Dec. 26, 1961 A. B. HILDEBRANDT ET AL 3,014,542

TURBO-TYPE EARTH DRILL

Filed Dec. 1, 1959 2 Sheets-Sheet 1

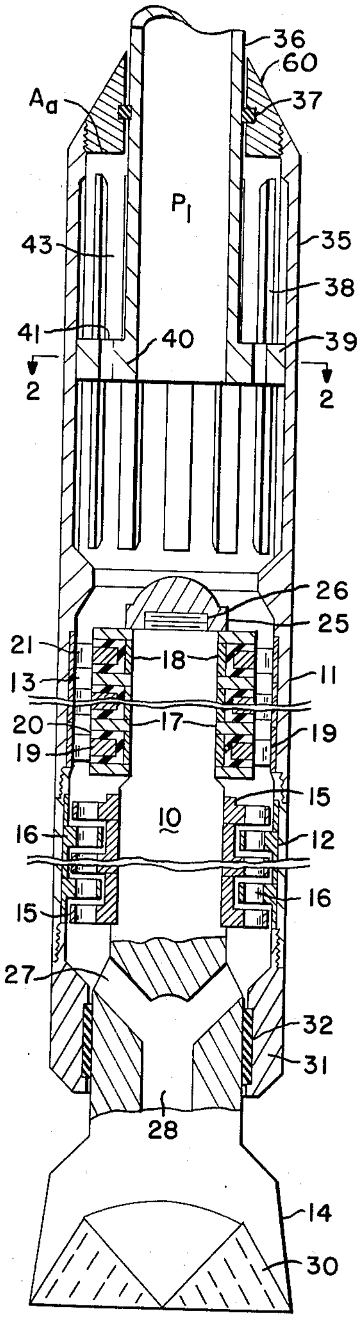

FIG.-1

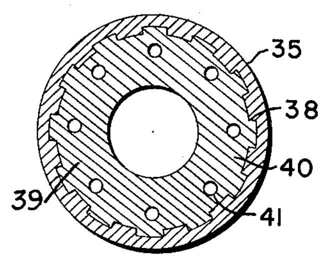

FIG.-2

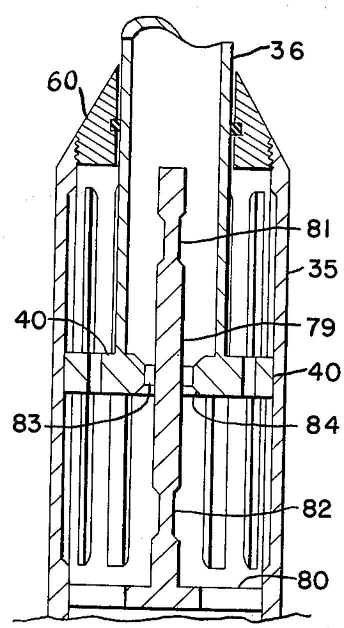

FIG.-3

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TURBO-TYPE EARTH DRILL

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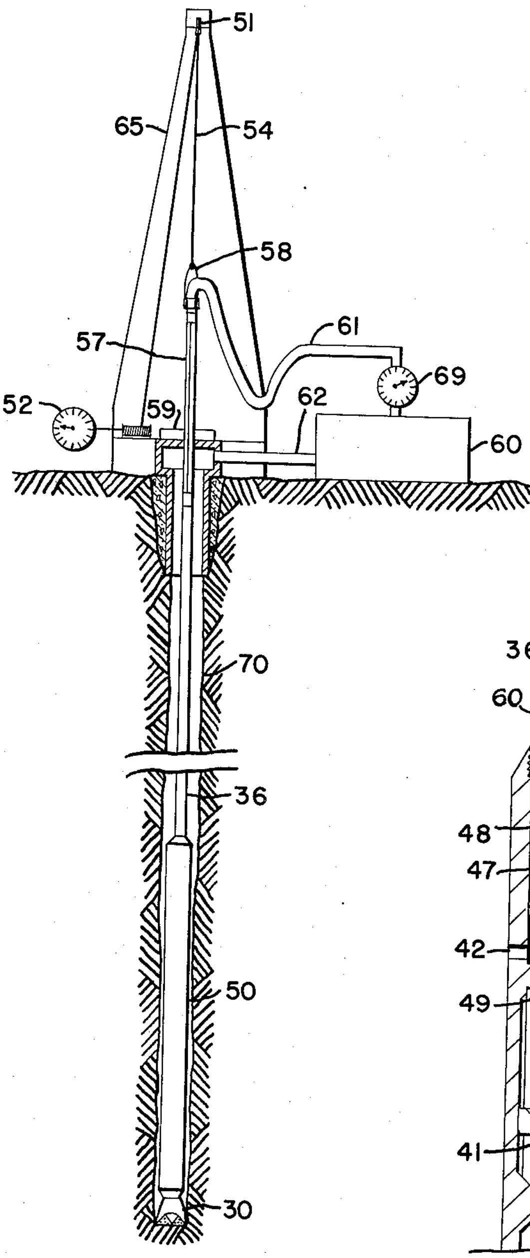

FIG.-4

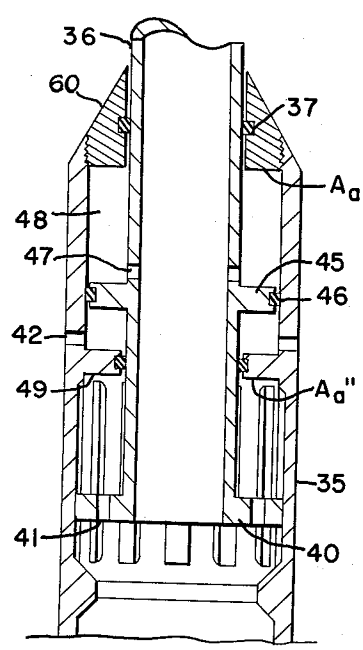

FIG.-5

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TURBO-TYPE EARTH DRILL

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6 Claims. (Cl. 175—107)

This invention pertain generally to borehole drilling equipment and more particularly to an improved type of fluid-driven turbodrill.

This application is a continuation-in-part application of copending application Serial No. 693,117, filed on the 29th day of October 1957, now abandoned.

An increasing interest is developing in the petroleum industry in adapting fluid-driven turbines to the problem of drilling boreholes. Several types of turbodrills have been built and tested, and continuing efforts in that direction are being made.

All of the turbodrills that have been built or suggested to date have, in general, the same basic construction. Each one of them has an external cylinder, which is attached to the lower end of a string of well pipe, and a rotor shaft which is mounted within the cylinder. Turbine blades are attached to the outer surface of the rotor and to the inner surface of the cylinder. The cylinder is maintained in a stationary position, and the rotor is then revolved by passing drilling mud or other suitable fluid down the well pipe and through the turbine blades. A drilling action is effected by attaching a drill bit to the lower end of the rotor shaft and by thrusting the bit against the earth. A thrust bearing is interposed between the rotor shaft and the external cylinder for the purpose of stabilizing the position of the shaft within the cylinder and providing force against rock.

In spite of the fact that a turbodrill is basically simple in its appearance, great difficulty has been experienced in attempts to adapt such a drill to the problem of drilling boreholes. Considerable progress has been made recently in this direction, but further improvements will be necessary before the tool is generally competitive with other forms of drilling equipment.

One of the major problems that has beset the turbodrill centers around its thrust bearing. The bearing must not only perform in the presence of very abrasive materials, but it must also be capable of handling very sudden and substantial changes in thrust. These two factors cause the bearing to wear very rapidly and thereby greatly decrease the operating efficiency of a turbodrill.

Recent developments in turbodrills have alleviated the thrust bearing problem to some extent, but the problem is still far from a really satisfactory solution. A rubber-type bearing has proven to be quite superior to metal bearings in the thrust application, but the rubber bearings have not afforded a completely satisfactory performance.

Excessive wear of the thrust bearing in a turbodrill is further explained, at least in part, by the fact that bit loadings are uncertain and difficult to control. For example, one procedure for starting a drilling operation with a turbodrill consists in first stalling the bit by applying excess weight on the bit through the drill string. Weight on the bit is then backed off several tons so as to enable the turbine rotor and the bit to start rotating. This procedure is quite inexact; and, from this, it will be appreciated that knowledge of the thrust or load on the thrust bearing is far from satisfactory.

The present invention improves upon conventional turbodrills by the incorporation of means for reducing wear in the thrust bearings of the drills. The nature of the invention may be best understood from the description that follows, especially when taken in conjunction with the attached drawing wherein:

FIGURE 1 is a vertical section taken through a turbodrill modified to include a preferred embodiment of the invention.

FIGURE 2 is a section taken along the lines 2—2 of FIGURE 1.

FIGURE 3 is a vertical section view of another embodiment of the invention.

FIGURE 4 is a schematic representation of a drilling system making use of the present invention.

FIGURE 5 is a schematic sectional view of a coupling device illustrating another embodiment of the invention.

Referring first to FIGURE 1, it will be observed that the apparatus shown in this figure includes a substantially conventional turbodrill modified in accordance with this invention. The turbodrill comprises a rotor shaft **10**, exterior cylinder **11**, turbine section **12**, thrust bearing section **13**, and bit **14**. While all of these components are substantially conventional and well known in the art, it is felt that a brief description of each one will aid in understanding the present invention.

Referring first to the rotor shaft **10**, it will be seen that this member is an elongated, substantially cylindrical body connected at its lower end to the drill bit **14**. One or more rows of turbine rotor blades **15** are mounted on the exterior surface of the shaft, and these blades are interposed between turbine stator blades **16**. The latter blades are mounted on the inner peripheral surface of the external cylinder **11**.

The thrust bearing section **13** shown in FIGURE 1 corresponds schematically with a thrust bearing design which is finding considerable favor in recent turbodrills. In general, the thrust bearing consists of a plurality of circular flat rings **17** which are secured to the shaft **10** and separated by sleeve sections **18**. A plurality of ring members **19** are secured to the inner surface of cylinder **11**, and a separate such ring member is interposed between each pair of flat rings **17**. Rubber inserts **20** are folded around the inner periphery of each ring member **19** and separate each ring member from the next adjacent flat rings **17**. Fluid passageways or ports **21** extending through each ring member **19** are provided around the periphery of the ring member. The entire assembly is held in position on the shaft as by means of a nut **25** engaging a threaded portion **26** at the end of the shaft **10**.

In a conventional installation and use of the turbodrill shown in FIGURE 1, the upper end of the external cylinder **11** is attached directly to the lower end of a string of well pipe. Drilling mud or other fluid is passed down the well pipe and thence through ports **21** in the ring members **19** to the turbine section **12**. At this point, the fluid passes through the rows or stages of stator and rotor blades. It then flows through suitable passageways **27** and **28** in rotor shaft **10** to discharge in the vicinity of conical cutters **30** of bit **14**. A collar or equivalent device **31** is normally attached to the lower end of external cylinder **11**. A fluid seal **32** positioned between this member and the rotor shaft directs the fluid discharging from the turbine section into passageways **27**.

As noted earlier, control and knowledge of the amount of thrust borne by the thrust bearing section **13** is extremely difficult—if not impossible— to obtain in the case of a conventional turbodrill. The load or thrust on the bit depends primarily upon two factors: (1) the mechanical force transmitted through the thrust bearing **13** from the weight of any drilling equipment in the string of well pipe above; and (2) the fluid reaction force on the rotor blades **15** caused by the drilling fluid passing over and around these blades, the aforesaid fluid reaction force being dependent upon the flow rate of drilling fluid through the turbine. It follows, then, that changes in the torsional loading of the well pipe, viscosity changes in the fluid, etc., may and do have a marked effect upon the loads that are placed on the thrust bearing. Changes in torsional loads on the well pipe cause the thrust bearing carried by the case to move up or down with respect to the bottom of the borehole in a coiled spring-like action. When the distance between the bottom of the hole and a point on the thrust bearing changes, the dynamic force transmitted through the thrust bearing also changes. The greater these changes in load become, the greater in general becomes the wear on the thrust bearing components.

The present invention avoids the shortcomings of a conventional turbodrill such as the one just discussed by means of a unique coupling device interconnecting the external cylinder **11** with the well pipe. Turning to FIGURES 1 and 2, it will be seen that this coupling device is preferably a hollow, cylindrical body **35**—which in effect may be an extension of the external cylinder **11**. The lower end of the coupling device is connected and sealed to the upper end of the external cylinder **11**; and the upper end of the device terminates in a telescoping, fluid-tight relation with the lower end of well pipe **36**. A seal ring **37** or equivalent means mounted in member **60** is preferably provided within the inner surface of the upper termination of the coupling device to effect the necessary sliding seal arrangement with the well pipe.

Also provided is suitable interconnecting means adapted to prevent the well pipe and the coupling device from rotating relative to one another. A particularly suitable arrangement of this type consists of longitudinally disposed splines 38 which are formed on the interior surface of the coupling device and which engage matching splines **39** on a flange **40** connected to the well pipe. The splines enable the well pipe and the coupling device to slide in longitudinal relation to one another while preventing relative rotational movement between these members. The splines, it will be apparent, help convey any torque experienced by the external cylinder **11** to the surface equipment.

A plurality of fluid ports or passageways **41** are positioned in the flange **40** and enable fluid to enter the annular volume **43** between the well pipe **36** and the coupling device. The important purpose behind this provision is to enable the pressure of fluid entering the turbodrill to be applied to the transversely disposed unbalance annular pressure area A_a. This portion of the wall surface of the coupling device **35** is, it will be noted, exposed on its interior side to the pressure of the fluid entering the turbodrill. The exterior portion of the area is exposed, on the other hand, to the pressure of the fluid that has discharged from the turbodrill. This explains the pressure forces on the unbalanced area A_a.

It will be recognized that the external cylinder **11** will normally experience a downward thrust as a result primarily of the force of downflowing fluid impinging against the stator blades **16** and to a much lesser and usually negligible extent from other fluid flow restrictions on the casing. The total downward thrust on the cylinder **11** is the total of this latter thrust plus the effective weight of the cylinder coupling device and other non-rotating elements. The downward force of the effective weight of the cylinder coupling device and other non-rotating elements is frequently rather small in comparison to thrust of the downflowing fluid impinging against stator blades **16**; and, may in many cases, be disregarded in determining A_a.

It will be apparent that, in normal operation of the drill, the coupling device **35** will normally experience an upward thrust as a result of the difference in pressures exerted on the areal portion A_a of member **60**. The total downward thrust on cylinder **11** is counterbalanced in accordance with this invention by preselection of the size of the area A_a. Thus, assuming the pressure of liquid entering the turbodrill to have a value of P_1 and the pressure of liquid leaving the turbodrill to have a value

of P_a, values of A_a effecting a counterbalance may be determined from the following formula:

$$(P_1-P_a)(A_s)+W=(P_1-P_a)(A_a)$$

where A_s is the effective area primarily of the stator blades and includes the effective area (which is normally small in comparison to the effective area of the stator blades) of any other fluid flow restriction on the casing of the turbine subject to hydraulic unbalance and W is the effective weight of the non-rotating components of the turbodrill assembly, including the coupling device. The term "effective weight" is used, since buoyant forces are present within the drilling system. Certain frictional forces may also be present as brought out hereinafter.

It will be seen in the above equation that the value of A_a to balance the equation in any given instance will vary with the term (P_1-P_a), the pressure drop across the turbodrill. It is therefore desirable to preselect A_a such that a counterbalance of the total downward thrust on the external cylinder of a drill is obtained at some predetermined pressure drop value for the drill—preferably the pressure drop occurring at the average expected operating pressure differential across the drill. Under normal conditions, relatively little variation in pressure drop across a drill should occur.

It will be noted at this point that methods of determining the pressure drop characteristics and the effective area A_s of a turbine are well known in the art; and a detailed discussion of such matters is therefore not felt to be a vital part of this description. Reference is made, however, to Mark's Handbood, 4th edition, pp. 1358–1359; and to Centrifugal and Axial Flow Pumps—Stepanoff—chaper 11, pp. 218–240, for an exposition of the principles behind such considerations.

In further regard to determining A_s, its definition may be conveniently developed algebraically as follows: Let A_a equal zero, and F represent the force required to keep the stator from moving vertically. (F may be measured with a dynamometer thrust stand). When the flow of fluid through the turbine is zero, $P_1-P_a=0$, and $W=F$. As the flow of fluid through the turbine is increased the pressure drop P across the turbine is P_1-P_a; the force balance equation on the turbine stator is:

$$(P_1-P_a)A_s+W=F$$

Then solving for A_s,

$$A_s=\frac{F-W}{P_1-P_a}$$

It is to be noted that the values of the terms on the right hand side of this equation are readily determined for any flow rate. Equating the upward force to the downward force:

$$(P_1-P_a)A_s+W=F+(P_1-P_a)A_a$$

It is clear that proper selection of A_a will let F equal zero for a given flow rate and near zero for a wide range of rates. With the value of F (the force required to keep the stator from moving vertically) at or near zero, the thrust transmitted through the thrust bearing section **13** of the turbine will also, and of necessity, be at or near zero. This will reduce the bearing wear considerably. A_s is primarily the effective area of the stator blades but includes the effective area of any other fluid flow restriction, if any should exist, on the casing. However, this latter effective area is quite small in comparison to the effective area of the stator blades. A_s then is essentially the effective area of the stator blades and for convenience will be referred to herein as such.

In the formula $(P_1-P_a)A_s+W=F$, W is most frequently small in comparison to $(P_1-P_a)A_s$, and, as a practical matter, may in such instances, be disregarded. For example, a typical 400 HP turbine having a throughput of 1000 GPM of driving fluid may have non-rotating components weighing around 500 pounds. A pressure drop of about 500 p.s.i. may be encountered through such a turbine having an area, A_s, of about 30 sq. inches. $(P_1-P_a)A_s$ in this instance is about 15,000 pounds which is about 30 times W. In determining the area A_a for a turbodrill in which W is small in comparison to

$$(P_1-P_a)A_s$$

W may be disregarded.

Summarizing momentarily, substantially continuous and complete hydraulic balance may be obtained across the turbodrill of FIGURE 1 by observing the criteria set forth above. The downward thrust on the external cylinder of the turbodrill is automatically and continuously compensated for or counterbalanced by the upward thrust on the area A_a. Excessive thrusts upon the thrust bearing section **13** are thereby minimized, and wear of this section's components is greatly reduced.

As mentioned earlier, excessive thrusts on the bearing section **13** may be occasioned in many instances by lack of control over the weight of the overall drilling assembly. Such lack of control may cause sudden and excessive loadings to be thrust upon the bearing section, resulting in increased wear of the bearing. Unbalances of this character are avoided in the system of the invention by virtue of the sliding longitudinal engagement between the well pipe **36** and the coupling device **35**. In other words, the coupling device enables torque to be transmitted between the well pipe and the coupling device to the substantial exclusion of any longitudinal thrust.

The length of the coupling device **35** is not particularly critical, although lengths of about one to five feet are contemplated to be particularly desirable.

It will be recognized that the coupling device **35** normally slides down relative to the well pipe **36** as a drilling operation progresses. It is therefore necessary periodically to move the drill string or well pipe **36** downward relative to the coupling device. This may be conveniently done by interrupting the drilling operation, lowering the well pipe a predetermined distance, and thereafter resuming the drilling.

Having thus identified and described the structural components of a preferred embodiment of this invention, it is felt that an even better understanding of the invention may be obtained by considering briefly the manner in which the invention operates. In this connection, attention is directed toward FIGURES 1 and 2 taken in conjunction with FIGURE 4. The latter figure shows the turbodrill and the coupling device of FIGURE 1 as one integral unit **50**. Unit **50** is attached at its lower end to bit **30** and at its upper end to the well pipe **36**. The upper end of the well pipe is connected to a kelly **57** which is suspended from a conventional swivel and traveling block assembly **58**. A rotary table **59** engages the kelly **57** and may be rotated by means of a conventional power source—if such rotation is desired. A cable **54** extending over the crown block **51** leads to a weight indicator **52**.

Drilling mud or other fluid is supplied from a mud pit or other suitable source **60** through line **61** to the interior of the kelly **57** and the well pipe **36**. The fluid may be returned to the source **60** by means of discharge line **62** which interconnects the source with the top of the well borehole. The usual surface casing, casinghead, blowout preventers, and the like may be used as desired. Likewise, any suitable type of conventional derrick **65** may be employed.

In practicing the invention, the drilling unit **50** and the bit **30** are lowered within the borehole **70** until the bit is adjacent the bottom of the hole. The well pipe is then further lowered until the flange **40** attached to the lower end thereof reaches the lower end of the splines **38** of the coupling device **35**. Detection of this occurrence may be had in several ways—e.g., by observation of the weight indicator **52**.

At this point, the string of well pipe is lifted and supported by the derrick at a point such that the weight of the well pipe is removed from the bit. Drilling fluid, such as conventional drilling mud, is then pumped through line **61** and down through the well pipe to the drill. Since the external cylinder **11** and the well pipe **36** are maintained substantially stationary in rotation, the fluid causes the rotor shaft **10** to revolve when it passes through the turbine blades.

It is important to note at this point that no portion of the weight of the drill string is transmitted to the thrust bearing in section **13** during drilling. Furthermore, no thrust occasioned by hydraulic unbalance across the turbine is transmitted to the bearing, since areal portion A_a has been preselected in the manner described earlier. The thrust bearing in the thrust bearing section **13** therefore becomes essentially a free-floating bearing, and bearing wear is greatly reduced.

The drilling operation at this point progresses in a normal manner with the drilling fluid exhaust from the turbodrill serving to flush cuttings from the bit **30** and to carry the cuttings up and out of the borehole to source **60**. When the drilling has progressed to the point where the coupling device **35** has reached its full extension beyond the flange **40**, the drilling operation is conveniently interrupted. The entire string of drill pipe is lowered a predetermined distance within the borehole, as described above; and the drilling operation is then resumed.

In order to simplify further the detection of the times when the flange **40** has reached one or the other end of the coupling device **35**, the coupling device may be modified as shown in FIGURE 3. This figure illustrates a coupling device which is substantially identical with the one shown in FIGURE 1. It differs from the former device in that it includes a central rod-like member **79** which is supported at one end from the coupling device as by means of one or more radial arms **80**. Notches **81** and **82** are provided or formed near each end of the rod **79**; and the rod proper forms an annular fluid passageway **83** between its exterior surface and the inner peripheral surface **84** of the flange **40**. Thus, as fluid flows down through the well pipe **36** and the annular passageway **83**, it experiences a pressure drop which remains substantially constant so long as the flange **40** is not opposite one of the notches **81** or **82**. When the flange reaches one or the other of these notches, the pressure drop through the passageway **83** is sharply reduced. This pressure reduction—by suitable design—may be made sufficient to give a visible indication on an indicator **69** positioned in the mud system. This indicator may conveniently be a flow-rate indicator, a pressure indicator, or the like.

While a preferred embodiment of the invention has been shown and discussed in this description, it will be recognized that numerous modifications, deletions, and additions may be made without departing from the spirit or scope of the invention. It will be recognized that the principles of the invention have application to turbodrills generally and are not limited to use with the particular type of turbodrill or thrust bearing shown and discussed in this description. It will further be recognized that other types of positive-drive connections permitting longitudinal sliding movement of the parts connected may be used in place of the spline connection illustrated in the figures. It will also be recognized that the coupling device and other components of the apparatus shown need not be one integral unit. Instead, the various components may be composed of several parts joined together for ease of manufacture and assembly. Again, it will be apparent that more than one coupling device may be used as, for example, where one such device does not present an adequate area A_a. A schematic simplified illustration of a multi-coupling device assembly is shown in FIGURE 5.

Turning to FIGURE 5, it will be seen that well pipe **36** has an additional flange **45** which is effectively a piston.

A piston ring **46** or equivalent means may be used to provide a fluid-tight sliding seal between the flange **45** and the internal surface of the cylindrical body **35**.

Ports **47** enable a portion of the fluid entering the turbodrill (not shown) to enter the chamber **48** and thereby exert a thrust against area A_a'. Similarly, another portion of the entering fluid enters the chamber **49** through the ports **41** and exerts a thrust against A_a''. Ports **42** enable exhaust fluid from the drill to enter the region below the flange or piston **45**. The result of this arrangement, then, is that an increased amount of area A_a is made available as compared to the arrangement of FIGURE 1.

To review briefly, then, this invention concerns an improvement in modern conventional turbodrill design. More specifically, the invention pertains to a coupling device operative to connect the lower end of a drill string with an otherwise conventional turbodrill. The coupling device provides a telescoping fluid-tight movement between the device and the drill string; and it is further operative to prevent relative rotational movement between these two components. The coupling device is still further characterized by possessing a laterally or transversely disposed areal portion which is exposed on one side to the pressure of fluid entering the turbodrill—and on the other side to the pressure of the fluid leaving the turbodrill. In a preferred embodiment, the areal portion is preselected in size so that the fluid-pressure differential acting across it exerts an upward thrust which is opposed and substantially equal to the downward thrust occasioned by the weight and fluid forces on the stator blades described hereinbefore. Since the force transmitted through the thrust bearing is approximately zero, the weight on the bit is caused essentially by fluid reaction on the rotor blades. The coupling device therefore serves to isolate the turbodrill and its thrust bearing from mechanical loadings otherwise derived from the drill string. It further relieves the bearing of downward thrusts occasioned by the force of fluid driving against the stator blades as well as thrusts resulting from the weight of the stationary components of the turbodrill assembly. The stationary components, as set forth previously, include the external cylinder, the coupling device, the stator blades, and other items attached to these components.

It will be recognized that an upward force on the stationary components of the turbodrill assembly will prevail as a result of friction whenever the assembly advances downward relative to the well pipe during drilling. This upward force acts to reduce the effective weight of the stationary components; and, while estimates may be made of its magnitude, its precise magnitude is difficult of definition. Since its actual value is relatively small in comparison with other prevailing forces, it may in general be ignored. However, where it is desired to take this force into consideration, it is contemplated that a value of about 5% to 25% of the effective weight of the stationary components may be assumed. It should be noted that this frictional force is actually an aid in applying the principles of this invention, since it tends to broaden the effective balancing range for any given value of the term A_a in the formula discussed hereinbefore. In other words, it tends to counterbalance and minimize the W term in the formula. The effect of this is to more nearly equate the terms A_a and A_s. If the term W is sufficiently small in comparison to the term $(P_1-P_a)A_s$ so that W may be ignored then A_s may for practical purposes equal A_a.

Throughout most of this description, it has been stated that the well pipe, the external cylinder, etc., are held stationary rotationally. Actually, it may be desirable—and it is not inconsistent with this invention—to rotate these items slowly—e.g., so as to avoid sticking or jamming of the well pipe.

The invention claimed is:

1. In a turbodrill assembly adapted for use with a string of well pipe for drilling a bore hole and including an external cylinder having turbine stator blades, a shaft disposed with said cylinder having turbine rotor blades, and a thrust bearing interposed between the shaft and the external cylinder, the improvement which comprises conduit-like coupling means connecting the upper end of said external cylinder to the lower end of the well pipe in a telescoping, fluid-tight, non-rotary relation, said coupling means including at least one transversely disposed wall portion, means providing fluid communication between the lower surface of said wall portion and the inlet to the turbodrill assembly, the upper surface being open to the borehole, the area of said wall portion being such that the fluid-pressure of the fluid supplied to the turbodrill assembly within a borehole will develop an upward thrust substantially equal to downward thrusts occasioned by fluid pressure acting downward on the effective area of the stator blades and by the weight of the non-rotating components of the turbodrill assembly.

2. In a turbodrill assembly using a turbine and adapted for use with a string of well pipe for drilling a borehole and including stationary components including an external cylinder provided with stator blades of the turbine and a thrust bearing, the improvement which comprises a conduit-like coupling device interposed between and connected to the lower end of the well pipe and the upper end of the external cylinder, the connection between the coupling device and the well pipe including means to prevent relative rotational movement and means to permit telescoping fluid-tight longitudinal movement therebetween, the exterior wall of said device including a portion disposed transversely within a borehole, means providing fluid communication between the lower surface of said portion and the inlet to the turbodrill, the upper surface being open to the borehole, the area of said portion being such that the pressure difference between the fluid entering and leaving the turbodrill assembly will develop a thrust longitudinally opposed and substantially equal to the thrust occasioned by the downward movement of fluid upon the effective area of the stator blades in addition to the effective weight of the stationary components of the turbodrill assembly.

3. A coupling device for use in conjunction with a turbodrill having rotating and non-rotating components and disposed at the lower end of a string of drill pipe, which comprises a conduit-like member interposed between and adapted to convey fluid from the drill pipe to the turbodrill, said member being rigidly connected at its lower end to the turbodrill and at its other end to the drill pipe in a longitudinally slidable and non-rotational relation therewith, said member being shaped to provide an effectively transverse wall portion, means exposing the lower interior surface of said wall portion to the pressure of fluid entering the turbodrill, the upper exterior surface of said wall portion being exposed to the pressure of fluid leaving the turbodrill, the area of said wall portion being sufficient with the differential pressure thereacross to develop an upward thrust substantially equal to the total downward thrust occasioned by downward fluid thrust upon the stator blades of the turbodrill and the weight of the non-rotating components of the turbodrill and the coupling device.

4. In a turbodrill assembly adapted for use with a drill string for drilling a borehole and including a bit attached to the lower end of a rotor shaft, a cylindrical housing containing the rotor shaft, and turbine blading and a thrust bearing interposed between the rotor shaft and the cylindrical member, the improvement which comprises a hollow cylindrical extension on the upper end of said cylindrical housing, interengaging means between said cylindrical extension and said drill pipe to prevent relative rotation therebetween, the lower end of the drill string terminating within the cylindrical extension in a telescoping fluid-tight manner, said cylindrical extension including a transverse wall portion, means providing fluid communication between the lower side of said wall portion and the inlet to the turbodrill assembly, the opposite

side being exposed to the pressure of fluid within the borehole, said transverse portion having an area substantially equal to the effective area of the turbine blading on the stator.

5. In a fluid-actuated turbine drilling assembly adapted for use with a string of well pipe for drilling a bore hole in the earth and including a turbine having a rotor shaft, turbine blading and a thrust bearing connected to and interposed between the rotor shaft and a surrounding cylindrical member, and a bit attached to the lower end of the shaft the improvement which comprises an upward cylindrical extension of the cylindrical member in telescoping relation to the lower end of said pipe string, fluid-tight sealing means between said extension and said pipe string, interengaging means between said well pipe and said cylindrical extension to prevent relative rotation therebetween, said cylindrical extension including a wall portion having an effective lateral surface with an area equal substantially to the effective area of the turbine blading attached to the cylindrical housing, and means providing fluid communication between the lower surface of said wall portion and the inlet to the turbine, the upper surface of said wall portion being open to the borehole.

6. In a turbodrill assembly for drilling a borehole in the earth including a string of well pipe, a central shaft having turbine rotor blades, an external cylinder having turbine stator blades, and a thrust bearing interposed between the central shaft and the external cylinder, the improvement which comprises an upward extension of said external cylinder engaging the lower end of the pipe string in a telescoping fluid-tight relation, interengaging means between said pipe string and said extension to prevent relative rotation therebetween, the wall surface of said extension including a transverse portion having an area substantially equal to the effective area of the stator blades, and means providing fluid communication between the lower surface of said transverse portion and the inlet to the turbodrill assembly, the upper surface being open to the borehole.

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