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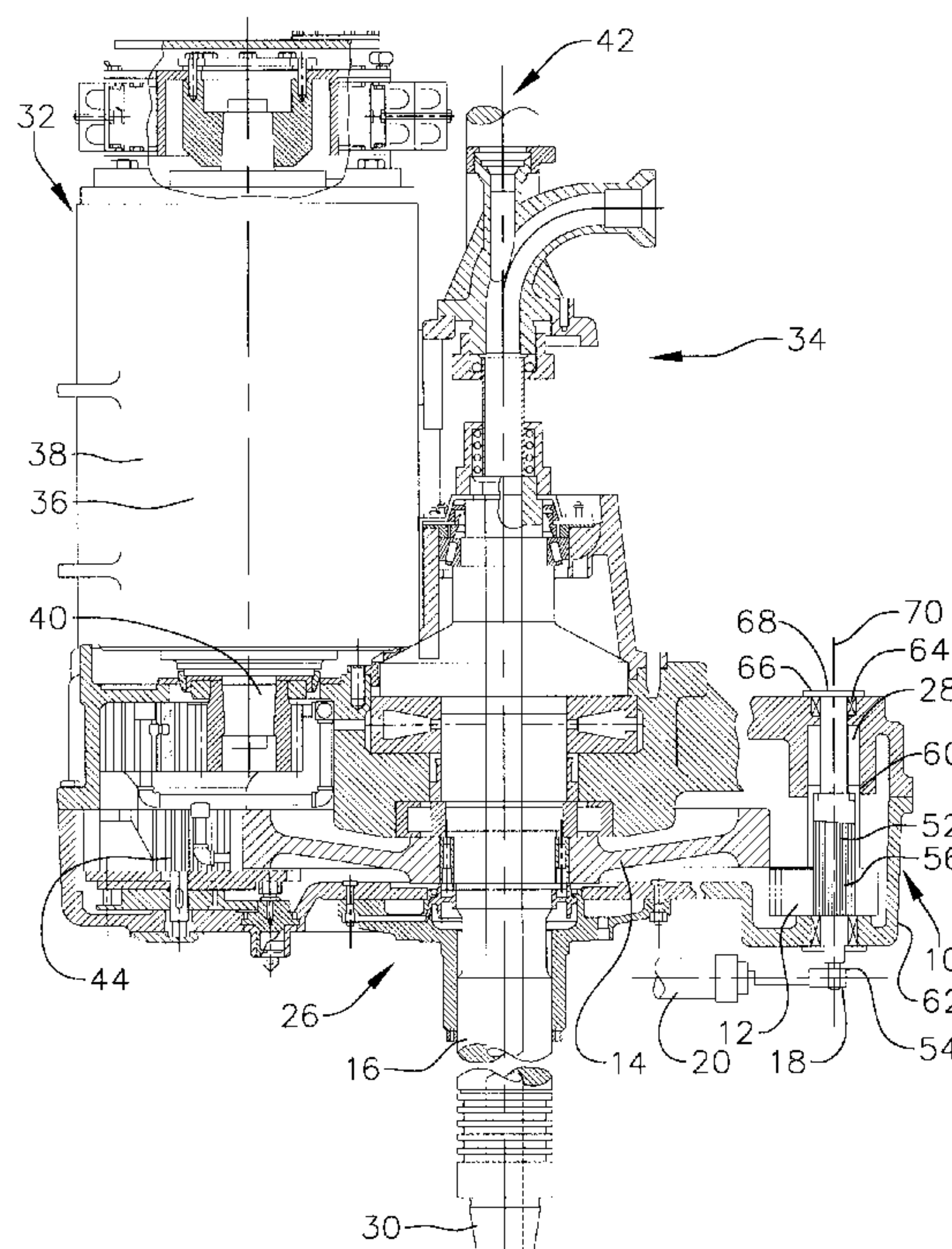
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(54) Title: TORQUE BOOST APPARATUS AND METHOD FOR TOP DRIVE DRILLING SYSTEMS



(57) **Abrégé/Abstract:**

The torque boost apparatus and method for top drive drilling systems of the present invention provides a light and compact modification of existing TDS designs in order to produce a short yet strong torque boost for the TDS main drive shaft. The present invention uses a hydraulic cylinder to power a gear segment for providing a torque boost to a spur gear attached to the TDS main drive shaft. It provides the TDS main drive shaft with enough added torque to break-out and make-up tightly connected drive stem components and can additionally be used to produce a high torque boost for the drill bit.

**TORQUE BOOST APPARATUS AND METHOD FOR TOP DRIVE DRILLING
SYSTEMS**

ABSTRACT

The torque boost apparatus and method for top drive drilling systems of the present invention provides a light and compact modification of existing TDS designs in order to produce a short yet strong torque boost for the TDS main drive shaft. The present invention uses a hydraulic cylinder to power a gear segment for providing a torque boost to a spur gear attached to the TDS main drive shaft. It provides the TDS main drive shaft with enough added torque to break-out and make-up tightly connected drive stem components and can additionally be used to produce a high torque boost for the drill bit.

TORQUE BOOST APPARATUS AND METHOD FOR TOP DRIVE
DRILLING SYSTEMS

5 **BACKGROUND OF THE INVENTION**

Top drive drilling systems (“TDS”) often have one or more Inside Blowout Preventer (“IBOP”) valves and a saver sub connecting the main drive shaft of the TDS to the drill string. For example, an upper IBOP valve is often threadedly
10 connected to the lower end of the main drive shaft, with a lower IBOP valve and a saver sub is threadedly connected below the upper IBOP valve. The drill string is then threadedly connected below the saver sub. Thus, rotational motion is transferred from the TDS’s drive shaft, down through the upper IBOP valve, the lower IBOP valve and the saver sub, to the drill string.

15 During drilling operations, rotational motion is imparted to the drill string utilizing at least one pinion to rotate a main spur gear of the TDS. The pinions are rotated by an electric motor of the TDS. Prior top drive well drilling systems utilizing such gear arrangements are described in U.S. Patent 4,421,179 to Boyadjieff and U.S. Patent 4,437,524 to Boyadjieff et al. Often, more than one
20 pinion is used to rotate the spur gear. For example, a low torque pinion may be used during normal drilling to rapidly rotate the drill bit with a maximum sustainable torque of approximately 35,000 foot-pounds. A second, high torque pinion is used to rotate the drill bit more slowly at a maximum torque of approximately 50,000 foot-

pounds for drilling through harder formations. These separate pinions may be brought into and out of engagement with the spur gear by a conventional Geneva-type gear mechanism.

The connections between the drive shaft of a TDS, the upper IBOP valve, the lower IBOP valve, the saver sub and the drill string are typically too tight to be made-up (tightened) or broken-out (loosened) by the torque of the TDS electric motor alone. This is particularly true of the connection between the drive shaft and the upper IBOP because it is normally torqued to a significantly higher level than the components below the upper IBOP. U.S. Patent 4,449,596 to Boyadjieff describes a special torque wrench, or pipe handler, that provides extra force for breaking tight connections between components of a drill string. This torque wrench works well for making-up and breaking-out the connections between the upper IBOP valve, the lower IBOP valve, the saver sub and the drill string, but has not been able to be used for making-up and breaking-out the highly torqued upper IBOP valve from the drive shaft of the TDS. The problem has been that the torque wrench cannot reach the main drive shaft to keep it from rotating while applying torque to the upper IBOP valve.

Rather than using a torque wrench, tight connections can be broken-out and made-up by increasing the output torque of the main drive shaft of a TDS. The prior art spur gear and pinions provide a maximum of approximately 60,000 foot-pounds of torque to the main drive shaft. However, over 90,000 foot-pounds of torque is often required for breaking-out tightly fastened drill stem components. In one prior art apparatus, in order to provide this additional torque, an additional spur gear of very large

diameter has been added to main drive shaft of a TDS. The gear's large diameter provides the gearing required for the motor of the TDS to apply greater torque to the main drive shaft, but the resulting apparatus is bulky and rather expensive. Since the TDS is suspended above the rig's floor, it is desirable to make it as light and compact as possible.

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SUMMARY OF THE INVENTION

The torque boost apparatus and method for top drive drilling systems of the present invention provides a light and compact modification of existing TDS designs in order to produce a short, yet powerful, torque boost for the TDS main drive shaft. The illustrated embodiment uses a hydraulic cylinder to power a partial gear segment for providing a torque boost to a spur gear attached to the TDS main drive shaft. It provides the TDS main drive shaft with enough torque, when combined with the torque of the TDS motor drive, to break-out and make-up tightly connected drive stem components, such as an upper IBOP carried at the bottom of the main drive shaft.

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To realize the advantages outlined above, the structure and method of the present invention relate to an apparatus for boosting torque in a top drive drilling system having a housing, a main shaft rotatable within the housing, and a main gear mounted for rotation with the main shaft, the torque boost apparatus comprising: a torque boost gear structure engageable with the main gear to provide torque to the main shaft; and a linear actuating mechanism for driving the torque boost gear structure relative to the main gear.

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In one embodiment, the torque boost gear structure is rotatable about an axis parallel to

the main shaft and has a crank portion actuatable by the linear actuating mechanism to rotate the main gear and thus the main shaft. The torque boost gear structure is then movable axially between positions of engagement and disengagement with the main gear, preferably upon a splined shaft. The torque boost gear structure may also include a fluid driven cylinder, which may be hydraulic. In such an embodiment, the torque boost gear structure typically moves axially into engagement with the main gear, rotates the main gear less than a full revolution under the influence of the linear actuating mechanism, and then retracts axially to a position of disengagement with the main gear. There may be at least one rotatable drive gear engageable with the main gear to drive the main shaft. The drive gear and the torque boost gear are then used to simultaneously apply torque to the main gear.

In a further aspect, the present invention provides a method for boosting torque in a top drive drilling system having a housing, a main shaft rotatable within the housing, and a main gear mounted for rotation with the main shaft, comprising the steps of:

- a) engaging a torque boost gear structure with the main gear; and
- b) rotatably driving the torque boost gear structure by a linear actuating mechanism to provide torque to said main gear.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, which constitute part of this specification, embodiments demonstrating various features of the invention are set forth as follows:

FIGURE 1 is a partial vertical cross-sectional view of a top drive

drilling system with a torque boost apparatus showing the torque boost gear structure disengaged from the spur gear;

FIGURE 2 is a vertical cross-sectional view of the top drive drilling
5 system of FIGURE 1 showing the torque boost gear structure engaged with the spur gear;

FIGURE 3 is a bottom plan view of the top drive drilling system of
FIGURE 1, shown with the lower portion of the housing removed.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Although detailed illustrative embodiments are disclosed herein, other suitable structures and machines for practicing the invention may be employed and will be apparent to persons of ordinary skill in the art. Consequently, specific structural and functional details disclosed herein are representative only; they merely describe
5 exemplary embodiments of the invention.

FIGURE 1 illustrates a top drive system or TDS having a torque boost apparatus 10 constructed according to one embodiment of the invention, the torque boost apparatus having a torque boost gear structure or "gear segment" 12 engageable with a
10 main bull gear 14 mounted for rotation in a driving relationship with a main shaft 16 of the TDS. One end 18 of a linear actuating mechanism 20, which may be a hydraulic piston and cylinder mechanism, is pivotally attached to a crank portion 22 of the torque boost gear structure 12 (FIGURE 3). A second end 24 of linear actuating mechanism 20 is pivotally attached to a gear housing 26 of the TDS to provide a suitable backup for the
15 force applied to the crank portion 22. A vertical travel cylinder 28, which may also be a fluid-driven piston and cylinder mechanism, is provided to actuate the torque boost gear structure 12 axially between the retracted condition of FIGURE 1 and the engaged position of FIGURE 2 in which the torque boost gear structure is engaged with the main gear 14 of the TDS in a torque boosting relationship. When the torque boost gear
20 structure 10 is in its engaged position, the desired level of torque is applied to the main shaft 16 by extending or retracting the cylinder 20.

As shown in FIGURES 1 and 2, the main drive shaft 16 passes through the gear housing 26 and terminates in an externally threaded pin end portion 30. An upper IBOP valve (not shown), which may be threaded onto the pin end portion 30, is typically torqued to a very high torque level, often over 90,000 foot-pounds, to prevent it from coming lose during normal drilling operations. A lower IBOP valve (not shown) and other components can then be threadedly connected to the upper IBOP, followed by a drill string made up of drill pipe and drill collars. Attached to the bottom of the drill string is a drill bit (also not shown). It will be understood, however, that other combinations and components can be used for connecting the main drive shaft 16 of the TDS to the drill bit.

The main drive shaft 16 of the TDS is driven by a power unit 32 that, that includes an electric motor 36 having a case or housing 38 containing the field coils of the motor and an armature shaft 40 mounted for rotation about an axis 42. A pinion gear or drive gear 44 is connected to the lower end of the armature shaft 40 and is engageable with the larger diameter main gear 14 disposed about the main drive shaft 16. The drive gear 44 has drive gear teeth or cogs 46 for engaging with main gear teeth or cogs 48.

As shown in FIGURE 3, one or more drive gears can be used to rotate the main gear 14. For example, a low torque drive gear 44 can be used during normal drilling to rapidly rotate the drill bit and produce a maximum torque of approximately 35,000 foot-pounds. A second, high torque drive gear 50, can be used to rotate the drill bit more slowly at a maximum torque of approximately 50,000 foot-pounds for drilling through harder formations. These two drive gears can be alternately brought into

engagement with the main gear 14 by way of a via a Geneva-type gear mechanism.

These drive gears can also be used to make-up, break-out, spin-out or spin-in drill stem components under some conditions.

5 The torque wrench or pipe handler disclosed in U.S. Patent 4,449,596 to Boyadjieff, cited above, can be used to secure a component against rotation while the main drive shaft rotates to make-up, break-out, spin-out or spin-in such a drill string component. The slips disclosed in U.S. Patent 4,449,596 to Boyadjieff can also be used to immobilize a component during these operations.

10 Some drill stem components are connected too tightly to be broken-out or made-up using the conventional drive gears, however. For example, over 100,000 foot-pounds of torque is sometimes required for breaking-out an upper IBOP valve. Usually, the existing low torque gear 44 produces approximately 35,000 foot-pounds of torque, and the existing high torque gear 50 produces approximately 50,000 foot-pounds of torque with a maximum of approximately 60,000 foot-pounds of torque being available
15 with the gear 50 for short periods of time. Thus, we have added the torque boost apparatus 10 to the TDS 34 to provide enough extra torque to break-out and make-up tight drill stem component connections, such as upper IBOP's. In one embodiment, the torque boost apparatus 10 of the present invention provides up to an additional 53,000 foot-pounds of torque, which can be added to the 60,000 foot-pounds of torque produced
20 by the high torque gear 50 in order to create 113,000 foot-pounds of torque for breaking-out or making-up extremely tight connections.

FIGURE 1 illustrates the torque boost apparatus 10 with the torque boost gear structure 12 disengaged from the main gear 14. A torque boost casing 62 can be integral with the gear housing 26, or can be a separate portion attached to the gear housing 26, as when the torque boost apparatus 10 is retrofitted to an existing TDS.

5 FIGURE 3 shows that one end 18 of the linear actuating mechanism 20 is pivotally attached to the crank portion 22 of the torque boost gear structure 12 and the other end 24 of the linear actuating mechanism 20 is pivotally attached to the gear housing 26. The crank portion 22 can be integral with the gear structure 12 or a splined shaft 52, or can be separately attached in any way that will effectively transfer force to the gear structure 12.

10 In the illustrated embodiments, the crank portion 22 is attached to the splined shaft 52 at the splined shaft end 54. The upper end of the splined shaft 66 has a head 68 for supporting the splined shaft 52 against the torque boost casing 62. A seal 64 creates a fluid-tight seal between the splined shaft 52 and the torque boost casing 62, while allowing rotation of the splined shaft relative to the torque boost casing 62. The torque
15 boost gear structure 12 engages the splines 56 of the splined shaft 52 so that rotation of the splined shaft 52 produces rotation of the torque boost gear structure 12.

The torque boost gear structure 12 is preferably only a partial gear with gear teeth extending only partially around its periphery. However, in other embodiments the torque boost gear structure 12 can be a pinion gear with teeth around it's entire rim, or
20 a linear gear rack. The splined shaft 52 rotates about an axis 70 parallel to the main drive shaft axis 42.

Attached to one end of the torque boost gear structure 12 is a fluid-driven piston portion 60 of the vertical travel cylinder 28, which creates a fluid-tight seal between the splined shaft 52 and the torque boost casing 62. The piston portion 60 is drawn up into the vertical travel cylinder 28 in order to draw the torque boost gear structure into engagement with the main gear 14. In one embodiment, the vertical travel cylinder 28 is a standard hydraulically-driven cylinder. In other embodiments the fluid-driven cylinder 28 can be pneumatically operated. The torque boost gear structure can also be moved into engagement with the main gear 14 using any other known actuating device.

In order to use the torque boost apparatus 10 to break-out a drill string component, for example an upper IBOP valve, the component must first be secured against rotation. This can be done using the torque wrench of U.S. Patent 4,449,596 to Boyadjief, for example. The linear actuating mechanism 20 may then be extended or retracted to place the crank portion 22 and the gear structure 12 in a rotational position corresponding to the starting point of their torque boost stroke. The fluid driven cylinder 28 is then activated to pull the torque boost gear structure 12 into engagement with the main gear 14 by pulling the cylinder piston portion 60 into the vertical travel cylinder 28, as illustrated in FIGURE 2. The electric motor 36 of the TDS is then activated to turn the high torque drive gear 50 and the linear actuating mechanism 20 is retracted or extended to the opposite end of its stroke. As the linear actuating mechanism 20 moves, it rotates the crank portion 22 and the torque boost gear structure 12 to turn the main gear 14, and thus provide torque to the main drive shaft 16, to break-out the drill stem component.

The linear actuating mechanism 20 continues to rotate the torque boost gear structure 12 until the last teeth of the torque boost gear structure are reached and the drill stem component is broken-out. When the torque boost gear structure reaches the end of its intended travel, it retracts and the electric motor 36 of the TDS continues to spin out the drive stem component until it is fully disengaged.

Drill string components can be made-up using a similar procedure. The component is first secured against rotation, such as by the torque wrench discussed above. The low torque drive gear 44 shown in FIGURE 3 is then used to spin the drill stem component into the drill stem until it is shouldered. The linear actuating mechanism 20 is then moved to the beginning of its tightening stroke and the fluid driven cylinder 28 is activated to engage the torque boost gear structure with the main gear 14 by pulling the fluid driven cylinder piston portion 60 into the fluid driven cylinder 28 as illustrated in FIGURE 2. The electric motor 36 of the TDS is then activated to turn the high torque drive gear 50 and the crank portion 22 is simultaneously actuated by the linear actuating mechanism 20. This rotates the torque boost gear structure 12, to apply torque to the main drive shaft 16 and make-up the drill string component. After making-up the drill string component to the desired torque, the component can be released from the device that was used to secure it.

The following example illustrates how a desired make-up or break-out torque can be achieved by setting a predetermined distance for the linear actuating mechanism 20 to extend or retract. When a connection to be broken-out is torqued to 90,000 foot-pounds, or a connection is to be made-up to 90,000 foot-pounds, the electric

motor 36 can be adjusted to provide 50,000 foot-pounds of torque. An additional 40,000 foot-pounds of torque must then be provided to supply the required total of 90,000 foot-pounds. In this example, we will assume that the main gear 14 is 48 inches in diameter, the effective radius of the crank portion 22 is 8 inches, and the effective radius of the torque boost gear structure 12 is 5 inches. In order to apply a desired torque boost of 40,000 foot-pounds over 10 degrees of main shaft rotation, the angular rotation of the torque boost gear structure 12 is approximately 30 degrees and the linear actuating mechanism 20 would extend or retract a distance of approximately 5 inches.

The torque boost apparatus can be used alone, or in combination with one or both of the low torque 44 and high torque 50 drive gears to make-up and break-out connections between components.

The torque boost apparatus 10 can also be used to provide an extra torque boost through the main drive shaft and the drill stem to the drill bit when, for example, the drill bit becomes stuck in a formation.

While the above description contains many specific features of the invention, these should not be construed as limitations on the scope of the invention, but rather as an exemplification of one preferred embodiment thereof. Many other variations are possible. Accordingly, the scope of the invention should be determined not by the embodiments illustrated, but by the appended claims and their legal equivalents.

CLAIMS**WHAT IS CLAIMED IS:**

- 1 1. Apparatus for boosting torque in a top drive drilling system having a
2 housing, a main shaft rotatable within the housing, and a main gear mounted for rotation
3 with the main shaft, comprising:
4 a torque boost gear structure engageable with the main gear to provide torque to
5 the main shaft; and
6 a linear actuating mechanism for driving the torque boost gear structure relative to
7 the main gear.
- 1 2. The apparatus of claim 1 wherein:
2 the torque boost gear structure is rotatable about an axis parallel to the main shaft.
- 1 3. The apparatus of claim 2 wherein:
2 the torque boost gear structure has a crank portion actuable by the linear actuating
3 mechanism to rotate the main gear and thus the main shaft.
- 1 4. The apparatus of claim 2 wherein:
2 the torque boost gear structure is movable axially between positions of
3 engagement and disengagement with the main gear.

1 5. The apparatus of claim 4 wherein:
2 the torque boost gear structure is movable between said positions upon a splined
3 shaft.

1 6. The apparatus of claim 5 wherein:
2 the torque boost gear structure is moved using a fluid driven cylinder.

1 7. The apparatus of claim 6 wherein:
2 the cylinder is hydraulic.

1 8. The apparatus of claim 5 wherein:
2 said torque boost gear structure is disposed to move axially into engagement with
3 the main gear to rotate said main gear less than a full revolution and then retract axially to
4 a condition of disengagement with the main gear.

1 9. The apparatus of claim 1 which further comprises:
2 at least one rotatable drive gear engageable with the main gear to drive the main
3 shaft.

1 10. The apparatus of claim 9 wherein:
2 the drive gear and the torque boost gear are disposed to simultaneously apply
3 torque to said main gear.

1 11. The apparatus of claim 1 wherein:
2 the torque boost gear structure has gear teeth extending only partially around its
3 periphery.

1 12. The apparatus of claim 11 wherein:
2 said drive gear is a pinion with a series of teeth disposed to engage the gear teeth
1 of said main gear.

1 13. The apparatus of claim 1 wherein:
2 the linear actuating mechanism is a fluid driven cylinder.

1 14. The apparatus of claim 13 wherein:
2 the cylinder is hydraulic.

1 15. A method for boosting torque in a top drive drilling system having a
2 housing, a main shaft rotatable within the housing, and a main gear mounted for rotation
3 with the main shaft, comprising the steps of:

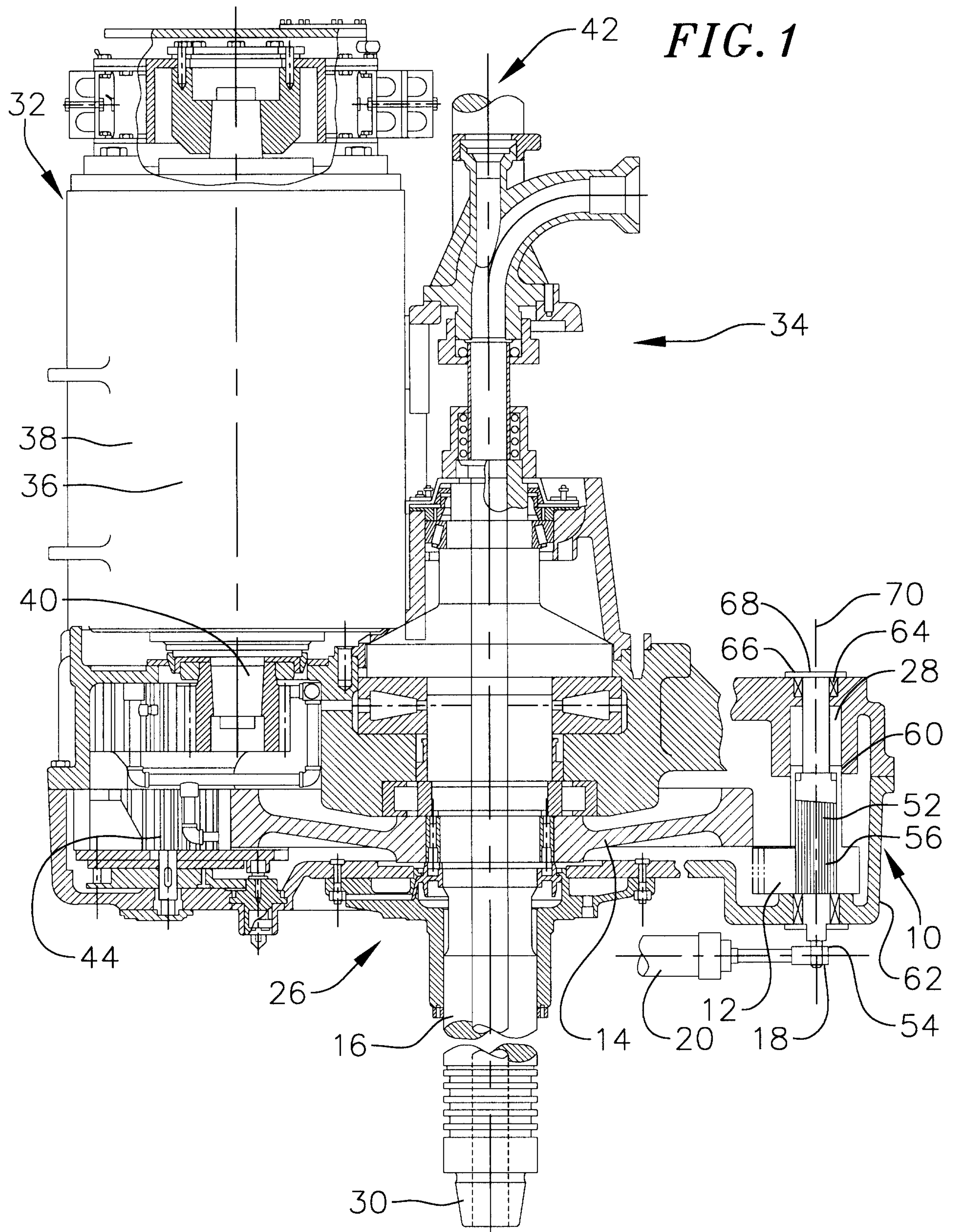
- 4 a) engaging a torque boost gear structure with the main gear; and
5 b) rotatably driving the torque boost gear structure by a linear actuating
6 mechanism to provide torque to said main gear.

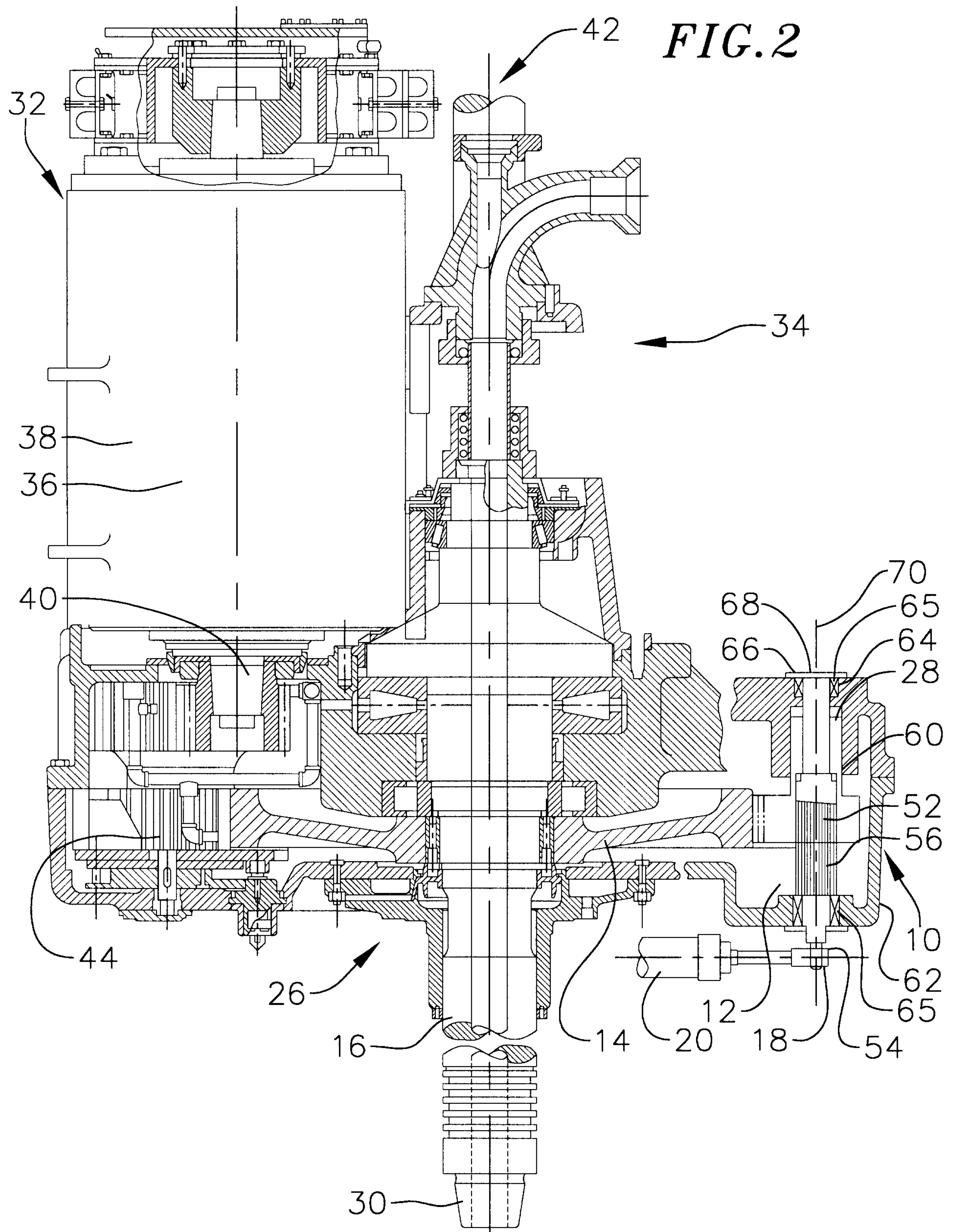
1 16. The method of claim 15, further comprising the step of:
2 simultaneously applying torque to said main gear using a drive gear and said
3 torque boost structure.

1 17. The method of claim 16 wherein:
2 the torque boost gear structure has gear teeth extending only partially around its
3 periphery;
4 said drive gear is a pinion with a series of teeth disposed to engage the gear teeth
5 of said main gear; and
6 the torque boost gear structure is moved axially between positions of engagement
7 and disengagement with said main gear.

1 18. The method of claim 15 wherein:
2 the torque boost gear structure is moved axially into a condition of engagement
3 with said main gear; and the torque boost gear structure is driven by extension of said
4 linear actuating mechanism.

1 19. The method of claim 15 wherein:
2 the torque boost gear structure is moved axially into a condition of engagement
3 with said main gear; and the torque boost gear structure is driven by retraction of said
4 linear actuating mechanism.





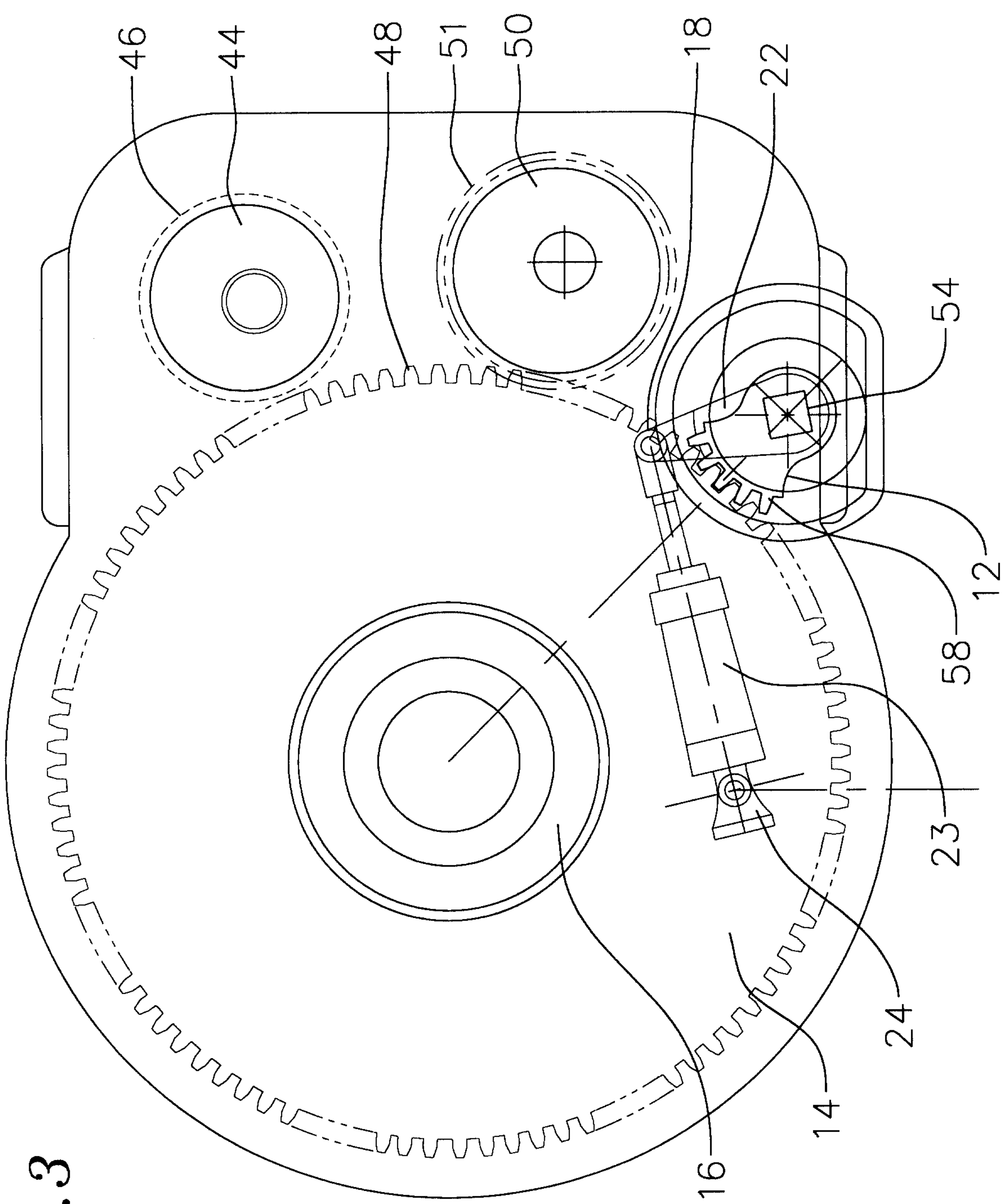


FIG. 3

