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㉙ **Adjustable bent sub.**

㉚ There is described an adjustable bent sub comprising a cylindrical housing having a first uphole portion and a second downhole portion, the up and downhole portions being axially offset to one another, a tubular mandrel having a first uphole end and a second downhole end, the up and downhole ends being axially offset to one another, the uphole end of the mandrel being receivable within the housing means for longitudinal and rotational movement relative thereto, connectors provided between the mandrel and the housing to prevent the relative rotation thereof when the mandrel is in a first locked position relative to the housing, a lock actuatable to maintain the mandrel in a first locked position thereof or to release the mandrel for longitudinal movement thereof relative to the housing into a second unlocked position in which the mandrel and housing are free to rotate relative to one another, a piston concentrically disposed in the housing for longitudinal movement relative thereto, and a spring concentrically disposed in the housing for biasing the piston into contact with an end of the mandrel, wherein the rotation of the mandrel relative to the housing increases or decreases the amount of bend in the bent sub between predetermined limits.

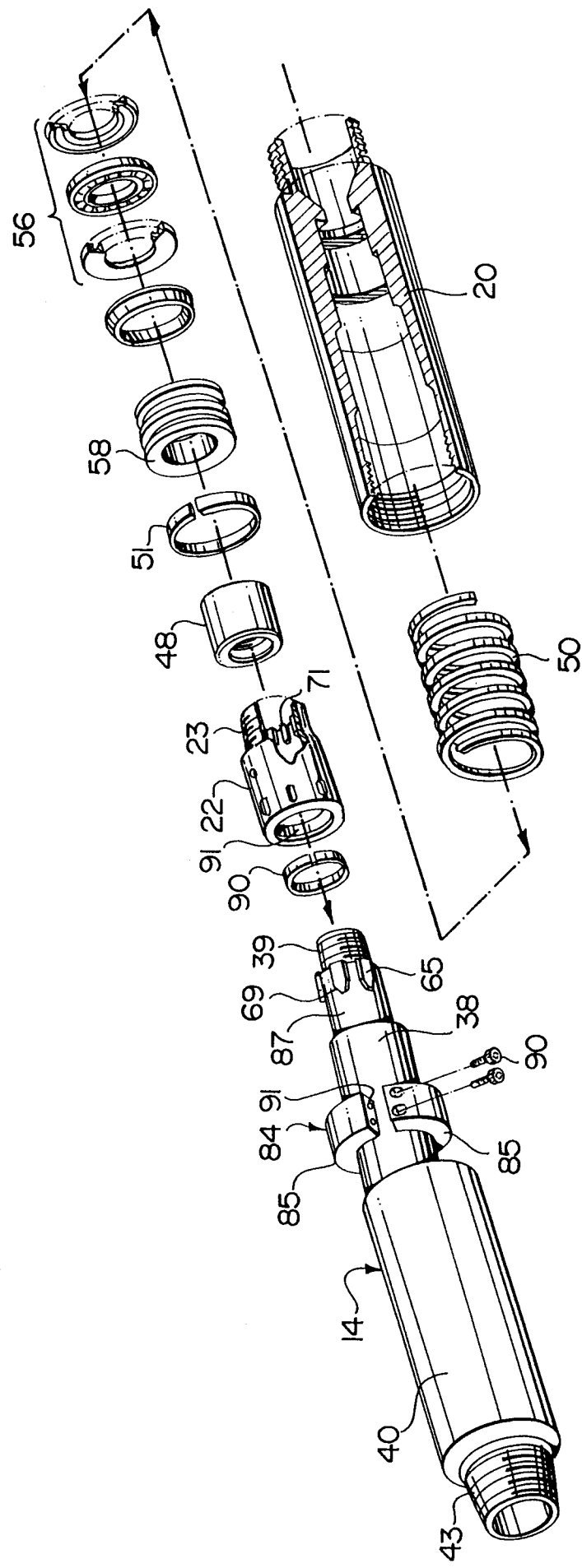


FIG. 2

The present invention relates to downhole drilling tools and more particularly to an adjustable bent sub useful in the directional drilling of well bores.

BACKGROUND OF THE INVENTION

"Bent subs" are commonly used in well drilling in order to deviate the borehole from vertical to a desired angle. "Subs" are short threaded sections of drill pipe. They are "bent" either by physical bending or machined to create an angular offset between the respective ends of the sub. When the bent sub is placed in the drill string, the bend in the sub causes the drill string to deviate from vertical as drilling progresses. One drawback in the use of bent subs is that the angle is fixed. This means that numerous bent subs must be kept at the drill site to provide a selection of a range of angles which may be required as drilling progresses. The trend in the industry has, therefore, been to develop a single bent sub on which the angle can be adjusted. The angle of the present sub is adjusted prior to insertion into the well, and remains fixed until withdrawn and readjusted. Subs of this type are therefore referred to as "surface adjustable" bent subs, to distinguish them from subs that are "downhole adjustable", that is, adjustable while in the well bore without being withdrawn to the surface.

SUMMARY OF THE INVENTION

The present invention represents an alternate structure for an adjustable bent sub.

According to the present invention, then, there is provided an adjustable bent sub, comprising cylindrical housing means having a first uphole portion and a second downhole portion, said up and downhole portions being axially offset to one another, a cylindrical mandrel having a first uphole end and a second downhole end, said up and downhole ends being axially offset to one another, the uphole end of said mandrel being receivable within said housing means for longitudinal and rotational movement relative thereto, engagement means provided between said mandrel and said housing means to prevent the relative rotation thereof when said mandrel is in a first locked position relative to said housing means, lock means actuatable to maintain said mandrel in said first locked position thereof and a second unlocked position wherein said mandrel is longitudinally movable relative to said housing means into a second unlocked position in which said mandrel and housing means are free to rotate relative to one another, piston means concentrically disposed in said housing means for longitudinal movement relative thereto and spring means concentrically disposed in said housing means for biasing said piston means into contact with an end of said uphole end of said mandrel, wherein rotation of said mandrel relative to said housing means

increases or decreases the amount of bent in said sub between predetermined limits.

Preferred embodiments of the present invention will now be described in greater detail, and will be better understood when read in conjunction with the following drawings, in which:

Figure 1 is a partially cross-sectional elevational view of the bent sub described herein;

Figure 2 is an exploded, perspective view of the bent sub of Figure 1; and

Figure 3 is a cross-sectional view of the bent sub along the line D-D.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to Figures 1 and 2, adjustable bent sub 10 for use in directional well drilling generally comprises a tubular housing 12 and a tubular mandrel 14 located downhole of housing 12.

Housing 12 actually comprises two separate cylindrical housings, namely a tail housing 20 and an offset drive housing 22 threadedly connected together at 28. As will be described in greater detail below, housings 20 and 22 are axially offset relative to one another.

Generally speaking, it is desirable that bent sub 10 be adjustable to provide up to 2° of total bend relative to the longitudinal axis 21 of tail housing 20. Tail housing 20 is itself symmetrical about its longitudinal axis 21, which axis is colinear with the longitudinal axis of the drill string (not shown) connected uphole thereof by means of threaded connection 38.

Approximately one-half of the bent sub's total adjustable offset, which in one embodiment constructed by the applicant is 1°, is non-adjustably provided in the threaded connection 28 between tail housing 20 and offset drive housing 22. In this regard, externally threaded end 23 of drive housing 22 is machined at an offset angle of 1° as measured from point "x" relative to the longitudinal axis 21 of tail housing 20. This therefore results in a 1° "bend", identified as angle α , between the tail and drive housings. The 1° offset of threaded end 23 is shown with some exaggeration in Figure 2.

The remaining one-half of the sub's total bend, which again in the case of one embodiment constructed by the applicant is 1°, is provided by mandrel 14. Mandrel 14 comprises a cylindrical tubular barrel 40 and a tubular stinger 38. The mandrel as a whole is preferably machined as a single piece, with barrel 40 including at its end 42 a threaded connection 43 used to connect the sub to a bearing assembly (not shown) which in turn supports the drill bit (also not shown).

Barrel 40 is symmetrical about the mandrel's longitudinal axis 46 but stinger 38 is machined at a 1° offset to barrel 40, the 1° offset being measured from point "y", the offset itself being identified as angle β .

Stinger 38 is otherwise symmetrical about its longitudinal axis 47 except internally at 51 where its inner diameter widens out into the inner diameter of barrel 40.

As shown in Figure 1, stinger 38 is telescopically received into drive housing 22 so that longitudinal axis 47 of stinger 38 parallels the outer surface of the drive housing. As will therefore be appreciated, the 1° bend in the connection between the drive and tail housings is completely offset by the 1° bend between barrel 40 and stinger 38, with the result that the two bends exactly cancel each other. Longitudinal axis 46 of barrel 40 and longitudinal axis 21 of tail housing 20 are therefore aligned so that sub 10 as a whole is perfectly straight.

It will be appreciated that if the sub's total adjustable bend is not divided equally between the mandrel on the one hand and the housing on the other hand, a complete offset of the two angles will not be possible, with the result that the sub will always possess a certain amount of bend depending upon the apportionment of the offset between the mandrel and the housing.

If mandrel 14 is rotated in the clockwise direction by 180°, the two bends described above will complement each other to provide a total cumulative bend in the sub of 2° measured from point "y". More specifically, longitudinal axes 47 and 21 will intersect each other at point "y" at an angle of 2°. A further 180° rotation of mandrel 14 in either the clockwise or counterclockwise direction will again bring the total bend in the sub to 0° to thereby straighten the tool.

It is desirable that the amount of bend in the sub be incrementally adjustable, and that means be provided to lock the sub for preventing accidental or unintentional changes to the sub's bend when in use downhole.

This requires that means be provided to non-rotatably connect stinger 38 to housing 12 when the sub is in use to prevent relative rotation therebetween. These means must however be releasable to permit such rotation when it is desired to change or adjust the sub's angle.

With reference to Figures 1, 2 and 3, connecting means 64 comprise a plurality of circumferentially spaced apart elongated splines 65 formed on the outer surface of stinger 38, and a plurality of cooperating circumferentially spaced apart elongated splines 71 formed on the inner surface of drive housing 22. Splines 65 are elongated in the longitudinal direction of the stinger, extend radially outwardly from the outer surface of the stinger and are chamfered at their downhole ends as at 69 as seen most clearly from Figure 2. Similarly, splines 71 are also elongated in the longitudinal direction of the stinger, extend radially inwardly from the inner surface of drive housing 22 and fit slidably closely between splines 65 when the sub is locked.

As shown most clearly in Figures 1 and 3, splines 65 and 71 engage each other to prevent relative rotation between the mandrel and housing. Drive housing 22 is maintained in this first locked position relative to stinger 38 by means of, for example, a removable split collar 84 comprising two C-shaped half-rings 85 connected together at opposite ends thereof by means of threaded fasteners such as bolts 90 received into threaded apertures 91.

To adjust the sub's bend, collar 84 is first removed and drive housing 22, with tail housing 20 attached, is moved in the downhole direction as indicated by arrow A into a second unlocked position relative to mandrel 14. Splines 71 are thereby longitudinally displaced in the downhole direction to disengage splines 65 and occupy an annular empty space 87 between the outer surface of stinger 38 and the inner surface of threaded portion 23 of drive housing 22.

With splines 65 and 71 disengaged, mandrel 14 is free to rotate relative to housing 12. If, as shown in Figure 3, there are 12 of each of splines 65 and 71, the possible settings for the sub's bend are, incrementally, 0°, 0.5°, 1.0°, 1.5°, 1.75°, 2.0°, 1.75°, 1.5° and further 1/2° increments back to 0°.

After the amount of bend has been selected, housing 12 is displaced uphole relative to mandrel 14 back into the first locked position to re-engage splines 65 and 71. Collar 84 is then replaced to lock the mechanism at its new setting. Calibrations (not shown) are provided on the outer surfaces of barrel 40 and drive housing 22 to provide an externally readable indication of the amount of bend dialled into the sub.

Stinger 38 is threaded at its uphole end 39 to threadably engage a correspondingly internally threaded cylindrical nut 48. Nut 48 is carefully dimensioned to include a downhole end 49 which, when nut 48 is securely torqued onto the stinger, abuts against the uphole end 25 of drive housing 22. This prevents the withdrawal of mandrel 14 from housing 12, and additionally permits the application of a compressive force to the downhole end 31 of drive housing 23 against collar 84. Shoulder 47 of barrel 40, end 31 and the abutting lateral surfaces of collar 84 are carefully machined to provide a close metal-to-metal seal.

At its uphole end 47, nut 48 is convexly rounded and abuts against a correspondingly concavely rounded surface 59 of a piston 58. This fit accommodates the eccentric movement of stinger 38 relative to the piston as mandrel 14 is rotated from time to time to set the sub's angle.

Piston 58 is slidably movable in the longitudinal direction of the housing against the inner bore 7 of tail housing 20. Piston 58 is sealingly compressed against nut 48 by the action of spring 50. A bearing 56 is placed between spring 50 and piston 58 to prevent torsional winding of the spring that could otherwise

result when tail housing 20 is threaded to drive housing 22, or that might be caused by the rotational movement of mandrel 14 relative to housing 12.

When collar 84 is removed for adjustment of the sub's bend, mandrel 14 and housing 12 are moved together relative to one another against the force of spring 50 and conversely, when the required adjustment has been made, spring 50 helps restore the mandrel and housing to their separated positions permitting reattachment of collar 84.

As will be appreciated by those skilled in the art, drilling mud will be pumped under considerable pressure through the interior of sub 10, including the housing and mandrel, to the drill bit (not shown). The mud will return to the surface through the annulus between the drill string, including sub 10, and the inner surface of the well bore. It is important that mud not escape through any of the sub's joints as this will result in a loss of circulation at the bit. Should this happen, the entire string must be removed for repairs to the sub, causing considerable delay and expense.

Commencing at the uphole end of housing 12, spring 50 and bearing 56 operate in mud. Sealing between piston 58 and bore 7 of tail housing 20 is provided by a polypac seal 60. Piston 58 additionally includes a composite wear ring 51 to minimize metal-to-metal contact between itself and bore 7. The rounded interface between nut 48 and piston 58 is sealed by an O-ring 62.

A metal-to-metal seal 101 is made in the seam between the drive and tail housings, with additional sealing provided by O-ring 30.

Another O-ring 88 seals the downhole end of drive housing 22 against stinger 38. A second wear ring 90 is received into a circumferential groove 91 formed in the inner surface of the drive housing, the purpose of the wear ring being to minimize metal-to-metal wear between the drive housing and stinger 38.

Oil plugs 108 are provided in the outer surface of housing 12 for the addition of oil or grease to the annular spaces between the mandrel and housing in the zone between these plugs.

Assembly of the sub consists of sliding drive housing 22 over stinger 38, followed by the connection of threaded nut 48 which is torqued tight. Spring 50, bearing 56 and piston 58 are preloaded into tail housing 20, which is then torqued into threaded engagement with drive housing 22.

Adjustments to the sub's bend are usually made at the surface when the sub is threaded to a piece of drill pipe or other uphole equipment suspended from a derrick. Barrel 40 may be clamped in the derrick's rotary table, collar 84 is removed, the derrick applies a compressive force to move housing 12 downwardly towards shoulder 47 of barrel 40 to unlock splines 65 and 71, and the required bend can then be dialled in using a pair of tongs to grip and twist the housing. The compressive force from the derrick is removed and

spring 50 helps restore the mandrel and housing to their spaced apart positions for reattachment of collar 84. The chamfering on-splines 65 facilitate their engagement with splines 71.

It will be apparent to one skilled in the art how the structure of the present invention permits an adjustment to be made of adjustable bent sub 10. It will also be apparent to one skilled in the art that modifications may be made to the preferred embodiment without departing from the spirit and scope of the invention.

Claims

1. An adjustable bent sub, comprising:

cylindrical housing means having a first uphole portion and a second downhole portion, said up and downhole portions being axially offset to one another;

a tubular mandrel having a first uphole end and a second downhole end, said up and downhole ends being axially offset to one another, the uphole end of said mandrel being receivable within said housing means for longitudinal and rotational movement relative thereto;

connecting means provided between said mandrel and said housing means to prevent the relative rotation thereof when said mandrel is in a first locked position relative to said housing means;

lock means actuatable to maintain said mandrel in said first locked position thereof or to release said mandrel for longitudinal movement thereof relative to said housing means into a second unlocked position in which said mandrel and housing means are free to rotate relative to one another;

piston means concentrically disposed in said housing means for longitudinal movement relative thereto; and

resilient means concentrically disposed in said housing means for biasing said piston means into contact with an end of said uphole end of said mandrel, wherein said rotation of said mandrel relative to said housing means increases or decreases the amount of bend in said bent sub between predetermined limits.

2. The bent sub of claim 1 including tubular nut means disposed on said uphole end of said tubular mandrel to be coaxial therewith.

3. The bent sub of claim 2 wherein said nut means are convexly rounded at an uphole end thereof and an opposing surface of said piston means is correspondingly concavely rounded.

4. The bent sub of claim 3 further including sealing

means between said nut means and said piston means to prevent the flow of fluid therebetween.

5. The bent sub of claim 4 wherein said lock means comprise a removable collar circumferentially disposable about said uphole end of said tubular mandrel between a shoulder on said tubular mandrel and an opposed end surface of said downhole portion of said cylindrical housing.

6. The bent sub of claim 5 wherein said nut means engage said cylindrical housing to prevent complete withdrawal of said tubular mandrel from said cylindrical housing means and to urge said cylindrical housing means against said collar to maintain close contact therebetween.

7. The bent sub of claim 6 wherein said nut means abut against a cooperating surface of said downhole portion of said cylindrical housing means whereby a torquing of said nut means onto said tubular mandrel moves said downhole portion into compressive contact with said collar.

8. The bent sub of claim 7 wherein said connecting means comprise a plurality of radially outwardly extending members disposed circumferentially about said uphole end of said tubular mandrel and a plurality of cooperating radially inwardly extending members disposed circumferentially about an opposing inner surface of said cylindrical housing means, said inwardly and outwardly extending members being slidable relative to each other in the longitudinal direction of said bent sub between said first locked position in which said members engage one another to prevent said relative rotation and said second unlocked position in which said members are disengaged permitting said relative rotation.

9. The bent sub of claim 8 wherein said inwardly and outwardly projecting members comprise a plurality of parallel splines elongated in the longitudinal direction of said bent sub, said outwardly projecting splines being equi-spaced about said tubular mandrel, and said inwardly projecting splines being correspondingly equi-spaced on said inner surface of said cylindrical housing means.

10. The bent sub of claim 9 wherein said first uphole and second downhole portions of said cylindrical housing means are threadedly connected together at a predetermined angle defining said offset therebetween.

11. The bent sub of claim 10 wherein said offset in said cylindrical housing means equals the offset

in said tubular mandrel such that said offsets cancel one another in a first radial position between cylindrical housing means and said tubular mandrel and fully complement one another when said housing means and said tubular mandrel are rotated 180° relative to one another from said first radial position.

12. The bent sub of claim 11 further comprising bearing means disposed between said piston means and said resilient means to minimize torsional winding of said resilient means.

13. The bent sub of claim 12 wherein said offset between said first and second portions of said cylindrical housing means is one degree.

14. The bent sub of claim 13 wherein said offset between the uphole and downhole between said uphole and downhole ends of said tubular mandrel is one degree.

15. The bent sub of claim 14 further including sealing means between said first and second portions of said cylindrical housing to prevent the passage of fluid therebetween.

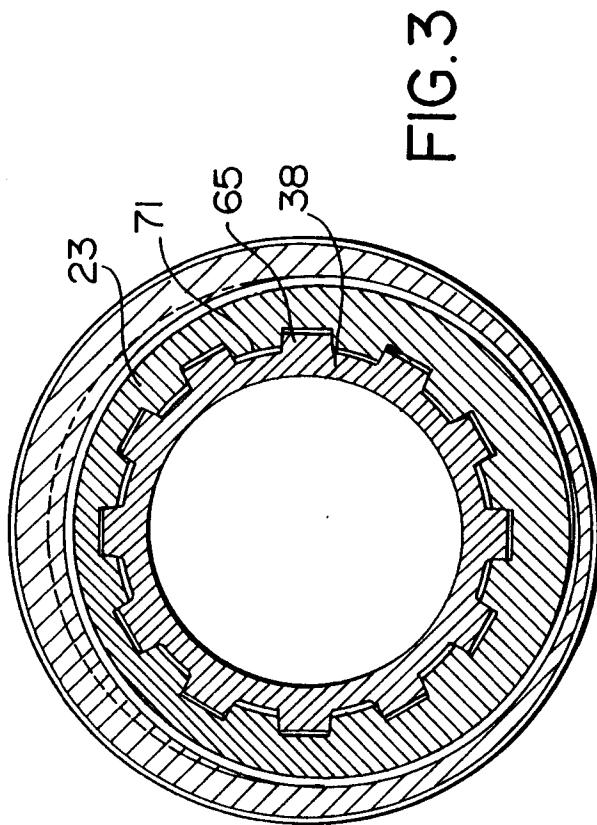
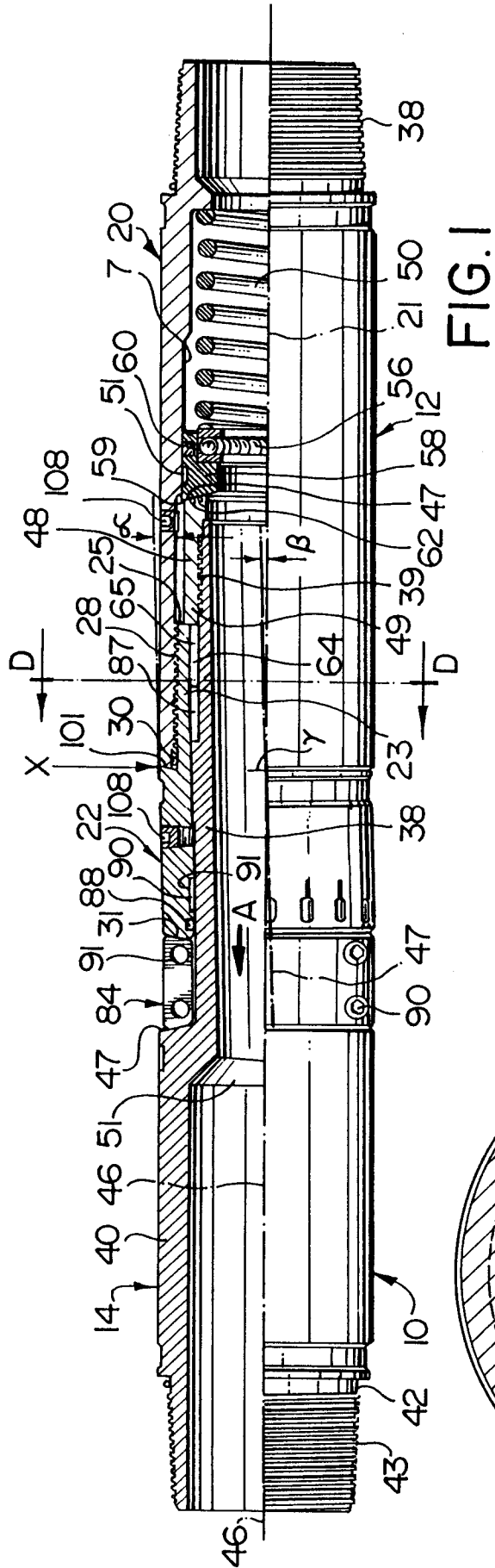
16. The bent of sub claim 15 further including sealing means between said downhole portion of said cylindrical housing means and said uphole portion of said tubular mandrel to prevent the passage of fluid therebetween.

17. The bent sub of claim 16 wherein the corners of said splines on said tubular mandrel are chamfered at the downhole ends thereof.

18. The bent sub of claim 17 including twelve of said splines on each of said tubular mandrel and said cylindrical housing means.

19. The bent sub of claim 18 wherein said resilient means comprise a spring.

20. An adjustable bent sub comprising a cylindrical housing and a tubular mandrel each having respective uphole and downhole portions axially offset to one another, one end of the mandrel being received within one end of the housing, whereby the amount of bend in the bent sub is dependent upon the relative angular positions of the mandrel and housing, and means for locking said mandrel and housing in relative angular positions thereof.



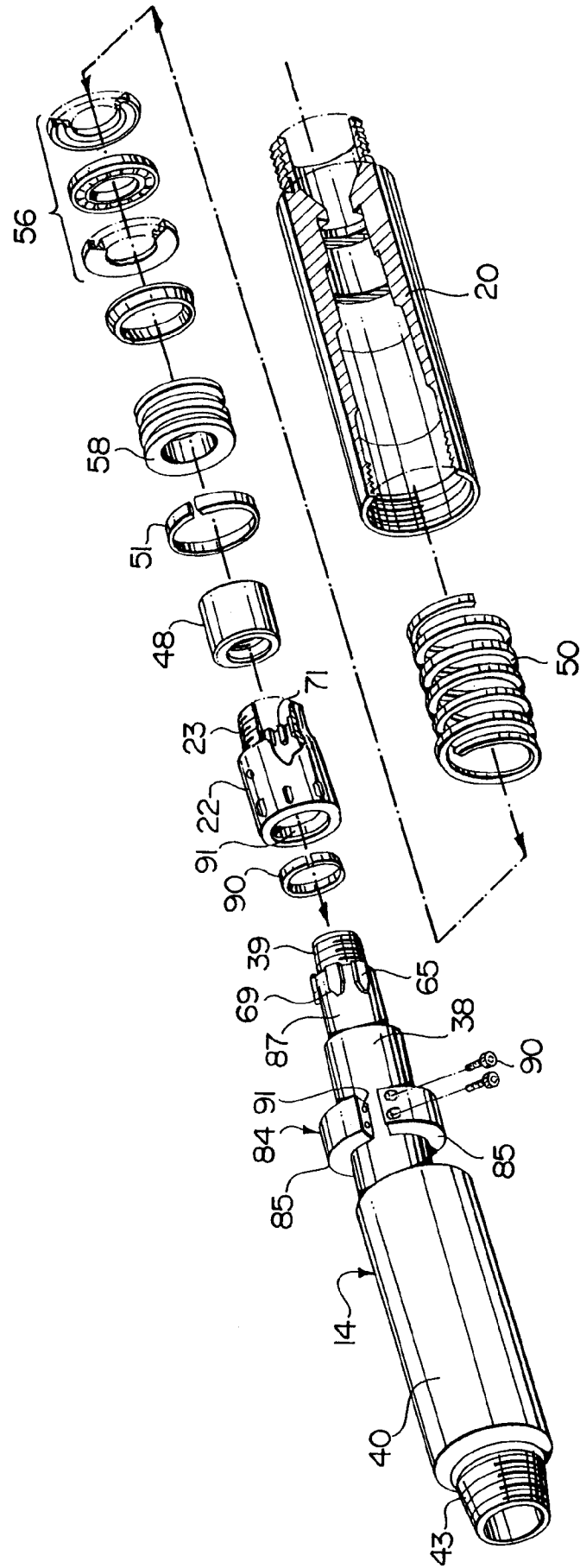


FIG.2