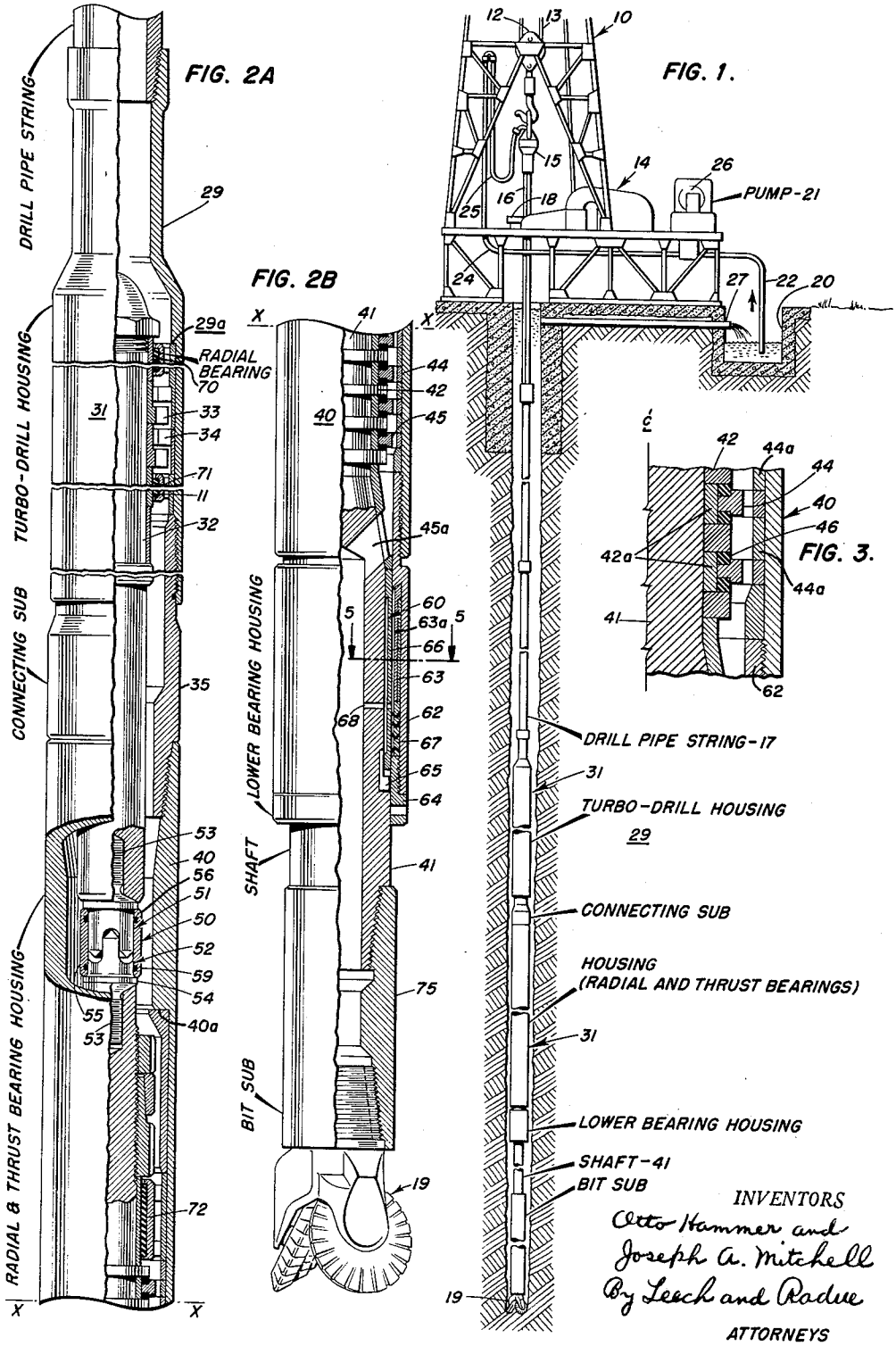
Dec. 1, 1964 O. HAMMER ETAL 3,159,222

TURBODRILL

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TURBODRILL

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FIG. 4A.

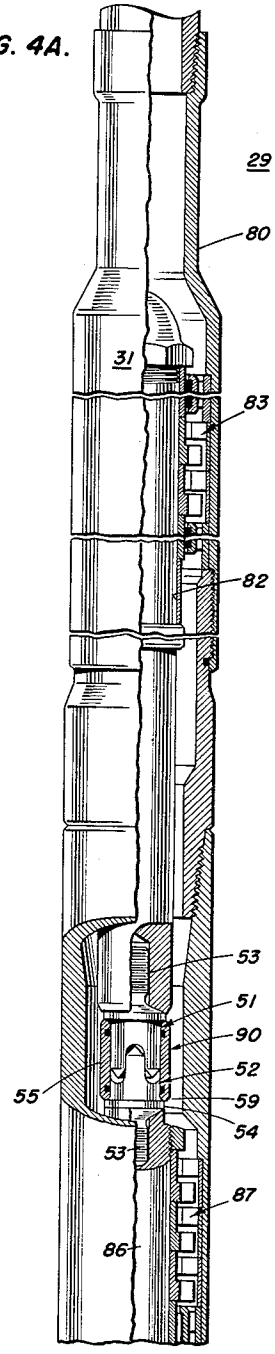


FIG. 4B.

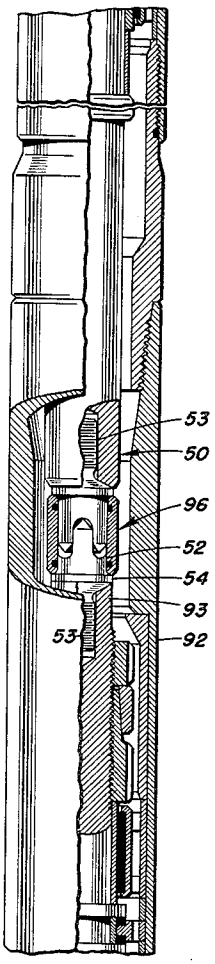


FIG. 4C.

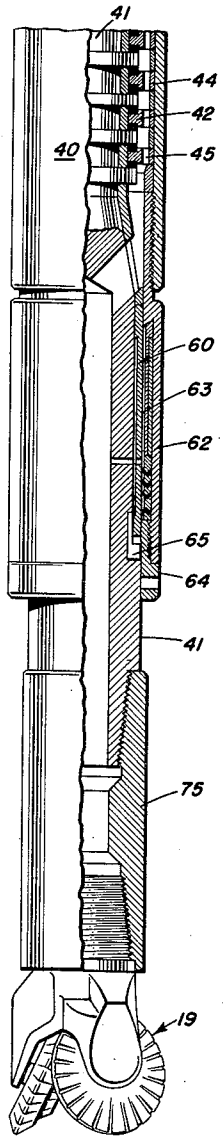
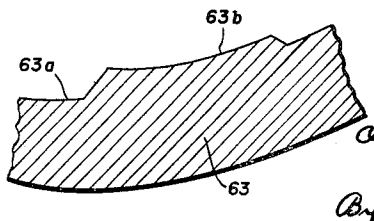


FIG. 5



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TURBODRILL

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8 Claims. (Cl. 175—107)

The present invention relates to a turbodrill or fluid driven turbine that is carried on the end of a drill string and, actuated by the downflowing drilling fluid, drives a rotary drill bit for the down-hole drilling of oil wells and the like.

Although the turbodrill has been known for a number of years, as evidenced by Cross Patent No. 142,992 issued in 1873, and Westinghouse Patent No. 307,606 issued in 1884, it is only in very recent years that the basic turbodrill invention has advanced the turbodrill toward a state of commercial usage. There were various technical reasons for the delay, such as the early development of direct rotary drilling which, following its adoption around 1900, became the acceptable procedure. Rotary drilling remains the standard procedure in this country, and from the standpoint of feet drilled per hour of operating time, it has not as yet been commercially superseded.

However, the early concepts of turbodrill operation and subsequent modifications have led the inventively minded in this field to give a great deal of consideration to the realization of the great economies which this form of drilling could afford. These are evident, because in rotary drilling there may be as much as 90% energy loss due to the friction of the rotary pipe in the bore hole. Moreover, the effect of the heavy loading on the bit, which now runs as much as 40,000 to 100,000 pounds, not only requires very heavy drill collar sections, but under many circumstances results in angular deviations in drilling that exceed the permissible limits for well bore verticality. With a reduction of load on the bit, there is an attendant reduction in rate of penetration and frequently supplemental equipment such as whipstocks must be used to correct these deviations.

The use of a turbodrill has the distinct advantage over rotary drilling in that the driving torque is close to the bit. It utilizes the drilling fluid which is necessary for removing the cuttings from the well and it can be made of adequate power to permit rapid drilling. The direct drive multiple stage type turbodrill does have a somewhat higher rotational speed as compared to normal rotary operation but with improved bits, the turbodrill can be expected to drill considerably faster and cheaper than is possible with rotary drilling.

A turbodrill is, however, a down-hole engine which operates in a fluid-laden well bore and the atmosphere of highly abrasive fluid stands in the way of any normal lubrication of the wear parts. Its limited diameter, which seldom exceeds twelve inches and is usually in the order of six to eight inches, also limits the internal design beyond that possible with turbines used above ground.

Furthermore a turbodrill is subjected to vertical loading on the thrust bearings which varies from high downward thrust due to the pressure of the circulation fluid on the turbine blades, to a very high upward thrust when the drill string weight on the bit exceeds the hydraulic down thrust on the shaft. With the added factor of the remoteness of operation from the ground level, it will be seen that substantial importance is attached to the mechanical details of design of the unit.

The principal object of our invention is to provide an improved turbodrill structure which has the facility of being readily manufactured, easily repaired or maintained at the rig site, and of greater efficiency with respect

to the application of available power to the bit as compared to previously available equipment.

A more detailed object of the invention is to provide standard unit assemblies for construction into a turbodrill at least one of which will include the vertical thrust bearings and the lower radial bearing which are the critical wearing parts so that field replacement of bearings can be accomplished without full disassembly of the turbodrill.

Another object of our invention is to provide a multi-unit turbodrill assembly having inter-shaft couplings whereby the relative longitudinal position of one or more turbine subassemblies is established and maintained by a separate thrust bearing sub-assembly.

A more specific object of the invention is to provide a relatively low cost sub-assembly of a turbodrill which sub-assembly includes the components which are subject to more frequent replacement and a means for replacing these components more efficiently at the rig site.

A further object of the invention is to provide an effective shaft sealing means at the lowermost bearing to direct all of the drilling fluid into and through the drilling bit circulation ports and prevent the diversion of the normally exhausted fluid which entered into the bore hole annulus to thereby improve the cooling and cleaning effect of the fluid on the drill bit.

Further objects and advantages of our invention will appear from the following description of preferred forms of embodiment of our invention taken in connection with the attached drawings which are illustrative thereof, and in which:

FIGURE 1 is a schematic diagram of apparatus in bore hole drilling attitude in an extended earth bore hole, and illustrating a general arrangement of a turbodrill and its associated parts.

FIGURES 2A and 2B are partially sectioned side elevations of the principal parts of a turbodrill showing the turbine elements producing bit rotation, certain bearing and sealing elements, and a coupling unit for transmitting torque and thrust from the driving shaft to the driven shaft.

FIGURE 3 is an enlarged vertical section of the lower portion of the turbodrill showing a portion of the thrust bearing and the adjacent components of the drilling bit assembly.

FIGURES 4A, 4B, and 4C are enlarged partially sectioned side elevations of the parts of a tandem turbodrill having two driving turbine units and a single thrust bearing unit.

FIG. 5 is a partial transverse cross-sectional view taken substantially on the line 5—5 of FIG. 2B showing a portion of the resilient sleeve bearing.

Referring now to the drawings and to FIGURE 1 in particular, there is depicted in diagrammatic style a drilling derrick 10 and associated equipment, situated over an earth borehole in which drilling equipment is in operating position. The derrick 10 supports a crown block (not shown) from which is suspended a traveling block 12. The traveling block 12 is traversed vertically by movements of a cable 13 which courses around the pulleys of the two blocks and is taken in or payed out by draw-works 14. Carried by the traveling block 12 is a swivel 15 which rotatably supports a kelly 16 which forms the upper element of a tubular drill string indicated generally at 17. The kelly 16 is adapted to be rotated or, alternatively, to be held fast from rotation, by a rotary table 18 which may be driven and braked through gearing from the draw works 14. The drill string 17, which may comprise joined lengths of drill pipe and structures attached thereto, such as drill collars, stabilizers, etc., is terminated by a drill bit 19, as is well understood in the deep well drilling art.

Drilling fluid or mud is drawn from the mud pit 20 by

power-operated pump means 21 through an intake pipe 22, and is forced under pressure into the upper end of the drill string through a pipe 24, a hose 25 and swivel 15. A surge chamber or pulsation dampener 26 may be connected at a suitable point in the pump discharge line to reduce or dampen pressure fluctuations caused by the pump. The drilling fluid, under high pressure, flows downwardly in a stream confined in the tubular drill string 17, and thence through a turbodrill unit indicated generally at 29, and exits through ports formed in the drill bit 19. The fluid or mud then returns to the top of the bore hole by way of the annular space around the drill string 17, carrying with it the material removed by the drill bit 19, and may return to the mud pit 20 through a return pipe 27.

The turbodrill 29 which is mounted close to and directly drives the drill bit 19 also serves to apply downwardly directed force to the bit to load the latter. The "weight" or force applied to the bit is derived from reaction thrust of the turbine rotor blades, and selectively also some of the weight of the drill string elements above the turbine, the latter of which may be varied by regulation of the amount of drill string weight applied to the turbodrill housing. Except as hereinafter made evident, the previously described structures and their function are not of themselves inventions of the applicants.

With reference to FIGURES 2A and 2B of the drawings, the turbodrill as generally shown at 29 includes one or more turbine units 31, each provided with an upper shaft 32 having rotor blades 33 which are alternately spaced with annular stator blades 34 mounted in the turbodrill housing. Conveniently these stator blades 34 and the spacers between them are jammed against a shoulder 29*a* in the turbodrill housing by screwing the connecting sub 35 into the housing as shown in FIG. 2A. The combination of the rotor and stator blades provides a multiple stage turbine unit which is actuated by the drilling fluid, and for typical operations has approximately one hundred pairs of blades or stages that develop from about one hundred fifty to three hundred horsepower. This, of course, will depend upon the drilling fluid circulation rate and is merely intended to reflect the approximate horsepower capacity.

Mounted below the turbine units 31 there is provided a separate bearing sub-assembly or "sub" generally indicated at 40. This includes a lower shaft 41 which has rotating thrust bearing disks 42 separated by spacer rings 42*a*. The alternately spaced stationary annular bearing members 44 having fluid ports 45, are spaced by spacer rings 44*a*. The construction is such that the spacer rings 44*a* and disks 42 are jammed against shoulder 40*a* on the housing 40 by screwing housing 62 into the housing 40 as shown in FIG. 2B. Thus there is both support for and resistance to vertical movement of the lower shaft 41. The spacer rings, through ports 45, permit free passage for the drilling fluid whereby the drilling fluid after it drives the turbine and passes down over the bearings passes through the port 45*a* into the lower shaft 41, and then to and through the drill bit 19.

The extent of this load will be appreciated when it is understood that with one form of turbodrill there is from six hundred to one thousand pounds per square inch pressure drop through the turbine which results in a downward hydraulic thrust of from eighteen to twenty thousand pounds.

If the bit is now moved into drilling position and a loading of eighteen thousand to twenty thousand pounds is placed on the turbodrill casing, the bearing faces in the bearing sub-assembly will float in a balanced condition. If, however, extra weight of the drill string on the bit is found desirable, the bearing faces become reversely loaded to the extent of the difference between the total drill string load and the hydraulic thrust. The stationary members of the bearings are normally covered with some flexible material such as rubber 46 for this reason.

In order to support the turbine by the lower shaft 41 with the necessary spacing between the rotor and stator blades 33 and 34, the upper shaft 32 is coupled to the lower shaft 41 through a coupling generally shown at 50 in FIGURE 2A. It includes two clutch members 51 and 52, each of which has interengaging wedge shape teeth which project from a shank portion 53 which is appropriately threaded into an adjacent threaded bore of the respective shafts 32 and 41. The shank portions 53 have a collar or shoulder section. These clutch members are in turn surrounded by a sealing collar or spacing ring 55 which is of extremely accurate length so as to precisely space the shoulder sections of the clutch members 51 and 52 one from the other. This coupling is more fully disclosed in Patent No. 2,990,895 to Madden T. Works, et al.

Preferably, the sealing collar and spacing ring 55 is provided with suitable channel recesses on the inner wall as indicated at 56 and is adapted to receive gaskets as, for example, resilient O rings, whereby the device becomes pressure tight against the introduction of any abrasive fluid particles. This is especially important in wells where the drilling fluid is heavily laden with abrasive particles.

In accordance with our invention, it now becomes entirely practical to replace the thrust bearing and the radial bearing in the self contained bearing sub-assembly without in any manner requiring disassembly of that unit. It is thus possible quickly to substitute a new bearing sub-assembly for a worn one by merely uncoupling the bearing sub and pulling the shafts apart. Thereafter, by blind stabbing, the new bearing shaft 41 may be engaged with the turbine shaft 32 and with the spacer collar 55 in place, there is again accurate positioning of the rotor and stator blades in the turbine with the bearings 42 and 44 carrying the thrust loads.

Shop repair of the bearing is also simplified when excessive wear requires replacement or adjustment of the thrust bearings. It is merely necessary to unscrew the housing 62 from the housing 40 and then remove the bearing parts including disks 42 and spacers 42*a* as well as the bearing members 44 and spacer rings 44*a*. At the same time the radial bearing 60 hereinafter described, may also be replaced if necessary.

The bearing sub-assembly 40 is also provided with a lower radial bearing generally indicated at 60 which is carried by a detachable lower bearing housing 62. This includes a cartridge and internally fluted sleeve type bearing element 63 which is held in position by means of a retainer ring 64. A key 65 engages the inner replaceable hard-surfaced sleeve 66 on the shaft 41 with which it cooperates. In view of the foregoing it is obvious that there must be some clearance between the upper, inner portion of the lower bearing housing 62 where it meets the upper and outer face of sleeve 66 since there is relative rotational movement between these two elements. Thus, a portion of the driving fluid discharged through the turbine will pass down therebetween and eventually will be returned to the main discharge flow in the center of shaft 41 by port means located in the lower portion of the sleeve 66 and port 68 in shaft 41.

In the preferred construction of bearing sub-assembly as shown in FIGURE 2B, we also include a sealing member 67, which may consist of chevron style packing to prevent leakage of drilling fluid from the turbine discharge into the bore hole annulus. A part of the drilling fluid discharged through passage 45 from the turbine is thus forced through flutes 63*a* in the bearing element 63 and thence through port 68 into the hollow shaft 41 and thence to the drilling bit. The sealing member 67 prevents the loss of a substantial portion of the drilling fluid directly out of the lower bearing housing 62, which, in the prior art not only interfered with the upward flow of cuttings but tended to starve the bit of its cooling requirements. The diverted part of the drilling fluid which passes across the bearing surfaces before rejoining the main part

of the drilling fluid in the center of the shaft 41 thus cools and lubricates this radial bearing which has a major loading due to its location at the downhole end of the turbodrill housing.

Radial bearings 70 and 71 are also provided in the turbine unit at the top and bottom of the drive shaft 32 and preferably at the top of the shaft 41 as indicated at 72. However, these bearings are usually not replaceable except with general disassembly as they are of relatively long life. This is not true of the lower radial bearing 60 which by being a part of the removable sub 40, can be replaced as needed, which is usually at the same cycle as the thrust bearings. The lower shaft 41 extends below the lower bearing housing and customarily has a bit "sub" 75 for connection to the drill bit.

While in the foregoing description reference has been made to a coupling 50 between an upper shaft and a lower shaft, and in such case, particular reference has been made to the upper shaft as a turbine unit and the lower shaft as part of a thrust bearing unit, it is also entirely possible to use the same type of coupling for coupling two turbine sections together.

It will be appreciated that as the drill goes deeper in a well, the horsepower loss increases rapidly (third power of flow quantity), due to hydraulic losses in the drill string. Although it might be possible to reduce these losses by using more pumps, or using larger drill pipe with lower pressure drop, it is better and cheaper and within the limits of the available equipment to compound or tandem the turbodrills. In such case, it is also essential that the rotors and stators of each turbine section be properly spaced and the coupling of the aforementioned type can be used for such purpose.

In FIGURES 4A, 4B and 4C, we have shown such a modified form of turbodrill generally having the first turbine housing 80 within which is the first drive shaft 82, the housing and shaft having complementary stator and rotor blades indicated at 83 and constituting the first turbine unit.

Mounted below the first turbine unit 83 is housing 85 having a second drive shaft 86, which housing and shaft also have complementary stator and rotor blades forming a second turbine unit 87.

This second turbine unit is coupled for torque and axial thrust to the first turbine unit by a coupling generally indicated at 50 and being generally of the type shown in FIGURE 2A. It is substantially similar to the first turbine unit 83 in that it has the same size and type of parts, and thereby standardization is possible.

Mounted below the lowermost turbine units (and more than two might be used on very deep wells or with relatively low available mud pressure) is the thrust bearing unit mounted in housing 92 and with driven shaft 93 supported by thrust bearings generally indicated at 42 and 44, such as described in connection with FIGURE 2A. A coupling 50 will be used to take thrust and torque between the drive and driven shafts as described in connection with the upper coupling 90.

Radial bearings 98 are indicated at both ends of the driving shaft 82 and bottom of shaft 86 and on both ends of the driven shaft 41. Other internal details of this form of embodiment of our invention are similar to those shown on the simplified form of FIGURES 2A and 2B.

While we have shown and described preferred forms of embodiment of our invention and the best mode of practicing the same, we are aware that modifications may be made thereto within the scope and spirit of such disclosure without departing from the principles thereof and the scope of the appended claims.

What we claim as new is:

1. A turbine drilling unit for attachment to the end of a drill string comprising a stator of annular form, first housing means containing said stator and connectible fixedly to said drill string to support said stator fixedly with respect thereto, a turbine rotor within said stator, said stator and rotor providing means engageable by a flowing drilling fluid and cooperating upon such engagement for effecting rotation of said rotor, a lower housing connected on and in fluid flow communication with said first housing means, a driven shaft in said lower housing and in substantial axial alignment with the turbine rotor, said driven shaft having annular bearing surfaces perpendicular to and extending about its axis, said lower housing having bearing surfaces extending perpendicularly of said axis and disposed in bearing relation to said annular bearing surfaces of said driven shaft to resist axial thrust thereon, and a detachable coupling means to couple said rotor to said driven shaft, said coupling means having a longitudinal compression transmitting element and interengaging torque transmitting elements whereby torque is transmitted from the rotor to said driven shaft and said driven shaft will resist the downward thrust of the rotor, said lower housing on engaging the first housing causing the torque transmitting elements and the compression transmitting element to become operative.

2. A turbine drilling unit for attachment to the end of a drill string as claimed in claim 1, and wherein radial bearings are provided in the lower housing to support said driven shaft radially in said lower housing, means to transmit a portion of the drilling fluid to said bearings for cooling and lubrication thereof and means to seal the lowermost end of said bearings to prevent discharge of said portion of the drilling fluid directly into the bore hole.

3. A turbine drilling unit for attachment to the end of a drill string as claimed in claim 1, and wherein an intermediate housing is mounted between the first housing in fluid flow communication therewith and the lower housing, said intermediate housing including a stator of annular form non-rotatable with respect to said intermediate housing and a turbine rotor of annular form mounted within said stator, said stator and rotor providing means engageable by a flowing drilling fluid for effecting rotation of said rotor, said drilling unit having coupling means between the lower end of the rotor in the first housing and the upper end of the rotor in the intermediate housing, and between the lower end of the rotor in the intermediate housing and the adjacent end of the driven shaft, each of the couplings having thrust receiving members and torque transmitting members whereby the driven shaft takes the thrust and establishes and maintains the spacing between the rotors and stators of the preceding turbine.

4. A turbodrill adapted to be mounted on the end of a drill string and constituting the driving means for a rock bit, said turbodrill being in fluid flow communication with said drill string and actuated by the flow of drilling fluid, said turbodrill comprising a turbine assembly and a bearing assembly, said turbine assembly in fluid flow communication with said drill string and including a housing having a stator therein, and non-rotatably fixed thereto, a driving shaft within said housing and having rotor blades adjacent said stator whereby the flow of drilling fluid will effect rotation of said driving shaft, a clutch member on the lower end of said driving shaft, said bearing assembly including a bearing housing threadedly connected to the turbine housing, said bearing housing having a driven shaft therein, said bearing housing and said driven shaft having perpendicular extending overlapping and cooperating thrust bearing surfaces whereby said driven shaft is positioned to resist axial thrust, clutch means between said driving shaft and said driven shaft and means to secure a drill bit to said driven shaft in fluid flow communication with said bearing housing, said bearing housing having a radial bearing at the lower end thereof, said radial bearing radially supporting said driven shaft in said bearing housing, means to pass drilling fluid to said radial bearing to cool and lubricate said bearing and means to

direct all of said cooling and lubricating drilling fluid from said radial bearing to the rock bit.

5. A bearing sub-assembly unit for a turbodrill having a turbine housing with a turbine shaft having a clutch member on one end thereof, comprising an annular housing, adapted to be connected to said turbine housing, a driven shaft within said housing, a clutch member on said driven shaft adapted to engage said clutch member on the turbine shaft, said driven shaft and said housing having interspaced thrust bearing surfaces to resist longitudinal movement of the driven shaft in either direction, and to resist thrust of the turbine shaft when said housings are interconnected, and a sleeve type resilient radial bearing mounted between the lower portion of the annular housing and the adjacent surface of the driven shaft and supporting said driven shaft radially in said annular housing.

6. A bearing sub-assembly unit for a turbodrill having a turbine, a turbine shaft with a clutch member on one end thereof and in which drilling fluid is passed through the turbine to rotate the turbine shaft, said unit comprising an annular housing below the turbine and connected thereto, a driven shaft within said housing, a clutch member on said driven shaft adapted to engage the clutch member on the turbine shaft, said driven shaft and said housing having interspaced thrust bearing surfaces to resist longitudinal movement of the turbine shaft and the driven shaft in either direction, and a radial bearing mounted between the lower portion of the housing and the driven shaft for supporting said driven shaft radially in said housing.

7. A sub-assembly unit for a turbodrill as claimed in claim 6 and wherein means are provided to transmit a portion of the drilling fluid to the radial bearing, the driven shaft being provided with an internal fluid port for the transmission of drilling fluid through the driven shaft and also being provided with a transverse port communicating with the inner surface of the radial bearing and extending to the internal port to provide a return circulation of fluid flow over the bearing surfaces and sealing means below the lower end of the radial bearing for preventing leakage of drilling fluid into the well bore from the housing.

8. The invention as set forth in claim 6 and wherein the clutch member on the driven shaft is provided with means for receiving compression thrust.

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