hole in an underground formation, a guide pipe having a fluid seal therein and adapted to be coupled at one end thereof to  
5 a source of fluid under pressure; a tube in the guide pipe in sealing engagement with said seal, said tube being movable through the guide pipe and outwardly thereof through the opposite end of the guide pipe, one end of the tube being open and in fluid communication  
10 with the guide pipe; and means on the opposite end of the tube for forming a surface against which fluid under pressure can be directed to cause a fluid force to be exerted on the tube to move it relative to the guide pipe and through said seal.
- 15 2. An apparatus as set forth in Claim 1 wherein said surface forming means comprises a drillhead having at least one fluid exit port therethrough.
3. The apparatus of Claim 1 in which said drillhead is free of means to impart rotational movement to it.
- 20 4. The apparatus of Claim 2 in which at least the drillhead and the forward portion of said drilling tube projects from said guide pipe into said underground formation so that said forward portion is surrounded by the underground formation.
- 25 5. The apparatus of Claim 1 together with means for supplying pressurized drilling fluid to said fluid passageway of said drilling tube.

-29-

6. The apparatus of Claim 1, the sealing means being mounted to the interior surface of said guide pipe and having fluid sealing engagement with said drilling tube.
- 5 7. The apparatus of Claim 1 together with means capable of forming a communicating connection between said guide pipe and said tube.
8. The apparatus of Claim 1 in which said one assembly is disposed within a well casing which projects into  
10 the region of the underground formation.
9. The apparatus of Claim 8 together with a downcomer pipe aligned with said one assembly and mounted in said well casing.
10. The apparatus of Claim 1 together with restraint  
15 means operatively associated with said piston means for controlling the maximum rate of movement thereof relative to the guide means.
11. The apparatus of Claim 2 in which at least one of the ports of said drillhead extends in a direction  
20 which is oblique in two different planes to the axis of the piston means.
12. The apparatus of Claim 2 together with rearwardly directed ports in said drillhead.
13. The apparatus of Claim 1 together with whipstock  
25 means adjacent the forward end of said guide pipe to cause said drilling tube to turn at a substantial angle to the axis of said guide pipe when said drilling tube is moved through the same.

-30-

14. The apparatus of Claim 13 in which said tube is formed with rigid metal walls capable of plastic deformation.

15. The apparatus of Claim 13 in which said whipstock  
5 means comprises a plurality of connected assemblies which when extended from a retracted position within the structure form an arcuate tube bending guideway, the arrangement being such that when hydraulic pressure is applied to the guide pipe, the tube is propelled  
10 downwardly through the guide pipe and through the guideway, thereby causing the tube to be bent to project the drilling head laterally toward the formation, each of said assemblies having a series of sheaves rotatably carried by the same to form a segment  
15 of the arcuate guideway when extended.

16. Apparatus as in Claim 13 in which the series of sheaves carried by each assembly are disposed to engage the walls of the tube on the outer sides of the tube bend to effect continual incremental bending of the  
20 tube.

17. Apparatus as in Claim 13 in which the first upper assembly of the bending means is secured to the structure and its lower end is pivotally connected to one end of the next lower assembly, and power means  
25 for moving the next lower assembly from a retracted position within the structure to an extended position in which it forms the arcuate guideway in conjunction with the first assembly.

18. Apparatus as in Claim 13, together with tube  
30 straightening means carried by the exit end of the lowermost assembly.

-31-

19. Apparatus as in Claim 18, in which the tube straightening means includes sheaves disposed to apply opposed bending forces to the upper and lower sides of the tube to straighten the same, said sheaves being 5 carried by the lowermost assembly.

20. Apparatus as in Claim 18, in which the tube straightening means includes opposed sheaves disposed to engage and press against the side walls of the exiting tube to reform the cross-sectional configuration 10 of the same from oval to more nearly circular form.

21. Apparatus as in Claim 19, in which the tube straightening means consists of a cruciform-like assembly that includes upper and lower rollers that are disposed to engage the upper and lower sides of the 15 tube and side rollers that engage and press against the side walls of the tube.

22. Apparatus as in Claim 20 in which the two side rollers are spaced apart a distance such that the tube in passing between the same is reformed from oval to 20 substantially circular form as viewed in section.

23. Apparatus as in Claim 13 in which three connected assemblies are employed (termed first, second and third assemblies), the first being pivotally connected at its lower end to the second and the second being pivotally 25 connected at its lower end to the third assembly, the first assembly being fixed to the structure, and power means connected to the third assembly for extending the second and third assemblies relative to the first assembly to form the arcuate guideway.

24. Apparatus as in Claim 18 in which the tube straightening means includes a sheave adapted to apply force to the tube on the outer side of the tube bend, and adjustable means for rotatably mounting the sheave  
5 whereby it may be advanced or retracted relative to the tube.

25. Apparatus as in Claim 13 together with means for introducing water into the bending means during application of hydraulic liquid under pressure to the  
10 piping.

26. Apparatus as in Claim 13 in which the whipstock means comprises means forming a curved guide way through which the tube is forced when pressurized hydraulic fluid is applied to the guide tube, said  
15 whipstock guide way including rotatable rollers or sheaves disposed to engage and apply forces to the drilling tube to bend the same.

27. Injection apparatus for injecting a treating fluid from a downwardly directed bore hole radially into an  
20 underground formation, said injection apparatus being in place in the underground formation and including an assembly comprising an elongate downwardly directed guide pipe having a sealing means mounted therein and terminating at its forward end in a whipstock, a tube  
25 having a head at its forward end and being open at its rearward end, the head having at least one fluid exit port, the rearward portion of said tube being retained in fluid sealing engagement with said sealing means within said guide pipe to define a fluid passageway  
30 extending from the rearward end of said guide pipe

through said tube to said head, said tube including a forward portion projecting radially from said whipstock into said formation, whereby treating fluid supplied to the rearward end of said guide pipe flows through said head port into said formation.

28. The apparatus of Claim 27 together with at least a second assembly disposed within said well casing, the guide pipe of said second assembly being aligned with said one assembly and at one side thereof, and the whipstocks of the two assemblies being in proximity with each other.

29. A method for forming a bore hole in an underground mineral bearing formation, using a drilling system comprising guide pipe means and a drilling tube within the guide pipe, said drilling tube having a drillhead of the hydraulic jet type of at least one port at its forward end and having its other end open; said method comprising the steps of:

(a) disposing said drilling tube within the guide pipe with the rearward open end of the drilling tube in communication with the guide pipe, with a seal between the drilling tube and the guide pipe;

(b) directing a hydraulic fluid under pressure into the guide pipe and from thence into the drilling tube to cause said fluid to apply force against the drillhead to move the drillhead and drilling tube into the formation.

30. The method of Claim 29 in which said drillhead does not rotate to any significant extent as said drilling fluid passes through said port.

31. The method of Claim 30 in which drilling fluid is directed through at least one port of the drillhead in a direction which is oblique in two different planes to the axis of the piston means.

32. The method of Claim 30 including the step of bending the drilling tube through a whipstock to direct it laterally toward the adjacent formation.

33. The method of Claim 32 in which said drilling tube is formed with solid walls of a normally rigid metal which is plastically deformed as it changes direction.

34. The method of Claim 32 in which said guide pipe is disposed within a well casing, together with the step of directing a pressurized abrasive fluid out said drillhead as it turns through said whipstock to erode an opening in said well casing.

35. The method of Claim 32 in which said guide pipe is placed into an existing well casing prior to step (b).

36. The method of Claim 32 together with the steps of discontinuing the flow of drilling fluid through the drilling tube after completion of a drilling operation, and then applying a treating fluid into the formation through the tube.

37. The method of Claim 32 in which during bending the tube is in contact with rotatable sheaves, and after bending, the tube is straightened.

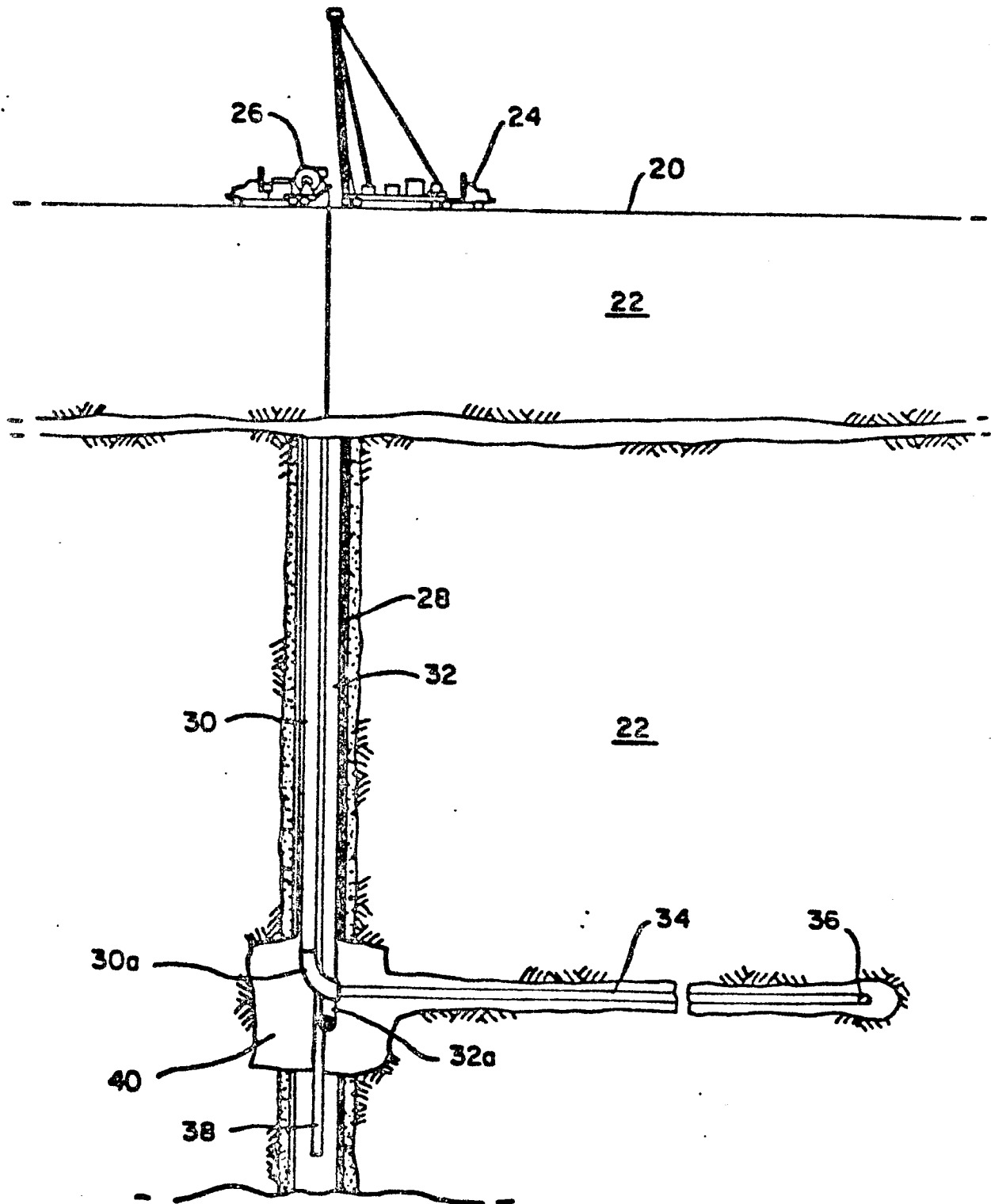


FIG.—1

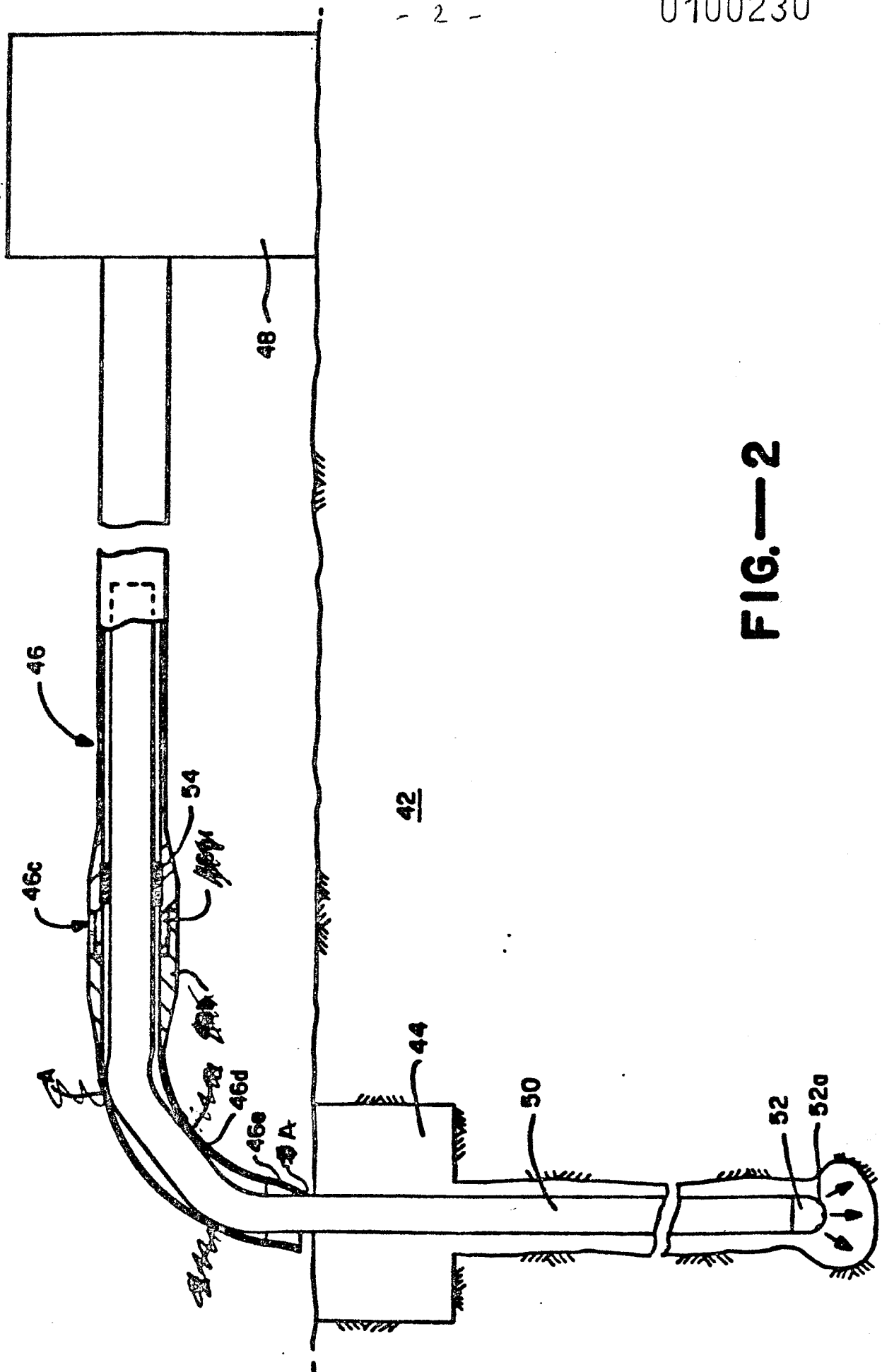


FIG.—2

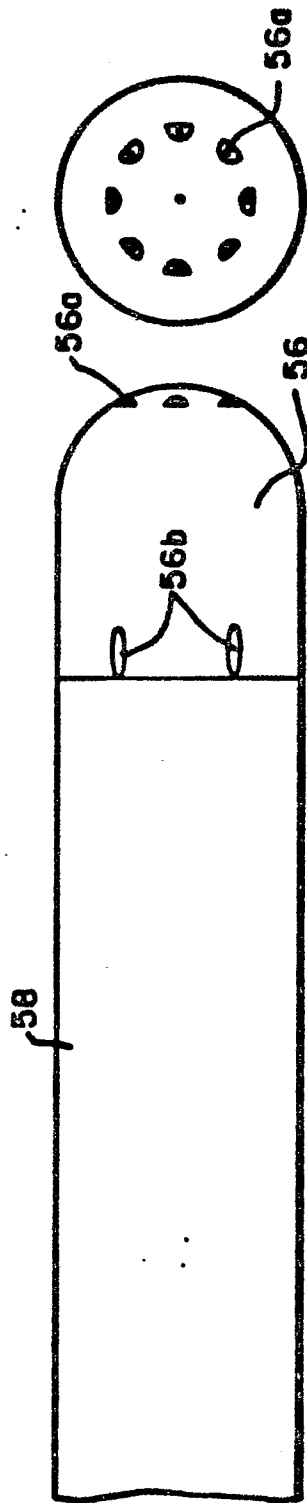


FIG.—3

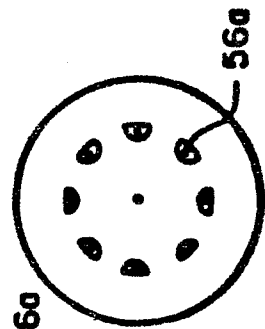


FIG.—4

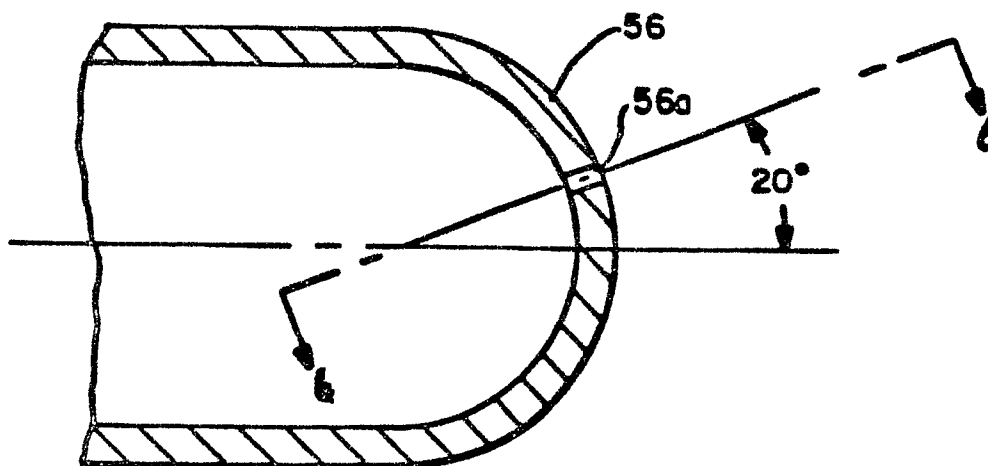


FIG.—5

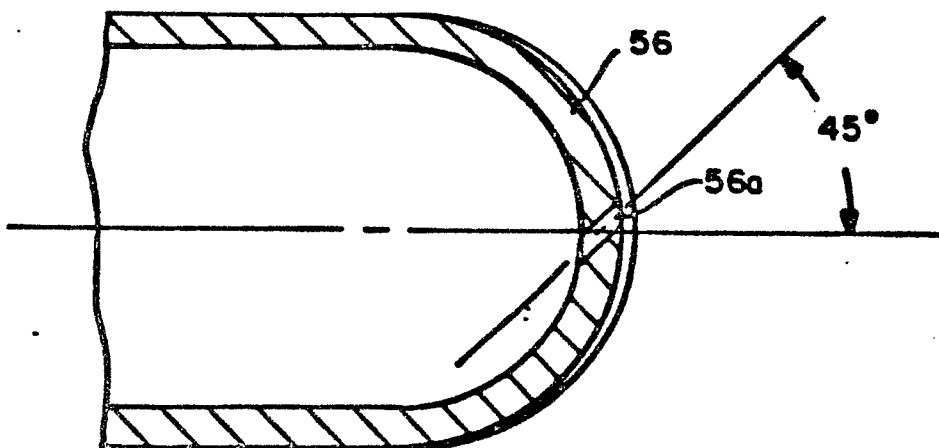
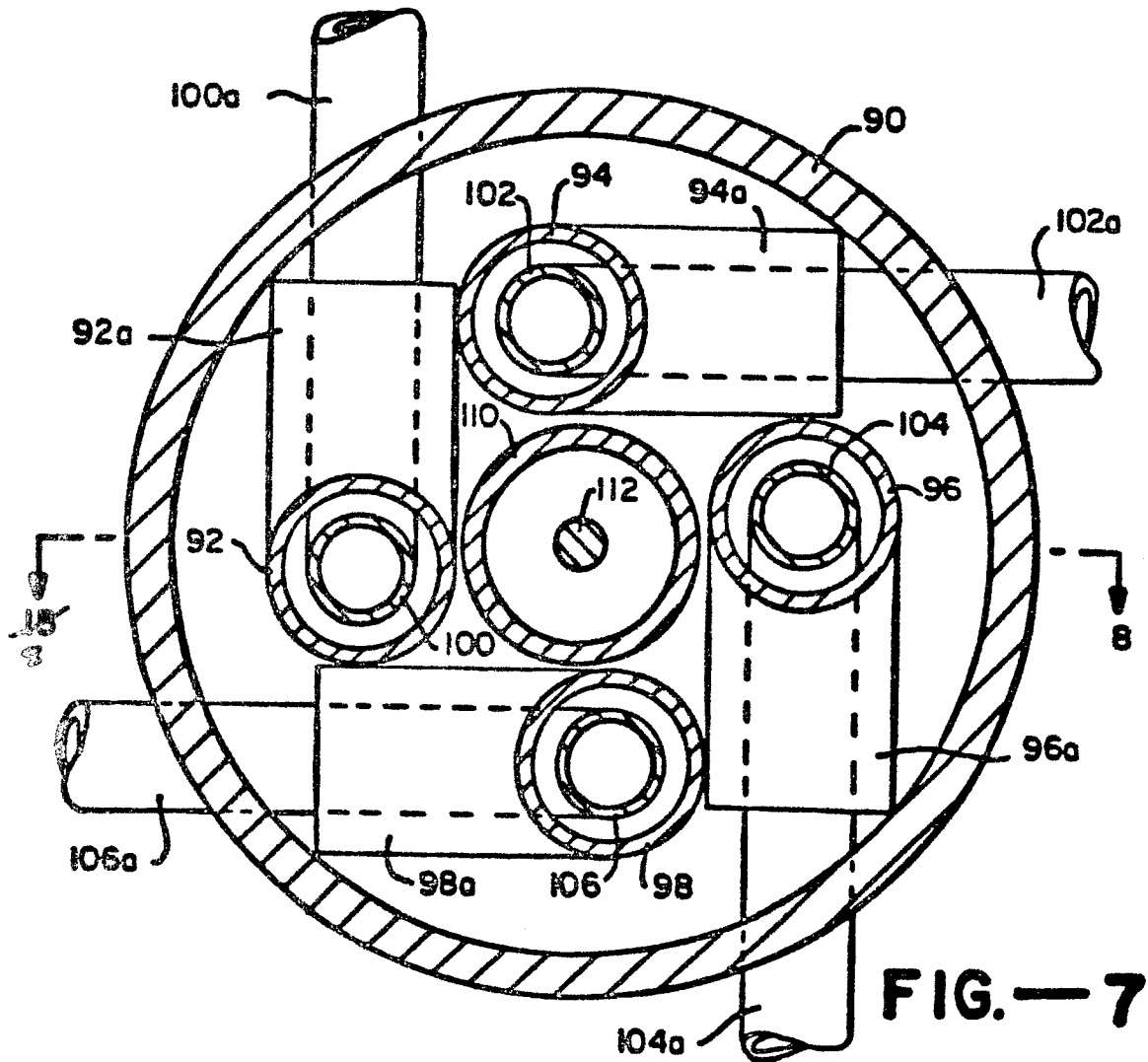
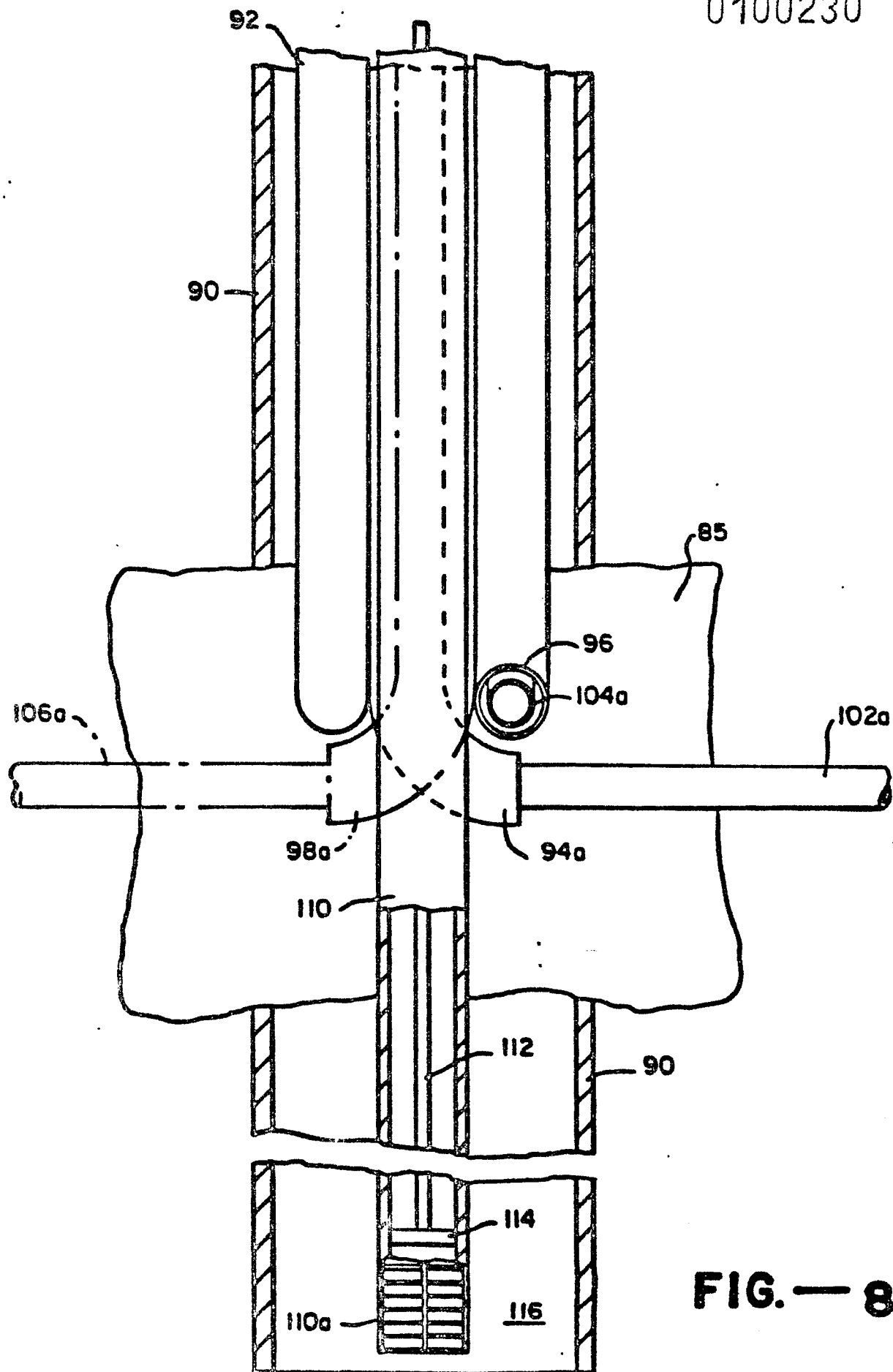


FIG.— 6



**FIG. — 8**

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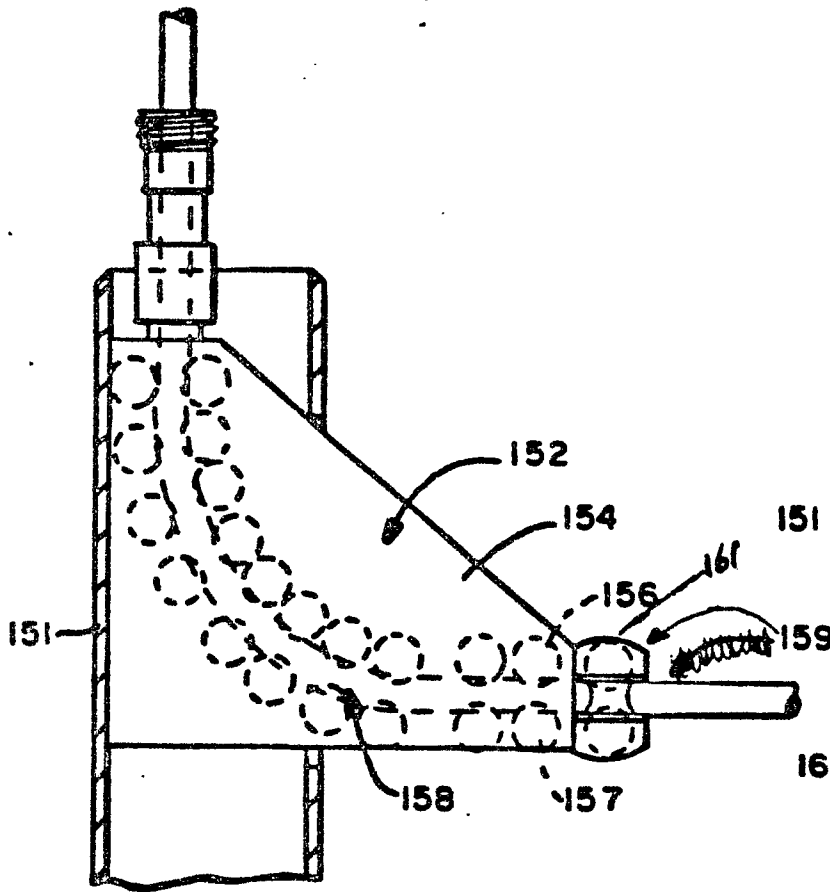


FIG.— 9

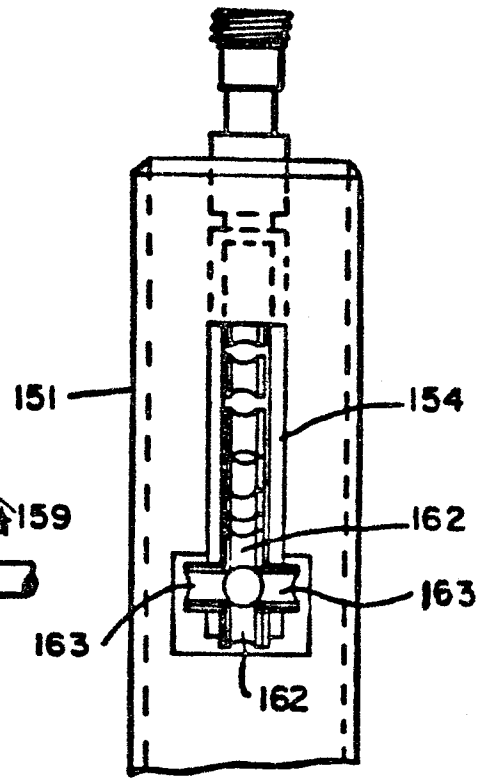


FIG.— 10

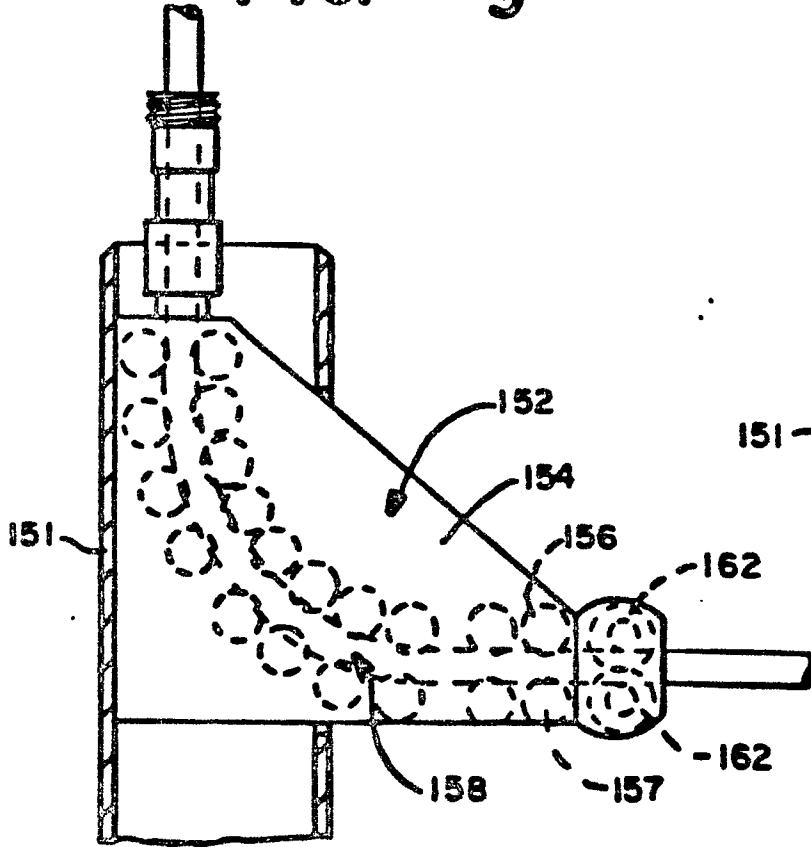


FIG.— 11

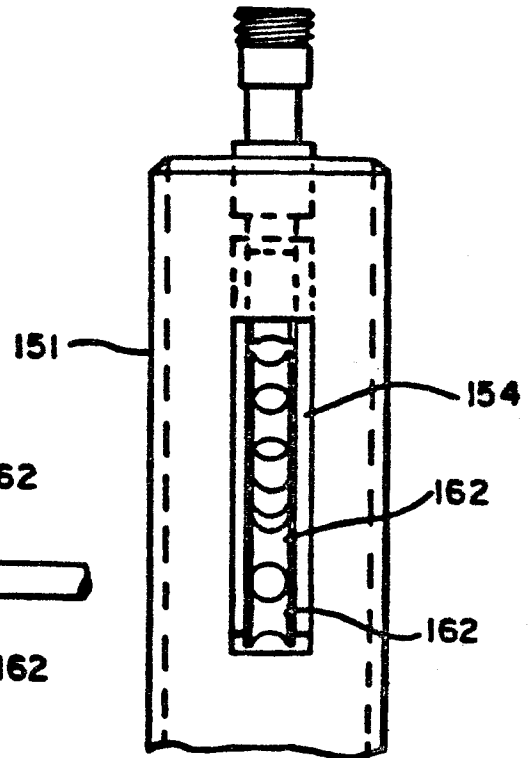


FIG.— 12

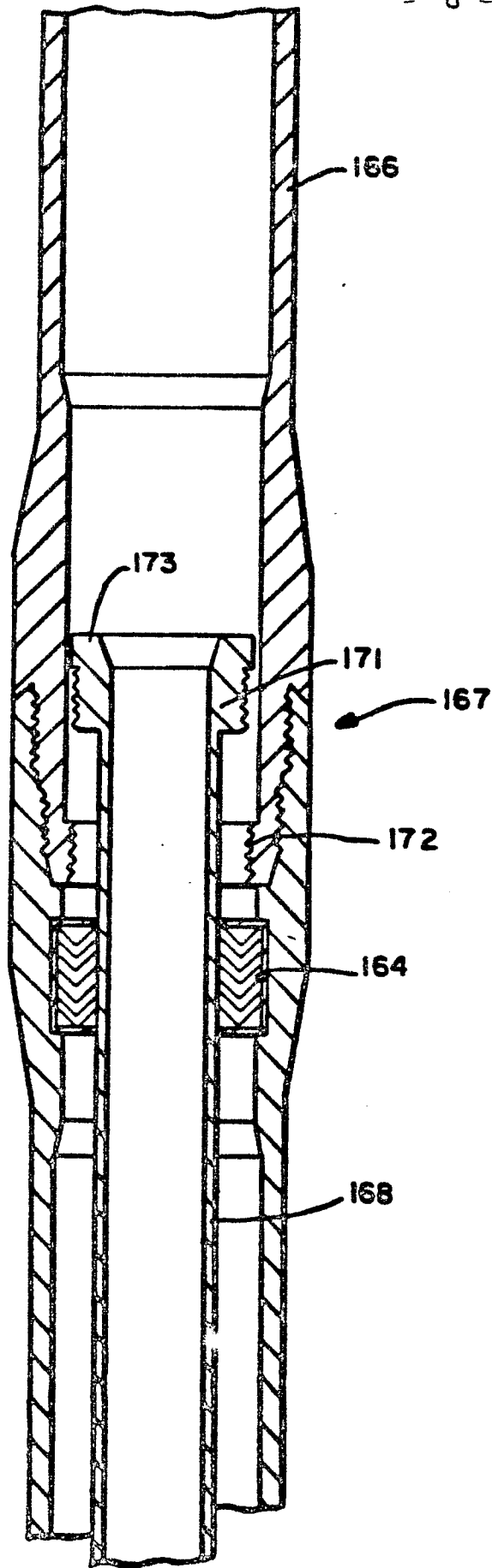


FIG.— 13

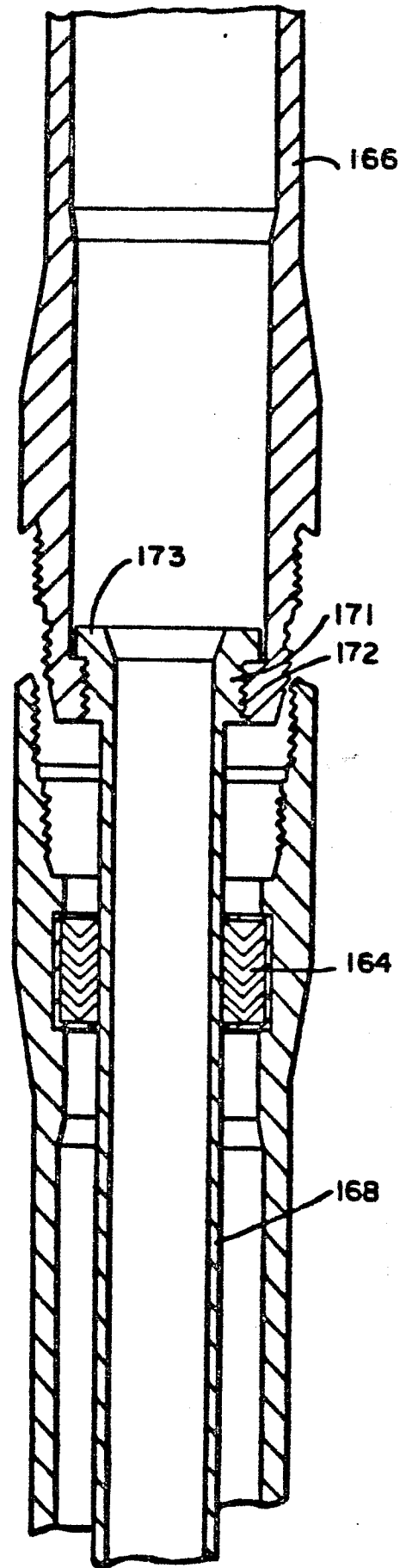


FIG.— 14

OL

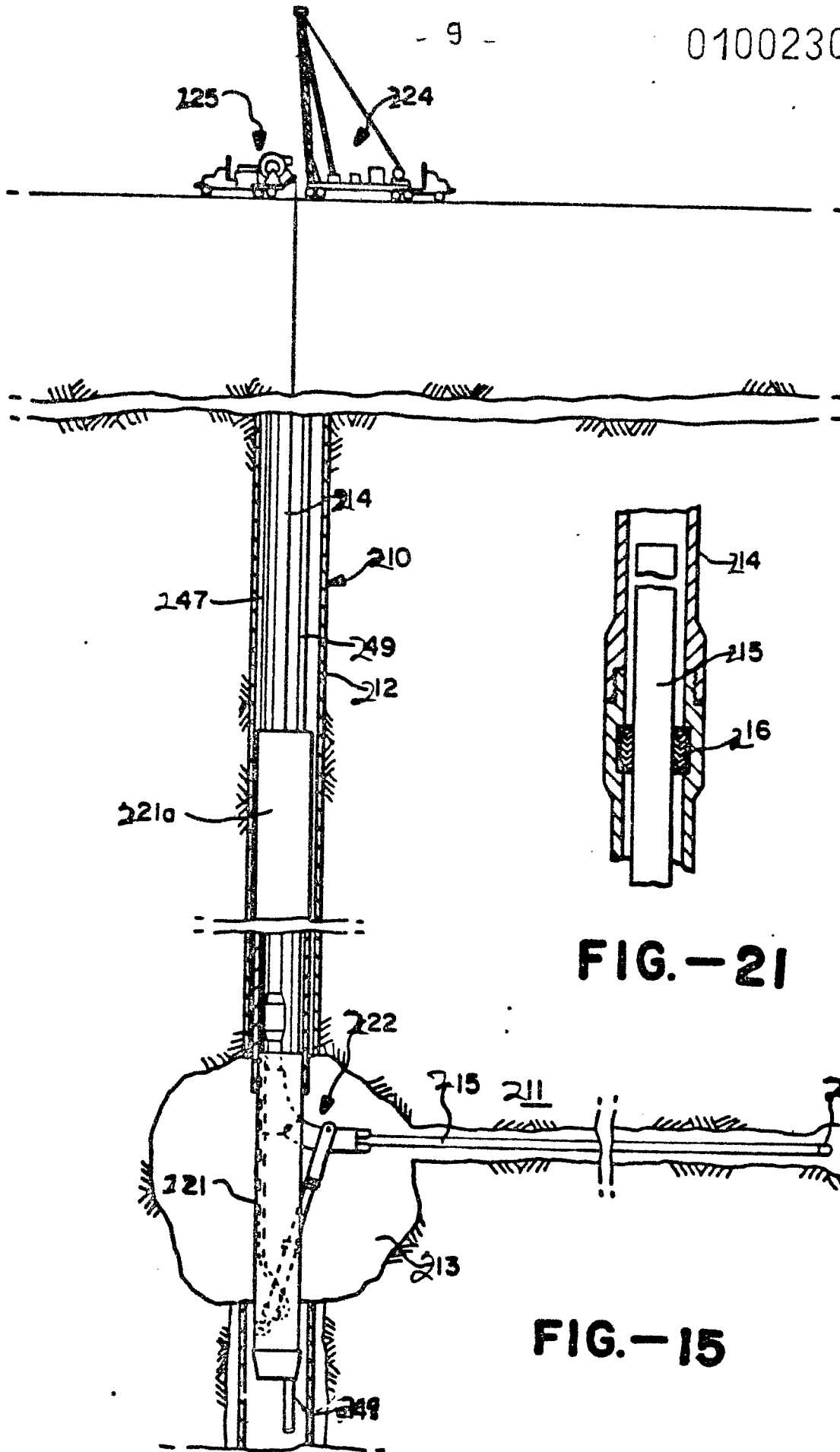


FIG.-21

FIG.-15

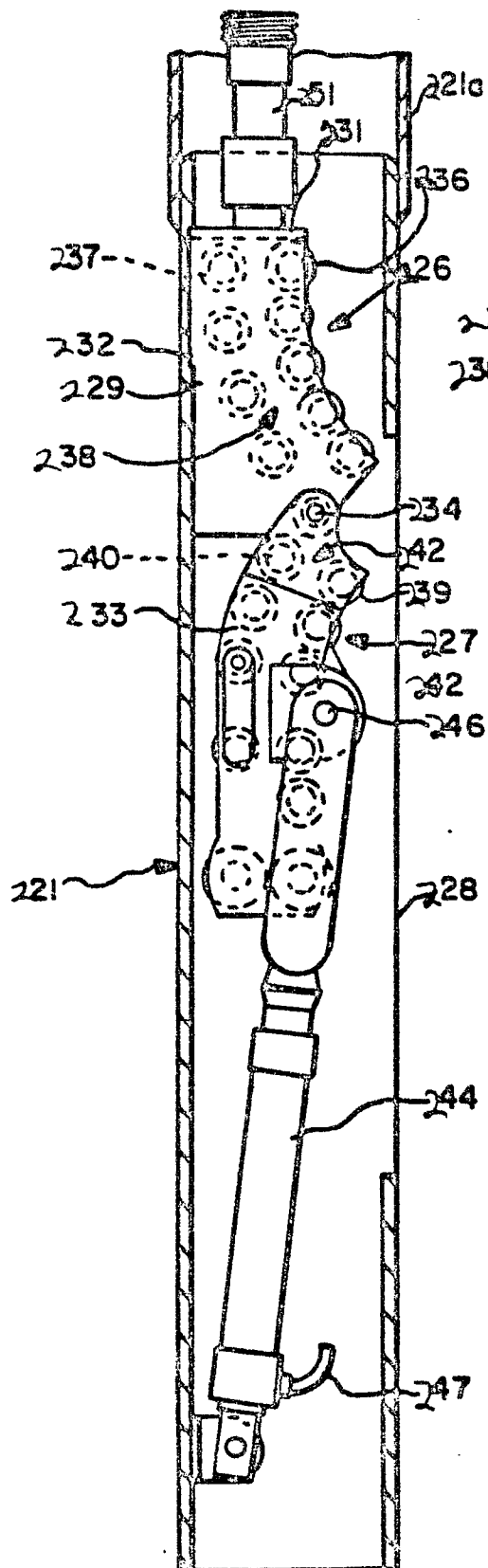


FIG. -16

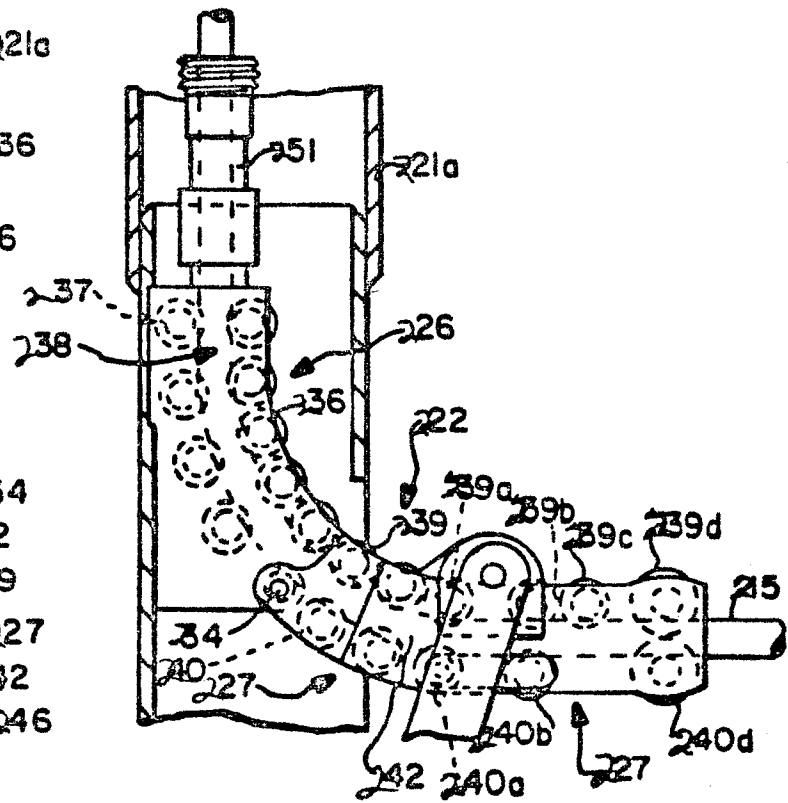


FIG. -17

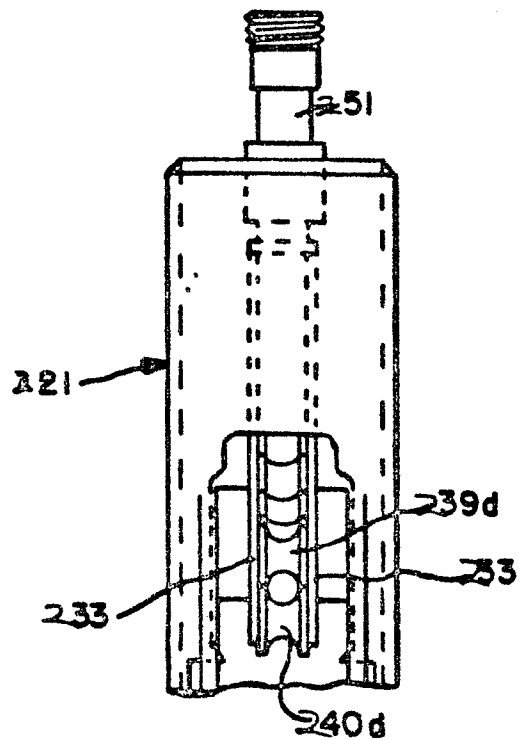


FIG. -18

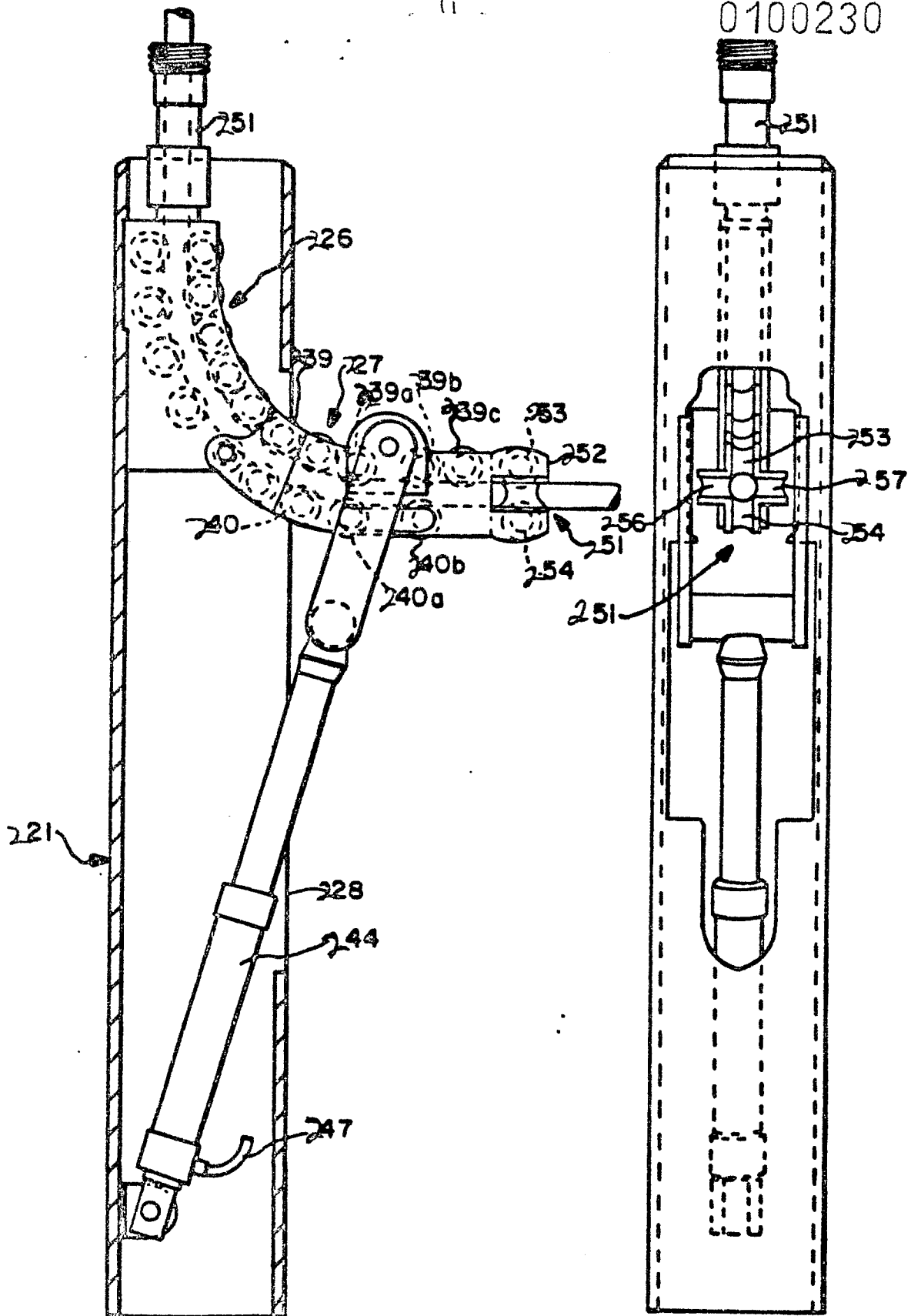


FIG. -19

FIG. -20

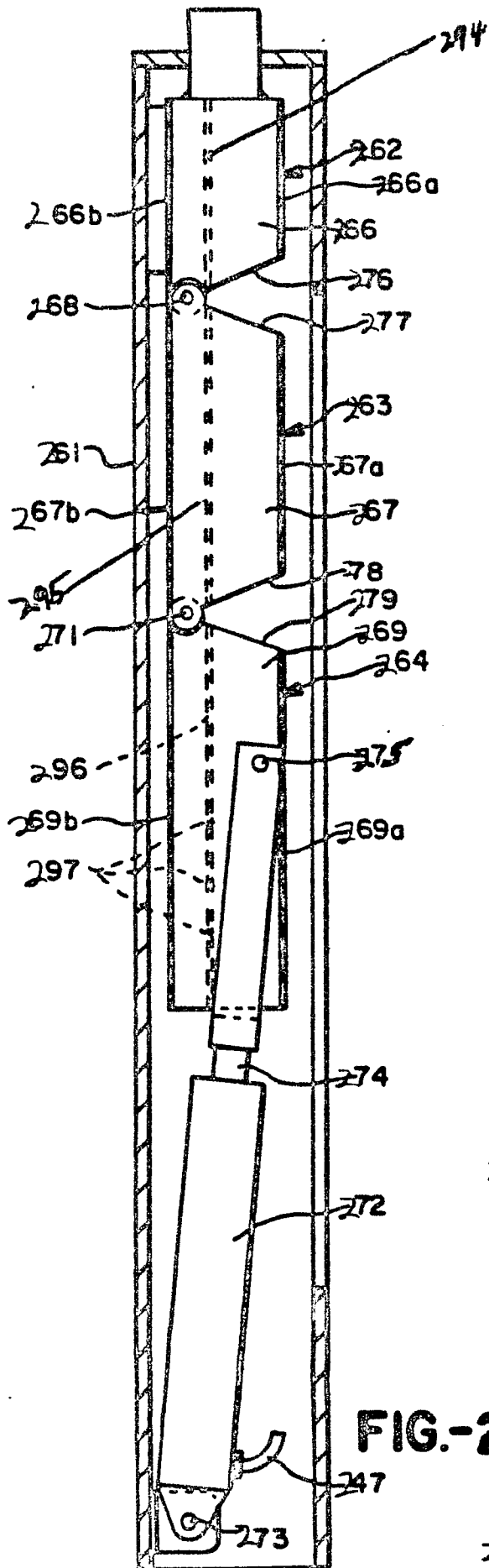


FIG.-22

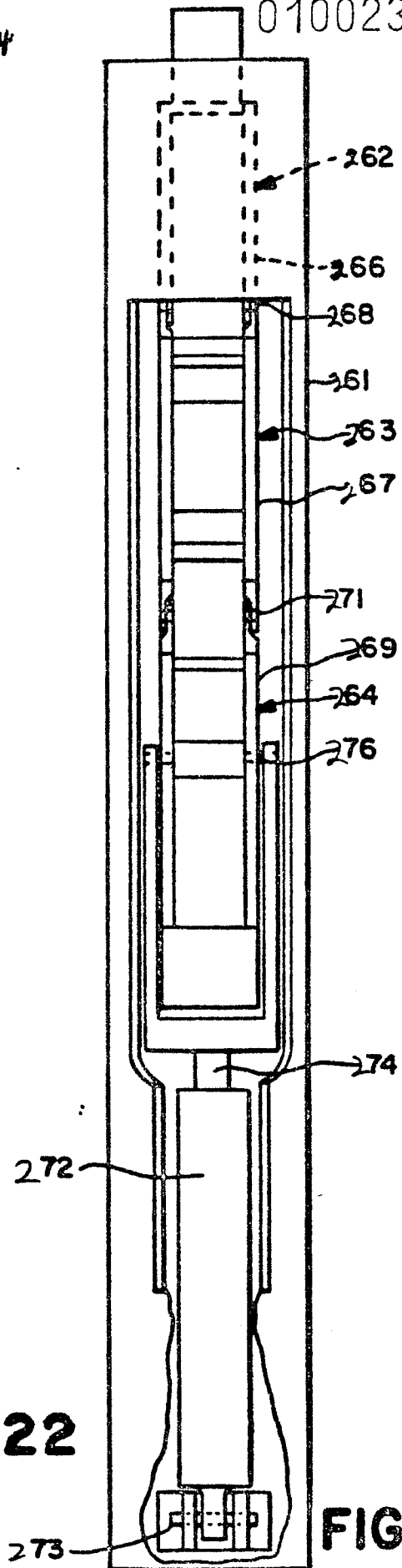


FIG.-23

