United States Patent [19]

Pereau

[11] **3,757,876**

[45] **Sept. 11, 1973**

[54] **DRILLING AND BELLING APPARATUS**

[75] Inventor: **Robert L. Pereau**, Irvine, Calif.

[73] Assignee: **Smith International, Inc.**, Newport Beach, Calif.

[22] Filed: **Sept. 1, 1971**

[21] Appl. No.: **177,037**

[52] **U.S. Cl.** **175/267,** 175/285
[51] **Int. Cl.** **E21b 9/26**
[58] **Field of Search** 175/267–269, 263, 272, 273, 284, 285

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Primary Examiner—David H. Brown
Attorney—Vernon D. Beehler et al.

[57] **ABSTRACT**

Apparatus for drilling a hole, and for belling out the lower end of the hole into a conical enlargement, in a single pass of the apparatus down the drill hole, which apparatus includes a combined drilling and belling tool. Both the extension and the retraction of the belling blades are positively driven.

The combined drilling and belling tool is characterized by the fact that the drilling blades are adapted to cut in one direction of rotation, while the belling blades are adapted to cut in the opposite direction of rotation.

9 Claims, 40 Drawing Figures

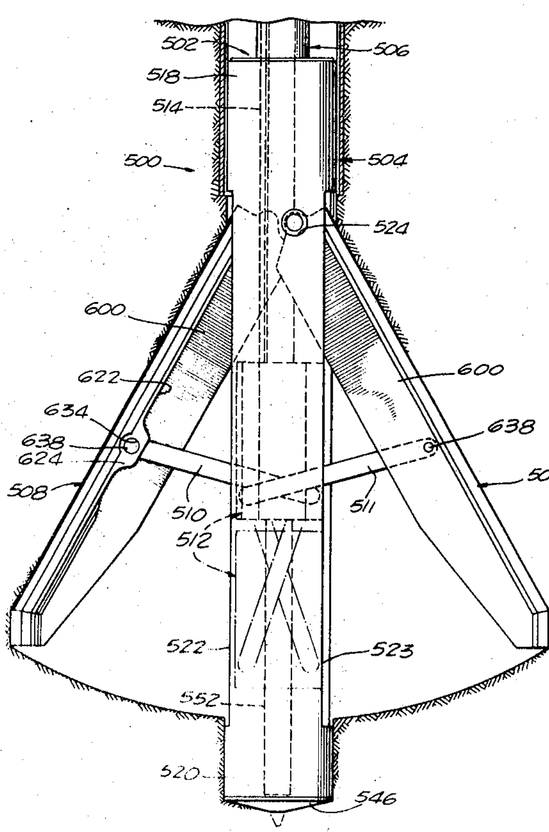
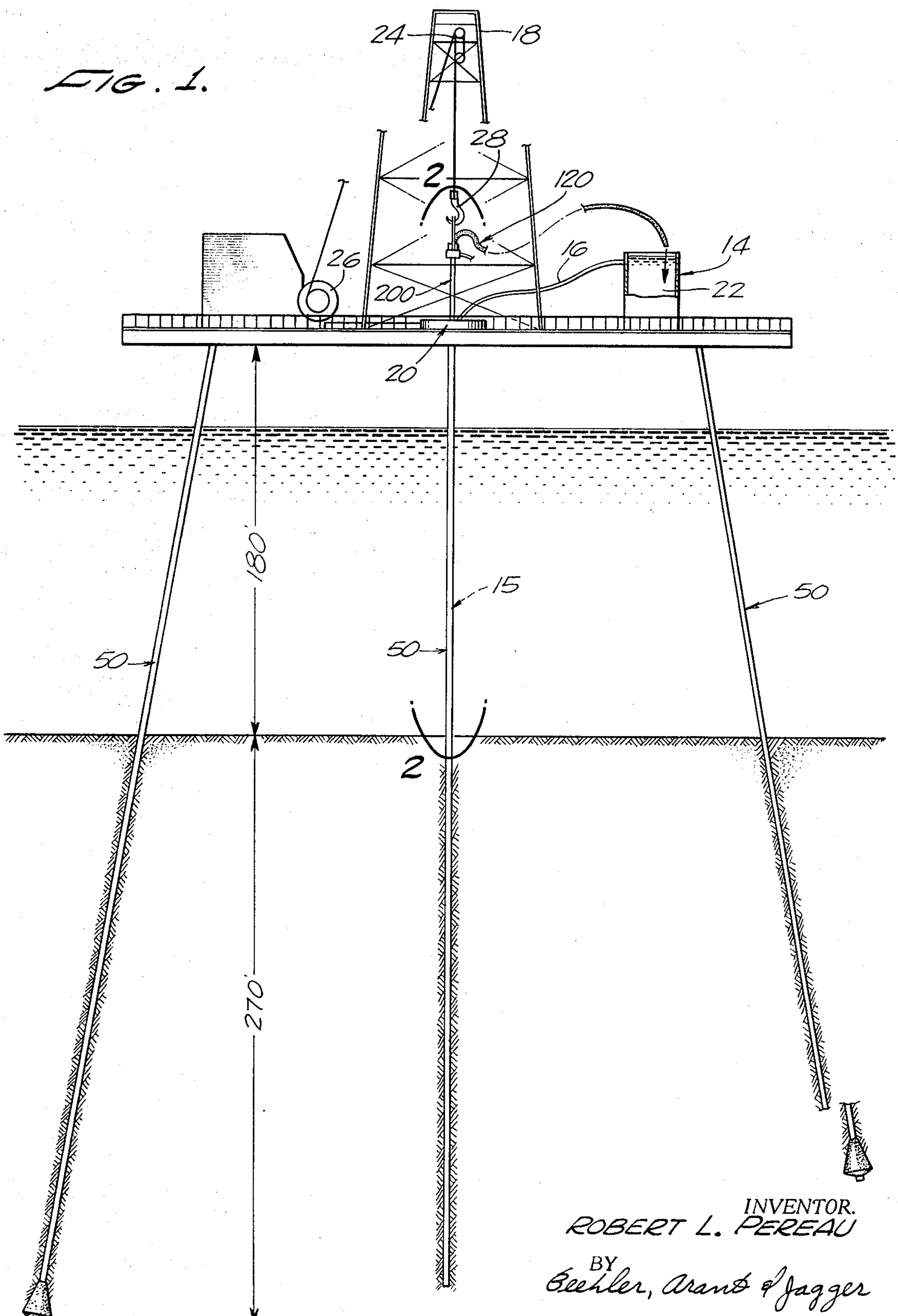


FIG. 1.



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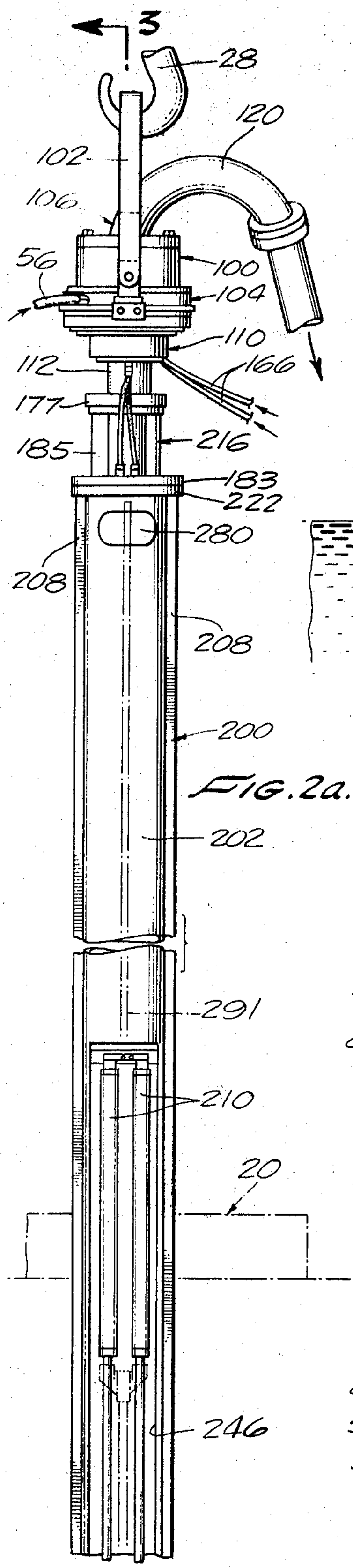

FIG. 2a.

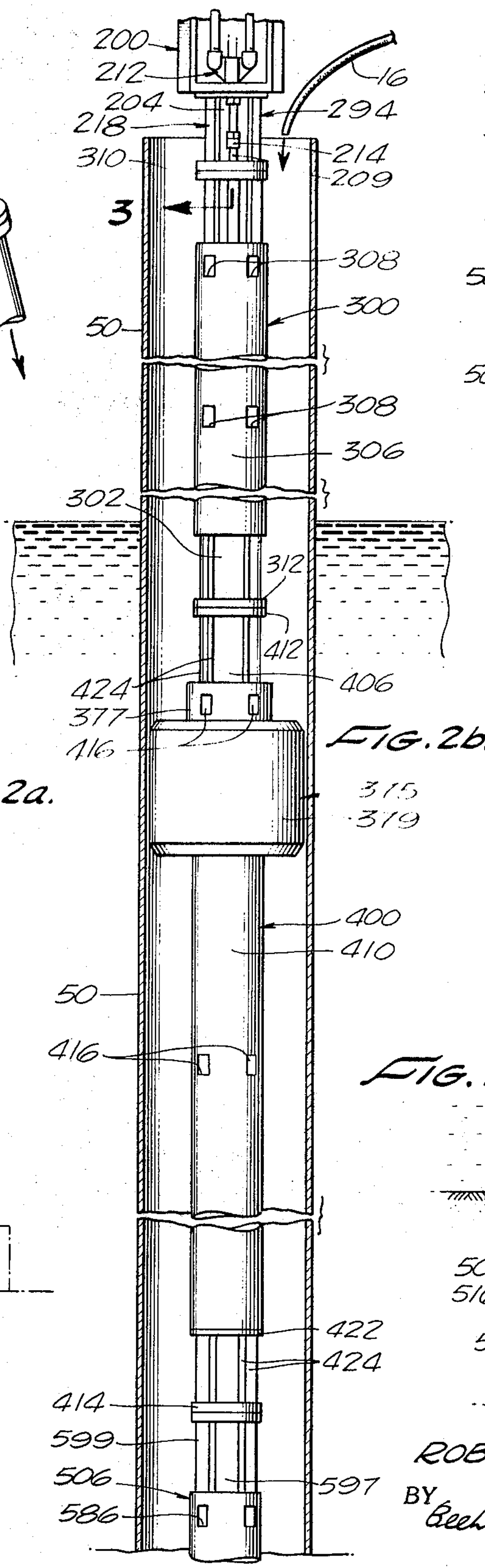

FIG. 2b.

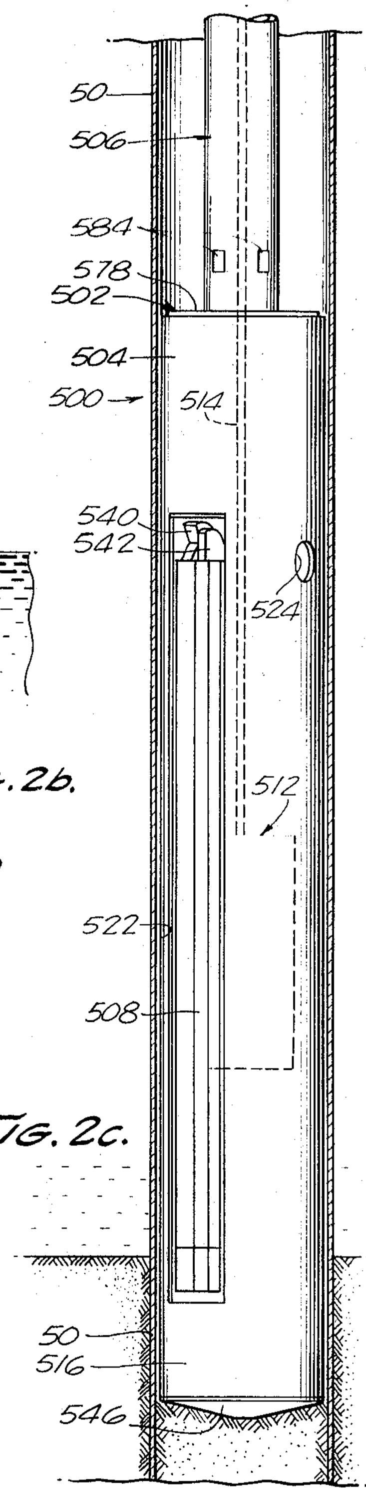

FIG. 2c.

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FIG. 3a.

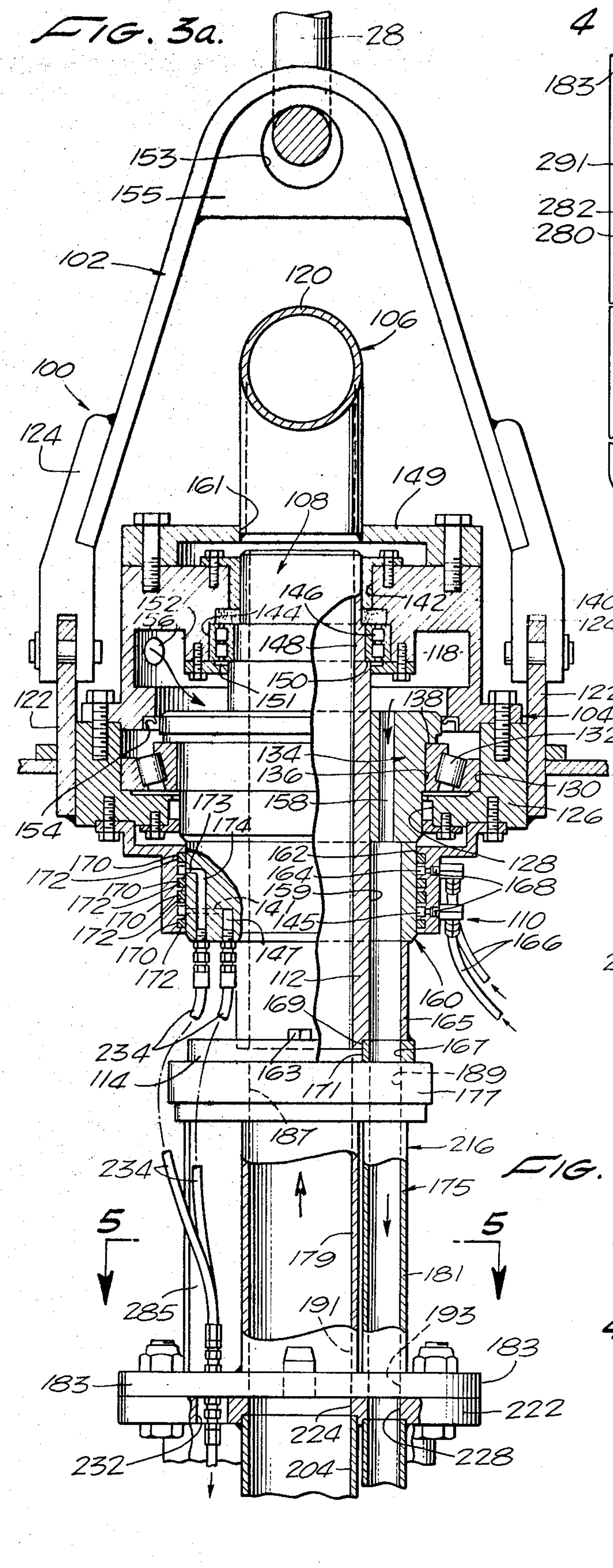
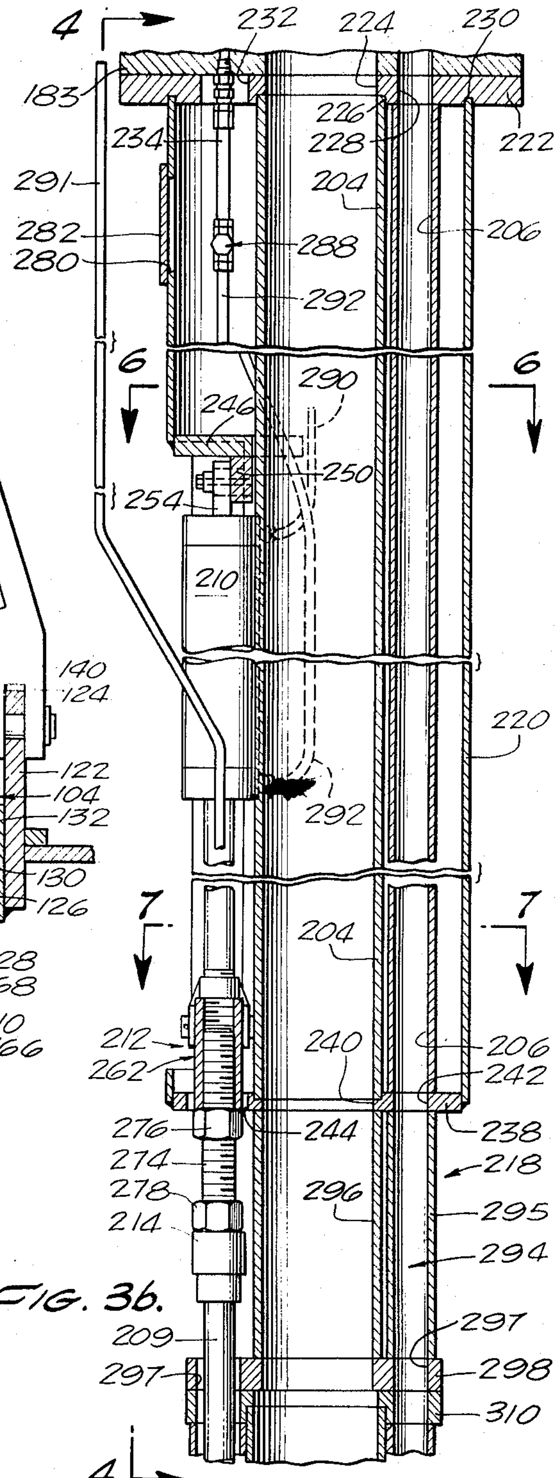


FIG. 3b.



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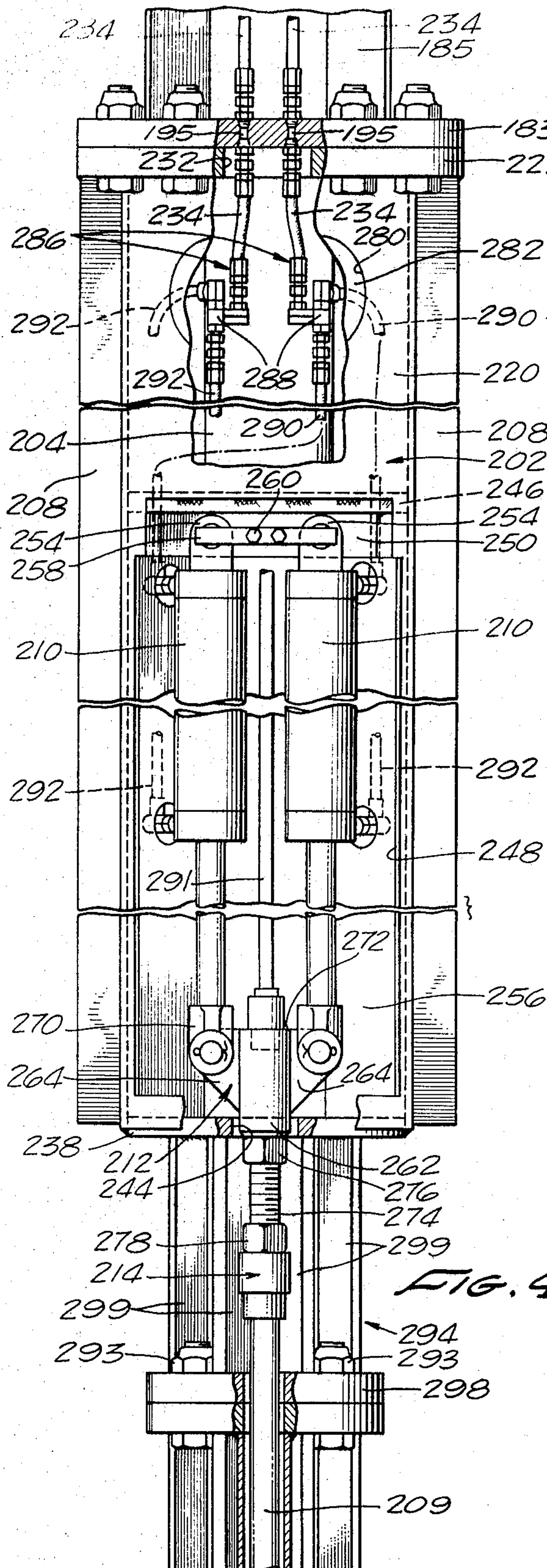

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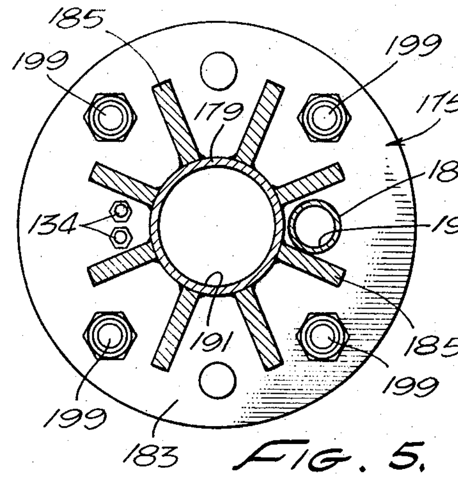

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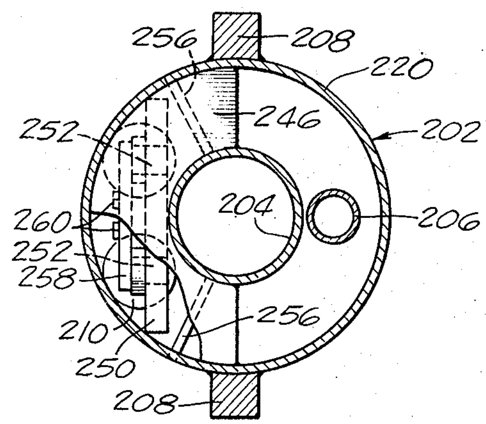

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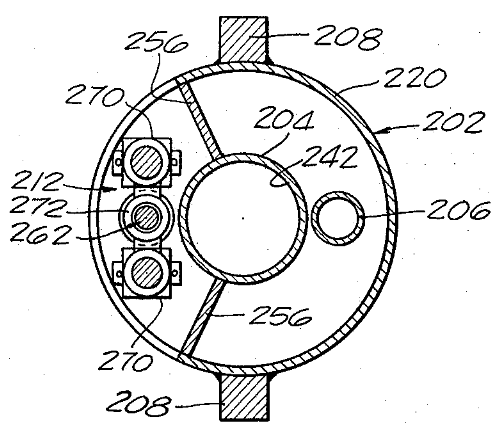

FIG. 7.

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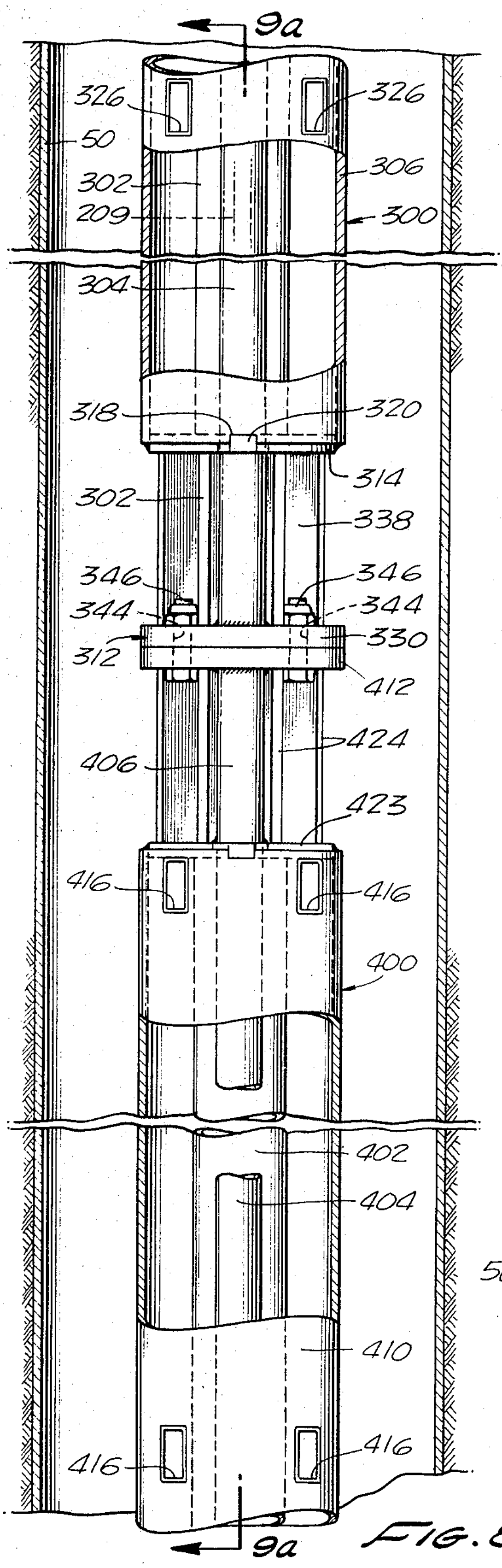

FIG. 8a.

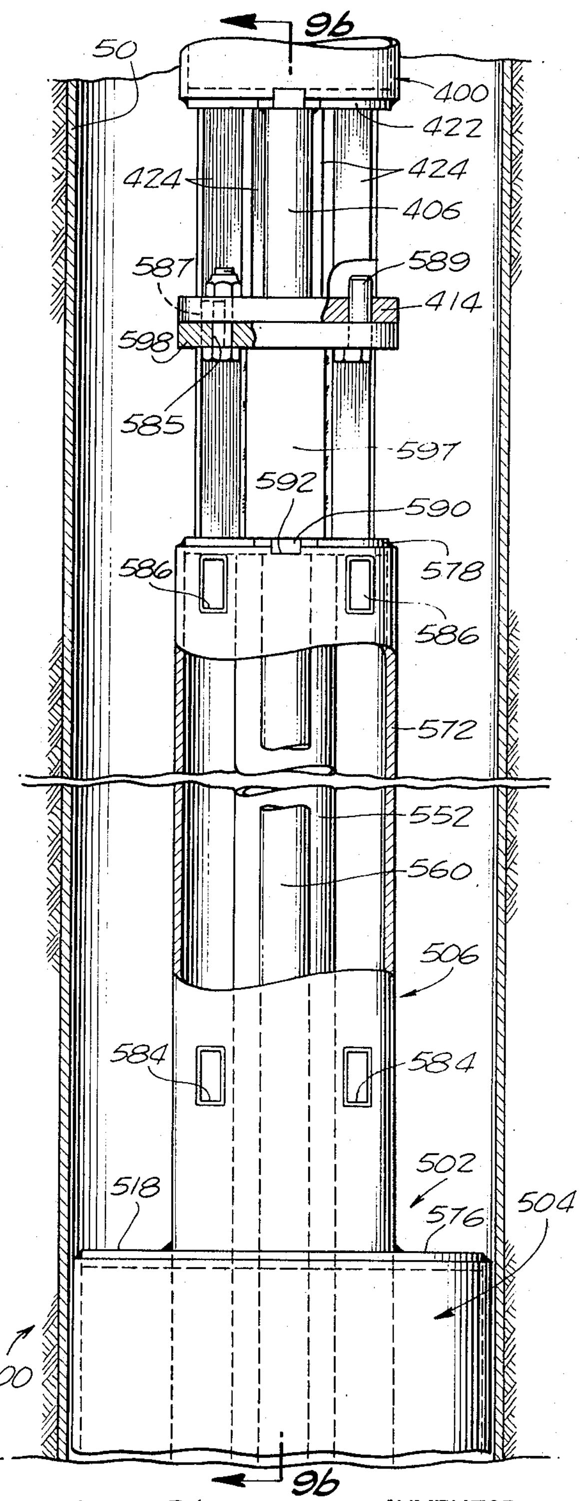

FIG. 8b.

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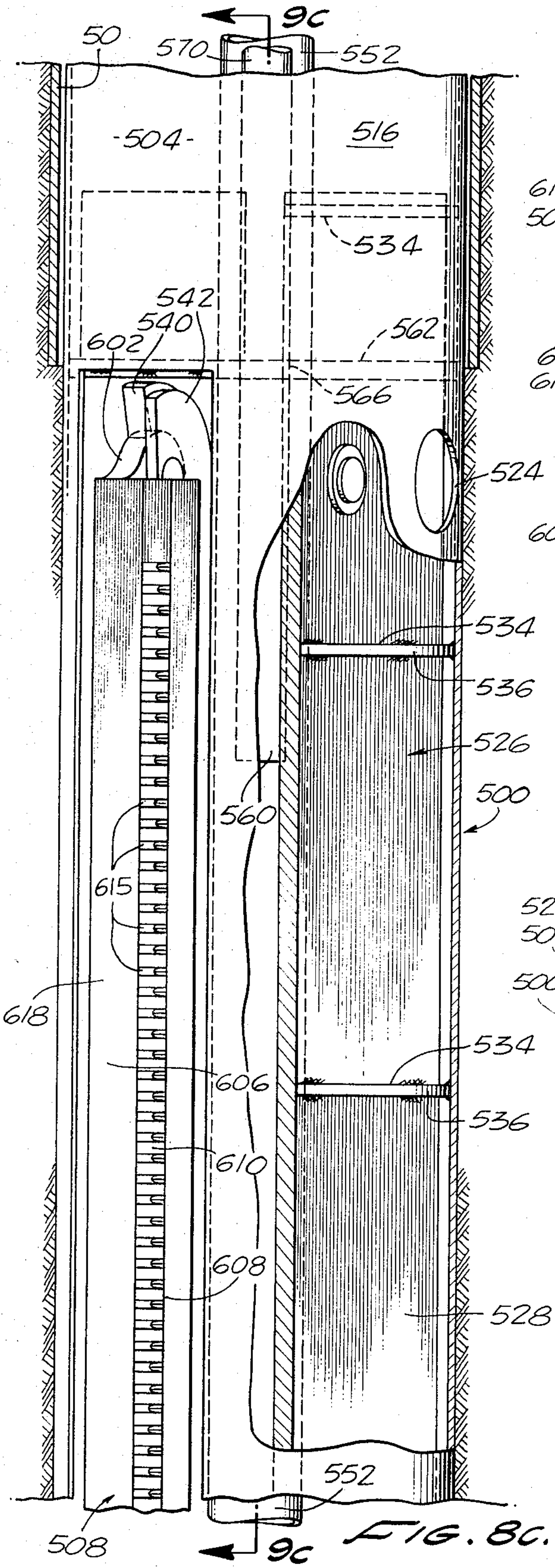

FIG. 8c.

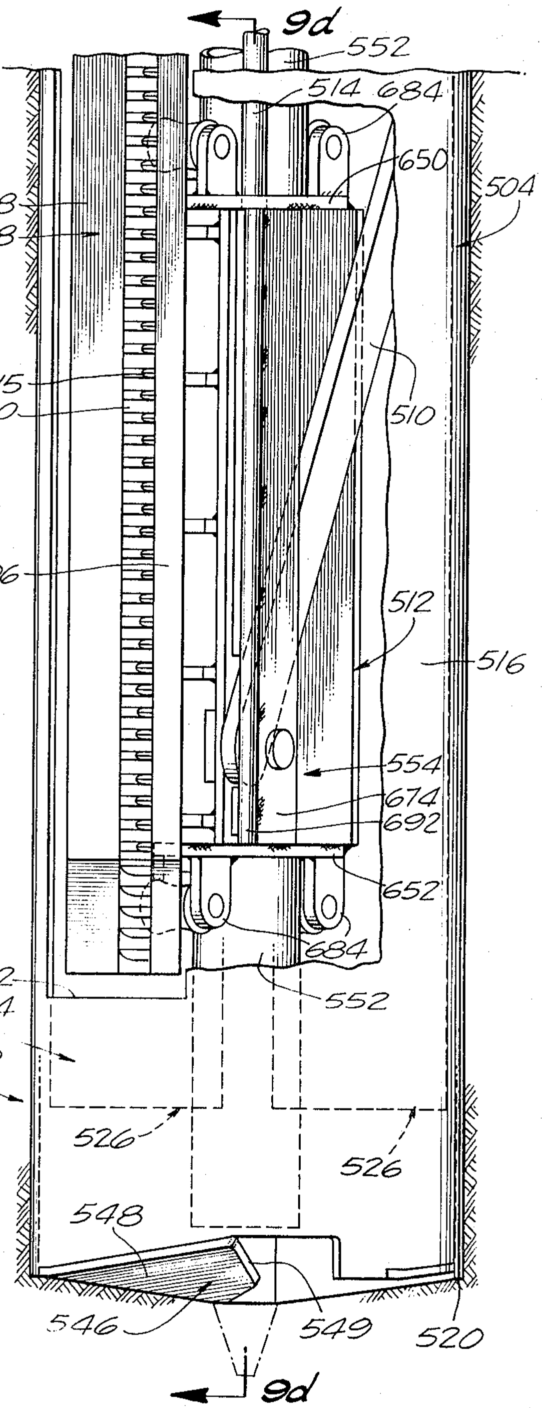

FIG. 8d.

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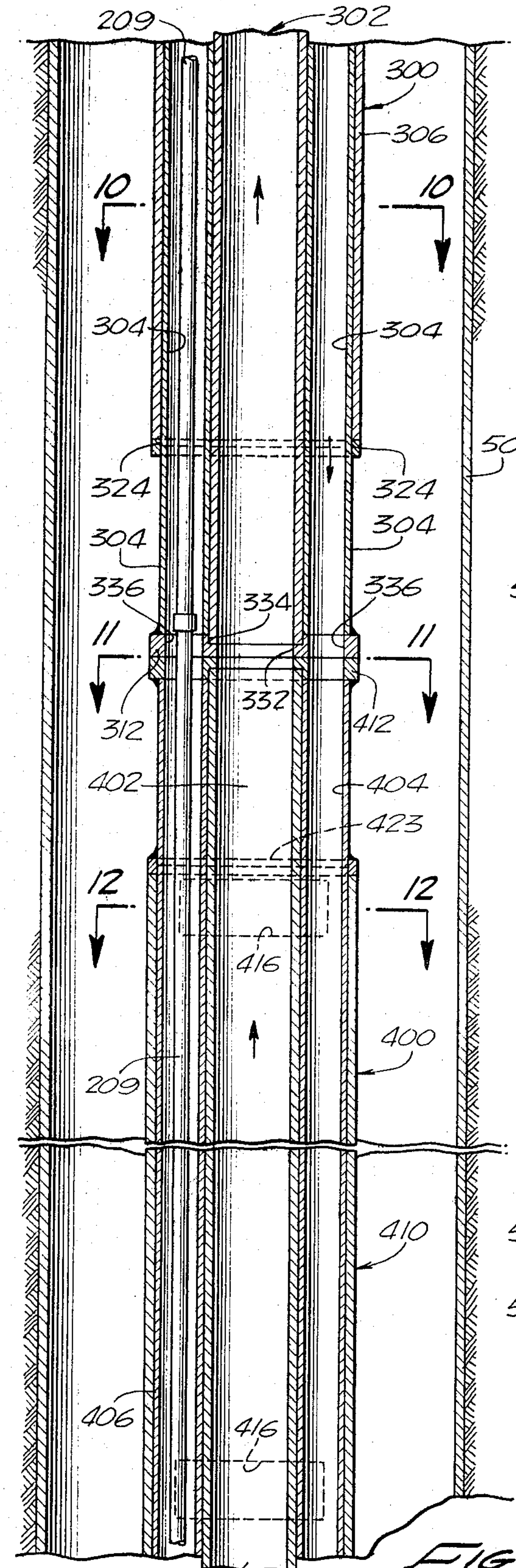

FIG. 9a.

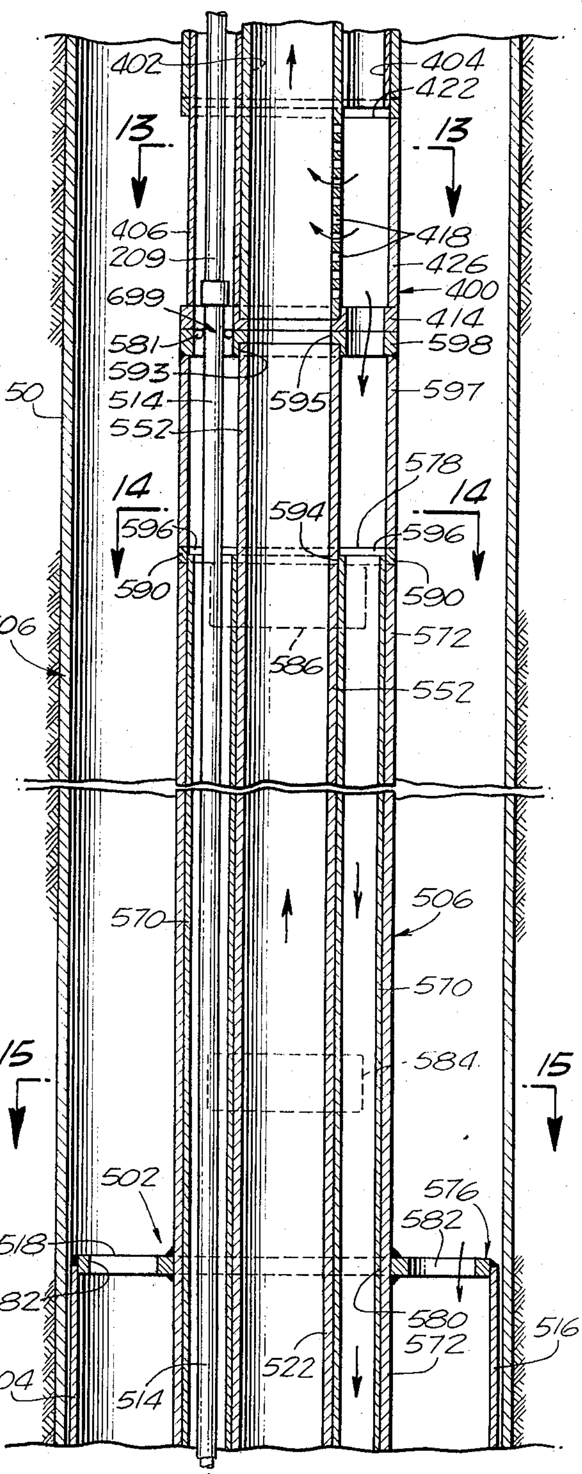

FIG. 9b.

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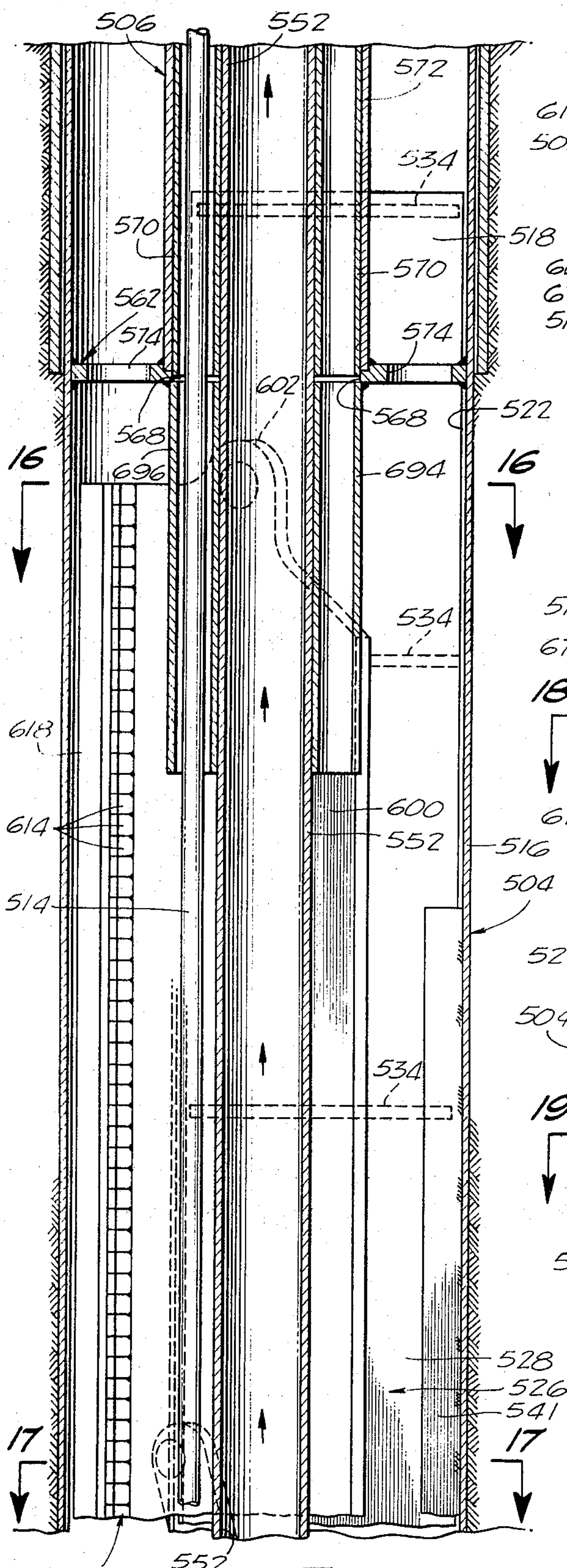

FIG. 9c

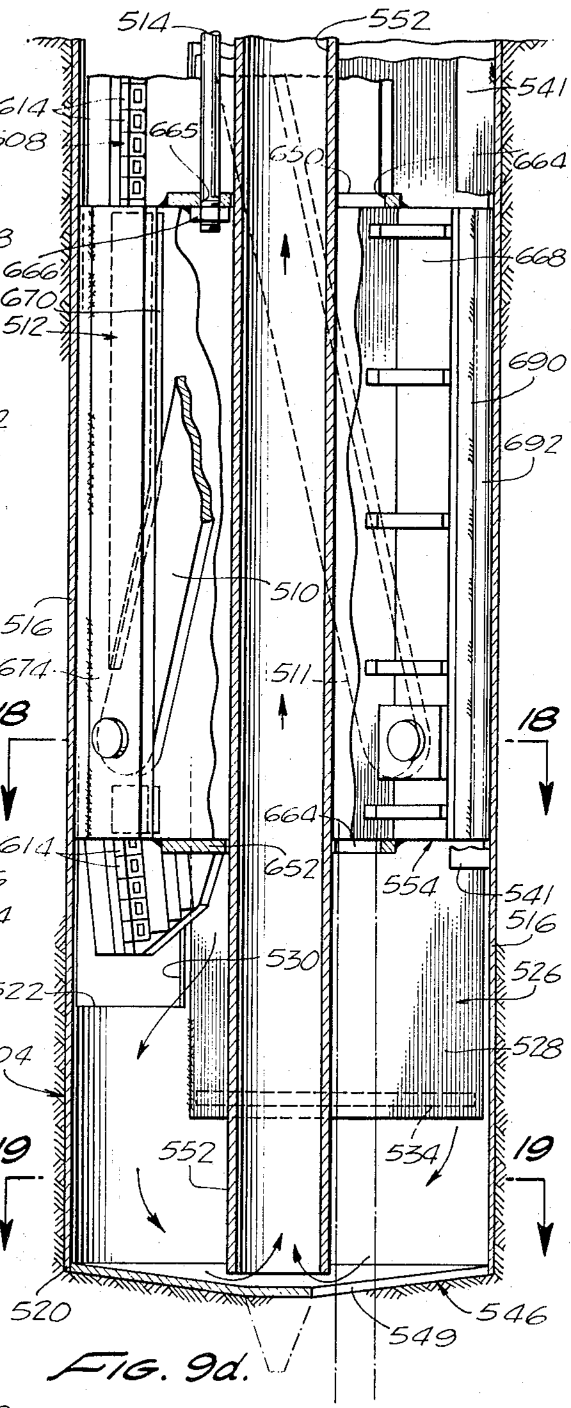

FIG. 9d.

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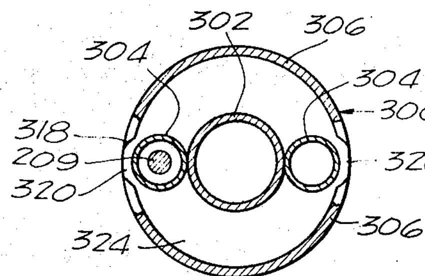

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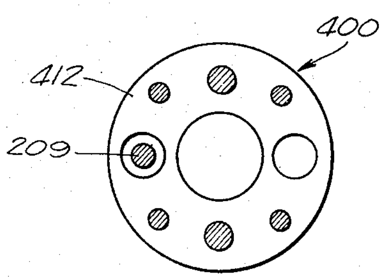

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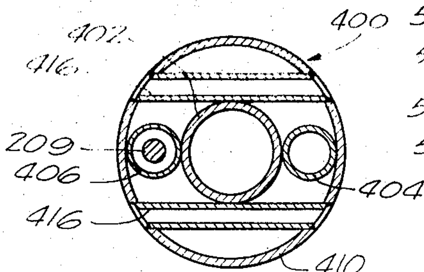

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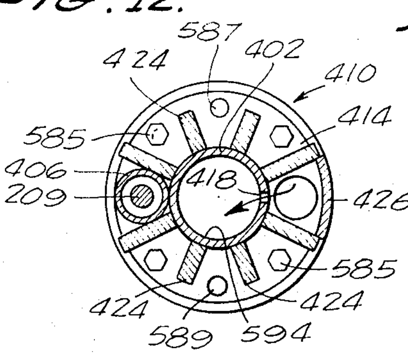

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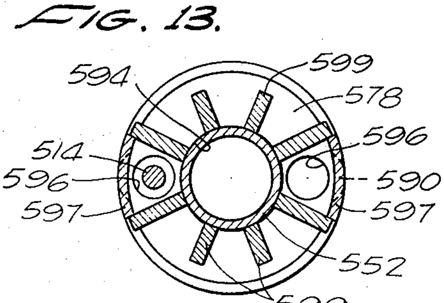
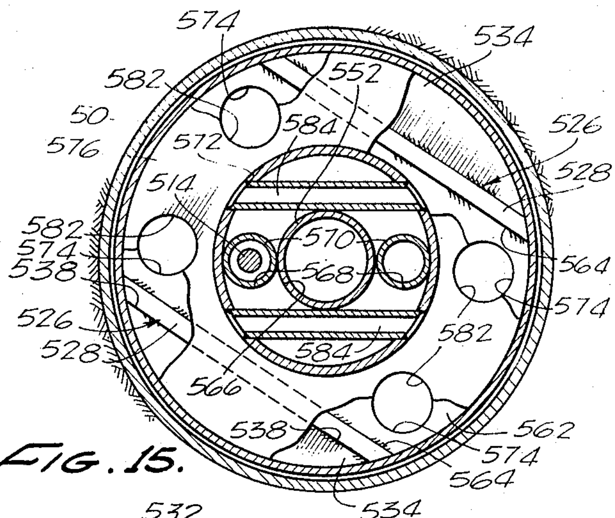


FIG. 14



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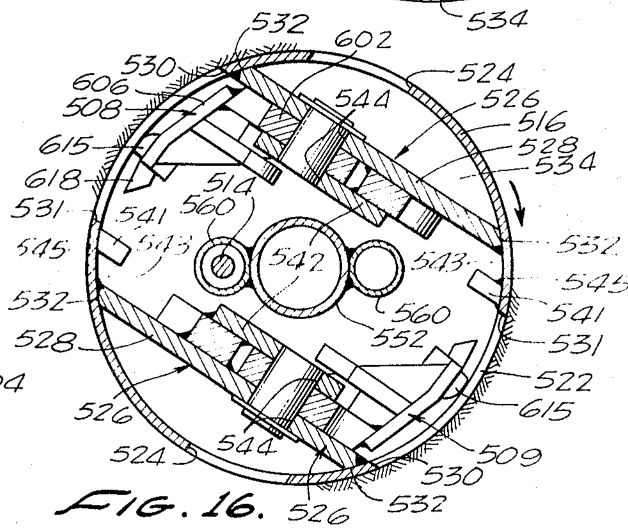

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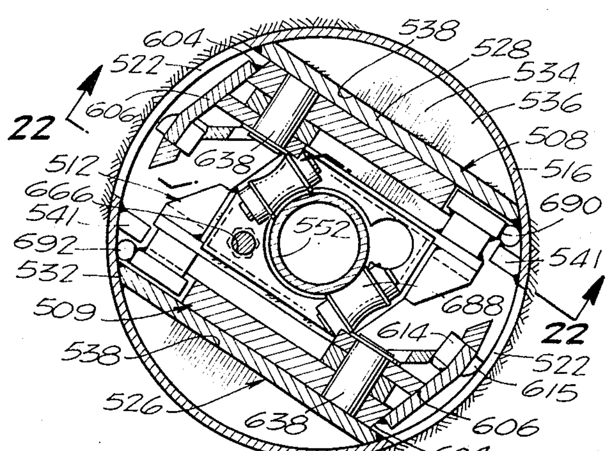

FIG. 17.

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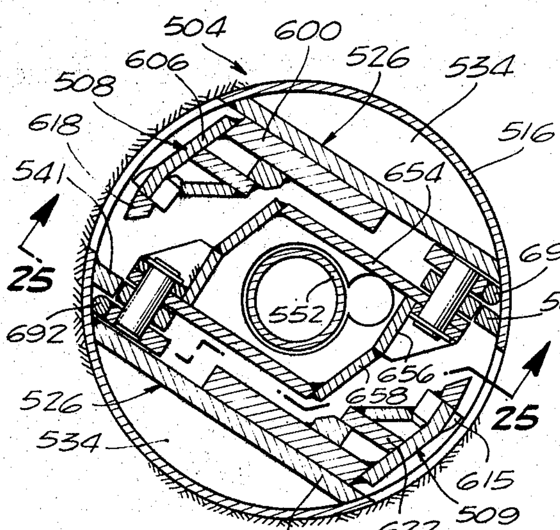

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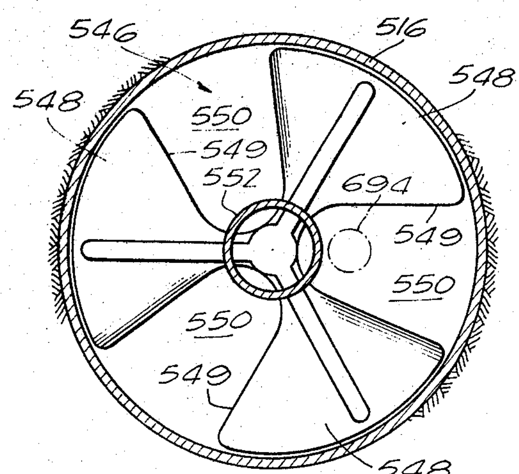

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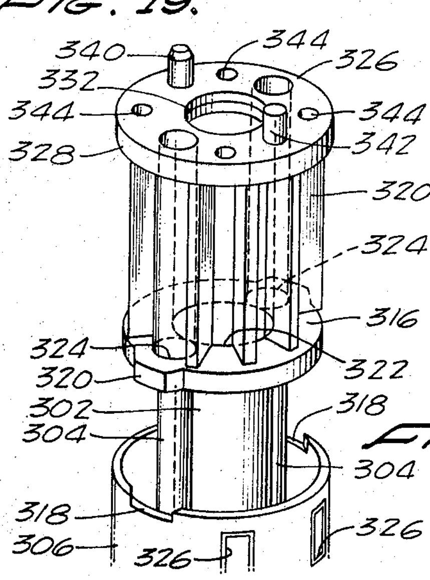

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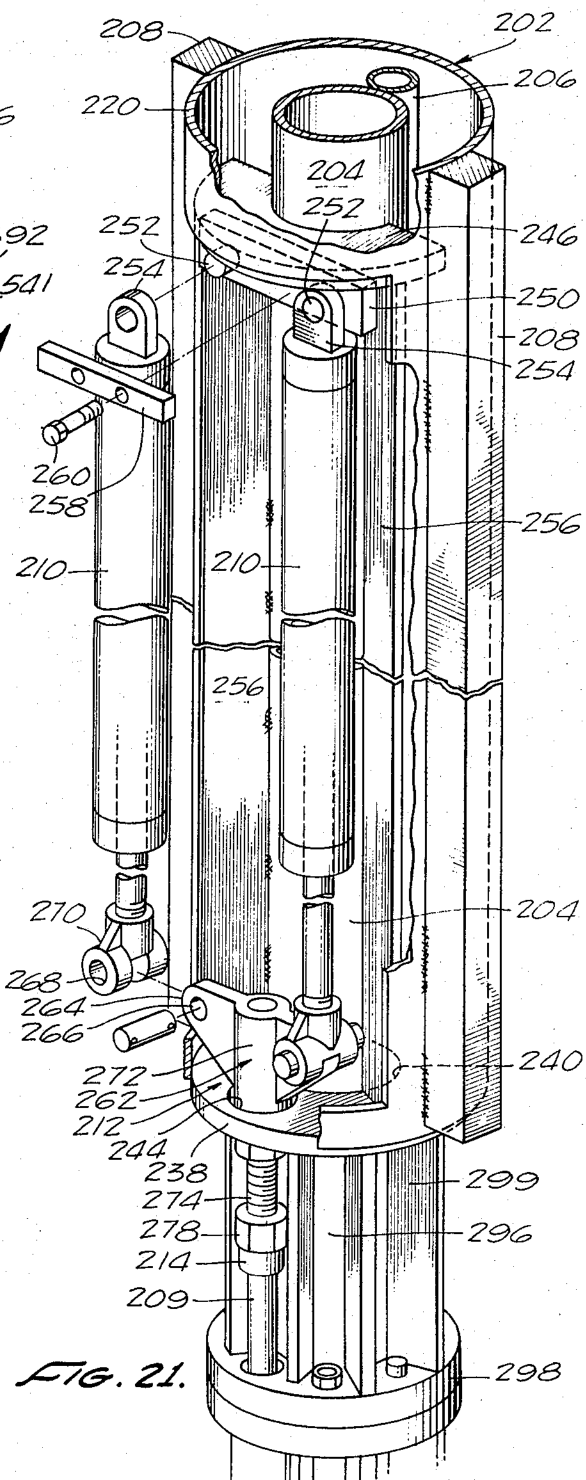

FIG. 21.

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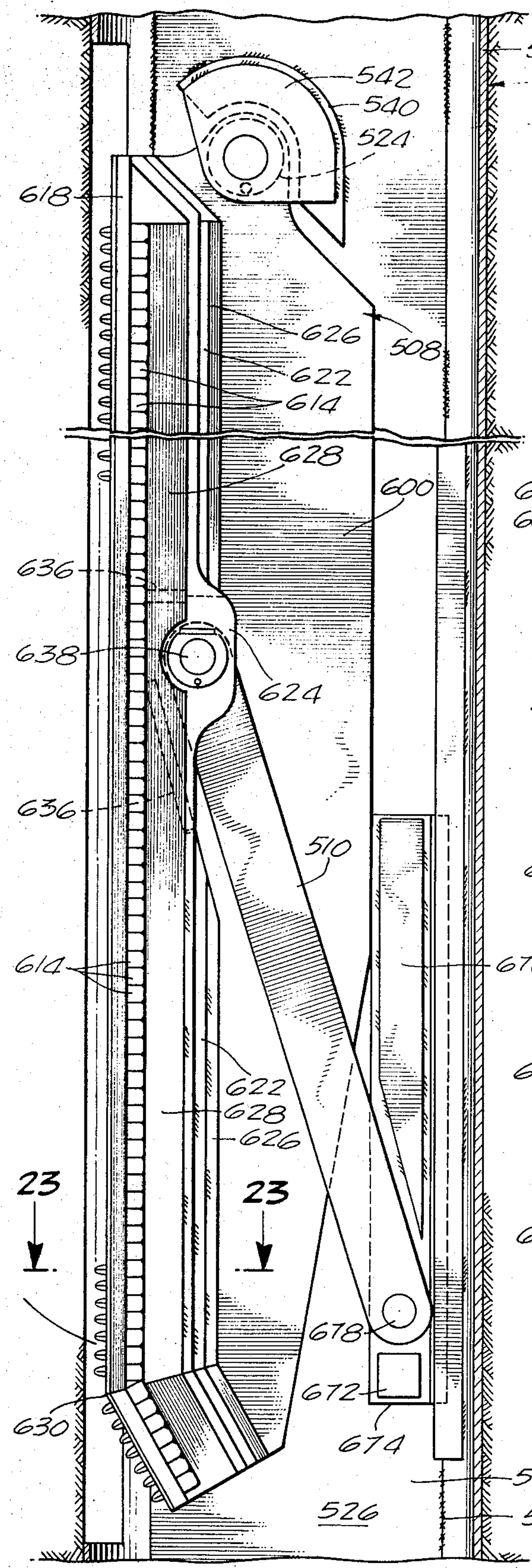

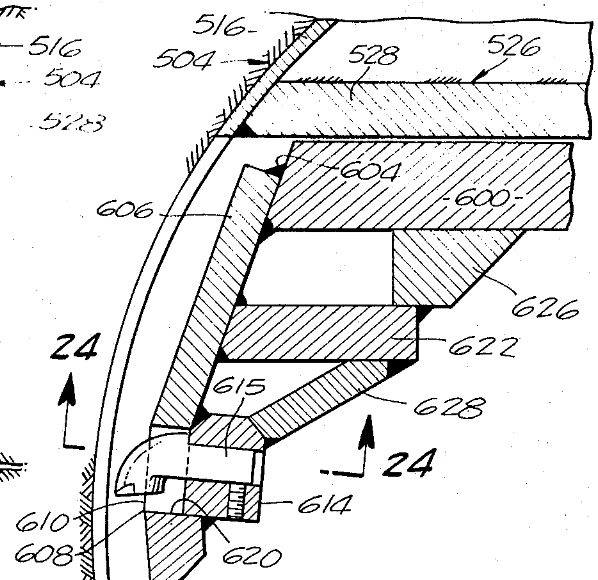

FIG. 23.

FIG. 22.

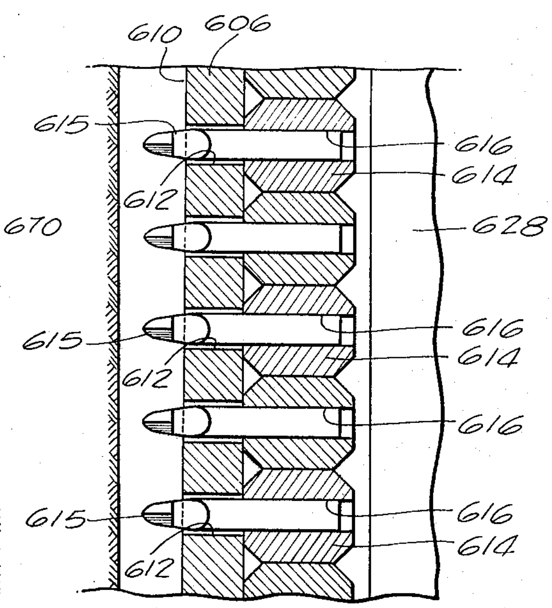

FIG. 24.

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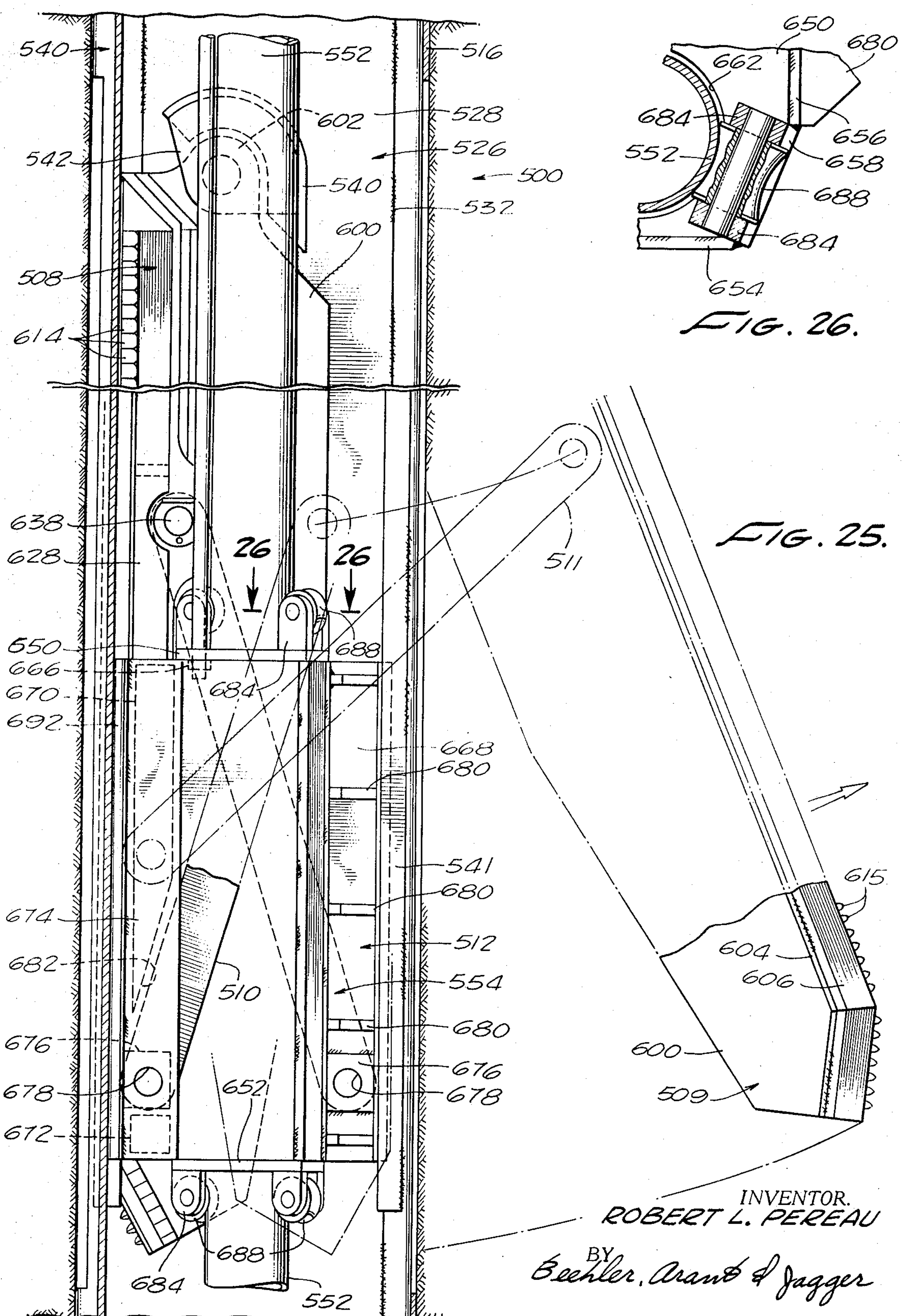

FIG. 26.

FIG. 25.

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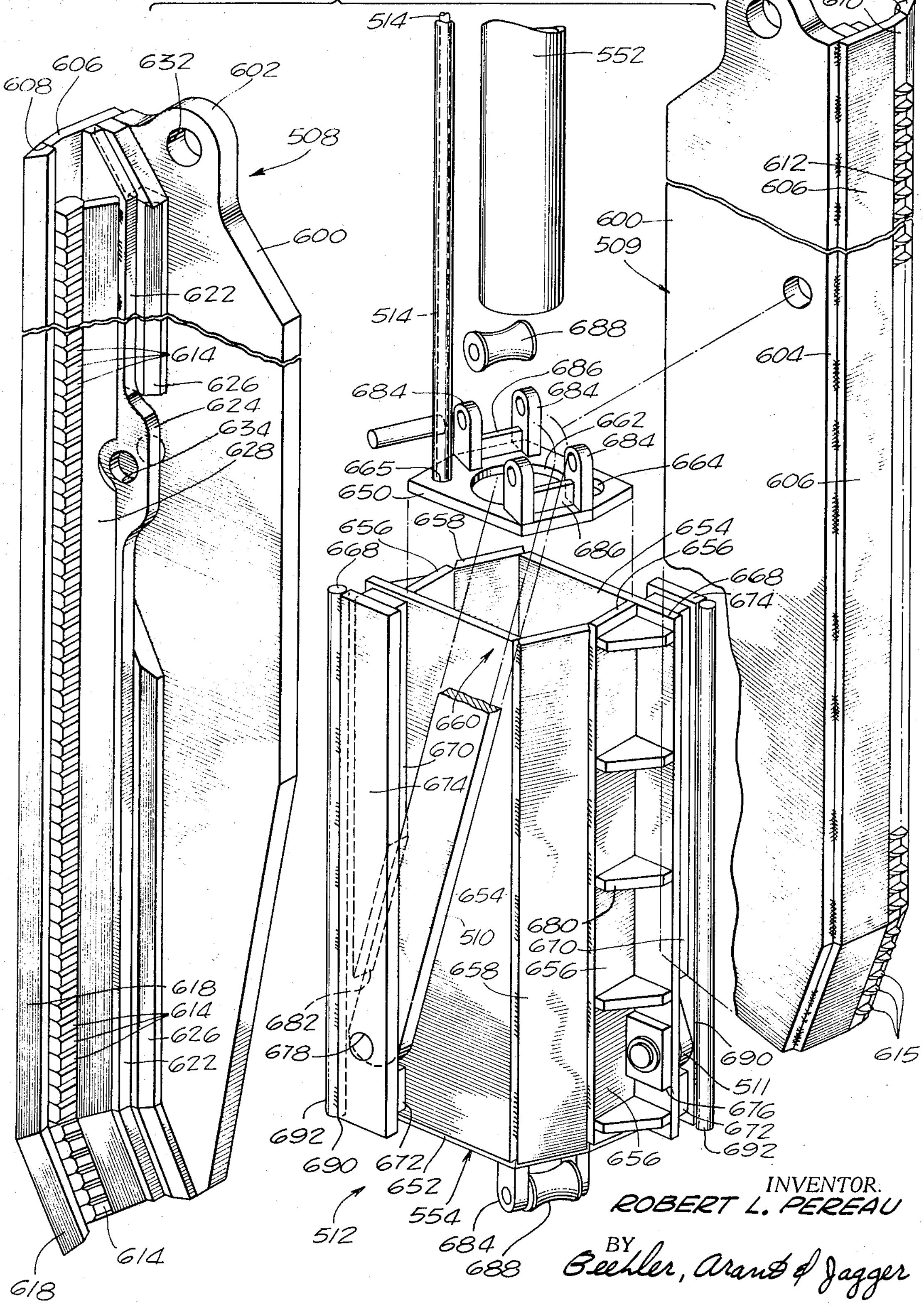
FIG. 27.



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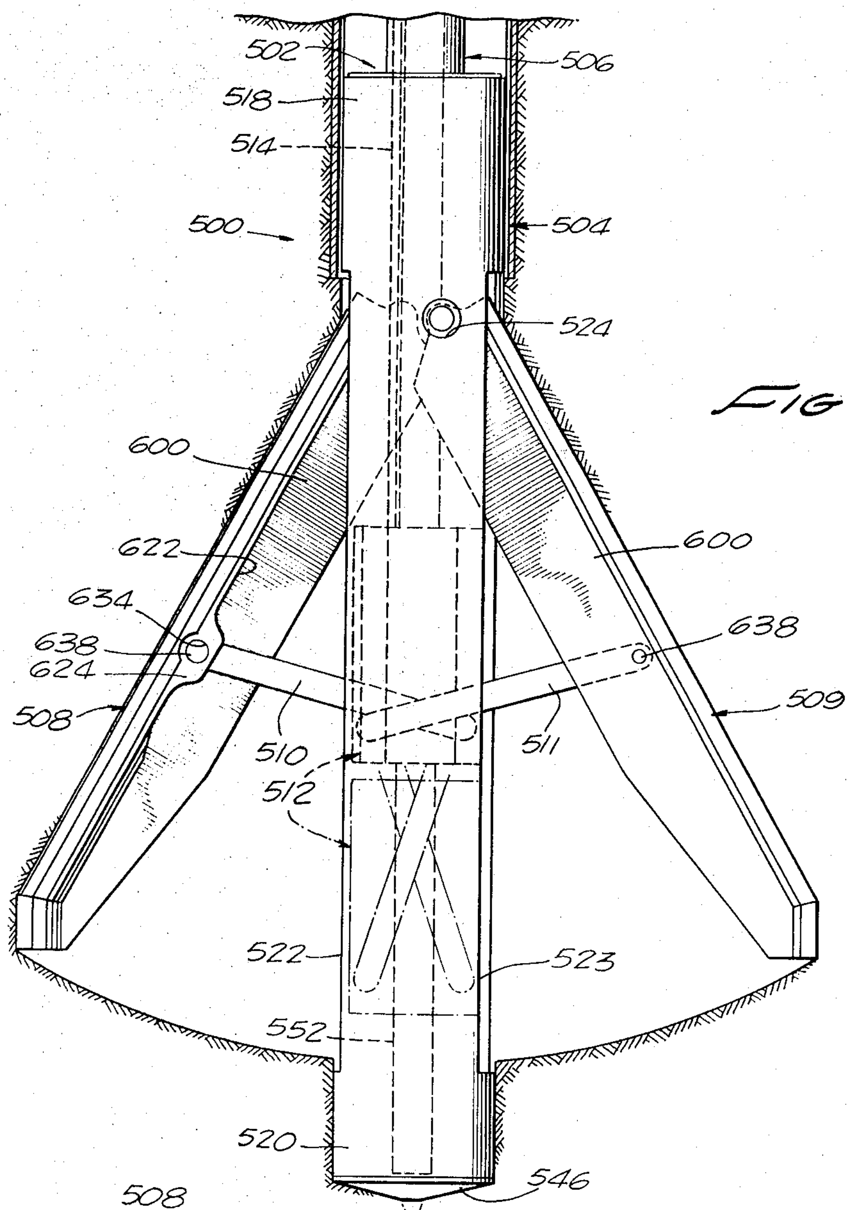

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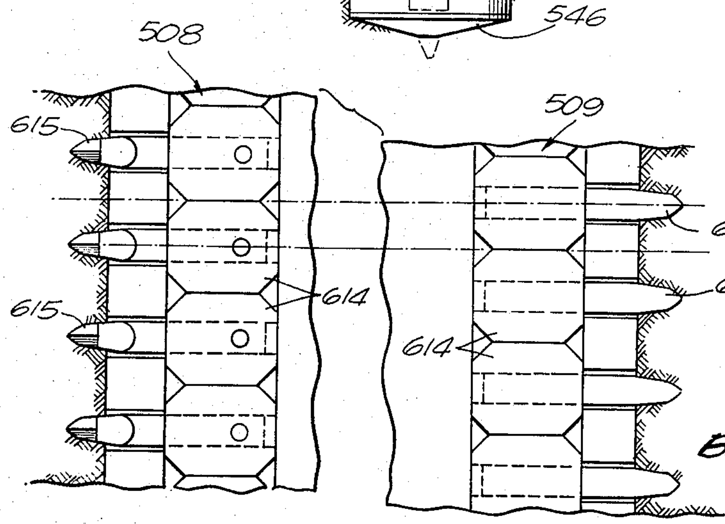

FIG. 29.

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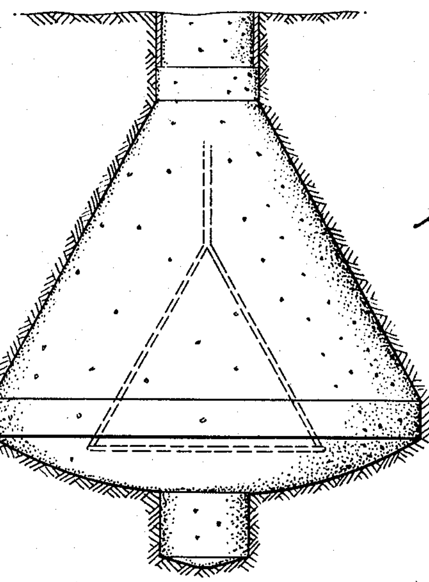
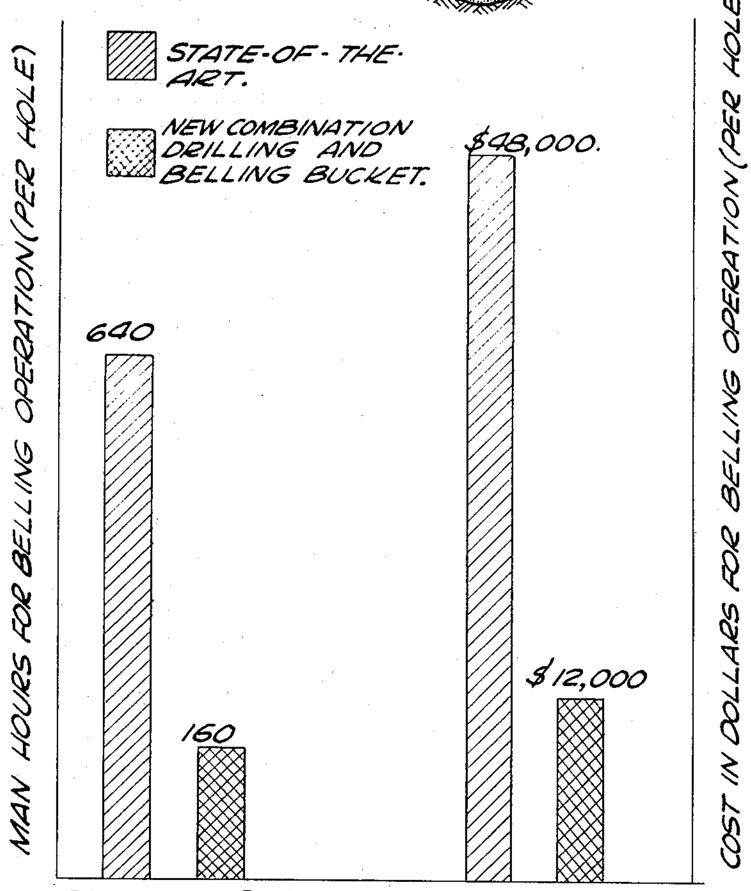


FIG. 30.



ECONOMIC SIGNIFICANCE OF THE COMBINATION DRILLING AND BELLING BUCKET.

FIG. 31.

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DRILLING AND BELLING APPARATUS

BACKGROUND OF THE INVENTION

In construction work it is often the practice to construct a footing or foundation member whose lower end portion is enlarged. Such footings are commonly constructed of reinforced concrete in which the steel reinforcing material provides the tensile strength which would otherwise be lacking. Enlargement of the lower end of the footing not only adds to the weight and hence the stability of the footing, but also provides a positive restraint against any upward pull on the footing.

One particular application of the present invention is in construction of ocean platforms to be used for oil prospecting or drilling operations. The ocean platform may be subjected to very strong ocean waves which place severe stresses on the platform legs in both horizontal and vertically upward directions. Furthermore, the work of constructing such a platform must be performed under conditions which are rather adverse, hence there is a high premium on efficiency in the initial performance of the construction work.

The art of drilling holes for reinforced footings, whether on land or under the ocean floor, has hitherto been well known. It has also been well known, after the initial hole has been drilled, to bell out or enlarge the lower end of the hole. However, the belling out of the lower end of the hole has always required a separate and distinct operation.

The principal object and purpose of the present invention, therefore, is to provide drilling and belling apparatus which is suitable for drilling a hole and then belling out its lower end, all in a single pass of the tool down the hole.

A more specific object of the invention is to provide such an apparatus which is suitable for use in constructing an ocean platform.

DRAWING SUMMARY

FIG. **1** is an elevational view of footings supporting a temporary ocean platform, in a typical ocean platform construction job where the apparatus of the present invention may be used;

FIGS. **2***a*, **2***b* and **2***c* together are an elevation view of the apparatus of the present invention, shown in use in the center of FIG. **1** for constructing a footing;

FIGS. **3***a* and **3***b* together show an elevational cross-sectional view of the swivel assembly and kelly bar assembly, taken on the line **3—3** of FIG. **2**;

FIG. **4** is an elevational view of the kelly bar assembly taken on the line **4—4** of FIG. **3**;

FIG. **5** is a transverse cross-sectional view taken on the line **5—5** of FIG. **3***a;*

FIG. **6** is a transverse cross-sectional view taken on the line **6—6** of FIG. **3**b;

FIG. **7** is a transverse cross-sectional view taken on the line **7—7** of FIG. **3**b;

FIGS. **8***a*, **8***b*, **8***c* and **8***d* together are an elevational view, partially in cross-section, of the drill stem assembly and combination drilling and belling tool;

FIGS. **9***a*, **9***b*, **9***c* and **9***d* together are a vertical cross-sectional view of the drill stem assembly and combination drilling and belling tool taken on the lines **9—9** of FIG. **8**;

FIG. **10** is a transverse cross-sectional view taken on the line **10—10** of FIG. **9***a;*

FIG. **11** is a transverse cross-sectional view taken on the line **11—11** of FIG. **9***a;*

FIG. **12** is a transverse cross-sectional view taken on the line **12—12** of FIG. **9**a;

FIG. **13** is a transverse cross-sectional view taken on the line **13—13** of FIG. **9***b;*

FIG. **14** is a transverse cross-sectional view taken on the line **14—14** of FIG. **9***b;*

FIG. **15** is a transverse cross-sectional view taken on the line **15—15** of FIG. **9***b;*

FIG. **16** is a transverse cross-sectional view taken on the line **16—16** of FIG. **9***c;*

FIG. **17** is a transverse cross-sectional view taken on the line **17—17** of FIG. **9***c;*

FIG. **18** is a transverse cross-sectional view taken on the line **18—18** of FIG. **9***d;*

FIG. **19** is a transverse cross-sectional view taken on the line **19—19** of FIG. **9***d;*

FIG. **20** is an exploded perspective view of the tubular casing of FIG. **8***a* showing above the casing a section of drill stem which is adapted for reverse circulation with air lift;

FIG. **21** is a perspective view, partially in cross-section, of the kelly bar assembly of FIGS. **2***a*, **3***b* and **4**;

FIG. **22** is an elevational cross-sectional view of the drilling and belling tool taken on the line **22—22** of FIG. **17**;

FIG. **23** is an enlarged fragmentary cross-sectional view of one of the belling blades taken on the line **23—23** of FIG. **22**;

FIG. **24** is an enlarged fragmentary cross-sectional view taken on the line **24—24** of FIG. **23**;

FIG. **25** is an elevational cross-sectional view taken on the line **25—25** of FIG. **18**;

FIG. **26** is an enlarged fragmentary cross-sectional view taken on the line **26—26** of FIG. **25**;

FIG. **27** is an exploded perspective view of the belling blade and carriage portions of the combined drilling and belling tool;

FIG. **28** is an elevational view of the combined drilling and belling tool showing the belling blades in their extended position;

FIG. **29** is an enlarged detail view showing the tooth locations for the belling blades;

FIG. **30** is an elevational view of the enlarged lower end of a completed footing; and

FIG. **31** is a chart showing the estimated savings achieved by use of the present invention.

PREFERRED EMBODIMENT

General Description

The combination drilling and belling tool assembly, FIGS. **2***a*, **2***b*, and **2***c*, consists of a combination drilling and belling bucket **500**, the necessary sections of reverse circulation drill stem with airlift **300**, a section of reverse circulation drill stem with air injection **400**, the necessary number of stabilizers **375**, a kelly bar assembly **200**, and a swivel **100**.

Referring to FIG. **1**, in order to make the tool operational it is also necessary to have compressed air and hydraulic fluid supplies (not shown), a settling tank **14** into which the drilling fluid **22** and drilling chips may be discharged, a return hose **16** for returning the drilling fluid to the drill hole, a tower **18** and block and tackle **24** to support the drill string during the drilling operation, a winch **26** to control the block and tackle, and a ring gear drive or rotary table **20** which engages the kelly bar **200**, and provides the rotary driving force to the drill stem assembly.

Referring to FIGS. 2*a*, 2*b*, 2*c*, and 3*a*, attached to the top of the kelly bar and drill stem assembly is a reverse circulation swivel **100** consisting of a bail **102**, a swivel body **104**, an elbow **106** attached to the top of the swivel body, a spindle **108**, and a hydraulic swivel housing **110**. The bail is provided with a means for pivotally attaching a block and tackle hook **28** at its top and is further provided with a means for the pivotal attachment of the swivel body **104** to its lower end. The spindle is centrally disposed within the swivel body and has a spindle center pipe **112** with a swivel flange plate **114** attached to its lower end. The swivel body is provided with a sealed cavity **118** surrounding the center pipe of the spindle and connected in a continuous manner to an auxiliary conduit **158** in the spindle. In addition, the purpose of the swivel is to provide the vertical support necessary to support the drilling tool while still allowing the spindle to freely rotate within the swivel body. The elbow **106** attached to the top of the swivel body has an elbow-shaped pipe **120** which acts as a discharge nozzle for the drilling fluid and drilling chips. It should be noted that the vertical displacement of the entire drill string is controlled by the vertical displacement of the swivel. The vertical displacement of the swivel is generally controlled by the attachment of a block and tackle **24** between the top of the drilling tower **18** and the top of the swivel bail **102**.

Attached between the top of the drill stem assembly and the swivel is a kelly bar assembly **200**. The kelly bar assembly has an elongated tubular frame **202**, a center pipe section **204** and an air auxiliary pipe section **206** (FIG. 3*b*), disposed within the tubular frame, two elongated ribs **208** attached to the outer circumference of the tubular frame, two hydraulic cylinders **210** disposed within the frame, a bracket **212** for coupling the action of the two hydraulic cylinders together, a sucker rod swivel **214** for attachment of the drill stem sucker rod **209** to the hydraulic cylinder bracket **212**, and top and bottom adapters **216** and **218** at the top and bottom ends of the kelly bar for attaching the kelly bar assembly **200** between the top of the drill stem assembly and the swivel **100**.

The function of the kelly bar assembly **200** is to provide a means for coupling the drill stem assembly to the rotary table **20**. This coupling is provided by the elongated ribs **208** on the outside of the kelly bar frame. The kelly bar is free to slide up and down through the rotary table while recesses within the rotary table ring gear engage with the ribs on the outside surface of the kelly bar assembly. Hence, the power drive provided by the rotary table is transmitted to the kelly bar which in turn transmits the rotary action to the drill stem assembly. The two hydraulic cylinders **210** disposed within the kelly bar frame are coupled at their upper or cylinder ends to the frame structure while the lower or piston ends of the cylinders are coupled to the bracket **212**, which in turn is coupled to the sucker rod swivel **214**. This sucker rod swivel provides connection to the previously mentioned sucker rod **209** which extends up through the drill stem. Hence, by activating the hydraulic cylinders the sucker rod is displaced in a vertical direction relative to the kelly bar and drill stem assemblies.

Attached to the bottom end of the kelly bar assembly is a section of reverse circulation drill stem with airlift **300**. It is seen that this section of drill stem consists of a center pipe section **302**, two auxiliary pipe sections **304** (FIG. 9*a*), a tubular casing **306**, four transverse openings **308** through the casing, and attachment or drill stem flange plates **310** and **312** at the upper and lower ends of the drill stem section. The center pipe section and auxiliary pipe sections are so oriented that they align with the center pipe section, the auxiliary air pipe section and the sucker rod swivel of the kelly bar assembly.

At least one section of reverse circulation drill stem with air injection **400** is used in the drill string. This section of drill stem is nearly identical to the previously described section of reverse circulation drill stem with airlift **300**. Its main components are a center pipe section **402**, two auixiliary pipes **404** and **406** (FIGS. 9*a* and (*b*), a tubular casing **410**, attachment or drill stem flange plates **412** and **414** at its upper and lower ends, and four transverse openings **416** through the casing. As with the previously described section of drill stem, one of the auxiliary pipes **406** shown in FIG. 9b may be used to house a section of sucker rod **209**. This auxiliary pipe is identified as the sucker rod auxiliary pipe. The essential difference between this section of drill stem and the previously described section of drill stem is revealed by examining the function of the other auxiliary pipe **404**. At the lower end of the drill stem section is seen a series of drilled holes **418** interconnecting the auxiliary pipe **404** and the center pipe **402** of the drill stem. Hence, as air pressure is applied to this auxiliary pipe it will necessarily flow through these holes into the center pipe. This is known in the art as an air injection process.

Attached at regular intervals along the drill string are stabilizers **375**. The stabilizer is a commercially available item and basically consists of a spindle **377** and an outer housing or body assembly **379**. The body assembly may be provided with a series of elongated roller bearings such that the body assembly is freely rotatable relative to the spindle. The outside diameter of the body assembly is made to match the diameter of the drill casing **50** and the inside diameter of the spindle is made to be firmly attached to the drill stem. Hence, when the stabilizer is firmly attached to the drill stem it acts to center the drill stem within the drill casing. The provision of the elongated roller bearings acting between the spindle and the stabilizer housing allows the drill stem to freely turn within the stabilizer housing while the stabilizer housing is riding against the drill casing.

The attached sections of drill stem assembly. Attached to the bottom of the drill stem assembly is the combination drilling and belling bucket **500**. The combination drilling and belling bucket **500** consists of an elongated generally cylindrical bucket frame **502**, two belling blades **508** and **509** (FIG. **28**), two actuating arms **510** and **511**, a carriage assembly **512**, and an elongated member **514** attached to the carriage assembly. The bucket frame is seen to consist of an outer shell assembly **504** which is provided with recesses, i.e., rectangular cutouts **522** and **523**, for receiving the belling blades. At the bottom of the outer shell assembly is attached a drilling bucket bottom **546**. This bucket bottom is a standard drilling bucket bottom and is provided with drilling blades for cutting and removing the soil from within the drill casing **50** as the bucket is rotated in a clockwise direction. The bucket frame outer shell assembly is provided with means for pivotally attaching the belling blades. These pivotal attachments are so oriented that the blades are positioned within the recesses provided in the outer shell of the frame. The remaining portion of the frame structure is provided by the drill stem assembly **506** which is centrally disposed within the outer shell assembly and is rigidly attached to its upper end. This drill stem assembly has a center pipe **552** which extends to the bottom of the bucket. Disposed between the bucket frame and the center pipe is the carriage assembly **512.** The carriage assembly may be vertically displaced relative to the bucket frame. Extending between the carriage frame and each belling blade are two actuating arms **510, 511.** One end of each of the actuating arms is pivotally attached to the lower end of the carriage frame. The other end of each of the actuating arms is pivotally attached to its respective belling bucket blade **508** or **509** near the blade longitudinal midpoint. As previously noted, the belling blade is pivotally attached at its upper end to the bucket frame and is so oriented that the lower end of the belling blade is free to swing into and out of the recess provided in the outer shell of the bucket frame. Attached to the upper end of the carriage assembly is an elongated member **514.** This elongated member passes through the bucket drill stem assembly **506** and terminates at the upper end of the bucket drill stem.

From the foregoing description it will be apparent that the operation of the belling blades is controlled by the selective raising and lowering of the carriage assembly. Referring to FIG. **28,** the selective raising and lowering of the carriage assembly **512** is accomplished by selectively raising and lowering the elongated member **514.** As the carriage assembly is raised, the ends of the actuating arms **510** attached to the carriage assembly are also raised. Because the actuating arm is a rigid member, the structure attached to its other end, that is, the belling blades **508** and **509,** must act to accommodate the upward movement of the actuating arm. The only way in which the blade can do this is by rotating about the pivotal attachment at its upper end. Hence, as the carriage assembly is raised the belling blade lower end is moved through an arcuate path away from the bucket frame. As the carriage assembly is lowered the blades are retracted into the recesses within the bucket frame.

In operation, the primary advantage of this tool is that with a single pass a drill hole of the desired diameter may be drilled to any desired depth and then without removing the tool a conical cavity may be cut at the lower end of the drill hole. Briefly the procedure for doing this is to drill down the desired depth by concurrently rotating and lowering the drill stem. It is necessary to add sections of the reverse circulation drill stem with airlift **300** as the drill string **15** lowered, and at selected intervals to also add the stabilizers **375.** During the drilling process, drilling chip removal is accomplished by the reverse circulation process. In this process pressurized air is connected to the swivel **100.** Referring to FIGS. **3***b*, **9***a*, and **9***b*, this air pressure is supplied through the swivel to kelly bar air auxiliary pipe section **206** and hence to one of the drill stem auxiliary pipes **304.** Upon reaching the reverse circulation drill stem with air injection **400,** the air is then injected into the center pipe of the drill stem, through the series of drilled holes **418.** The air then bubbles up through the center pipes **402** and **302** of the drill stem and kelly bar center pipe **204** into the swivel **100,** FIG. **3,** and through the elbow discharge nozzle **120** to the settling tank **14,** FIG. **1.** This air flow creates lift in the center pipe which in turn lifts the drilling fluid from the bottom of the drilling bucket **500** and carries with it the drilling chips as they are cut from the bottom of the drill hole. In this manner, the drilling fluid is carried up through the center pipes of the drill stem and kelly bar to the swivel center pipe and through the discharge nozzle to the settling tank. Drilling fluid is then returned to the drill hole after the drilling chips have settled out. In this manner a reverse circulation is set up whereby the fluid flows down the outside of the drill stem assembly to the bottom of the drill hole and then returns through the center of the drill stem assembly to the settling tank carrying with it the drilling chips.

Once the desired depth of the drill hole is reached, the lowering of the drill string is stopped and the rotation is reversed to the counterclockwise direction. The hydraulic cylinders **210** in the kelly bar assembly **200** are then actuated to pull the sucker rod **209** in a vertical direction. Since the sucker rod **209** is attached to the elongated member **514** of the combination drilling and belling bucket **500,** which in turn is attached to the carriage assembly **512,** the vertical displacement of the hydraulic cylinders **210** causes the vertical displacement of the carriage assembly **512** relative to the bucket frame **502.** As has been previously described, this action causes the belling blades **508** and **509** to extend and, since the rotation of the bucket **500** is continued, the belling blades cut a conical cavity at the bottom of the drill hole. During this entire process the air injection procedure is continued, thereby effecting the drilling chip removal in the manner just described. Once the blades have been fully extended, the direction of the hydraulic cylinder travel is reversed causing the sucker rod **209** to reverse the direction of travel of the carriage assembly **512,** thereby causing a reversal in the direction of the blade movement. This is continued until the blades are fully returned into the recesses in the bucket frame **502.** At this point the drill hole is completed, and the entire drill stem assembly and bucket are removed from the drill hole.

SWIVEL ASSEMBLY

Now, the drill string components will be considered in more detail. Attached to the top of and supporting the drill stem and kelly bar assemblies is a reverse circulation swivel **100,** FIG. **3***a*. This swivel has a bail **102** to which is pivotally attached a swivel body **104.** This pivotal attachment is accomplished by pinning two attachment ears **122,** which extend from the swivel body, into the clevises **124** provided on the lower ends of the swivel bail. These attachment ears extend from the swivel body lower housing **126.** This swivel body lower housing has a center opening **128** and a concentric counter bore **130** in its top surface which extends through a substantial portion of a swivel body lower housing thickness. Disposed within this counter bore is a tapered roller bearing **132.** The inside diameter of the tapered roller bearing is approximately the same as the diameter of the center opening in the swivel body lower housing. Disposed within the lower housing and tapered roller bearing is a spindle **108.** This spindle has a center pipe **112** to which is attached a cylindrical collar 134. This collar has a reduced diameter 136 on its lower portion which matches the inside diameter of the tapered roller bearing. The upper portion of the collar forms a shoulder 138 which seats on the upper surface of the tapered roller bearing. Thus, the spindle 108 is supported in its vertical direction by the seating contact provided between the collar shoulder and the tapered bearing but is still allowed to freely rotate because of the free rotation of the tapered bearing.

Attached to the top of the lower housing is a swivel body upper housing 140. This upper housing has a central opening 142 concentric with the center opening 128 in the lower housing 126. Concentric with this center opening, the upper housing is provided with a counter bore 144 which receives a roller bearing 146. As seen, the center pipe of the spindle extends up into the upper housing and is provided with a reduced diameter 148, which matches the inside diameter of the roller bearing 146 and thereby forms a shoulder 150 against which the roller bearing is seated. In addition, the upper housing is provided with an air chamber 152. This air chamber extends circumferentially around the center opening 142 provided in the upper housing and is in continuous contact with the spindle collar 134. The air chamber is sealed by providing air tight seals 154 and 151 which act between the spindle collar and the upper housing and the spindle center pipe and the upper housing. Air is admitted to this air chamber through an air inlet port 156 which is connected to an air compressor.

The air outlet is provided by a bored hole 158 extending through the spindle collar from its top to its bottom surface. This bored hole extending through the spindle collar is in turn aligned with and concentric to a bored hole 159 in a hydraulic coupling collar 160. The hydraulic coupling collar is a cylindrical collar whose inside diameter matches the outside diameter of the center pipe 112 of the swivel spindle 108. The hydraulic coupling collar is attached to the center pipe and is adjacent to the lower surface of the spindle collar 134. As noted, this hydraulic coupling collar has a bored hole 159 extending through its thickness and aligned with and concentric to the bored hole 158 in the spindle collar 134. Thus, a continuous exhaust port is provided which communicates the air chamber 152 with the bottom of the hydraulic coupling collar.

Attached to the bottom surface of the swivel body lower housing 126, is a hydraulic housing 110. This hydraulic housing has a central opening 162 whose diameter matches the outside diameter of the hydraulic coupling collar 160. Two circumferential grooves 164 are provided at different elevations on the inside surface of the center opening of the hydraulic housing. These circumferential grooves are coupled to hydraulic lines 166 through drilled and tapped holes 168 which extend through the wall of the hydraulic housing and intersect the circumferential grooves. In addition, a seal groove 170 is cut on each side of the previously described circumferential grooves 164, 145, thus forming recesses which receive seals 172 which extend around the outside surface of the hydraulic coupling collar 160 thereby providing a fluid tight seal on each side of the circumferential grooves 164 and 145. Oppositely disposed from the bored hole 159 in the hydraulic coupling collar are two drilled holes 174 and 147. As seen, the drilled hole 174 on the left hand side extends to a depth matching that of the top circumferential groove 164 containing hydraulic fluid. The coupling between this drilled hole and the circumferential groove is achieved by a second drilled hole 173 which is at right angles to the first drilled hole 174 and extends through the wall of the hydraulic collar and intersects the circumferential groove 164 containing the hydraulic fluid. The drilled hole 147 on the right extends to an elevation matching that of the first or lower circumferential groove 145 containing hydraulic fluid. This drilled hole is coupled to the circumferential groove by a second drilled hole 141 extending through the wall of the hydraulic coupling collar and intersecting the circumferential groove 145 containing the hydraulic fluid, but not intersecting the drilled hole coupling the top circumferential groove. In this manner, two entirely independent hydraulic fluid circuits are maintained and coupling from the external hydraulic power supply to the rotating member is achieved.

The center pipe 112 of the spindle extends beyond the bottom of the hydraulic coupling collar 160 to a swivel flange plate 114. The swivel flange plate is a circular disc with a concentric central opening 171 whose diameter approximates the nominal diameter of the spindle center pipe 112. The bottom end of the spindle center pipe is provided with a recess 169 on its outside surface forming a section of pipe of reduced diameter matching the inside diameter of the center opening 171 in the swivel flange plate and extending longitudinally the distance of approximately one half of the swivel flange plate thickness. The swivel flange plate is also provided with a bored hole 167 adjacent the center opening 171, whose diameter matches the diameter of the bored hole 159 in the hydraulic collar. The swivel flange plate is fitted over the bottom end of the spindle center pipe and the auxiliary hole 167 in the flange plate is aligned with the auxiliary hole 159 in the hydraulic coupling collar 160. The flange plate is firmly attached to the end of the spindle center pipe and a section of auxiliary pipe 165 whose inside diameter matches the diameter of the bored holes in the flange plate and hydraulic coupling collar is aligned with the two bored holes 167 and 159 and attached to the top surface of the swivel flange plate 114 and extends to the bottom surface of the hydraulic coupling collar 160 and is attached thereto. Thus a continuous conduit for the passage of the air from the air chamber 152 in the swivel body upper housing 140 through the spindle collar 134, the hydraulic coupling collar 160, the auxiliary pipe 165 and through the swivel flange 114 is provided.

Finally, the swivel flange plate 114 is provided with a series of equally spaced bolt holes near its outer circumference which match with a series of equally spaced bolt holes in the adapter top flange plate. The coupling of the kelly bar adapter top flange plate to the swivel flange plate is accomplished by fastening the two sections together with bolts 163. Hydraulic lines 234 are then attached to pass from the hydraulic outlet provided in the hydraulic coupling collar to the hydraulic attachments provided in the top surface of the adapter bottom flange plate 183. In this manner the hydraulic lines are coupled to the hydraulic cylinders 210 disposed within the Kelly Bar casing 220.

The spindle center pipe 112 is seen to extend up through the swivel body upper housing 140. Attached to the swivel body upper housing is an elbow 106. This elbow consists of a retainer plate 149 with a central opening 161 concentric with the central opening in the swivel body upper housing and matching the outside diameter of the spindle center pipe at its upper end. An elbow shaped section of pipe **120** whose outside diameter matches the diameter of the center bored hole **161** in the retainer plate and whose inside diameter matches the inside diameter of the spindle center pipe is disposed within the center bored hole in the retainer plate and firmly attached thereto. In this manner, a continuous conduit is provided through the elbow shaped section of pipe down through the spindle center pipe and out through the swivel flange plate. With this design the spindle center pipe **112** is free to rotate while the elbow shaped section **120** is firmly attached with respect to the swivel body. To support the entire swivel assembly, the top end of the bail is provided with a support plate **155** which has a bored hole **153** aligned with the center line of the spindle center pipe. A supporting hook **28**, such as, that suspended from a block and tackle, may then be used to support the swivel.

It should be apparent that with the entire drill string assembled, that is, the swivel, the kelly bar, the drill stem, and the combination drilling and belling tool, the entire vertical support is provided by the vertical support of the swivel. Thus the vertical displacement of the drill string is controlled by the vertical displacement of the swivel. Because the swivel must move through a vertical displacement, the coupling of the air compressor to the swivel body is accomplished through a flexible hose **56** attached to the swivel body air inlet port **156** and the coupling of the hydraulic power supply to the hydraulic housing is accomplished through the coupling of flexible hydraulic lines **166** to the hydraulic housing inlet ports. With the entire drill string assembled, it can be seen that there is a continuous conduit formed by the drill string which leads from the air chamber **152** in the upper housing of the swivel body through the swivel body and the kelly bar assembly to the drill stem. This coupling of the air chamber with the drill stem is maintained at all times because the air chamber is circumferentially continuous around the swivel spindle. In addition, there is a continuous coupling of the hydraulic power supply to the hydraulic cylinders disposed within the kelly bar assembly. In turn, the hudraulic cylinders are always coupled to the sucker rod **209** which extends through one of the auxiliary pipes **304** in the drill stem and ultimately engages with the elongated member **514** of the combination and drilling bucket **500** which in turn is attached to the carriage assembly **512.** Thus, there is continuous control of the vertical position of the carriage assembly which in turn controls the angular expansion and retraction of the belling blades. In this manner, the belling blades are always under positive control.

KELLY BAR ASSEMBLY

Attached between the swivel and the drill stem is the kelly bar assembly **200.** The kelly bar is an elongated, generally cylindrical structure which is slightly longer than the individual drill stem sections. The basic function of the kelly bar is to serve as a means for coupling the drill stem and the rotary table together thereby providing a means for imparting the rotary motion of the rotary table to the drill stem. However, when used with the combination drilling and belling bucket **500,** the kelly bar must also provide a means for driving the carriage assembly **512** of the bucket and thereby control the expansion and contraction of the belling blades **508** and **509.** In FIGS. 3*b* and 4 it can be seen that the basic structural unit has a center pipe section **204** and an air auxiliary pipe section **206** adjacent to the center pipe and jointly extending over the length of the kelly bar. These two pipes are disposed within a tubular casing **220** which also extends over the length of the kelly bar.

Attached to the top end of the tubular casing is a top flange plate **222.** This flange plate is a circular disc whose diameter is greater than the diameter of the tubular casing. Concentric with the outside diameter of the flange plate is a bored hole **224** extending through the plate and having a diameter matching the inside diameter of the center pipe. Concentric with this bored hole is a counter bore **226** whose diameter matches the outside diameter of the center pipe. Adjacent to the counter bore is a bored hole **228** extending through the flange plate and having a diameter equal to the inside diameter of the air auxiliary pipe **206.** In order to secure the tubular casing to the top flange plate, a concentric groove **230** is cut in the bottom surface of the top flange plate. This groove has a diameter and width matching that of the tubular casing **220.** Opposite the bored hole **228** for receiving the auxiliary pipe are two bored holes **232** for receiving the hydraulic lines **234** which pass through the flange plate. Finally, a series of equally spaced bolt holes are drilled through the flange plate near its outside circumference.

To support the center pipe and auxiliary pipe at their lower ends, a casing bottom end plate **238** is provided. This bottom end plate is a circular disc whose outside diameter matches the inside diameter of the tubular casing **220.** Concentric with the outside diameter of the bottom end plate is a bored hole **240** extending through the plate and having a diameter matching the inside diameter of the center pipe. Adjacent to the center bored hole is a bored hole **242** whose diameter matches the inside diameter of the auxiliary pipe **206.** Adjacent to the center pipe and oppositely disposed from the auxiliary pipe hole is another bored hole **244** extending through the casing end plate. This bored hole is provided to receive the sucker rod swivel **214** and its attachments which extend on down through the drill stem to the carriage assembly **512** of the combination drilling and belling bucket **500.** The casing bottom end plate is disposed within the kelly bar tubular casing **220** and abutts against the center pipe **204** and auxiliary pipe **206** of the kelly bar. The relative length of the tubular casing and center and auxiliary pipes are such that the casing bottom end plate **238** is disposed within the casing but extends beyond the bottom end of the tubular casing by approximately one half of the plate thickness. The casing bottom end plate is then firmly attached to the bottom of the center pipe, the auxiliary pipe, and to the bottom of the tubular casing.

Attached to the outside surface of the tubular casing and extending from the bottom surface of the top flange plate to the bottom end of the tubular casing are two oppositely disposed rectangular bars or ribs **208,** FIG. **21.** These bars are provided to engage complimentary recesses in the ring gear of the rotary table. To impart a heard drive to the sucker rod **209,** a pair of double acting hydraulic cylinders **210** are disposed within the tubular casing. These can be seen through the rectangular cutout **248** provided in the lower portion of the tubular casing **220.** This rectangular cutout begins near the lower end of the tubular casing and extends over a substantial portion of the casing length. At the top of the rectangular cutout a reinforcing plate **246**, FIG. **6**, is disposed between the inside surface of the tubular casing and the outside surface of the center pipe. This reinforcing plate is firmly attached to the casing and center pipe surfaces. Attached to the bottom surface of this reinforcing plate and extending over a substantial portion of the width of the rectangular cutout is a support bar **250**. This support bar is provided with two cylindrical pins **252** whose diameter matches the bore diameter of the support bracket **254** of the top of the hydraulic cylinders and whose length is equal to or slightly greater than the thickness of the support bracket. Two reinforcing plates **256** are utilized to make up for the strength loss in the kelly bar casing due to the rectangular cutout. These reinforcing plates extend between the top surface of the casing bottom end plate **238** and the bottom surface of the support plate **246** and extend between and are attached to the inside surface of the tubular casing **220** and the outside surface of the center pipe **204**.

The two hydraulic cylinders **210** are attached to the kelly bar by slip fitting the support bracket **254** of the hydraulic cylinder onto the pins **252** of the support bar **250** of the kelly bar assembly. These hydraulic cylinders are then held in place by a retainer bar **258**, which in turn is firmly attached to the support bar by two attachment bolts **260**. These two hydraulic cylinders are of such a length that when the pistons are near their full extension, the bottom end of the piston is very near the bottom of the rectangular cutout of the kelly bar. The action of the two hydraulic cylinders is joined together by the coupling of the pistons of a bracket **262**, FIG. **21**. This bracket has two ears **264**, each ear having a bored hole **266** which is aligned with the bored hole **268** in the clevis **270** or attachment end of the cylinder pistons. This bracket has a cylindrical portion **272** which is located along the center line of the bracket and midway between the two bored holes in the bracket ears. This cylindrical portion is tapped on its lower end to receive a threaded stud **274**. This threaded stud is in turn provided with a jam nut **276** for locking the threaded stud with respect to the bracket. Attached to the bottom end of the threaded stud is a sucker rod swivel **214**. This swivel is held in place by a second jam nut **278** on the threaded stud. The purpose of the swivel is to concurrently provide for free rotation of the sucker rod **209** and positive control it its vertical displacement. It should be noted that the pistons are so oriented that the cylindrical portion **272** of the bracket **262** is concentric with and just enters the respective bored hole **244** in the casing bottom end plate as the pistons reach their bottom position.

The pistons are driven by a hydraulic power supply outside of the kelly bar. The coupling between this hydraulic power supply and the pistons is provided by a series of hydraulic lines **234**. Near the top of the kelly bar casing is shown an oval cutout **280** whose minor axis is approximately aligned with the longitudinal axis of the rectangular cutout **246**. This oval cutout is covered with a cover plate **282** which is attached by a series of attachment screws. This cover plate is removed to allow access to the coupling joints **286** of the hydraulic lines. As can be seen, the hydraulic lines extend down through the previously noted drilled holes **232** in the kelly bar top flange plate **222** and are coupled to a T-joint **288** disposed within the kelly bar casing **220** and located directly behind the previously noted cover plate **282**. From this T-joint, each hydraulic line branches into two separate lines, either hydraulic cylinder top lines **290** or hydraulic cylinder bottom lines **292**. The purpose of this arrangement is to provide a coupling of each hydraulic line **234** to each of the hydraulic cylinders **210**.

Although the particular arrangement is optional, as shown in FIG. **4** the hydraulic line **234** on the right hand side is coupled to the top end of both of the hydraulic cylinders through lines **290** and the hydraulic line on the left hand side coupled to the bottom end of both of the hydraulic cylinders through lines **292**. Thus when hydraulic pressure is applied to the hydraulic line on the left hand side and the pressure is released from the line on the right hand side, the hydraulic fluid is forced into the bottom end of the cylinder driving the piston in an upward direction. To drive the piston in the downward direction the line pressures are reversed.

Disposed from the bottom surface of the casing bottom end plate **238** is the bottom adapter **294** of the kelly bar assembly **200**. This adapter has a center pipe **296** which is concentric with the center hole **240** in the casing bottom end plate and is rigidly attached to the bottom side of the casing bottom end plate. This center pipe extends down to and is rigidly attached to a kelly bar bottom flange plate **298**. This bottom flange plate is identical to the bottom flange plate of the subsequently described drill stem sections **300** and **400**. Attached to the center pipe **296** and extending between and attached to the casing bottom end plate **238** and the kelly bar bottom flange plate **298** is a series of radial ribs **299**. These ribs provide the necessary reinforcing of the kelly bar bottom adapter section **294**.

As can be seen, the auxiliary holes **297** bored in the kelly bar bottom flange plate **298** are aligned with and concentric to the holes **242** and **244** of the casing bottom end plate. Extending between the bored hole **297** in the kelly bar bottom flange plate **298** and the hole **242** in the kelly bar casing end plate **238** is a section of auxiliary pipe **295** whose inside diameter matches the inside diameter of the bored holes. This section of pipe is rigidly attached to the bottom of the casing bottom end plate **238** and to the top of the kelly bar bottom flange plate **298**. With this kelly bar design, the kelly bar assembly **220** may be rigidly attached to the top of any of the subsequently described sections of drill stems **300** and **400**. The drill stem section and the kelly bar section are coupled together and held in place by a series of bolts **293** as shown in FIG. **4**.

Attached to the top of the kelly bar is a kelly bar top adapter **175**, FIGS. **3***a*, **3***b*, **4** and **5**. This adapter is designed to provide a coupling between the kelly bar top flange plate **222** and the swivel **100** located at the top of the drill string. This top adapter consists of an adapter top flange plate **177**, a center pipe **179**, an auxiliary pipe **181**, an adapter bottom flange plate **183**, and a series of radial ribs **185**. The top flange plate is a circular disc with a concentric bored hole **187** whose diameter matches the inside diameter of the center pipe **179**. Adjacent to the center bore is an auxiliary bored hole **189** whose inside diameter of the auxiliary pipe **181**. The center pipe and auxiliary pipe are attached to the bottom side of the top flange plate **177** concentric to their respective bored holes. These two pipes are equal in length and extend down to and are attached to the bottom flange plate **183** of the adapter. This bottom flange plate is a circular disc whose outside diameter matches the outside diameter of the top flange plate **222** of the kelly bar casing. This bottom flange plate has a concentric center bored hole **191** whose diameter matches the inside diameter of the center pipe **179**, and an auxiliary bored hole **193**, whose diameter matches the inside diameter of the auxiliary pipe **181**. The bottom flange plate **183** is firmly attached to the center and auxiliary pipes and is so oriented that the center and auxiliary bored holes are aligned with and concentric to their respective pipes. To reinforce this structure, a series of radial ribs **185** is attached to the center pipe and extends between the bottom surface of the top flange plate **177** and the top surface of the bottom flange plate **183** and are attached thereto.

To provide coupling of the hydraulic lines to the kelly bar casing, two drilled and tapped holes **195** are provided in this bottom flange plate which are concentric to and aligned with the drilled holes **232** previously described in the kelly bar casing top flange plate **222**. In this manner, the hydraulic line **234** may be coupled to the top of this bottom flange plate **183** and then the hydraulic lines **234** within the kelly bar casing may be attached to the bottom surface of the adapter bottom flange plate **183**, thereby establishing the coupling of the hydraulic lines outside of the kelly bar casing to their respective hydraulic lines inside of the kelly bar casing.

To couple the adapter to the kelly bar casing **220**, the adapter bottom flange plate **183** is provided with a series of equally spaced bolt holes near its outer circumference. These bolt holes align with the previously described bolt holes in the kelly bar casing top flange plate **222** and are so oriented that the air auxiliary hole **193** of the adapter aligns with the air auxiliary hole **228** in the kelly bar casing top flange plate **222** and the hydraulic fluid line holes in the adapter bottom flange plate **183** and the kelly bar casing top flange plate **222** are aligned and concentric. The adapter is then firmly attached to the kelly bar casing by coupling the two sections together with a series of bolts **199**. The resulting structure forms the kelly bar assembly **200**.

There is one final feature of the kelly bar assembly which has not been described. That is the belling blade position indicator **291**. The belling blade position indicator is actually a part of the kelly bar assembly. As seen in FIGS. **3***b* and **4**, this indicator consists of a rod attached to the top surface of the cylindrical portion **272** of the bracket **262** connecting the two hydraulic cylinder pistons together. This rod extends in a vertical direction parallel to and passing between the two hydraulic cylinders **210** for a distance which approximates the length of the hydraulic cylinders in their closed position. At this point the bar dog-legs away from the kelly bar longitudinal axis and passes outside of the kelly bar assembly. Then the rod dog-legs back to a vertical direction and passes beyond the kelly bar assembly. Because the position of this rod relative to the kelly bar casing reflects the position of the carriage assembly **512** relative to the combination drilling and belling bucket frame, the displacement of the carriage assembly relative to the bucket frame may be monitored by calibrating the rod position with respect to a fixed point on the kelly bar assembly. As has been previously described the motion of the belling blades is controlled by the displacement of the carriage assembly relative to the bucket frame. Thus, in effect what the rod position relative to the reference point on the kelly bar assembly will indicate is the angular displacement of the belling blades. Hence, this tool provides both a positive monitoring and positive control of the belling blade position. This is a distinct advantage over the prior art and is a feature which is unique to this tool.

THE DRILL STEM

Turning now to a detailed description of the drill stem, it can be seen that there are two basic drill stem sections. One section is characterized as a reverse circulation drill stem with airlift **300** and the other is characterized as a reverse circulation drill stem with air injection **400**. The reverse circulation drill stem with air injection, with few exceptions, is identical to the reverse circulation drill stem with airlift. These exceptions will be pointed out and discussed later. Considering first the entire drill stem as it extends down into the drill hole, it can be seen that this drill stem is formed by the coupling together of repetitive sections of drill stem pipe FIGS. **2***a*, *b*, and *c*. The basic repetitive unit is the reverse circulation drill stem with airlift **300**. This section of drill stem is shown in detail in FIGS. **8***a* and **9***a*. It is seen that it consists of a center pipe section **302** running nearly the entire length of the drill stem section. Oppositely disposed on the outside surface of this center pipe are two auxiliary pipes **304**. These three pipes are disposed within a close fitting tubular casing **306**. This casing is centered with respect to the longitudinal axis of the center pipe and extends over a substantial portion of the length of the center pipe.

The three pipes are supported within the tubular casing and rigidly held in place by two casing end plates **314** and **316**. These casing end plates may be referred to as a bottom casing end plate **314** and a top casing end plate **316**, FIG. **20**. As can be seen, the casing end plates are located with respect to the casing by providing the casing with oppositely disposed notches **318** on its top and bottom ends. The casing end plates are seen to consist of a circular plate whose outside diameter matches the inside diameter of the tubular casing. Oppositely disposed on the outside diameter of the circular plate are two arcuate ears **320**. These ears are so positioned and dimensioned that they match the provided notches in the tubular casing. The notches in the ends of the tubular casing are seen to extend to a depth of one half of the end plate thickness. The end plate is also provided with a central hole **332**, whose diameter matches the outside diameter of the center pipe, and with two oppositely disposed auxiliary holes **324** adjacent to the center hole and having a diameter matching the outside diameter of the auxiliary pipes. The center and auxiliary pipes extend through these openings. Hence, the casing end plates support and hold the center and auxiliary pipes in place and at the same time are located with respect to the tubular casing. When the ears of the casing end plates are fully seated within the notches provided in the tubular casing, one half of the end plate thickness is disposed within the tubular casing and the end plate is firmly attached to the tubular casing.

Also, the tubular casing is provided with four transverse openings **326**. Two of these rectangular conduits are located near the top of the tubular casing and the other two are located approximately one third of the way down the tubular casing. These transverse openings are seen to extend through the casing and adjacent to the center pipe and run parallel to the line joining the longitudinal axis of the center and auxiliary pipes. In addition, the longitudinal axis of the rectangular conduits lie in a plane perpendicular to the longitudinal axes of the center pipe of the drill stem section. The purpose of these transverse openings is to receive pins which may be extended through the rectangular conduits and used to lift and handle the stem sections while the drill string is being assembled and disassembled for the drilling operation.

Attached to each end of the drill stem center pipe is a drill stem flange plate. These may be characterized as the top drill stem flange plate **328**, FIG. **20** and the bottom drill stem flange plate **330**. These flange plates are seen to have a center bored hole **332**, whose diameter matches the inside diameter of the center pipe, and a concentric counter bore **334**, which extends through approximately one half of the flange plate thickness and whose diameter matches the outside diameter of the center pipe. Adjacent to the counter bore and concentric with the longitudinal axis of the auxiliary pipes are two bored holes **336**. The diameter of these bored holes matches the inside diameter of the auxiliary pipes. As can be seen, when the top and bottom flange plates are located onto the top and bottom ends of the center pipe of the drill stem section, the auxiliary pipes extend between the inside surfaces of the top and bottom flange plates and are aligned with the auxiliary bored holes in the top and bottom flange plates. The flange plates are attached to the ends of the auxiliary pipes in this orientation. To reinforce the portions of the drill stem which extend beyond the tubular casing, i.e., between the bottom end of the tubular casing and the bottom flange plate and the top end of the tubular casing and the top flange plate, a series of radial ribs **338** are attached to the center pipe and extend between the respective casing end plates and drill stem flange plates and are attached thereto. To protect the auxiliary pipes, a rib is located adjacent to each side of the auxiliary pipe.

The remaining detail of the top drill stem flange plate is identical with that of the drill stem flange plate on the combination drilling and belling bucket, which is subsequently described. This consists of O-ring grooves around the center pipe hole and auxiliary pipe holes, a long dowel pin **340**, a short dowel pin **342**, and a series of four equally spaced bolt holes **344** to receive bolts **346** for attaching the drill stem sections together. The bottom drill stem flange plate is provided with two bored holes to receive the dowel pins from an adjoining drill stem section, such as, the dowel pins in the top drill stem flange plate **328** or in the bucket drill stem flange plate **598**. The bottom drill stem flange plate is also provided with four equally spaced bolt holes **344** that match the four equally spaced bolt holes in the top drill stem flange plate. Hence, to couple any drill stem sections together one need only align the two bored hole with the dowel pins, and then bolt the two sections together by passing bolts through the four aligned bolt holes in the drill stem flange plates. It should be noted that the bottom drill stem flange plate does not have the O-ring grooves around the center pipe hole and auxiliary pipe holes that were provided in the top drill stem flange plate. During the coupling operation, O-rings are placed in the O-ring grooves provided in the top surface of the top drill stem flange plate **328** and then the drill stem section to be joined is fitted onto the dowel pins provided in the top drill stem flange plate and the two sections are bolted together.

The only difference between the reverse circulation drill stem with air injection **400** and the reverse circulation drill stem with airlift **300** is that the reverse circulation drill stem with air injection is provided with means for coupling one of the auxiliary pipes **404** and **406**, FIG. **8***a* and *b* and **9***a* and *b* with the center pipe **402** of the drill stem section. This is accomplished by drilling a series of holes **418** through the wall of the center pipe at the lower end of the drill stem section. In the air injection drill stem section the air auxiliary pipe **404** terminates at the outside edge of the casing bottom end plate **422**. As previously described, a series of radial ribs **424**, FIG. **13** are attached to the center pipe and extend between the casing end plate **422** and **423** and the drill stem flange plate **412** and **414**. Also, it was previously noted that two of these ribs are so aligned that they lie adjacent to the outside diameter of the auxiliary pipes. To accomplish the air injection, a series of holes **418** is drilled along the longitudinal axis of the center pipe extending from the casing bottom end plate **422** to the bottom flange plate **414** and lying midway between the two radial ribs adjacent the air auxiliary pipe. A sealed cavity is then formed by fitting a section of a tubular casing **426**, whose diameter is the same as the diameter of the drill stem casing, between the two ribs and extending from the casing bottom end plate to the top surface of the drill stem bottom flange plate. This section of casing is then firmly attached to the ribs, to the casing bottom end plate, and to the top surface of the drill stem bottom flange plate. Hence, when air pressure is applied to the air auxiliary pipe **404** it will pass down through the drill stem until it reaches the series of holes coupling the air auxiliary pipe and the drill stem center pipe. At this point, the air will pass through these holes into the center pipe. This accomplishes the air injection.

THE DRILLING AND BELLING BUCKET

Now, considering the combination drilling and belling bucket **500** components in more detail, it is seen that the bucket frame **502** consists of an outer shell assembly **504** and a drill stem assembly **506** disposed within this outer shell. The outer shell assembly **504** consists of a tubular pipe **516** of substantial length having a top **518** and bottom **520** end and two rectangular cutouts **522**, oppositely disposed on the circumference of the tubular pipe **516** and running a substantial portion of the pipe length. These rectangular cutouts are offset from the longitudinal axis of the tubular pipe and are of sufficient length and width to receive two belling blades, a left hand belling blade **508** and a right hand belling blade **509**. Near the top end of the tubular pipe are drilled two holes **524**, FIG. **16**. These holes are also offset from the longitudinal axis of the tubular pipe.

Oppositely disposed within the tubular pipe are two support plate assemblies **526**. These support plate assemblies consist of a large, rectangular plate **528** attached to the inside surface of the tubular pipe **516** and running a substantial portion of the pipe length, extending beyond the rectangular cutouts on both ends. The rectangular plates are aligned with and adjacent to the outside edge **530** of their respective rectangular cutouts and lie in a plane parallel to each other and to the longitudinal axis of the tubular pipe. The longitudinal edges **532** of the rectangular plates are cut to receive the inside diameter of the tubular pipe **516** and the rectangular plates **528** are attached to the inside diameter of the tubular pipe along these longitudinal edges. In addition, spaced at regular intervals along the length of the rectangular plates are several spacer plates **534** having a radiused edge **536** cut to receive the inside diameter of the tubular pipe and a flat edge **538** for receiving the rectangular plate. These spacer plates are attached to the back side of the rectangular plate serve to locate and support the rectangular plate against the inside diameter of the tubular pipe. The arcuate spacer plates at the top and bottom ends of the rectangular plate are attached to the inside surface of the tubular pipe. Attached to the each support plate near its upper end is a arcuate spacer bar **540,** FIG. **25.** The spacer bar is so oriented as to have its center of curvature concentric with its respective drilled hole **524,** FIG. **16** in the tubular pipe. Further, attached to this curved spacer bar, is a arcuate flange plate **542.** The arcuate flange plate also has its center of curvature concentric with the respective drilled hole **524** in the tubular pipe. Finally, there is a bored hole **544,** FIG. **16** concentric with the drilled hole **524** in the tubular pipe and extending through the rectangular plate **528** and the radiused flange plate **542.** Because there are two support plate assemblies, this structure is seen in duplicate.

It should again be noted that the drilled holes **524** do not have a common center line and are not aligned with the longitudinal axis of the tubular pipe. However, these holes are at a common distance from the bottom end **520** of the tubular pipe. As is shown, these elements are so arranged that the rectangular cutouts do not extend across the entire tubular pipe surface that exists between the two parallel support plates. Rather, a section **545,** FIG. **16** of the tubular pipe's wall extends beyond the support plate opposite the support plate aligned with the longitudinal edge of the respective rectangular cutout. Between the first said support plate and the section edge **531** of the rectangular cutouts and attached to the inside surface of the tubular pipe **516** are two counter torque bars **541.** These counter torque bars run parallel to the section edges **531** of the rectangular cutouts and support plates. The bars **541** form grooves **543** between the rectangular plates **528** and the bars **541** beginning near the lower end of the rectangular cutouts **522** and extending up to near the top end of the rectangular cutouts. Because there are two support plates **526** and two counter torque bars **541,** there are two grooves **543** formed as shown in FIG. **16.**

Finally, attached to the lower end of the tubular pipe **516** is a bucket bottom **546.** This bucket bottom consists of a blade shaped plate having three drilling blades **548** with three cutting edges **549** and three openings **550** extending from the cutting edge of one blade to the back edge of the leading blade. These blades are so shaped that when the bucket is rotated in the clockwise direction, they will cut and remove the soil from the bottom of the drill hole and funnel it into the center of the drilling bucket to be removed by the drilling ship removal process. Also, it should be noted that a drilling point or fish tail, which is standard in the art, may be attached to the bucket bottom to facilitate the cutting of the soil in the bottom of the drill hole.

The remainder of the bucket frame consists of the drill stem assembly **506** which is disposed within and extends above the outer shell **504** of the bucket frame **502.** This stem assembly has a center pipe section **552,** which extends the full length of the bucket drill stem assembly, that is, from the top of the drill stem assembly to the bottom of the drilling and belling bucket. In addition, there are two bucket auxiliary pipes **560** attached to and oppositely disposed on the outer surface of the center pipe. These auxiliary pipes begin at approximately the longitudinal midpoint of the center pipe section and extend up to a support and alignment plate **562** which extends between the support plate assemblies **526** of the outer shell assembly **504** and is firmly attached thereto. This support and alignment plate **562** is located at the top edge of the rectangular cutouts **522** and has an outside diameter matching the inside diameter of the tubular pipe **516.** In addition it has two parallel edges **564** cut to match the spacing between the support plate assemblies attached to the outer shell assembly. Concentric with the outside diameter of the support and alignment plate is a bored hole **566** drilled to receive the center pipe of the bucket drill stem assembly. Adjacent this center hole are two diametrically opposed drilled holes **568** to receive the auxiliary pipe sections **560** and concentric with the center hole is a groove cut to receive a tubular drill stem casing **572** which has an inside diameter that matches the diameter formed by the center and auxiliary pipes. Finally, there are four large diameter holes **574** drilled in the support and alignment plate **562.** The purpose of these holes will be explained in subsequent discussion.

Attached to and extending above the support and alignment plate are the previously mentioned tubular drill stem casing **572,** the center pipe section **552,** and two additional sections of the auxiliary pipe **570.** This casing assembly extends up through a bucket end plate **576** and on up to a casing end plate **578.** The bucket end plate consists of a circular plate with an outside diameter matching the inside diameter of the tubular pipe **516** of the outside shell assembly **504** and having a center hole **580** concentric with the outside diameter and matching the outside diameter of the tubular drill stem casing **572.** This bucket end plate is firmly attached to the stem casing and is located such that when the center pipe of the stem assembly extends to the bottom of the bucket, the said bucket end plate has only one half of its plate thickness disposed within the outer shell assembly tubular pipe. This bucket end plate is firmly attached to the outer shell tubular pipe and cooperates with the support and alignment plate and rigidly affording the bucket drill stem assembly **506** within the outer shell assembly. Also, it is seen that there are four drilled holes **582** in this bucket end plate which are drilled to be aligned with the four previously mentioned large diameter holes **574** in the support and alignment plate **562.**

The bucket drill stem assembly extends a substantial distance above the bucket end plate. Just above the bucket end plate are seen two lower rectangular conduits **584** extending through the stem casing and which run parallel to a line joining the longitudinal axes of the center pipe and auxiliary pipes. Two identical upper rectangular conduits **586** are seen near the casing end plate **578** near the top end of the bucket stem assembly. This casing end plate is a circular plate having an outside diameter matching the inside diameter of the casing **572** and having two radiused ears **590** oppositely disposed on the outside diameter of the plate and of sufficient radial thickness to extend slightly beyond the outside diameter of the stem casing. The stem casing is notched at is upper end to receive the ears of the casing end plate. This notch **592** extends to a depth sufficient to allow approximately one half of the casing end plate thickness to be disposed within the stem casing. The casing end plate is firmly attached to the stem casing once it is located into position by the mating of the notches in the stem casing and the ears on the casing end plate. The casing end plate has a center hole **594**, FIG. 9b concentric with its outer diameter and cut to receive the center pipe of the drill stem assembly. In addition, it has two smaller diameter holes **596**, FIG. **14** and 9b adjacent the center hole and bored to receive the auxiliary pipes adjacent the center pipe. It should be noted that the auxiliary pipes end at the casing end cap **578** whereas the center pipe extends up to and attaches to the drill stem flange plate **598.** Between the casing end cap and the drill stem flange plate and attached to the center pipe of the drill stem is a series of radial ribs **599,** FIG. **14.** It should be noted that there is a rib adjacent to each side of the holes **596** bored in the stem casing end cap. Also, a piece of stem casing **597** is attached to and extends between the ribs adjacent the bored holes and extends between and is attached to the stem casing end cap and the drill stem flange plate thus forming a sealed cavity extending between the stem casing end cap and the drill stem flange plate and aligned with the auxiliary pipes of the drill stem assembly.

Finally, it is seen that the drill stem flange plate **598** is a circular plate having an outside diameter matching the outside diameter of the drill stem casing and having bored holes to receive the center pipe and auxiliary pipe cavities. The center hole **595** in the drill stem flange plate is of a diameter matching the inside diameter of the center pipe. Concentric with this center hole it is seen that in the bottom side of the flange plate there is a counter bore **593** extending approximately one half of the flange plate thickness and of a diameter cut to receive the outside diameter of the center pipe. Hence, the drill stem flange plate may be positioned onto the center pipe and firmly attached thereto. In this manner the flange plate may be given its necessary alignment and location. Also, it is seen that an orientation of **90** degrees from the auxiliary holes **591** in the flange plate there are located two dowel pins **587** and **589.** Further examination shows that one of these is a long dowel pin **587** which is longer than the diametrically opposed short dowel pin **589.** The purpose of these dowel pins is to facilitate the alignment of the drill stem and to provide additional strength in the coupled joint. The purpose of having one dowel pin longer than the other dowel pin is to facilitate the joining of the bucket stem assembly to the drilling stem. Because one dowel pin is longer than the other, the section of drill stem to be connected to the bucket stem assembly may be located on the longer lowel pin and then rotated to align with the shorter dowel pin. This avoids the probelm of having to orient the stem section with both dowel pins at the same time.

In order to rigidly clamp the two sections together, it is seen that there are four drilled bolt holes **585** in the drill stem flange plate. These bolt holes are spaced between the previously mentioned ribs and are equally spaced about the circumference of the drill stem flange plate. To couple the bucket stem assembly to the drill stem it is only necessary to run bolts through these drilled holes, said bolts being received into the bottom flange plate of the drill stem. In order to provide an adequate seal between the two sections, each of the bored holes in the drill stem flange plate is provided with an O-ring groove around its circumference. That is, the center pipe has an O-ring groove and each of the auxiliary holes also have their respective O-ring grooves. By providing these O-ring grooves in the top drill stem flange plate, the coupling of the bucket stem assembly and the drill stem is facilitated because gravity will hold the O-rings into position in their respective grooves while the coupling procedure is accomplished. This completes a detailed description of the bucket frame. Although there are some features of the bucket frame which have not been described in their operational sense, these features will be described in subsequent sections.

Attached to their respective support plate assemblies **526**, are the belling blades **508** and **509**, FIG. **16.** The belling blade is a rigid structure consisting of a main plate **600**, FIG. **27** having an attachment ear **602** on its upper end and generally tapering to a narrow width at its lower end. The outer longitudinal edge **604**, FIG. **23** of the main plate is cut with a bevel and receives a runner plate **606** which is a generally rectangular plate extnding from the upper end of the blade to near its bottom end. The leading edge **608** of this runner plate is bent to form an inclined surface **610**, the inclination being at an angle which is less than the bevel cut on the outside longitudinal edge of the main plate. This inclined surface is notched with equally spaced rectangular slots **612.** The sapcing of these slots is cut so that mining teeth holders **614** may be installed in mutual contact with each other with mining teeth **615.** These mining teeth holders are attached directly beneath this runner plate and have their slotted openings **616** aligned with the rectangular slots in the runner plate. Attached to the leading edge of the runner plate and to the mining teeth holders is a leading edge bar **618.** The back edge **620** of the leading edge bar is cut with a bevel, the bevel being somewhat larger than the difference between the bevel cut on the outside longitudinal edge of the main plate **604** and the bend angle in the runner plate **606.** In this manner, the leading edge of the leading edge bar is slightly recessed, the runner plate and the leading edge bar forming an outer surface of a generally arcuate shape with the mining teeth located at the crown of this arced surface.

Attached to and disposed from the underside of the runner plate is a center plate **622** which runs parallel to and extends the length of the blade main plate **600.** This center plate is attached to the runner plate at approximately the mid point of the width of the runner plate and is provided with an actuating ear **624** located at it approximate longitudinal mid point. A spacer bar **626** is located between the center plate and the main plate of the blade and a reinforcing plate **628** runs between the center plate and the mining teeth holders. This arrangement provides the generally wedge shaped structure of sufficient rigidity to withstand the cutting force involved in the belling operation. In addition, the general wedge shape of the blade provides a sweeping action and establishes a flow of fluid within the drill hole that will direct the chips towards the center of the drill hole to facilitate drilling chip removal. It should be noted that the lower edge of the blade is provided with a sharp angular recess **630.** The purpose of this angular recess is merely to obtain the geometric configuration desired in the particular bell cavity. This angular break is accomplished by merely reproducing the structure already described an attaching it to the lower end of the blade at the desired angle.

The attachment ear on the upper end of the blade main plate has a bored hole **632**. The diameter of the bored hole matches the diameter of the bored holes in the support plate assembly **526** of the bucket frame outer shell assembly **504**. This ear fits into the recess formed between the arcuate flange plate **542** and the rectangular plate **528** and is pinned in place. This provides the pivotal connection between the belling blade and the bucket frame. The ear located at the longitudinal mid point of the center plate of the belling blade also has a bored hole **634**. This bored hole extends on through the main plate of the belling blade. It should also be noted that two stopper plates **636**, FIG. **22** are provided to block the cavity between the center plate and the main plate in the vacinity of the center plate actuating ear. These stopper plates prevent the flow of drilling mud around the pivotal connection provided by this ear.

As can be seen, the pivotal connection between the belling blade and the actuating arm **510** is provided by the pin **638** extending through the hole **634** in the blade actuating ear. The actuating arm consists of a solid member of generally rectangular shape but having smoothly radiused ends. Concentric with the radius on each end is a bored hole matching the bored hole diameter through the ear of the centered plate of the belling blade and the belling blade main plate. Hence, the pivotal attachment between the belling blade and the actuating arm is accomplished by inserting the actuating arm between the main plate **600** and the actuating ear **624** of the center plate **622** and pinning the actuating arm into place.

The other end of the actuating arm is attached to the carriage assembly **512**, FIG. **27**. This carriage assembly is disposed between the center pipe section **552** of the bucket drill stem assembly **506** and the outer shell assembly **504** of the bucket frame. The carriage assembly has a rigid carriage frame **554** formed by two end plates **650** and **652**, two sides plates **654**, and four rectangular plates, i.e., two wise plates **656** and two narrow plates **658**. The two side plates and four rectangular plates are attached together to form a tubular structure **660** of generally rectangular shape the wide and narrow rectangular plates forming two angled sides. The top end plate **650** has a geometric configuration matching that of the tubular structure. The center of the plate, however, has a bored hole **662** of somewhat larger diameter than the outside diameter of the center pipe **552** of the bucket drill stem assembly **506**. In addition, there is a bored hole **664** adjacent to the center bored hole in the end plate which has a diameter slightly larger than the inside diameter of the auxiliary pipe **560** of the drill stem and is concentric with the center line of one of the auxiliary pipes attached to the center pipe of the bucket stem assembly. Diametrically opposed to this auxiliary bored hole is a smaller diameter drilled hole **665**. This drilled hole is concentric with the center line of its respective auxiliary pipe. Attached to the underside of this top end plate and concentric with this drilled hole is a nut **666**. The bottom end plate **652** is basically the same as the top end plate except that the bottom end plate does not have the drilled hole **664** or the nut **666** attached thereto. These end plates are attached to their respective top and bottom ends of the tubular structure **660**.

It should be noted, that the side plates **654** have a flange portion **668** which extends beyond the longitudinal edges of the previously discussed tubular structure **660**. Because these two flanges and the associated structure therewith are identical, discussion of the structure of one of the flanges is deemed sufficient. Attached to the outside surface of the flange is a spacer plate **670** and a spacer block **672**. Attached to the outside surface of the spacer plate and spacer block, is a retainer plate **674**. Near the lower end of the tubular structure a reinforcing block **676** is attached to the flange on the inside surface, that is, the same side as the tubular structure is attached. As can be seen, the spacer plate and spacer block are so arranged as to leave an opening opposite the location of the reinforcing block. At this location there is a bored hole **678** which extends through the retainer plate, the flange, and the reinforcing block. This forms the basic supporting structure for the pivotal connection of the actuating arm **510** to the carriage assembly **512**. To reinforce the flange portion **668**, a series of equally spaced gussets **680** is placed along the length of the carriage frame and extedning between the flange **668** and the angled side **656** of the tubular structure **660**. In order to allow the actuating arm to be freely rotating about the pivotal connection, it is necessary to provide the spacer plate **670** with an angled surface **682**.

Attached to each of the end plates **650** and **652** are four roller support brackets **684**. Extending between these brackets is a spacer and reinforcing bar **686**. Two of these brackets plus the spacer and reinforcing bar act as the support for the single roller. Hence, two rollers may be attached to each end of the carriage assembly. These brackets are so positioned that the contoured rollers **688** which are pinned into the brackets are concentric with the center hole **662** of the end plates **650** and **652** and at the same time provide a close fit between the rollers and the outside diameter of the center pipe **552** of the bucket drill stem assembly **506**. In this manner a closely toleranced, low friction guide and support of the carriage assembly is provided as the carriage moves along a center pipe. In order to provide rotational stability, round bars **692** are attached to the outside edge **690** of the retainer plates **674**. These bars extend the full length of the carriage assembly and are so designed that they engage the previously described groove **543** in the outer shell assembly **504** of the bucket frame **502**. In this manner the round bars **692** of the carriage assembly **512** are locked into the grooves **543** of the bucket frame.

This locking action prevents the carriage assembly from rotating about the center pipe of the bucket drill stem assembly. In addition, it provides orientation and guidance of the carriage assembly. This action is particularly important during the belling operation when high forces will be exerted through the actuating arms **510** to the carriage assembly **512**. Because the attachment point of the actuating arms to the carriage assembly is not on the center line of the pipe, these forces cause a high torque to be exerted on the carriage assembly. This torque is counteracted by the counter-torque exerted on the carriage assembly through the engagement of the round bar **692** on the retainer plate **674** and the counter-torque bar **541** of the outer shell assembly **504** of the bucket frame.

It is also important to note the orientation of the various parts as they exist in the bucket. Identifying one of the auxiliary pipes as the air pipe **694** and the other as the sucker rod pipe **696**, it can be seen that the bucket bottom **546** is so oriented that one of the openings between the bucket blades **548** is positioned directly below the air pipe. In addition, the carriage assembly is so oriented that the bored hole **664** adjacent to the center hole in the end plates of the carriage structure is aligned with the air pipe. Hence, the diametrically opposed drill hole **665** and attached nut **666** are aligned with the sucker rod pipe. Within the sucker rod pipe is disposed an elongated member **514**. This elongated member has a threaded end which passes through the drill hole in the carriage assembly end plate and engages the threads of the nut attached thereto. This elongated member passes through the sucker rod pipe and up through the bucket drill stem flange plate **598**. As can be seen thre elongated member terminates just beyond the flange plate. The upper end of the elongated member is seen to have and internal thread. In addition to the O-ring seal **581** provided around the sucker rod pipe, it is seen that a sliding seal **699** is provided to act between the surface of the elongated member and the drill stem flange plate auxiliary hole **591**. This seal provides a water tight seal to prevent the flow of drilling mud into the sucker rod pipe of the drill string.

At this point the operation of the combination drilling and belling bucket should be rather apparent. The pivotal connection of the actuating arms to the carriage assembly is accomplished by pinning the arm end opposite that pinned to the belling blade to the carriage assembly at their respective bored holes in the lower end of the carriage assembly. It can be seen that any vertical displacement of the carriage assembly is in turn transmitted to an angular displacement of the belling blades. This action is rather easily visualized by examining the figures. However, there are some more subtle details of the particular design relating to this opening action which ought to be pointed out in more detail.

One such detail has already been discussed, that being, the particular method employed for providing guidance and orientation of the carriage assembly and at the same time providing the counter-torque deemed necessary to prevent the carriage assembly from rotating about the center pipe. From the previous discussion of the torque developed because of the action of the actuating arm on the carriage assembly, one may wonder why the pivotal connection of the actuating arm to the carriage assembly is not aligned with the longitudinal axis of the center pipe of the bucket drill stem assembly. The reason for locating the pivotal connection off the center pipe center line is best understood by considering the orientation of the three pivotal connections that effect the action of any one blade. That is, the pivotal connection of the upper end of the blade to the bucket frame, the pivotal connection of one end of the actuating arm to the longitudinal mid-point of the belling blade, and the pivotal connection of the other end of the actuating arm to the carriage assembly. It is particularly appropriate to consider the orientation of these three pivot points when the belling blades are in the retracted or closed position. One of the crucial stages in the belling operation is during the initial opening of the belling blades. During this period it is necessary to develop enough force acting through the actuating arm on the belling blade to open the belling blades against very high cutting forces. This is particularly crucial during the initial opening of the blade because of the low angle of attack of the actuating arm acting on the belling blades. By providing the pivotal attachment of the actuating arm to the carriage assembly on the side opposite the respective blade being acted upon, this angle of attack is increased to its maximum. Since the angle of attack is increased to its maximum, the resulting opening force acting on the belling blade is increased to its optimum. This is not only a unique feature of the combination drilling and belling tool, but is an essential part of its optimum design.

Another particularly unique and valuable feature of the invention, is the multiple use of the center pipe of the bucket drill stem assembly. The center pipe acts as a guide and support for the carriage assembly and at the same time acts as the conduit for the drilling chip removal. As such it is possible to extend this center pipe all the way to the bottom of the bucket and maintain the center pipe at that location during all operations. In previously known belling tools, this feature was not available. This was because the actuating means was provided by a downward motion of the center pipe of the drill stem. Hence, the conduit for chip removal was not at the bottom of the drill hole until the belling blades were completely extended, which results in very inefficient chip removal. With the belling bucket of the present invention the conduit for chip removal is always at the bottom of the drilling bucket, and the maximum efficiency of chip removal is always maintained.

Another unique feature that is provided by the combination drilling and belling bucket is that the bucket blades on the bottom of the drilling bucket are made to cut in one direction of rotation, such as in the clockwise direction of rotation of the belling bucket, while the belling blades are provided with teeth which cut in the opposite direction of rotation, such as counterclockwise. In this manner, any possible damage from accidental expansion of the belling blades during the drilling operation is minimized or eliminated because the blades are operating in the reverse direction from their cutting action. At the same time any possible cutting action or hang up of the drill bucket bottom during the belling operation is eliminated because the blades on the bottom of the bucket are rotating in a direction opposite from their cutting action during the belling operation.

A final feature of this combination drilling and belling bucket involves the design of the belling blade itself. As already noted this blade is designed with a generally wedge shaped structure which tends to establish a flow within the belling cavity which will direct the flow of ships into the center of the cavity. This facilitates chip removal especially then it's considered in cooperation with the fact that the chip removal conduit, that is, the center pipe of the bucket drill stem assembly, is located at the bottom of the drilling bucket. In addition to this feature, however, it should be noted that the arcuate shape of the outer surface of the belling blade and its larger runner surface behind the mininig teeth act to prevent any possible suck-in of the blade during the belling operation. This is particularly important because in other blade designs where suck-in occurs, large slabs are cut from the cavity wall. These large slabs are either impossible to remove from the bottom of the belling cavity or tend to block the chip removal conduit, either at its bottom entrance or somewhere along the drill stem. It is believed that the location of the mining teeth at the crown of the arcuate surface and behind the leading edge of the blade will eliminate this possibility. These features are all considered novel and are, to my knowledge, new to the art.

One final feature of the belling blades should be pointed out. As shown in FIG. **29**, the mining teeth in one blade, such as blade **508**, are offset by one half of an intertooth spacing with respect to the teeth in the other blade **509**. Hence, the teeth in the left hand blade **508** having cutting lines midway between the cutting lines in the right hand blade **509** and vice-versa.

NORTH SEA PLATFORM

Although there are many potential applications of the combination drilling and belling tool, one anticipated application is in building the supporting structures for drilling platforms for oil well exploration in the North Sea. The following detailed description of the operation of the combination drilling and belling tool when used for that purpose clearly shows the advantages of this tool and its basic mode of operation. In establishing a drilling platform in such a location, steel casings are driven into the bottom of the ocean floor, and then platform legs are built inside the casings. In the anticipated location, the depth of the ocean floor is approximately **180** feet. To counteract the forces created by the severe weather and ocean conditions that exist in this region, it is necessary to extend the platform legs at least **270** feet below the ocean floor. To build a leg for one of these oil drilling platforms, it is therefore necessary to drive a steel casing to a depth of approximately 270 feet below the ocean floor.

The casings are driven from a floating barge which is floated to the location where the platform is to be established. This is accomplished by welding **30**-foot sections of the steel casing together to form a section **180** feet long, which is set on the ocean floor, and then another section is welded to the top end. This is accomplished from the previously mentioned floating barge. Then the pipe is driven into the ocean floor at the appropriate angle. Once the pipe has been driven for a distance of 30 feet, it is necessary to weld another **30**-foot section of the steel pipe onto the top end of the steel casing. Once this is accomplished, the pipe is then further driven for a distance of 30 feet, and the process is repeated until the necessary length of pipe has been driven into the ocen floor. That is, 270 feet or nine sections of the 30-foot pipe are driven into the ocean floor, in addition to the 180 feet of pipe extending between the ocean floor and the ocean surface.

Then another steel casing is driven at the appropriate location and orientation into the ocean floor utilizing the process just described. This process will be repeated until the necessary number of steel casings are positioned. It is anticipated that this will be somewhere between six and 12 casings, each casing being the beginning structure for the formation of a drilling platform leg.

These casings extend out of the water a specified distance. A drilling template is swung across from the floating barge and mounted onto the top ends of these casings. The drilling template forms the working platform from which the oil drilling platform legs will be constructed. The drilling template has a freely movable drilling tower mounted on its top surface. The tower is positioned over one of the drill casings. This is diagrammatically shown in FIG. **1**. As there shown, the drilling tower consists of a rigid structure with a block and tackle attached to its crown. A rotary table or ring gear is positioned concentric with and directly above the driven casing. A hook extends from the block and tackle and is attached to the swivel. In addition, the drilling template includes a settling basin into which the drilling fluid is returned from the bottom of the drill hole, and an operator station and winch. The winch is connected to the block and tackle and is used to raise and lower the drill string.

ASSEMBLING THE DRILL STRING

To assemble the drill string, the swivel is attached to the hook and raised to an upward position. At this point, the Kelly bar assembly is attached to the swivel flange by bolting the top flange plate of the top Kelly bar adaptr to the swivel flange plate. The Kelly bar and swivel are then raised again to another upward position and attached to the top of the combination drilling and belling bucket drill stem. This attachment is accomplished by coupling the bottom flange plate of the Kelly bar bottom adapter to the drilling bucket drill stem flange plate. This entire assembly is then raised and centered in the driven casing. The bucket is then lowered into the casing by lowering the block and tackle hook until the swivel, Kelly bar, and drilling bucket assembly reach a lowered position such that the rectangular conduits near the top end of the drilling bucket drill stem are level with the top of the rotary table. At this point pins are set through the rectangular conduits and extending beyond the inside diameter of the rotary table on both ends. Then the drill string is lowered until the set pins support the weight of the entire drill string. At this point the drilling bucket is uncoupled and the Kelly bar and swivel assembly are raised to an upward position and a piece of the reverse circulation drill stem with airlift, is coupled to the bottom end of the Kelly bar. This coupling is accomplished in the same manner as the coupling of the belling bucket. Then this entire assembly consisting of the swivel, the Kelly bar assembly, and the section of drill stem, is centered over the drilling bucket, and the drill stem is coupled to the top of the combination drilling and belling bucket. In this coupling process, O-rings are placed in the grooves around the center and auxiliary pipes, and then the drill stem section is securely bolted to the bucket drill stem. This entire drill string is then raised and the pins removed. Then the drill string is lowered into the casing until the rectangular conduits in the top of the first drill stem section are approximately even with the top of the rotary table. At this point the pins are set into the rectangular conduits and the drill string is lowered until the conduit supports the weight of the drill string. At this point the Kelly bar and drill stem section are uncoupled and the Kelly bar is raised to an upper position. Then a 30-foot section of sucker rod is lowered through the sucker rod auxiliary hole and will engage the threaded end of the drilling bucket elongated member. This sucker rod section is securely screwed into the elongated member, thus forming a continuous, elongated member extending from the bucket carriage assembly up to the top of the drill stem section. Then the O-rings are placed in their respective grooves in the top flange plate of the drill stem section and the operation is repeated until three reverse circulation drill stem sections with airlift have been added to the top of the drilling bucket. At this point the same operation is repeated, except a section of reverse circulation drill stem with air injection is added instead of a section of reverse circulation drill stem with airlift. Then, the operation is repeated with a section of reverse circulation drill stem with airlift. With the addition of this last drill stem section, we then have a drill string below the Kelly bar assembly which is 180 feet long. This puts the top of the drill string at the top of the drill casing, and we are ready to begin the drilling operation.

Although it is optional, one may desire to have the sucker rod disosed within the sucker rod auxiliary pipe of the drill string attached to the sucker rod swivel which is disposed from the hydraulic cylinder bracket of the Kelly bar assembly. This may be easily accomplished by pinning the top of the drillstring through the rectangular conduits in the top drill stem section, disconnecting the Kelly bar assembly from the top of the drill stem section, inserting the sucker rod into the drill stem section and attaching it to the sucker rod in the drill stem section immediately below it, placing the O-rings in their respective center and auxiliary pipe grooves, lowering the Kelly bar into place on top of the drill stem section and coupling it thereto, and then attaching the sucker rod swivel to the top of the sucker rod disposed within the drill stem. At this point, one is ready to begin to drill and remove the soil from within the bottom section of the stell casing.

One additional feature which has not been described at this point is the addition of the stabilizers. This is shown schematically in FIG. 2*b*. Although this feature is optional, it is deemed desirable to add a stabilizer every third or fourth section of the drill stem. The function of this stabilizer is to center the drill stem within the stell casing, thus minimizing any wobble of the drill stem. These stabilizers are frequently provided with roller bearings which allow the drill stem disposed within the stabilizer to freely rotate with respect to the outside casing of the stabilizer. This provides a very low frictional guidance and a centering of the drill stem within the steel casing. An additional feature is that the stabilizers are provided with openings extending from their top surface through the entire stabilizer assembly area. The purpose of these openings is to provide passages for the free flow of drilling fluid in the vertical direction.

It should also be noted that the purpose of positioning the reverse circulation drill stem section with air injection in the particular location chosen is that for optimum efficiency in the drilling operation it is desirable to have the air injection section at its highest possible location in the drill string. Experience has shown that the air injection should occur at a distance of approximately 60 feet below the water surface. The particular sequencing of drill stem sections just described approximates this location of the air injection.

THE DRILLING OPERATION

At this point the drilling operation may be begun by lowering the drill string such that the Kelly bar is lowered into the rotary table with its longitudinal ribs engaging the teeth of the rotary table ring gear. The drilling operation is begun by rotating the rotary table in a clockwise direction at approximately 33 rpm. The rotary table engages the ribs of the Kelly bar and rotates the drill stem in a clockwise direction. At the same time, air pressure is applied from an air compressor through the swivel inlet port. As previously described, the air cavity within the swivel body upper housing is coupled to the Kelly bar auxiliary air pipe which is in turn coupled to the auxiliary air pipe of the drill stem sections. That is, the auxiliary pipe oppositely disposed from the sucker rod auxiliary pipe. The air passes down through this continuous conduit until it reaches the air injection holes at the bottom of the air injection drill stem section. At this point the air will enter into the center pipe and will naturally bubble up through the center pipe of the drill stem section into the center pipe of the Kelly bar assembly to the center pipe of the swivel spindle, which in turn is coupled to the elbow attached to the top of the swivel body. This bubbling action sets up a lift within the center pipe which draws fluid from the bottom of the center pipe, that is, from the bottom of the combination drilling and belling bucket, and lifts the fluid up to and through the swivel assembly. From the swivel elbows, the fluid is discharged into a settling basin. In the settling basin, the drilling chips settle out to the bottom of the fluid, and the clean drilling fluid is returned to the drill casing. Thus, a circulation is established between the annular region defined between the outside surface of the drill stem and the inside surface of the casing to the bottom of the drill hole and back up through the center pipe of the drill stem to the swivel elbow and discharged into the settling basin. From the settling basin the fluid is returned to the steel casing for recirculation. During this recirculation process, the drilling fluid picks up the drilling chips from the bottom of the drill hole and deposits them into the settling basin.

The vertical cutting rate is established by the rate at which the drill stem is lowered during the drilling process. This rate is approximately 12 feet per hour. When the drill hole has been increased in depth by approximately 30 feet, the Kelly bar is in its lower position. In this lower position the ring gear of the rotary table is near the top of the Kelly bar and the Kelly bar has been lowered through its entire travel through the ring gear of the rotary table. At this point it is necessary to add a new section of reverse circulation drill stem with airlift. This is accomplished in the manner previously described. This drilling process is continued with new sections of reverse circulation drill stem with airlift added until a drill hole depth of 450 feet is accomplished. At this point the bucket bottom is at the bottom end of the steel casing. The drill hole is continued on for a distance slightly greater than the vertical height of the combination drilling and belling bucket.

SAMPLING SOIL OF THE OCEAN FLOOR

At this point, the Kelly bar assembly is disconnected from the top of the drill stem and a soil sampler whose outside diameter is slightly less than the inside diameter of the air auxiliary pipe is passed down through the air auxiliary pipe of the drill stem. The soil sampler passes down through the air auxiliary pipes of the drill stem sections to the air auxiliary pipe of the bucket drill stem. As previously noted, the bucket drill stem auxiliary air pipe terminates at approximately the midpoint of the longitudinal axis of the bucket drill stem. However, as previously noted, the air auxiliary pipe of the bucket drill stem aligns with an auxiliary bored hole in the end plates of the bucket carriage assembly. In turn, the opening between two of the bucket bottom blades is aligned with the coincident center lines of the air auxiliary pipe of the drill stem and the bored holes in the carriage assembly top and bottom plates. Hence, the soil sampler can pass through the carriage assembly by passing through the bored holes in its end plates and it may pass on down through the bottom of the drill bucket to the soil in the bottom of the drill hole. A soil sample is then taken from the bottom of the drill hole, and the soil sampler is retrieved. The soil is then tested and if it is determined that the soil is appropriate, the bottom of the drill hole will then be belled out to form an enlarged cavity to anchor the oil well drilling platform leg.

BELLING OUT THE HOLE

The necessity for the enlarged cavity at the bottom of the drill hole is created by the severe environmental conditions that exist in areas such as the North Sea. During "calm seas" it it not uncommon to have 17-foot high swells in the ocean surface. During rough weather, winds frequently develop velocity in excess of 110 miles per hour. Obviously, the ocean swells become much worse in such weather, and, in addition, these swells are given high lateral force. The combined action of the ocean swells and wind exert both high vertical thrust forces on the platform and high lateral forces acting horizontal to the ocean surface. Hence, it is necessary to anchor the platform legs into the ocean floor.

This anchoring is accomplished by forming an enlarged conical cavity at the bottom of the leg drill hole. The purpose of the present invention, the combination drilling and belling tool, is to drill the leg hole and form the enlarged cavity at its bottom end, with a single pass of the drill tool down the hole. After the drill hole has been drilled to the necessary depth, and the soil sample has been tested, the Kelly bar and sucker rod swivel are reattached to the drill stem and the drill stem and the combination drilling and belling bucket are held in a fixed vertical position at the bottom of the drill hole. The drill stem and the drill bucket are then rotated in a counter-clockwise direction, that is, the reverse direction of rotation from that used during the drilling operation, by operating the rotary table such that its ring gear is driven in a counter-clockwise direction. The ring gear then drives the Kelly bar in a counter-clockwise direction, which in turn drives the drill stem and bucket in a counter-clockwise direction. The bucket is preferably rotated at an angular velocity of about 11 rpm during the drilling operation. Concurrent with the counter-clockwise rotation, the belling baldes are extended by actuating the hydraulic cylinders disposed within the Kelly bar. The hydraulic cylinders are driven in the upward direction at a controlled rate, which in turn causes the carriage assembly disposed within the combination drilling and belling tool to be driven in the upward direction at the same controlled rate. As previously described, the upward displacement of the carriage assembly relative to the bucket frame causes the extension of the belling blades. As the belling blades extend, the mining teeth disposed on their outside surfaces engage the wall of the drill hole and cut a cavity of the desired geometry. As the soil is removed from the cavity wall by the blades, the drill chips are directed to the center and bottom of the drill bucket by the combined actions of the wedge-shaped blade and the reverse circulation of the drilling fluid. These chips are then picked up and carried with the fluid as it rises through the center pipe of the drill stem and is discharged into the settling basin. The belling operation may be monitored by following the vertical rise of the belling blade indicator previously described. When the belling blade indicator is raised to its top position, the blades are in their fully extending position, and the conical or bell-shaped cavity at the bottom of the drill hole is fully formed.

At this point, the hydraulic cylinders are then actuated in the opposite direction. That is, the pistons are driven in the downward direction, which in turn drives the carriage in a downward direction and retracts the blades into the recesses provided in the bucket. The final step of the drilling operation is then to simply remove and disassemble the entire drill string.

COMPLETING THE PLATFORM

When one leg hole and bell have been drilled out, the drilling tower is then moved to another new drill casing to drill the next hole. To complete the leg construction, steel reinforcing is lowered into the drill casing. The steel reinforcement extends from the cavity up to the top of the drill casing. Concrete is pumped into the drill hole, and a solid steel reinforced concrete structure filling the drill hole and cavity is thereby formed. This completes the construction of one of the legs. The process is repeated until all of the drilling platform legs have been formed.

As will be understood by those skilled in the art, what has been described are preferred embodiments in which modifications and changes may be made without departing from the spirit and scope of the accompanying claims.

What is claimed is:

1. A combination drilling and belling tool for drilling an underground hole and then belling out a portion of the hole into a conical configuration on a single pass comprising:

- a generally cylindrical frame, the lower end of said frame forming a drilling bucket bottom;
- said frame having at least two exterior recesses formed in circumferentially spaced positions thereon and extending a substantial distance lengthwise of said frame;
- at least two elongated belling blades, said belling blades being normally received in respective ones of said recesses;
- means provided at the upper end of each of said recesses for pivotally supporting the upper end of the associated belling blade, whereby the lower end of each belling blade is movable in an arcuate path away from said frame;
- operating means coupled between said frame and said belling blades for selectively extending said blades in unison;
- and an elongated member disposed within and longitudinally movable relative to said frame, and coupled to said operating means for extending said blades when said elongated member is pulled upward;
- the intended mode of operation being such that said frame is first driven down and rotated with said blades in their normal position for drilling the hole by means of the drilling bucket bottom, then the downward movement of said drame is stopped and said elongated member is pulled upward while said

frame is rotated in order to accomplish the belling operation by means of said belling blades;

wherein said frame includes a generally tubular outer shell in which said recesses are formed, a tubular drill stem oncentrically disposed within and spaced away from said outer shell, and means at the upper end of said frame supporting said drill stem and said outer shell in fixed relationship to each other; and wherein said operating means includes a carriage disposed between said drill stem and said outer shell and normally positioned near the lower end of said frame, and a plurality of arms having their inner ends pivotally coupled to said carriage and their outer ends pivotally coupled to respective ones of said belling blades; said carriage being selectively movable upward relative to said frame and said elongated member being connected to said carriage for selectively raising the same.

2. A combination drilling and belling tool as claimed in claim **1** which further includes first and second auxiliary pipes, of smaller diameter than said drill stem, and attached to the exterior surface of said drill stem in diametrically opposed portions thereon, said drill stem and auxiliary pipes extending to the upper end of said frame, one of said auxiliary pipes housing said elongated member and extending only a short distance down the length of said frame, the other of said auxiliary pipes being adapted for supply of a pressurized fluid to the hole and extending below the carriage when the carriage is in its lowermost position.

3. The combination drilling and belling tool claimed in claim **1** wherein said carriage encircles said drill stem, and which further includes two pairs of rollers attached to the upper and lower ends of said carriage, respectively, and which rollingly support said carriage upon said drill stem; the inner ends of said operating arms being laterally displaced from the longitudinal axis of said carriage whereby the raising of said carriage tends to produce a counter-torque for rotating said carriage; and which further includes means providing a sliding lock between the outer surface of said carriage and the inner wall of said shell, whereby said carriage may slide up and down within said shell but its rotation is prevented.

4. A combination drilling and belling tool as claimed in claim **1** wherein said carriage encircles said drill stem, and which further includes roller means supporting said carriage upon said drill stem, said drill stem acting both as a track for said carriage and as a conduit for removal of drilling chips from the hole.

5. A combination drilling and belling tool as claimed in claim **4** wherein said drill stem extends to the lower end of said frame.

6. A combination drilling and belling tool for drilling an underground hole and then belling out a portion of the hole into a conical configuration on a single pass comprising:

a generally cylindrical frame, the lower end of said frame forming a drilling bucket bottom;

said frame having at least two exterior recesses formed in circumferentially spaced positions thereon and extending a substantial distance lengthwise of said frame;

at least two elongated belling blades, said belling blades being normally received in respective ones of said recesses;

means provided at the upper end of each of said recesses for pivotally supporting the upper end of the associated belling blade, whereby the lower end of each belling blade is movable in an arcuate path away from said frame;

operating means coupled between said frame and said belling blades for selectively extending said blades in unison;

and an elongatd member disposed within and longitudinally movable relative to said frame, and coupled to said operating means for extending said blades when said elongated member is pulled upward;

the intended mode of operation being such that said frame is first driven down and rotated with said blades in their normal position for drilling the hole by means of the drilling bucket bottom, then the downward movement of said frame is stopped and said elongated member is pulled upward while said frame is rotated in order to accomplish the belling operation by means of said belling blades;

wherein said drilling bucket bottom is provided with blades having cutting edges adapted to cut in one predetermined direction of rotation of said frame, and said belling blades are provided with longitudinal cutting edges which are adapted to cut in the opposite direction of rotation of said frame.

7. A combination drilling and belling tool as claimed in claim **6** wherein the cutting edge of each of said belling blades has a generally wedge shaped cross-section, thereby directing drilling chips towards the center of the drill hole.

8. A combination drilling and belling tool for drilling an underground hole and then belling out a portion of the hole into a conical configuration on a single pass comprising:

a generally cylindrical frame, the lower end of said frame forming a drilling bucket bottom;

said frame having at least two exterior recesses formed in circumferentially spaced positions thereon and extending a substantial distance lengthwise of said frame;

at least two elongated belling blades, said belling blades being normally received in respective ones of said recesses;

means provided at the upper end of each of said recesses for pivotally supporting the upper end of the associated belling blade, whereby the lower end of each belling blade is movable in an arcuate path away from said frame;

operating means coupled between said frame and said belling blades for selectively extending said blades in unison;

and an elongated member disposed within and longitudinally movable relative to said frame, and coupled to said operating means for extending said blades when said elongated member is pulled upward;

the intended mode of operation being such that said frame is first driven down and rotated with said blades in their normal position for drilling the hole by means of the drilling bucket bottom, then the downward movement of said frame is stopped and said elongated member is pulled upward while said frame is rotated in order to accomplish the belling operation by means of said belling blades;

wherein aid operating means includes a carriage disposed within said frame and adapted for vertical reciprocation therein, and a plurality of arms having their inner ends pivotally coupled to said carriage and their outer ends pivotally coupled to respective ones of said belling baldes, said elogated member being coupled to said carriage for selectively raising the same; and

wherein the inner end of each of said operating arms extends beside and beyond the longitudinal axis of said carriage, and is pivotally coupled to said carriage on the side therefrom opposite the respectively associated belling blade.

9. A combination drilling and belling tool for drilling an underground hole and then billing out a portion of the hole into a conical configuration on a single pass comprising:

a generally cylindrical frame having a lower end forming a drilling bucket bottom, and having at least two exterior recesses formed therein;

at least two elongated belling blades normally received in respective ones of said recesses;

means pivotally attaching the upper end of each of said belling blades to said frame whereby the lower end of each belling blade is movable in an arcuate path away from said frame;

a tubular drill stem concentrically supported within said frame and extending to the lower end thereof, thus providing a channel for continuous fluid circulation so as to remove chips from the hole during both drilling and belling operations;

and operating means for selectively extending said blades in unison, including a carriage disposed about said drill stem and a plurality of arms having their inner ends pivotally coupled to said carriage and their outer ends pivotally coupled to respective ones of said belling blades;

said operating means further including an elongated member coupled to said carriage and extending above said carriage beside said drill stem for selectively raising said carriage.

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