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Warder

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[54] **HYDRAULIC ROTARY WELL DRILLING MACHINES**

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[52] **U.S. Cl.** **418/211**; 175/107; 418/217; 418/231

[51] **Int. Cl.** **F03c 3/00**

[58] **Field of Search** 418/231, 230, 228, 229, 418/232, 233, 217, 219, 211, 210, 212-216, 418/218; 175/107, 95, 101

[56] **References Cited**

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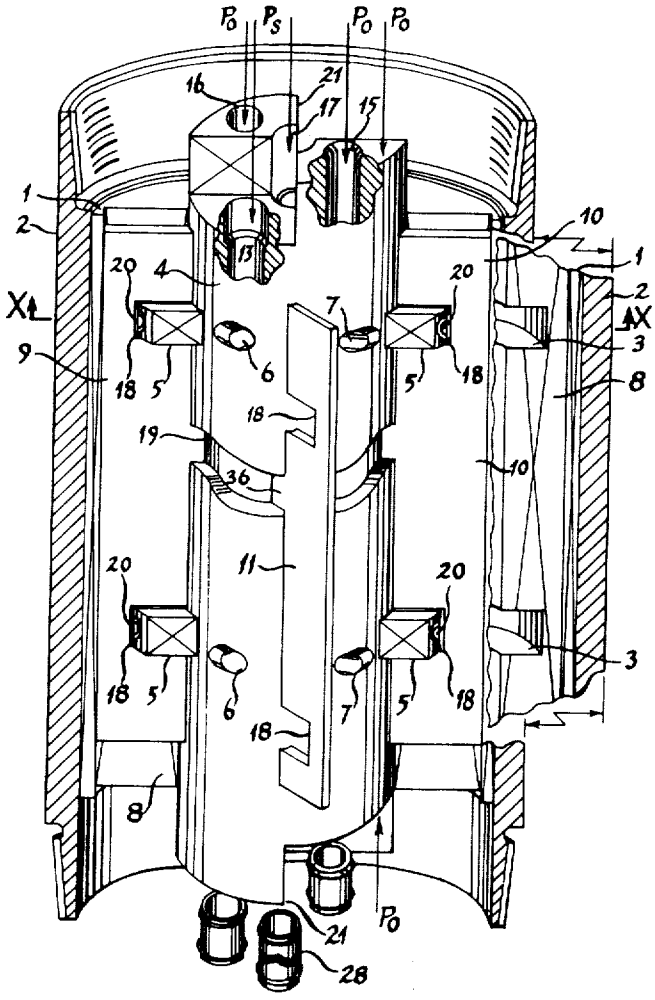
[57] **ABSTRACT**

The object of the invention is to furnish a new and improved form of Hydraulic Rotary Well Drilling Machine actuated by a positive-displacement torque-producing sub-unit or units adapted to thrust-resisting sub-units above and below comprising the assembly of a power-driven rotary tool holder usually known by the general term of "Turbo-drill."

7 Claims, 5 Drawing Figures



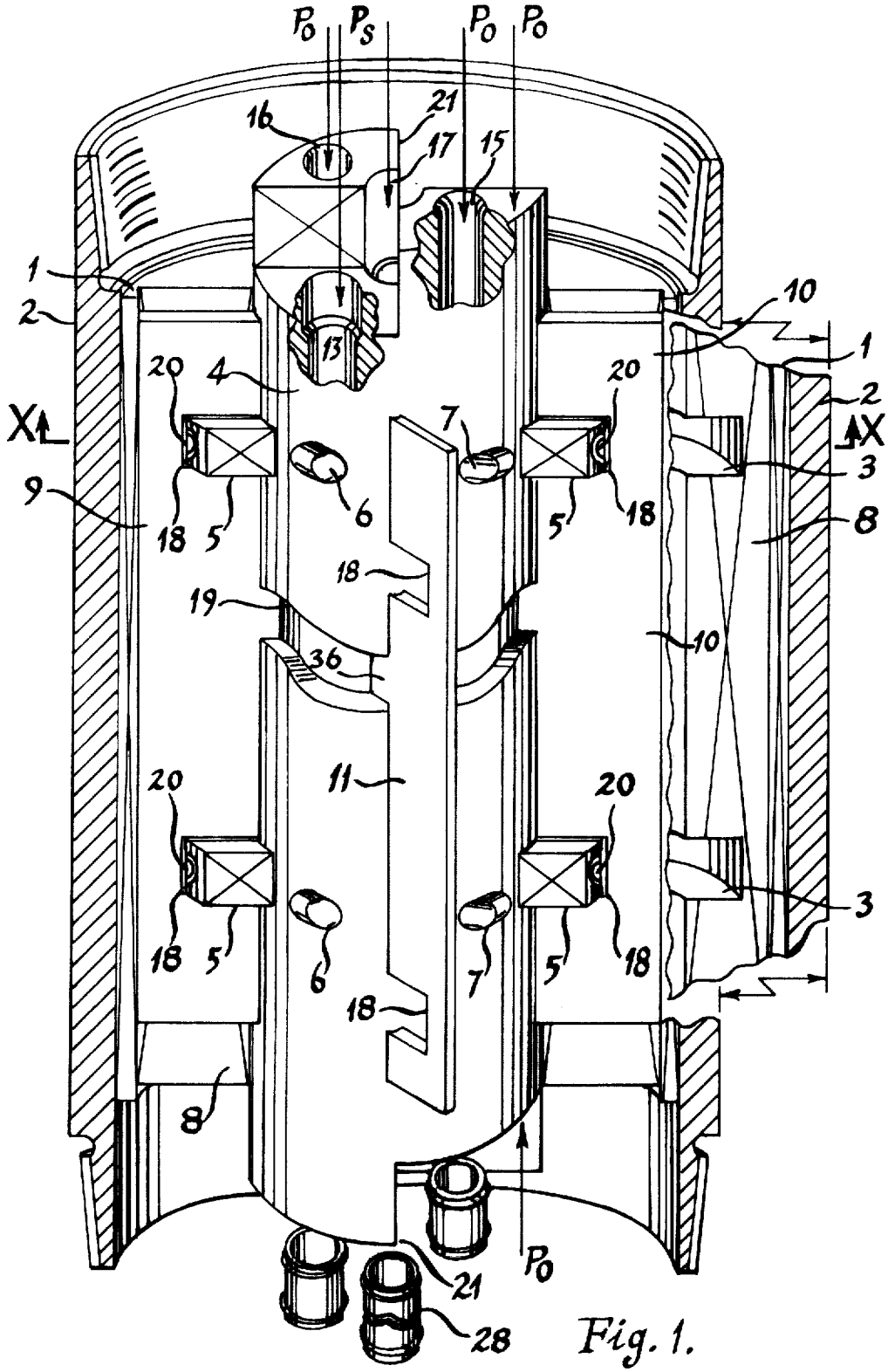

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Fig. 1.

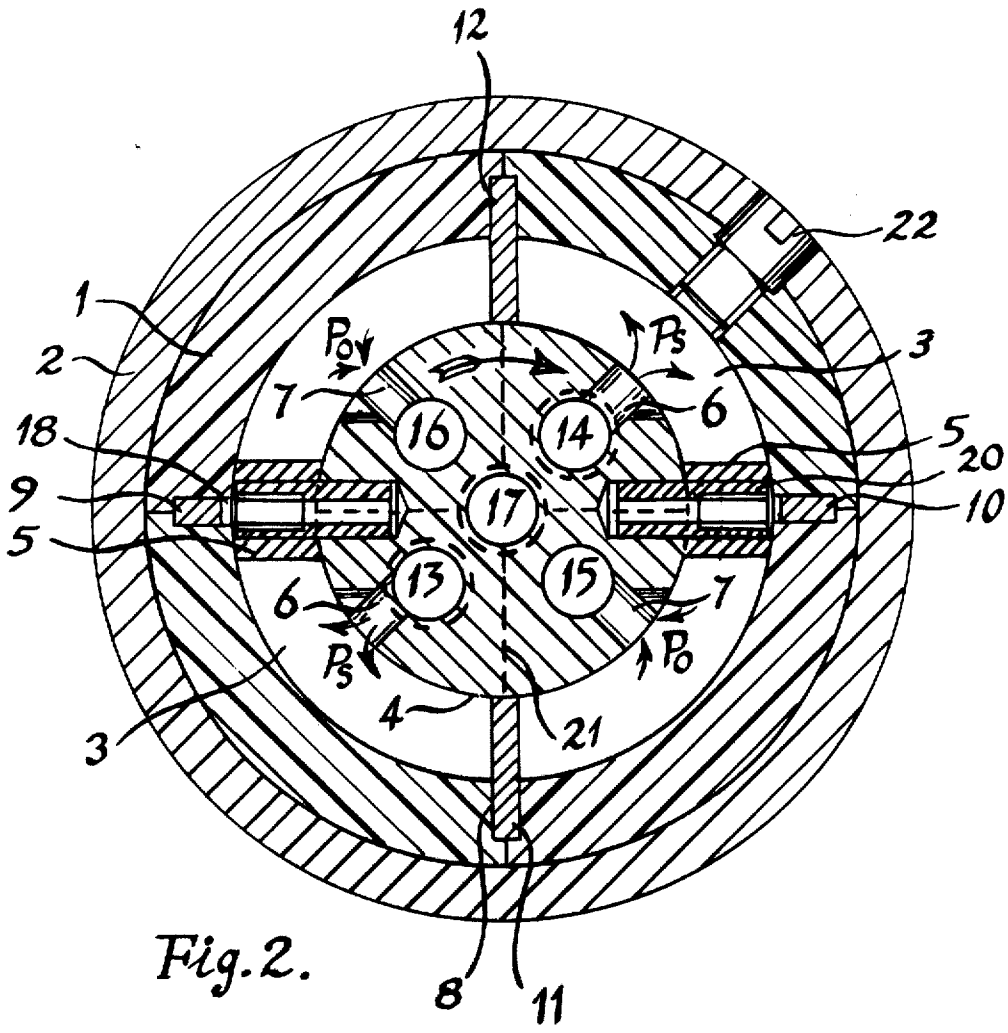

Fig. 2.

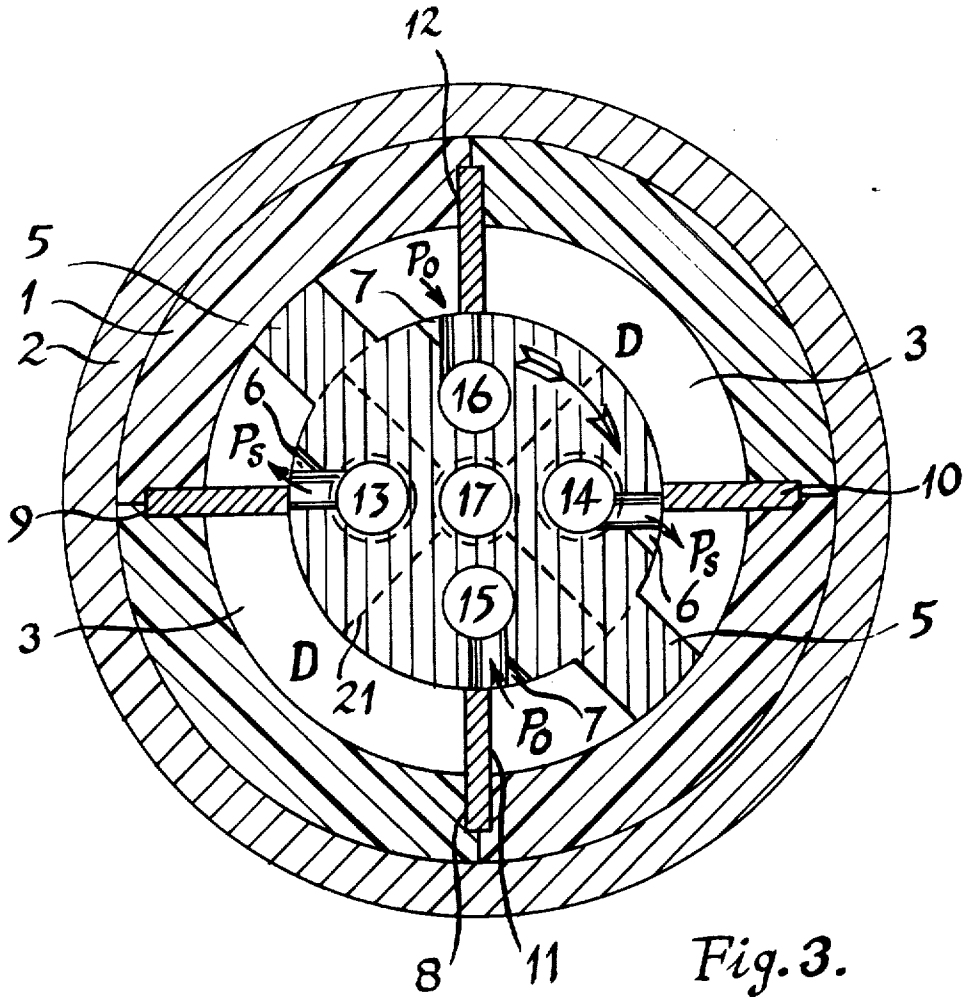

Fig. 3.

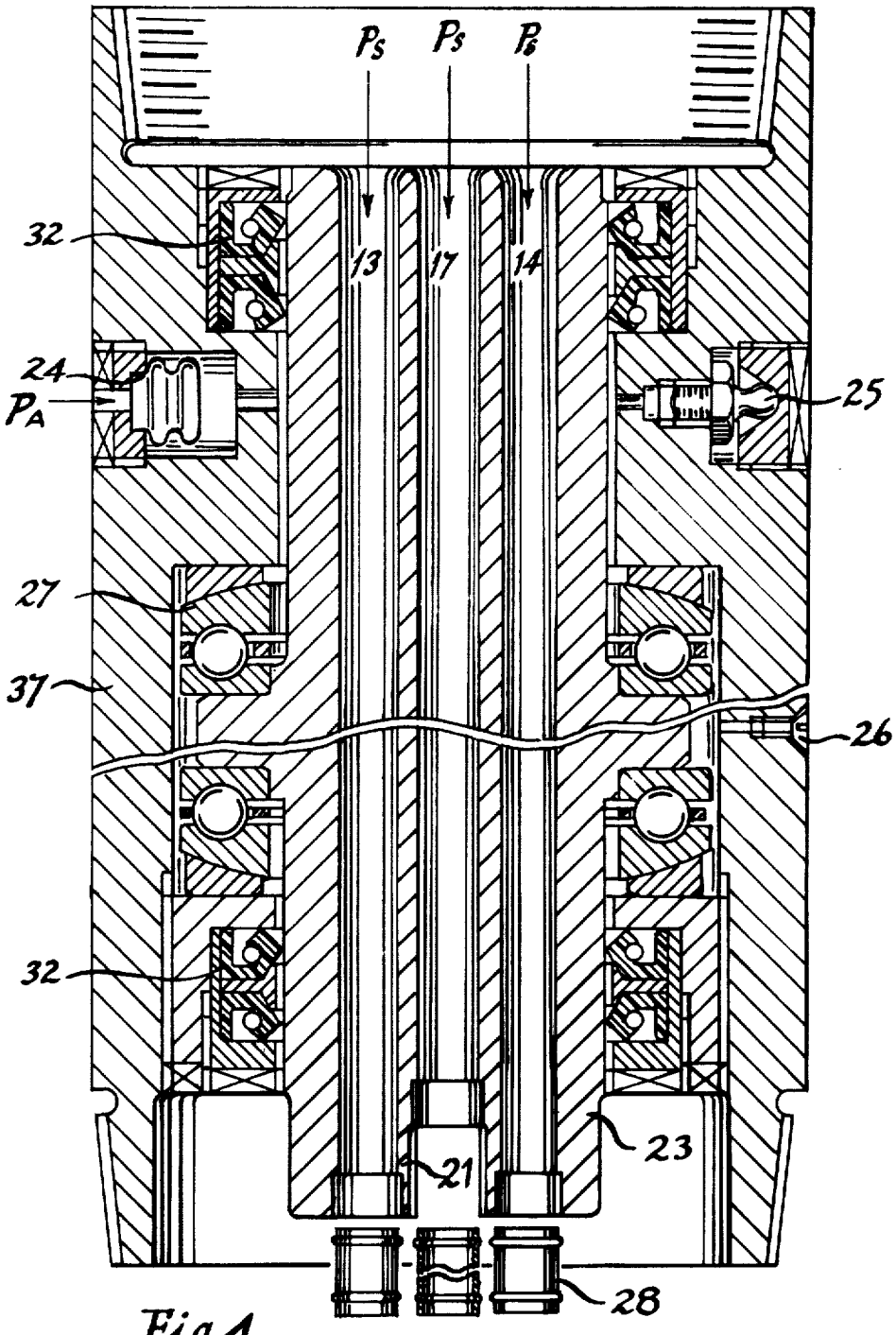

Fig.4.

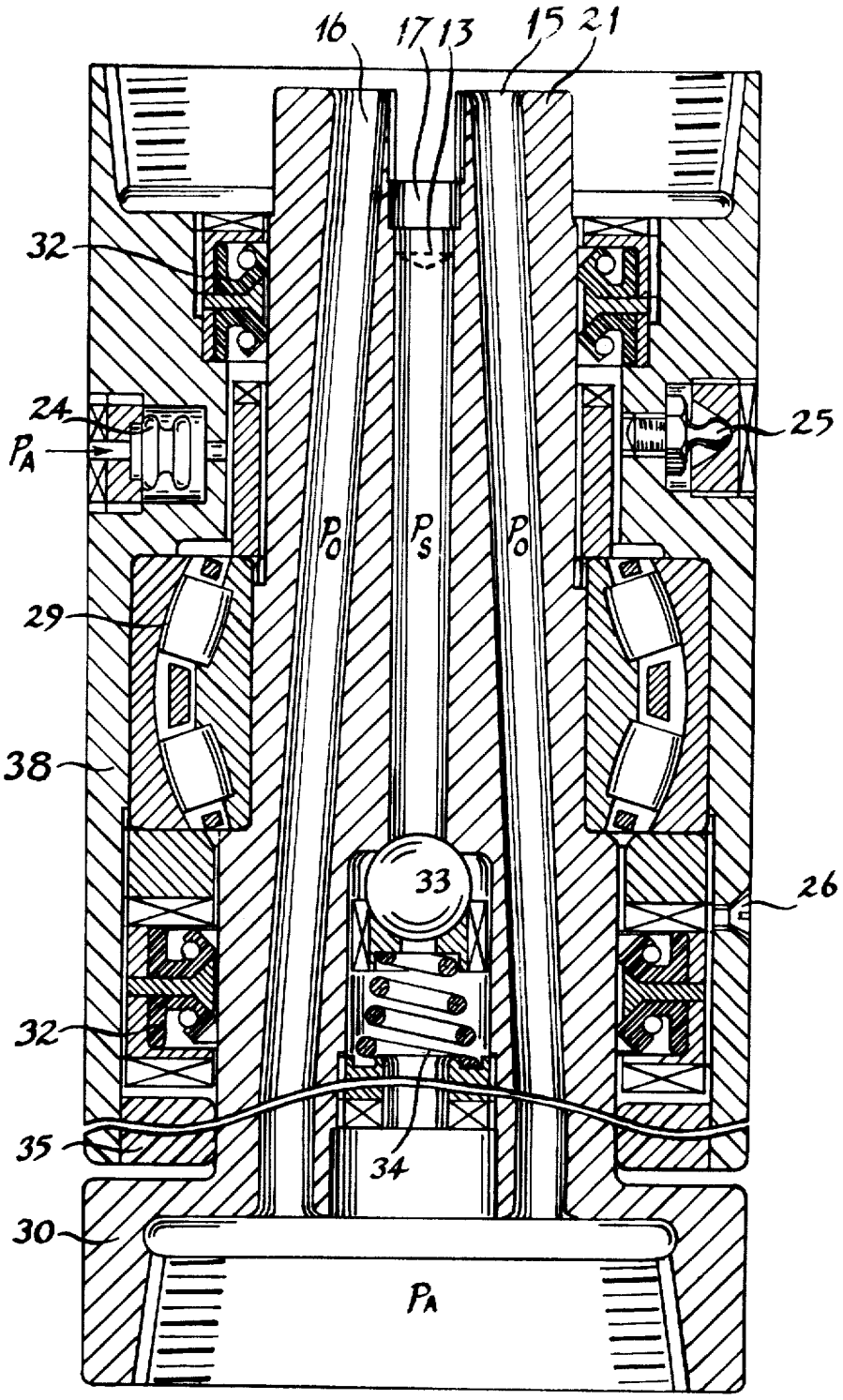

Fig. 5.

HYDRAULIC ROTARY WELL DRILLING MACHINES

The invention consists of certain parts and details and combinations of same, based on one type of machine constructed according to the invention cited, adapted to the practice of rotary well drilling or to other cognate uses, that is to say to tunnel boring, sewer clearing or the like remote rotary tool operating.

In the accompanying drawings:

FIG. 1 is a isometric perspective view, partially cut away and partially displaced, of a torque producing hydraulic motor sub-assembly according to the invention;

FIG. 2 is a horizontal section taken on the plane x-x of FIG. 1 viewed in the direction of the arrows

FIG. 3 is a horizontal section similar to FIG. 2, with the rotor and stator displaced 45° from the position of FIG. 2, and showing a modified construction;

FIG. 4 is a vertical section of a thrust bearing sub-assembly formed to receive and cooperate with one or more of the motor sub-assemblies according to FIG. 1;

FIG. 5 is a similar view showing a rotary tool holder and thrust bearing sub-assembly adapted for assemblage to the lower end of a torque producing subassembly according to FIG. 1.

REFERRING TO THE DRAWINGS IN MORE DETAIL

FIG. 1 is an illustrative sectional view of one hydraulic positive-displacement torque-producing sub-unit, showing a portion of one stator segment 1 broken away to reveal annular recesses or chambers 3, 3 and a slideway 8 for a vane.

The torque-producing sub-unit includes a stator 1 conforming externally to the bore 2 of a drill stem pipe, said stator comprising four segments for case of manufacture and assembly.

The stator 1 has a cylindrical bore, with two internal annular recesses or chambers 3,3 spaced axially and includes four axial radial slots 8 within the bore spaced angularly at 90 degrees in planes including the axis, formed half in each adjacent segment, somewhat deeper than the annular recesses 3,3 forming guideways for vanes.

A rotor 4 has a cylindrical external surface fitting within the stator 1, and includes two pairs of abutments 5, each pair arranged diametrically opposite and in axial alignment in positions to fit closely into and occupy portions of the annular recesses 3,3 formed in the stator 1, dividing each of them into two chambers.

Inlet ports 6 and outlet ports 7 are included in the rotor 4, respectively admitting supply fluid at pressure P/S and passing outgoing fluid at pressure P/O located adjacent to the radial faces of the abutments 5 and so elongated arcuately that during rotation when they are crossing the vanes the hydraulic pressures on the opposite faces of the vanes are equalized, reducing the work of moving them axially.

Four vanes, 9,10,11, 12 essentially not fewer than two for each abutment, are shown, vanes 9,10 being in their axially displaced position so that the abutments 5,5 projecting from the rotor 4 are passing thru their gateways 18,18 while vanes 11 (slightly canted for visibility) and 12 (not shown; se FIG. 2) are in their active positions crossing and dividing two half-chambers 3,3 simultaneously, and receiving the reaction of the hydraulic force P/S acting on the adjacent abutments producing torque. Each pair of abutments exerts a couple about the axis.

Said vanes touch the rotor 4 along one of their edges which match its radius, whilst partially occupying and sliding in the slots 8 in the stator 1.

Passages 13,14,15,16 passing axially thru the rotor 4 communicate with respective inlet and outlet ports 6,7, the passages 13, and 14 (not shown in this FIG., see FIG. 2) containing fluid at supply pressure P/S, and passages 15,16 conveying fluid at the outlet pressure P/O.

A central passage 17 is included in the rotor 4 passing fluid at the supply pressure P/S, leading via a thrust-bearing sub-unit (FIG. 5) assmebled below the torque-producing sub-unit FIG. 1 to a spring-loaded "dumping valve" 33.

The vanes 9.10,11,12 are moved axially in pairs by means of a cam 19 included in the rotor 4, so that a pair of gateways 18,18 in each vane coincides with and allows the passage thru them of the abutments 5,5 at one extremity of the travel of the vanes, and they cross and divide the chambers 3,3 at the other extremity of travel.

When the vanes are in the latter, or active, position, their gateways 18,18, full of fluid, are clear of the chambers which they cross and the vanes are subject to the difference of hydraulic pressure on their opposite faces whilst not in motion.

The cam 19 controlling and displacing the vanes takes the form of a groove in the rotor 4 engaging cam-following projections 36 on the vanes, and having sinusoidal axial ramps and dwell arcuate portions, so that the vanes are displaced with the minimum of work during their simple harmonic motion and are held stationary while said abutments pass thru said gateways and while the vanes are subjected to difference of fluid pressure on their opposite faces in turn.

Means for fixing the abutments 5 to the rotor 4 are furnished by dowels 20, each provided with a tapped hole for its extraction, allowing an uninterrupted cylindrical surface on the rotor 4 to be produced, but other metallurgical methods of manufacture may allow the abutments to be formed integrally with the rotor as illustrated in FIG. 3. Moulding methods of manufacture may be applied to all components, since the closest of fits are not essential the whole may be constructed virtually without machining. All leakage fluid flows usefully thru the tool attached below the lower thrust beaing sub-unit (FIG. 5), and in view of the more than adequate pumping energy usually employed considerable losses due to wear can be accepted. So long as the necessary pressure difference across the inlet and outlet of the hydraulic machine can be maintained, the necessary torque will be produced.

The rotor 4 is furnished at both ends with dog couplings 21 to mate with those of adjacent sub-units above and below, and the passages 13,14,17 each containing fluid at the supply pressure P/S, are coupled to corresponding passages in the adjacent sub-units by connecting sleeves 28.

In the couplings between the rotor 4 and the thrust bearing sub-unit above (FIG. 4) which is blind as regards outlet fluid passages, and between the rotor 4 and thr rotating tool holder and thrust sub-unit below, (FIG. 5) the outlet passages are not coupled by connecting sleeves as 28, so that balanced end-thrust due to the outlet pressure P/O acts on the cross-sectional

areas of both ends of the rotor **4** and the only end-thrust thereon, borne by the abutments **5,5** rotating in the annular recesses **3,3** in the stator **1** is due to the weight of the rotor. The leakage from each end of the rotor mixes with the outlet fluid.

Assembly of the sub-units described into a drill stem may be facilitated by the use of slave guide rods inserted into the passages **13.14,17**, upon which the connecting tubes **28** are slipped, in order to engage the dog couplings **21** whilst each outer pipe is screwed onto the next above.

FIG. **2** illustrates a cross section on X—X (FIG. **1**) showing an angular position at which two vanes **9,10** are fully displaced axially and the abutments **5,5** are passing thru the gateways **18,18**, clearance, full of fluid, being provided on both sides of the abutments which are essentially thicker than the vanes, to reduce the requirements of precision in the cam mechanism, and also at the "lintels" of the gateways.

Two vanes **11,12** are shown dividing the half-chambers **3,3** providing reaction to the fluid pressure propelling the abutments **5,5**. Means for resisting the torque reaction of the stator **1** upon the drill-stem tube **2** are shown typically by the "fitted" screw **22** and the relative angular positions of successive stators **1,1** upon screwing together torque-producing sub-units is of no account so long as the dog couplings **21** between successive units do not "bottom"

FIG. **3** illustrates the same cross-section as in FIG. **2**, but with the rotor turned through an angle of 45 degrees relative to the stator.

It is essential in the practise of well drilling that the threads between the lengths of drill pipe be always tightened, and as the normal direction of operation can be taken as clockwise viewed from above the direction of rotation of the hydraulic machine is such that its torque reaction tightens the connecting threads.

The outer drill pipe is rotated at slow speed by means of the well-known "Kelly" above to avoid sticking in the borehole, and the tool is driven faster in the same direction by the means here described.

At the angular position shown in FIG. **3** in the cycle of operation of the hydraulic machine, torque is being produced by the abutments **5,5**, the hydraulic pressure P/S reacting upon the vanes **9,10** crossing the chambers **3,3**, the inlet ports **6,6** having just passed the now active vanes wilst the outgoing fluid at pressure P/O is continuously passing thru the outlet ports **7,7**. At this instant in the cycle, and for a brief arcuate distance, "dead" volumes of fluid D,D are trapped at constant volume between the vanes **9,11** and **10,12**. These volumes of fluid shortly mix with the outgoing fluid so that the passage of fluid thru the machine is continuous and uninterrupted, and the torque is constant.

FIG. **4** illustrates an upper thrust-bearing sub-unit primarily acting to relieve the rotor **4** (FIG. **1**) of the torque-producing sub-unit below of unbalanced end-thrust due to the supply-pressure fluid P/S. The thrust-bearing rotor **23** is drilled axially providing passages **13,14,17** to pass fluid at supply pressure P/S from the drill stem tubing e.g. via a component known as a "drill collar" the weight of, which is not, however, imposed upon the thrust bearing of this sub-unit.

The positions in the rotor **23** opposite the outlet passages in the sub-unit below are left blind, so that whilst supply pressure P/S acts on the upper end face of the rotor **23**, outlet pressure P/O acts upon an equal area of its lower face.

Well-known self-aligning double thrust rolling bearings **27** are employed, essentially lubricated by an arrangement to minimize the leakage of grease or the ingress of the very hostile "mud" or slurry fluid. These means include a resilient plug **24** illustrated in the form of a blind-ended bellows mounted in the unit housing **37**. The bearing is pre-charged with grease via the nipple **25**, excluding air via the air vent plug **26**, finally compressing the bellows which are also filled with grease acted upon by the external pressure P/A.

In service, the ambient pressure P/A acting without and within the pipe stem and sub-units and contained within the earth may be say 4000 lbs. per sq. inch, but the grease will compress only according to its volumetric strain, with minimal tendency to leak.

The grease seals **32** of the sub units will, however, be subjected to the difference of pressure P/S minus P/O actuating the torque-producing machine, this pressure difference being of moderate magnitude, say 350 lbs. per sq. inch.

While the threads connecting the various sub-units are standard in the well-drilling industry, those of the various inserts and locking rings may be chosen of a self-locking pitch to diameter ratio. Close radial fits are not essential, as the dog-couplings must not bind.

FIG. **5** illustrates a rotating tool holder and thrust bearing sub-unit as for a rotary well drilling or coring bit to be assembled below the torque-producing sub unit or units (FIG. **1**), furnished with a well known type of self-aligning rolling thrust bearing **29** selected for the heavy loads involved.

The lubricating and sealing arrangements illustrated are as for the upper thrust-bearing sub-unit (FIG. **4**)

It is noted that the lowermost pipe thread is inverted, as in well-drilling practise.

This sub-unit, shown shortened in FIG. **5**, may be extended below the thrust bearing **29** to give adequate stability to the tool holder **30** in an elongated bearing **35**, so incurring minimal misalignment to the dog-coupling **21** connecting it to the sub-unit above.

The central passage **17**, coupled to the sub-unit above by a connecting sleeve **28** (FIG. **1**), is terminated by a "dumping valve" **33**, illustrated as a ball valve loaded by a varying rate coil spring **34** set for a somewhat higher lifting pressure than that required in the hydraulic fluid supply when the machine is exerting its maximum torque before stalling, thus giving the drilling operator an indication of the condition, upon which the downward force is relieved by the draw-works.

All the fluid pumped down the well continues to discharge through the tool, and continues to force spoil up the borehole clearance E/C around the drill-stem when stalling occurs.

The two passages thru the sub-unit above (FIG. **1**) containing fluid at the supply pressure P/S are coupled to the bottom thrust bearing rotary tool-holder **30** by means of connecting sleeves **28,28**, but these fit into blind bores in the rotor **30** in order to seal off said passages using common components. The open passages **15,16** thru the rotor **30** convey outlet fluid to the tool.

Double thrust bearing provision **29** allows for the forcible withdrawal of a stuck tool.

In the unlikely event of a complete seizure of the hydraulic sub-unit or units, drilling can be continued without withdrawal by speeding up the "Kelly."

The sequence of assembly of the lower part of a well drain-stem from the top is as follows: To the series of drill pipes may be attached a drill collar of great weight in order to feed the tool and to ensure tension at all times in the drill stem; any "bent sub" unit which may be employed for directional drilling; a "bypass" valve of well known pattern, if used, discharging radially into the borehole clearance and set a somewhat higher lifting pressure than that of the valve **33** illustrated in FIG. **5** in order to give the drilling operator an indication of a stalled condition completely blocking the flow of fluid from issuring around the tool; the upper thrust-bearing sub-unit described (FIG.**4**); one or more torque-producing sub-units described (FIG.**1**); the rotating tool holder in the lower thrust-bearing sub-unit described (FIG.**5**), and the tool.

The term "tool" is here used in its widest sense and includes a rotary earth-boring or coring bit, or other form of cutting, scouring, or penetrating device which may rotate, reciprocate, expand and contract, or urge axially with rotary actuation of its mechanism.

Having thus fully described my invention, I claim as new and desire to secure by Letters Patent:

1. A hydraulic rotary well drilling machine comprising:

a. a first thrust bearing unit adapted to be secured to the lower end of a drill stem,

b. a set of units comprising one or more torque producing units and adapted to be secured seriatim to the lower end of said first thrust bearing unit,

c. a second thrust bearing unit adapted to be secured to the lower end of said set of units,

d. each of said units (a), (b) and (c) comprising an outer member and an inner member relatively rotatable therein, said outer members comprising mating coupling elements at their ends for assembling them together and said inner members comprising mating dog couplings at their ends for coupling said inner members to rotate together,

e. said torque producing units of said set each having at least one hydraulic motor chamber therein between said outer and inner members with inlet and outlet ports thereto,

f. the inner members of said set of units having pressure fluid inlet passages extending longitudinally therethrough for mutual alignment when said units are assembled, and also having separate fluid outlet passages extending longitudinally therethrough for mutual alignment when said units are assembled, said inlet and outlet ports being formed in said inner members and communicating, respectively, with said inlet and outlet passages therein, and said inlet passages being sleeve coupled between units of said set,

g. said first thrust bearing unit having a pressure fluid supply passage therethrough connecting to said inlet passage when said units are assembled, and also sealing off said outlet passage when said units are assembled,

h. said second thrust bearing unit comprising mounting means for attachment of a well drilling tool thereto and sealing off said inlet passage when said units are assembled and having a relief-valved passage therethrough coupled to said third passage.

2. A machine as claimed in claim **1**, the units of said set and said second thrust bearing having a third pressure fluid passage extending longitudinally therethrough and communicating with said supply passage and sleeve-coupled between units when said units are assembled, and said second thrust bearing unit having a pressure relief valve therein communicating with said third passage.

3. A hydraulic rotary well drilling machine comprising, in combination, a set of units including at least one torque producing unit, said torque producing unit including:

a. a first member having a cylindrical bore with an annular groove therein,

b. a second member rotatably fitting in said cylindrical bore and having spacedprojections fitting in said annular groove and with said second member defining fluid chambers in said groove,

c. each said chamber being sub-divided by at least two longitudinally slidable vanes per projection, said vanes being carried in slideways in the bore of said first member equally spaced in planes radial to said groove,

d. cam means on said second member coupled to said vanes for longitudinally sliding said vanes in said slideways,

f. said vanes bearing thinner then said projections and each vane having a fluid filled cut-out coinciding with and allowing passage therethrough of a projection when in one cam-controlled dwell position and crossing and sub-dividing the chamber when in another cam controlled dwell position,

g. said second member having longitudinal fluid inlet and outlet passages therethrough open at both ends of said second member and having inlet and outlet ports connecting said passages to said chambers, respectively, adjacent to opposite faces of said projections,

h. said second member having at its respective ends dog coupling units and sleeve means for sealing said inlet passage and having a third fluid passageway extending therethrough not in communication with said groove,

i. said ports being elongated arcuately to a sufficient extent to bridge said vanes for pressure equalization during sliding of said vanes,

j. said first member having threaded coupling elements at respective end adapted to mate with adjacent units of said set;

said drilling machine further comprising thrust bearing units with threaded elements mating with said coupling elements for enabling assembly of said set between said thrust bearing units,

said thrust bearing units comprising means for closing said inlet passage at the lower end of said set and for closing said outlet passage at the upper end of said set.

4. A positive-displacement hydraulic rotary torque-producing machine adapted to the practice of well drilling and cognate purposes for rotating tools, comprising a unit comprising a first rotor member of cylindrical form closely fitting within a second cylindrical stator member arranged for relative rotation, the rotor carrying abutments projecting from its cylindrical surface in sets equally spaced arcuately and said sets spaced axially to rotate within and to partially occupy and to subdivide annular grooves formed within the stator and correspondingly spaced axially, said rotor including arcuately elongated ports for the admission and outlet of hydraulic fluid to and from the sub-division of said annular grooves in the stator, located adjacent to the

faces of said abutments, and the stator including grooves arranged longitudinally within its bore in planes including the axis somewhat deeper than said annular grooves therein, forming slideways for vanes, vanes slidably mounted in said slideways, said vanes touching the rotor and being essentially thinner than the abutments and essentially two in number for each abutment in one annular groove, each of said vanes having gateways therein correspondingly spaced to coincide with and to allow passage of said abutments simultaneously during rotation when in one axial position and said vanes crossing and subdividing said portions of annular grooves when in another axially displaced position with their gateways, full of fluid, clear of said annular grooves, there being at all times at least one vane crossing and dividing portions of annular grooves between abutments simultaneously (a) to receive hydraulic pressure reaction to the forces rotating the abutments, and (b) at one arcuate portion of the rotation of the rotor to trap "dead" volumes of fluid between adjacent vanes at constant volume shortly releasing it to mix with outgoing fluid in its uninterrupted passage through the machine, generating constant torque, such axial motion of the vanes being controlled by a cam groove in the rotor having sinusoidal axial ramps and having dwell arcuate portions engaging cam-followers projecting from said vanes so that the vanes are moved back and forth between their dwell positions essentially whilst the ports are crossing them in order to equalize the hydraulic pressures acting on opposite faces of the vanes to reduce the work of moving them, said gateways having clearances full of fluid at each side of the abutments to reduce the requirements for precision in said cam mechanism, and at the "lintels" of said gateways, said rotor including passages passing thru it in an axial direction admitting and allowing exit of fluid by interconnecting respective inlet and outlet ports leading fluid to and from the subdivided portions of said annular grooves in the stator simultaneously, and also an axial passageway conveying fluid not in communication with said grooves, dog couplings at each end of said hydraulic machine rotor to mate with rotors of units attached above and below said machine, said couplings being furnished with sleeves to connect and isolate the passages thru successive coupled units which convey inlet fluid, the passages conveying outlet fluid essentially not being connected by such sleeves in order to equalize end thrusts upon said rotor and to allow leakage fluid from each end of said rotor to mix with outgoing fluid, such torque-producing hydraulic machine essentially being capable of combination with a thrust-bearing unit above and a thrust-bearing unit below said hydraulic machine, the latter forming a rotating tool holder

5. A positive displacement hydraulic rotary torque-producing machine according to claim **1** having a plurality of said units coupled together and to a first thrust-bearing rotor contained in an attachable housing having axial passages thru it corresponding to the supply fluid passages in the hydraulic machine rotor and connected thereto by isolating sleeves but being blind opposite the outlet fluid passages in said hydraulic machine rotor in order to relieve it of excess end thrust due to supply pressure fluid.

6. A positive-displacement hydraulic rotary torque-producing machine in accordance with claim **5,** said plurality of coupled units being coupled to a second thrust bearing rotor at the opposite end of the assembly forming a rotating tool holder, and having its housing similarly attachable and its rotor furnished with open-ended passageways thru it to convey outlet fluid to tool and with an axial passageway to correspond to the central thru passage in the hydraulic machine rotor and connected thereto by an isolating sleeve, said axial passage closed by a spring-loaded "dump" valve set to lift at a pressure limiting that applicable to actuate the hydraulic machine, blind bores being furnished in the rotor to receive isolating sleeves sealing off the passageways in the hydraulic machine rotor containing supply-pressure fluid.

7. A positive-displacement hydraulic rotary torque-producing machine according to claim **6,** said thrust bearing units being furnished with lubricant-retaining devices including resilient blind-ended bellows or diaphragms so that when the assembly of associated units is in conditions of great hydraulic pressure without and within, as in well drilling, the lubricating fluid can be compressed only to the extent of its volumetric strain with minimal leakage or ingress of hydraulic fluid to the bearings.

* * * * *