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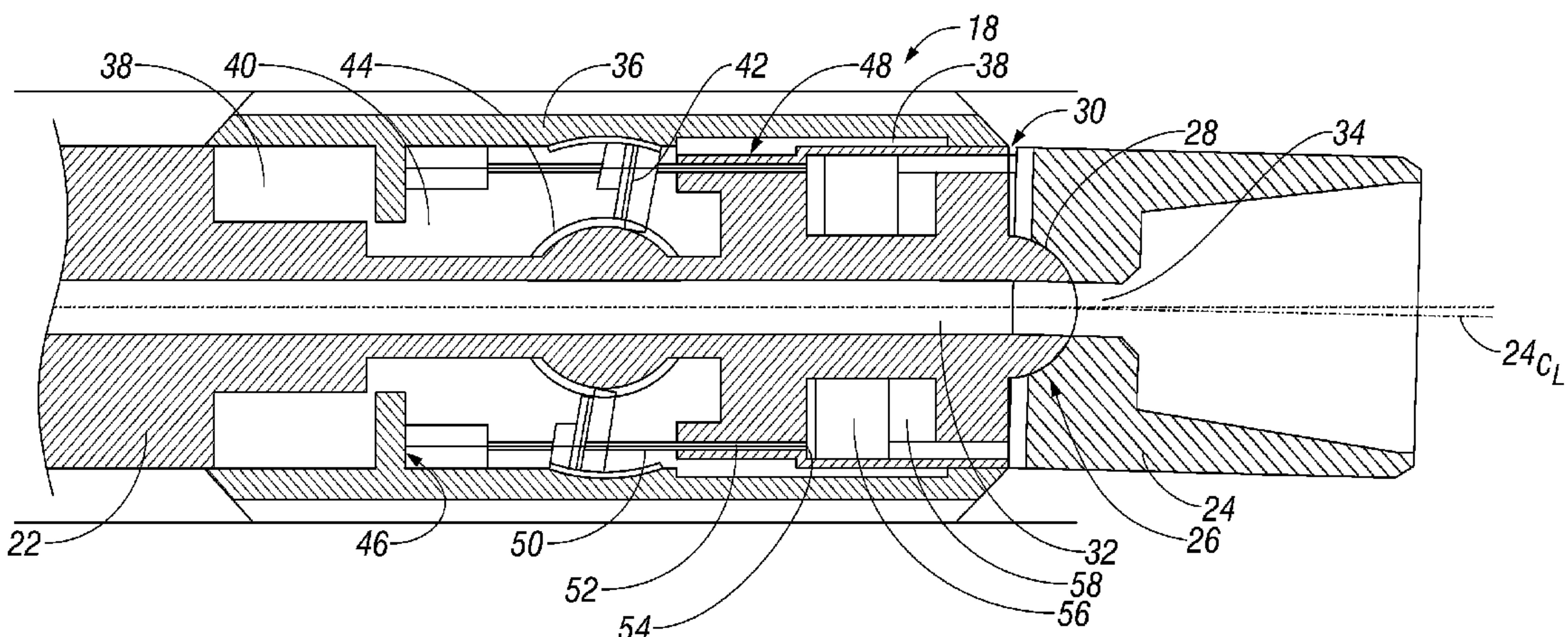
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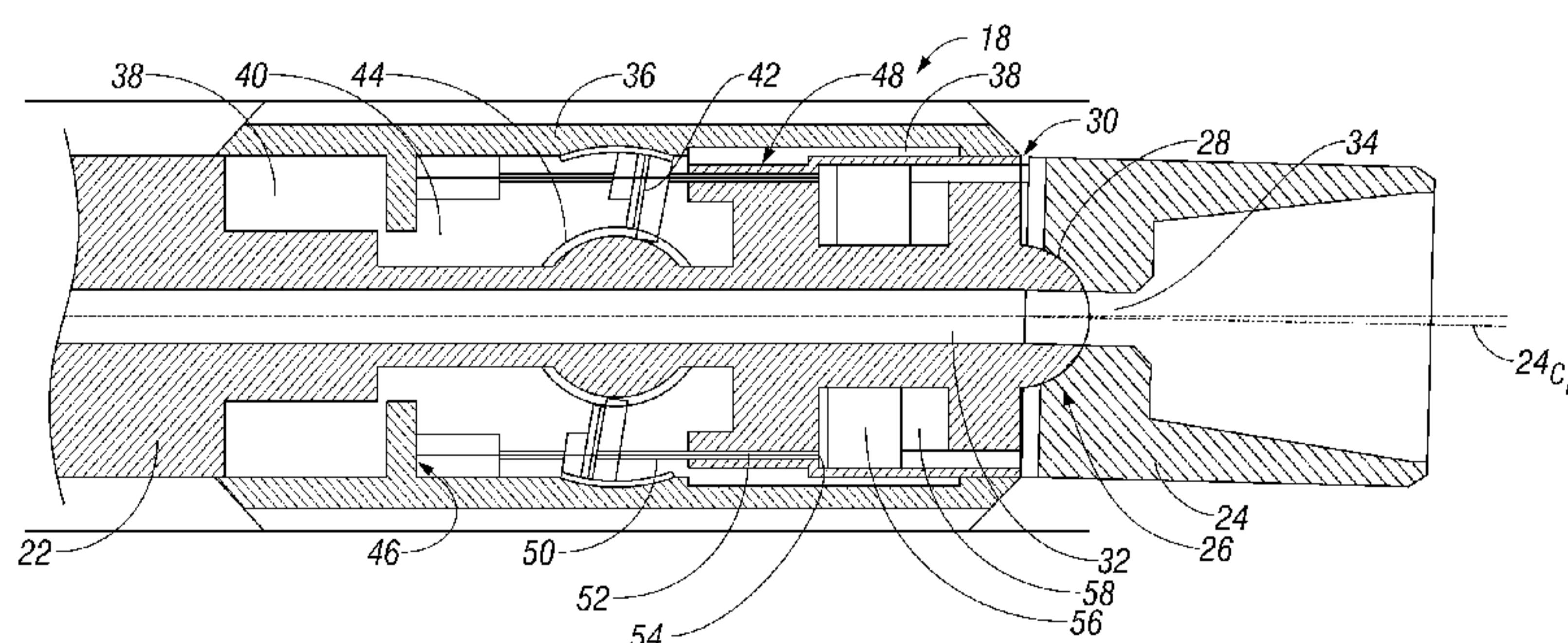
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50952-49

1

STEERABLE SYSTEM

This invention relates to a steerable system, for example for use in the formation of boreholes.

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It is commonplace in the field of borehole formation, for subsequent use in the extraction of hydrocarbons, to use a steerable drilling system to allow control over the path of the borehole. A number of steerable drilling systems are known. For example systems are known in which a bias unit is located close to the drill bit, the bias unit 10 being operable to apply a laterally directed load to the drill bit urging it away from the axis of the borehole in a desired direction. Another form of steerable drilling system includes a bent housing upon which the drill bit is mounted, steering of the system being achieved by controlling the orientation of the bent housing to ensure that the drill bit is pointed in a desired direction. In some arrangements the bent housing is 15 adjustable to control the direction and angle of the drill bit. In other arrangements, the bent housing is of fixed inclination and adjustment of the direction in which the drill bit is pointed is achieved by controlling the angular position of the bent housing.

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According to an embodiment of the present invention, there is provided a steerable system comprising a first rotatable housing, a second rotatable housing connected to the first rotatable housing by an adjustable joint, a cam member held against rotation, in use, and cam

follower means cooperable with the cam member and moveable to drive the second rotatable housing for movement relative to the first rotatable housing about the adjustable joint.

- 5 Such an arrangement is advantageous in that the axis of rotation of the second rotatable housing can be held in a substantially fixed position whilst the first and second rotatable housings are rotated. A drill bit carried by the second housing can thus be held in a desired orientation whilst drilling takes place.
- 10 Preferably, the first and second rotatable housings are connected to one another in such a manner that rotation of the first housing is transmitted to the second housing. A clutch mechanism, for example in the form of a dog clutch, may be provided to allow rotation of the first housing relative to the second housing.
- 15 The cam member is conveniently adjustable to permit adjustment of the orientation of the second housing. The cam member is conveniently in the form of a swash plate. The cam member is preferably mounted to a sleeve which surrounds at least part of the first housing and which is held against rotation in normal use. For example, the sleeve may comprise a stabiliser. A spherical bearing is preferably provided on the first housing
- 20 and arranged to support the cam member. One or more linear actuators are preferably provided to drive the cam member for movement relative to the sleeve to adjust its position. The or each linear actuator may be electrically driven or, alternatively, may be hydraulically powered.

50952-49

The cam followers means preferably comprise follower pistons arranged to be driven by the cam member and moveable to cause movement of drive pistons. The follower pistons are conveniently of smaller diameter than the drive pistons so as to provide a mechanical advantage. Movement of the drive pistons is conveniently transmitted to the second housing by associated push rods.

5 The push rods are conveniently aligned with the corresponding ones of the follower pistons. In such an arrangement the second housing will be inclined relative to the first housing in the same direction as the cam member, but the angle of inclination will be smaller.

According to another embodiment of the present invention, there is provided a steerable system comprising a first rotatable housing, a second rotatable housing connected to the first rotatable

10 housing by an adjustable joint, a cam member held against rotation, in use, and a cam follower cooperable with the cam member, the cam follower comprising follower pistons which are reciprocable in corresponding bores, the follower pistons causing movement of associated drive pistons having larger diameters than the follower pistons such that each associated drive piston is moved over a smaller distance than the corresponding follower piston when acted on by the
15 corresponding follower piston to provide mechanical advantage which enables the associated drive pistons to apply a larger force, wherein the associated drive pistons are moveable to drive the second rotatable housing for movement relative to the first rotatable housing about the adjustable joint.

20 The invention will further be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic view of a steerable drilling system incorporating the steerable system of one embodiment of the invention; and

Figure 2 is an enlarged, sectional view illustrating the steerable system of the drilling system of Figure 1.

50952-49

3a

Referring to the accompanying drawings there is illustrated a steerable drilling system being used in the formation of a borehole. The steerable drilling system comprises a drill string 10 supporting a number of downhole components. The drill string 10 is

supported, at the surface, by a rig which serves both a supporting function and also drives the drill string 10 for rotation.

The drill string 10 carries a number of intermediate stabiliser units 12 and, at its lower 5 end, carries a bottom hole assembly 14. The bottom hole assembly 14 includes a downhole motor 16, a steerable system 18, and a drill bit 20. In use, the motor 16 serves to drive the drill bit 20 for rotation. The rotation of the drill bit 20, in combination with weight on bit loadings applied thereto, causes the drill bit 20 to gauge, scrape or abrade material from the formation in which the borehole is being formed, 10 extending the borehole.

Although the arrangement illustrated makes use of a downhole motor, arrangements are also possible in which the drill bit is driven by the rotation of the drill string.

15 The steerable system 18 operates to ensure that, whilst drilling is taking place, the drill bit 20 is held in a desired orientation, thus controlling the direction in which the borehole is extended.

As best illustrated in Figure 2, the steerable system 18 comprises a first rotatable 20 housing 22 arranged to be connected to the output of the downhole motor 16 so as to be driven for rotation thereby. A second rotatable housing 24 is connected to the first housing 22 by an adjustable joint 26, for example in the form of a universal joint or swivel. The joint 26 includes a part spherical thrust bearing 28 thus permitting the transmission of axially directed loadings from the first housing 22 to the second housing

24, whilst permitting the angle of the axis 24a of the second housing 24 to be adjusted relative to that of the first housing 22.

A releasable torque transmission arrangement in the form of a dog clutch 30 is provided

5 between the first and second housings 22, 24 such that, when desired, rotation of the first housing 22 about its axis can be transmitted to the second housing 24, release of the dog clutch 30 permitting the first housing 22 to rotate independently of the second housing 24.

10 An axially extending passage 32 extends through the first housing 22 and the joint 26 to a passage 34 provided in the second housing 24, thus permitting drilling fluid or mud to be supplied through the steerable system 18.

A stabiliser sleeve 36 surrounds part of the first housing 22. The sleeve 36 bears against

15 the wall of the borehole and remains substantially fixed against rotation, in use. The sleeve 36 is mounted to the first housing 22 by bearings 38, which also serve as seals, so as to allow the first housing 22 to rotate whilst the sleeve 36 remains fixed against rotation. The sleeve 36 and first housing 22 together define a chamber 40 within which a cam member in the form of a swash plate 42 is located. The swash plate 42 is keyed

20 or splined to the sleeve 36 such that, in normal use, it is held against rotation. The nature of the connection between the swash plate 42 and the sleeve 36 is such that the angular orientation of the swash plate 42 can be adjusted. A spherical bearing 44 is provided between the inner part of the swash plate 42 and the adjacent part of the first housing 22 to accommodate such movement whilst supporting the swash plate 42. A

series of linear actuators 46 are mounted upon the sleeve 36 and engage the swash plate 42, the linear actuators 46 being operable under the control of an appropriate control system (not shown) to adjust the orientation of the swash plate 42 relative to the sleeve 36. The linear actuators 46 may take a range of forms. For example, they could be 5 electrically or electromagnetically actuated, or alternatively they may be hydraulically operated.

The opposite face of the swash plate 42 to that which cooperates with the linear actuators 46 engages a series of cam follower means 48. The cam follower means 48 10 each comprises a relatively small diameter follower piston 50 which bears against the swash plate 42 and which is reciprocable within a corresponding bore 52 formed in the first housing 22. The bore 52 opens into a larger diameter bore 54 in which a larger diameter drive piston 56 is reciprocable. It will be appreciated that, with such an arrangement, movement of the follower piston 50 causes movement of the associated 15 drive piston 56 in the same direction. The drive piston 56 will move through a smaller distance than the follower piston 50, but is able to apply a larger force by virtue of the mechanical advantage so gained.

A series of push rods 58 bear against the drive pistons 56, transmitting movement 20 thereof to the second housing 24.

In use, in the position illustrated in Figure 2 it will be appreciated that the swash plate 42 is angled relative to the first housing 22, and that the second housing 24 is tilted relative to the first housing 22 in the same direction as the swash plate 42 but by a

smaller angle. From this position, rotation of the first housing 22 due to the operation of the motor 16 causes the follower pistons 50, in turn, to ride up and over the swash plate 42, the follower pistons 50 each being pushed further into the corresponding bores 52 by their movement over the swash plate 42. The movement of the follower pistons 50 is transmitted, by the fluid within the bores 52, 54, to the associated drive pistons 56, extending the push rods 58 and urging the second housing 24 to tilt about the joint 26. The tilting movement of the second housing 24 so achieved drives the push rods 58, and drive and follower pistons 56, 50 on the radially opposite side of the steerable system in the reverse direction towards a retracted position. It will be appreciated that this action ensures that the axis of rotation 24a of the second housing 24 is held substantially fixed in space whilst the first and second housings 22, 24 are rotated. Consequently, the drill bit 20 is held in a desired orientation whilst drilling takes place.

Appropriate adjustment of the position of the swash plate 42 by the linear actuators 46 can be used to adjust the degree of inclination of the second housing 24 relative to the first housing 22 and to adjust the direction or orientation of the axis of rotation 24a of the second housing 24 relative to the first housing 22. It will thus be appreciated that, by appropriate control of the position of the swash plate 42 using the linear actuators 46, the direction of drilling of the steerable drilling system can be controlled.

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The mechanical advantage due to the nature of the cam follower means ensures that a sufficiently large magnitude force is available to deflect or tilt the second housing 24 in the desired direction, even when large loading resisting such movement are applied.

It will be appreciated that a wide range of modifications and alterations can be made to the arrangement described hereinbefore without departing from the scope of the invention.

50952-49

CLAIMS:

1. A steerable system comprising a first rotatable housing, a second rotatable housing connected to the first rotatable housing by an adjustable joint, a cam member held against rotation, in use, and a cam follower cooperable with the cam member, the cam follower comprising follower pistons which are reciprocable in corresponding bores, the follower pistons causing movement of associated drive pistons having larger diameters than the follower pistons such that each associated drive piston is moved over a smaller distance than the corresponding follower piston when acted on by the corresponding follower piston to provide mechanical advantage which enables the associated drive pistons to apply a larger force, wherein the associated drive pistons are moveable to drive the second rotatable housing for movement relative to the first rotatable housing about the adjustable joint.
2. A system according to Claim 1, wherein the first and second rotatable housings are connected to one another in such a manner that rotation of the first housing is transmitted to the second housing.
3. A system according to Claim 2, further comprising a clutch mechanism operable to allow rotation of the first housing relative to the second housing.
4. A system according to Claim 3, wherein the clutch mechanism comprises a dog clutch.
5. A system according to Claim 1, wherein the cam member is adjustable to permit adjustment of the orientation of the second housing.
6. A system according to Claim 1, wherein the cam member is mounted to a sleeve which surrounds at least part of the first housing and which is held against rotation during use.
7. A system according to Claim 6, wherein the sleeve comprises a stabiliser.

50952-49

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8. A system according to Claim 6, wherein a spherical bearing is provided and arranged to support the cam member relative to the sleeve.
9. A system according to Claim 6, wherein one or more linear actuators are provided to drive the cam member for movement relative to the sleeve to adjust its position.
- 5 10. A system according to Claim 9, wherein each linear actuator is electrically driven, electromagnetically driven or is hydraulically powered.
11. A system according to Claim 1, wherein the cam member is in the form of a swash plate.
12. A system according to Claim 1, wherein movement of the drive pistons is
10 transmitted to the second housing by associated push rods.
13. A system according to Claim 12, wherein the push rods are aligned with the corresponding ones of the follower pistons.
14. A system according to Claim 1 further comprising a motor arranged to drive the first rotatable housing, and a drill bit mounted to the second housing thereof.

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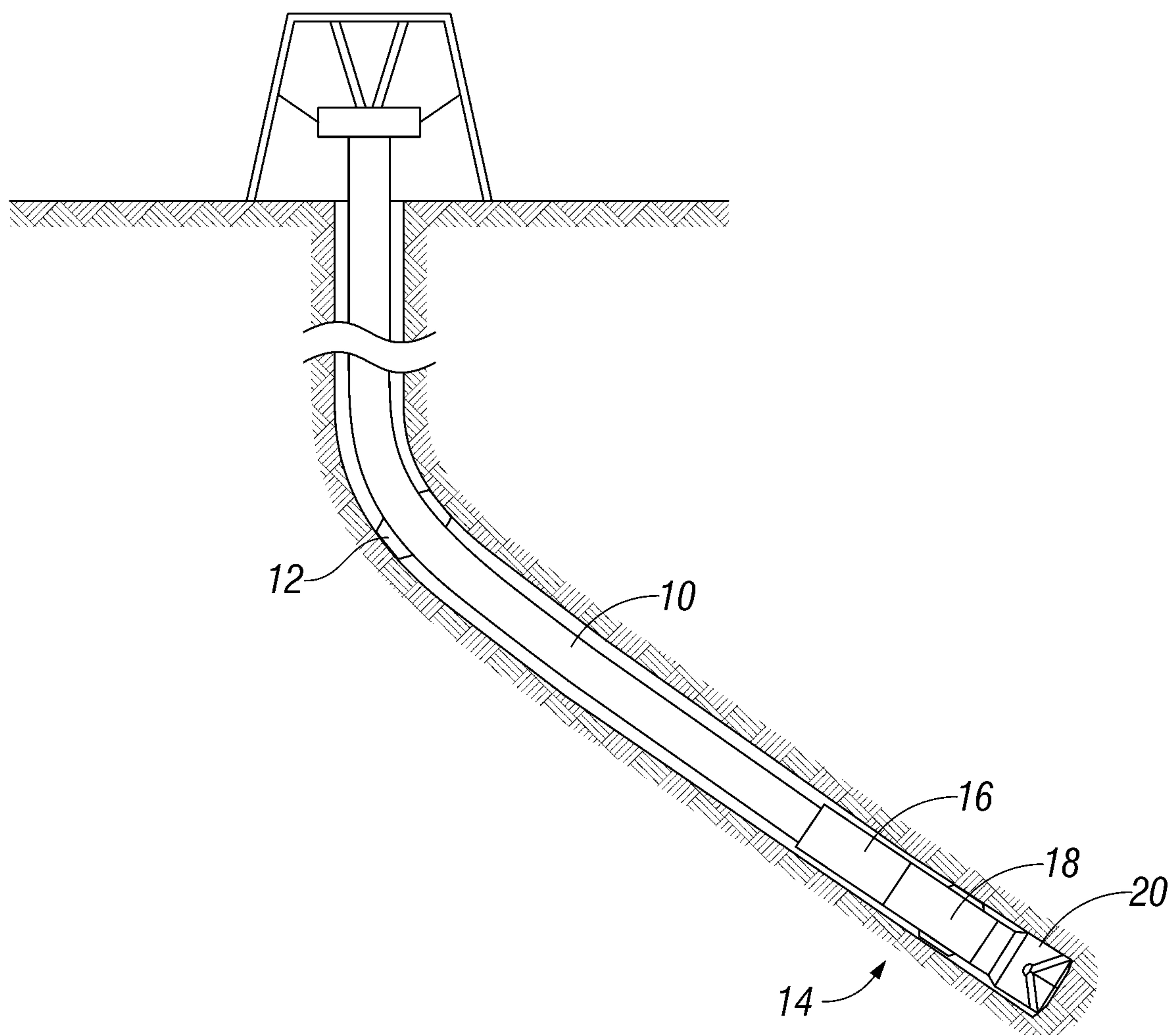


FIG. 1

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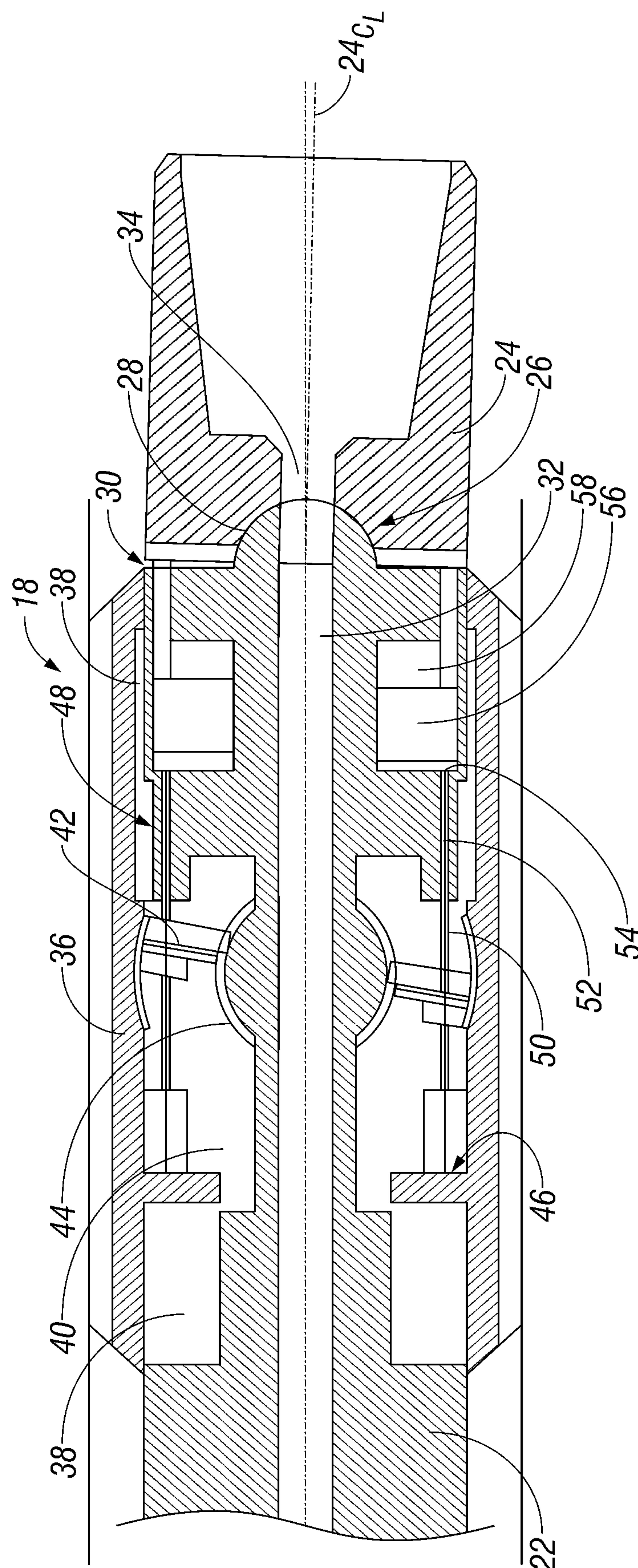


FIG. 2

