A drilling assembly, deviation sub therewith, and method of using same, wherein the deviation sub is for directional drilling of a well bore, and has an elongate deviation sub body adapted to be positioned in the well bore for extending longitudinally therein, and having a temperature differential in opposing longitudinal portions of the deviation sub body for causing the body to deviate from a first longitudinal position to a second longitudinal position at an angle to the first longitudinal position.
3,903,974

DRILLING ASSEMBLY, DEVIATION SUB THEREWITH, AND METHOD OF USING SAME

BACKGROUND OF THE INVENTION

The field of this invention relates to directional drilling apparatus and methods. Prior art deviation subs and method include devices and methods such as those disclosed in U.S. Pat. Nos.: 3,667,556; 3,627,356; 3,224,513; and 3,141,512.

Numerous disadvantages are found in the prior art, such as complicated gyroscopic mechanisms, slip clutches to independently rotate the drill bit from its housing, or complicated multiple elbow assemblies.

SUMMARY OF THE INVENTION

The present invention provides a new and improved drilling assembly, deviation sub therewith, and method of using same wherein the deviation sub is for directional drilling of a well bore, the preferred embodiment of which has a longitudinally extending heated portion and a longitudinally extending, articulated-sectioned, non-heated portion, such that when the heated portion expands the non-heated portion is allowed to bend or deviate about the articulated sections of the non-heated portion causing the heated portion to also bend, thus causing a deviation in drilling of the longitudinal direction of the well bore.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevational view showing the deviation sub of the present invention as used in a drill string;

FIG. 2 is an elevational view of the present invention, partly in section as taken along the lines 2—2 of FIG. 3;

FIG. 3 is a sectional plan view of the present invention as taken along the lines 3—3 of FIG. 2.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the drawings, the letter S designates the deviation sub of the present invention which as shown in FIG. 1 is incorporated in a drilling assembly having a drill string D disposed within a well bore W and extending to the surface of the well. The deviation sub S includes both a heated portion H and a non-heated portion N. Unless otherwise noted, the components of this invention are made of steel, iron or other materials capable of taking relatively heavy stresses and strain without failure.

Considering the invention in more detail, the drill string D is connected to a downhole motor 12 having drilling mud or fluid tubes 10 therewith. The downhole motor 12 can be any suitable commercially available downhole motor, but the electric downhole motor as disclosed in U.S. Pat. No. 3,291,230 is preferably used with this invention. A power cable 14 having three wires therein extends for the length of the drill string D from the surface to the motor 12 with two wires therein providing the electrical connection to a power source at the surface for operating the downhole motor 12.

A shock absorber 16 is mounted below the downhole motor 12 to dampen any excessive shocks or vibration encountered in drilling the well bore W. as well as to protect the working parts of the downhole motor 12 from unusually high stresses or strains encountered in drilling through rock or other hard formations.

A drive shaft 22 is connected by universal coupling 18 to the shock absorber 16 and by a lower universal coupling 20 to a drill bit 24. The universal couplings 18, 20 allow the drive shaft 22 to rotate freely when not in longitudinal parallel alignment with the downhole motor 12 or the drill bit 24 when the drill bit 24, located within the well bore W, deviates from a first longitudinal position in bore portion 26 to a second longitudinal position in bore portion 28 such that the second longitudinal position is at an angle to the first longitudinal position. The drill bit 24 is connected to a shaft 24s which is surrounded by a connective housing 24h, as will be more evident hereinafter. A bearing 24b is provided between the shaft 24s and the housing 24h to facilitate rotation of the shaft 24s and the bit 24 relative to the housing 24h.

Disposed between the motor 12 and the drill bit 24 is deviation sub S of the present invention. The deviation sub S has an outer elongate body 30 formed with a plurality of articulated sections 32. The articulated sections 32 are disposed on the non-heated portion N of the deviation sub S, being integrally formed with the outer body 30 having a gap 32g therebetween the equal, parallel and adjacent sections 32. Longitudinal supports 34 are welded or otherwise attached to the outer elongate body 30 and an inner elongate tubular body 36 in the annular space therebetween. Heat insulating material 38 such as polystyrene is disposed in the heated portion H of the deviation sub S between the inner elongate body 36 and the outer elongate body 30 such that the heat insulation material 38 is longitudinally constrained by the longitudinal supports 34 and faces opposite the articulated sections 32. Any durable insulating material capable of resisting the flow of high levels of heat energy is suitable for heat insulation material 38. Heater tubes 40 are mounted in the insulation material 38 such that the heater tubes 40 contact the inner elongate body 36 without contacting the outer elongate body 30, which retains the insulation material 38. Electrical resistance heater elements 42 are mounted within the heater tubes 40, the elements 42 being of any suitable type such as those manufactured by the Watlow Electric Manufacturing Company. The heater elements 42 are electrically connected to a single wire cable 44, which is one of the wires leading from the three wire power cable 14 for energizing the heater elements 42. It is preferred that the single wire cable 44 be utilized with the drill string D acting as a ground to electrically complete the connection although a two-wire cable arrangement could be used if desired. The heater element 42 is thus grounded to the inner elongate body 36 at a ground point 46. Appropriate electrical connections 48 may be used to insure mechanically strong, safe and reliable electrical connections between the various elements of the drill string D. A further heat insulating layer 50 of polystyrene or other suitable material is bonded or otherwise securely to the inner elongate body 36 adjacent that portion of the inner elongate body 36 that is mounted with the insulating material 38.

Threads 52 are provided at the lower end of the inner elongate body 36 to provide a means for coupling the deviation sub S of the present invention to the drill bit housing 24h. The threads 52 are connected to the housing 24h of the drill bit 24 by a union joint having a coupling 56 of suitable construction. Similar threads 53 at the upper end are connected to the motor 12 through
a union coupling 54 or other suitable means. The union joints 54, 56 are preferably designed such that only the union couplings 54, 56 require rotation to connect the motor 12 to the deviation sub S and the deviation sub S to the drill bit 24 while the motor 12, the deviation sub S, and the drill bit 24 all remain stationary with respect to one another.

It will be appreciated, as is well known in the art, that drilling fluids such as drilling mud are necessary for proper operation of the drill bit 24. As such, appropriate fluid passage means or openings 58, 62 are formed in the mud tubes 10. The flow of the drilling fluid is schematically represented by the arrows 60 and as such enters into the mud tubes 10 at the opening 58, flows longitudinally externally of the downhole motor 12, exits the mud tube 10 at opening 62, enters and flows through the inner chamber 64 of the inner elongate body 36 wherein the drive shaft 22 rotates immersed in drilling fluid, enters the connecting housing 24h of the drill bit 24, flows into the openings 66 of the drill bit shaft 24s for normal use by the drill bit 24 in drilling the well bore W.

In the use or operation of the form of the invention illustrated in FIG. 1-3, a substantially longitudinal wellbore W is drilled utilizing the drill bit 24 powered by the downhole motor 12 and through the drive shaft 22. In this mode of operation, the present invention acts as a conventional drilling apparatus. When it is determined by the operator that a deviation from the first longitudinal position to a second longitudinal position is necessary or desirable, the drill string D is aligned such that the center of the articulated sections 32 of the non-heated portion N faces the direction of the desired deviation. Appropriate surface recording instruments (not shown) may be utilized to keep an accurate trace of where the articulated sections 32 are located within the wellbore W so that any necessary rotational adjustments to the drill string D can be made to insure that the drill string D deviates in the proper direction.

Once in the proper position, a remote switch (not shown) located on the surface is actuated. This electrically energizes the tubular heater elements 42. As the tubular heaters 42 heat, thermal energy is directed from the elements 42 through the heater tubes 40 to the inner elongate body 36 of the heated portion H. It will be appreciated that the insulation material 38 effectively isolates the heater tubes 40 from one another as well as thermally isolates the heated portion H of the deviation sub S from the relatively cold drilling fluid within the inner chamber 64. Thus, heat energy is directed radially inward to the heated portion of the inner elongate body 36 in proximity to such tubes 40 of the heated portion H of the deviation sub S. Due to the insulating characteristics of the insulation material 38, heat energy is prevented from being dissipated circumferentially and radially outwardly in the insulation material 38. The insulation material 38 and the insulating layer 50 help to prevent migration of heat energy from the heated portion H of the deviation sub S to the drilling fluid within the inner chamber 64. With the heater elements 42 so activated, a thermal stress results in the inner elongate body 36 due to the unequal heating of the longitudinal portions thereof. As the temperature increases in the heated portion H, the heated portion H remains unaffected by the relatively cold drilling fluid in the inner chamber 64 due to the insulation material 38 and the insulating layer 50. Concurrent with the temperature rise in the heated portion H of the body 36, resultant expansion thereof ensues as the body 36 expands due to the thermal energy imparted by the heater elements 42. The deviation sub S then begins to deviate about the articulated sections 32 such that once parallel articulated sections 32 having gaps 32g therebetweon, no longer are parallel but are disposed at acute angles with respect to one another, in the process thereof closing up a portion of the gaps 32g therebetweon (FIG. 1). The amount of deviation depends upon the temperature variation between the heated and non-heated portions H, N respectively, of the deviation sub S as well as the length of time drilling is pursued with the heater elements 42 so activated. For example, a five foot deviation sub will deflect two degrees from the first bore position 26 to the second bore position 28 with a temperature differential of 200⁰ F. between the heated portion H and the non-heated portion N of the deviation sub S. It will be appreciated that alternatively this same effect can be accomplished by cooling the non-heated portion N with a resultant contracting of the non-heated portions N of the body 36 about the articulated sections 32. It will be appreciated that a further embodiment of this invention may incorporate both the heating elements 42 and a cooling mechanism to be located in the area designated generally in the drawings by the letter C described above to accomplish an appropriate temperature differential to insure a deviation of the deviation sub S.

The heater elements 42 remain activated as the drilling operation progresses until the desired direction of the second longitudinal bore 28 is reached. Tracing or detection equipment (not shown) is commercially available which provides an accurate trace or detection of the angle of the drill bit 24 as it deviates or bends due to the expansion-contraction action of the deviation sub S. With the angle of deviation so monitored, when the tool bit 24 reaches the proper heading, the remote switch (not shown) mentioned supra is deactivated, thus turning off the heater elements 42. With the source of heat energy thus terminated, the heated portion H then returns to its original configuration such that a straight well bore W at the deviated angle may further be drilled.

Instead of using electrical heaters 40, other heating means such as hot fluid may be used to create the longitudinal temperature differential for causing the change in longitudinal drilling direction as explained hereinabove.

The foregoing disclosure and description of the invention are illustrative and explanatory thereof, and various changes in the size, shape, and materials as well as in the details of the illustrated construction may be made without departing from the spirit of the invention.

I claim:
1. A deviation sub adapted to be used with a drill bit and drilling fluid in a drill string for downhole directional drilling, comprising:
   an elongate deviation sub body adapted to be positioned in a well bore for extending longitudinally therein, and,
   longitudinal deviation means forming a part of said body and extending longitudinally on said body for causing said body to deviate from a first longitudinal position to a second longitudinal position at an angle to said first longitudinal position, wherein
said longitudinal deviation means includes temperature variation means for causing a temperature differential in opposing longitudinal portions of said deviation sub body having a longitudinal higher temperature portion opposing a longitudinal lower temperature portion of said deviation sub body.

2. The structure of claim 1, wherein said temperature variation means includes:
   longitudinal heating means for raising the temperature of said higher temperature portion of said deviation sub body.

3. The structure of claim 1, wherein said lower temperature portion of said deviation sub body includes:
   a plurality of articulated sections such that when said higher temperature portion of said deviation sub body expands or said lower temperature portion of said deviation sub body contracts, said lower temperature portion deviates or bends about said articulated sections.

4. The structure of claim 1, wherein said temperature variation means includes:
   cooling means for lowering the temperature of said lower temperature portion of said deviation sub body.

5. The structure of claim 1, further including:
   an insulating means for preventing transfer of heat from said higher temperature portion of said deviation sub body to the drilling fluid.

6. A drilling assembly, comprising:
   a drill string adapted to be lowered into a well bore for extending longitudinally therein; and
   a temperature differential deviation sub connected between said drill bit and said drill string for deviating the longitudinal direction of drilling with said drill bit.

7. The assembly of claim 6, wherein said deviation sub includes:
   flow passage means for allowing circulation of drilling fluid through said deviation sub.

8. The assembly of claim 6, wherein said deviation sub includes:
   temperature variation means for causing a temperature differential in opposing longitudinal portions of said deviation sub having a longitudinal higher temperature portion opposing a longitudinal lower temperature portion of said deviation sub.

9. The assembly of claim 8, wherein said temperature variation means includes:
   longitudinal heating means for raising the temperature of said higher temperature portion of said deviation sub.

10. The assembly of claim 8, wherein said lower temperature portion of said deviation sub includes:
     a plurality of articulated sections such that when said higher temperature portion of said deviation sub expands or said lower temperature portion of said deviation sub contracts, said lower temperature portion deviates or bends about said articulated sections.

11. The assembly of claim 8, wherein said temperature variation means includes:
    cooling means for lowering the temperature of said lower temperature portion of said deviation sub.

12. The assembly of claim 8, further including:
    an insulating means for preventing transfer of heat from said higher temperature portion of said deviation sub to the drilling fluid.

13. The assembly of claim 6, further including:
    a downhole motor for powering said drill bit.

14. The assembly of claim 13, further including:
    drive shaft located within said deviation sub having universal mountings for connecting said downhole motor with said drill bit and for providing power thereto, when said deviation sub deviates or bends from the longitudinal direction of drilling.

15. The assembly of claim 14, further including:
    shock absorbing means mounted with said downhole motor for absorbing shock variations encountered in drilling.

16. A method for changing the angle of inclination of a well bore during the drilling thereof, comprising the steps of:
    disposing a deviation sub between a tool bit and a well string; and
    creating a temperature differential between longitudinal sections of the deviation sub for causing a change in the angular direction of drilling with the drill bit in the well bore.

17. The method set forth in claim 16, including:
    lowering the temperature of a portion of the deviation sub by cooling a longitudinal section of the deviation sub.

18. The method set forth in claim 16, including:
    insulating the longitudinal sections of the deviation sub having a temperature differential therein, to localize the temperature differences therebetween.

19. The method set forth in claim 16, including:
    raising the temperature of a portion of the deviation sub by heating a longitudinal section of the deviation sub.

20. The method set forth in claim 19, including:
    isolating the deviation or bending of the deviation sub about a longitudinal non-heated, articulated section when heating the deviation sub.

21. A method for changing the angle of inclination of a well bore during the drilling thereof, comprising the steps of:
    disposing a deviation sub between a tool bit and a well string;
    drilling a well bore in a first longitudinal position with the deviation sub so disposed;
    creating a temperature differential between longitudinal sections of the deviation sub for causing a change in the angular direction of drilling with the drill bit in the well bore from the first longitudinal position to a second longitudinal position.

22. The method set forth in claim 21, including:
    discontinuing the temperature differential after the wellbore has deviated from the first longitudinal position to the second longitudinal position so as to remain directed in the second longitudinal position.

23. The method set forth in claim 22, including:
    drilling the wellbore in the second longitudinal position without deviation of the wellbore, with the deviation sub disposed between the tool bit and the drill string.