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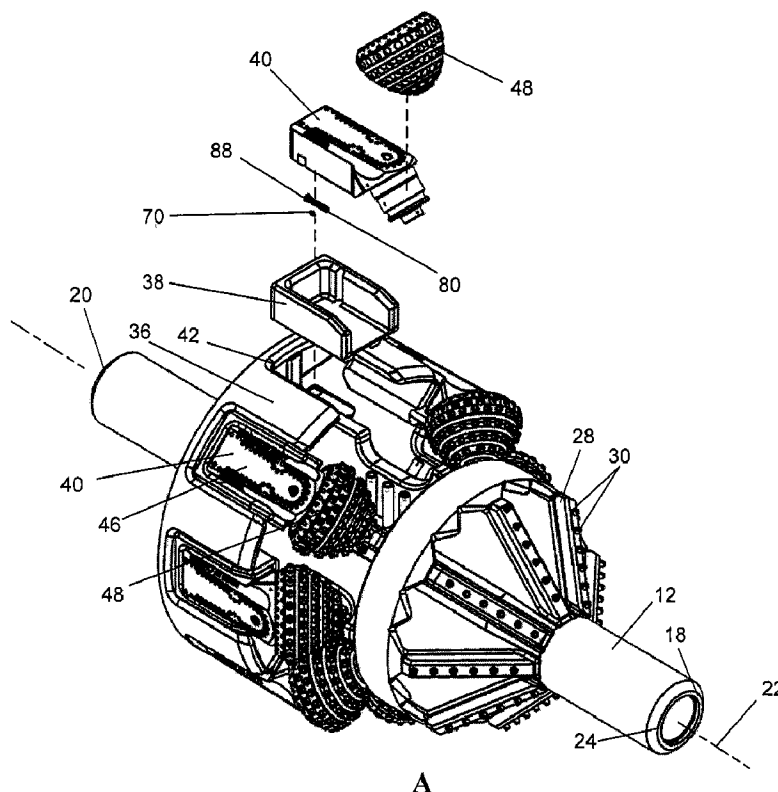
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(54) Titre : ELARGISSEUR POUR UN FORAGE DIRECTIONNEL HORIZONTAL

(54) Title: HOLE OPENER FOR HORIZONTAL DIRECTIONAL DRILLING



(57) Abrégé/Abstract:

A hole opener for use with a drilling rig, the hole opener having a shaft configured for rotation by the horizontal directional drilling rig, a body coupled to the shaft for rotation with the shaft, a cutter coupled to the body for rotation relative to the body, and a

(57) **Abrégé(suite)/Abstract(continued):**

lubrication system at least partially located within the body, the lubrication system operable to supply lubricant to the cutter. The lubrication system includes a duct in the body and a pressure regulator that increases and decreases a volume of the duct in response to the change in pressure of the lubricant to regulate a pressure of lubricant in the duct.

ABSTRACT

A hole opener for use with a drilling rig, the hole opener having a shaft configured for rotation by the horizontal directional drilling rig, a body coupled to the shaft for rotation with the shaft, a cutter coupled to the body for rotation relative to the body, and a lubrication system at least partially located within the body, the lubrication system operable to supply lubricant to the cutter. The lubrication system includes a duct in the body and a pressure regulator that increases and decreases a volume of the duct in response to the change in pressure of the lubricant to regulate a pressure of lubricant in the duct.

HOLE OPENER FOR HORIZONTAL DIRECTIONAL DRILLING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application No. 62/777,368, filed December 10, 2018, the entire contents of which are hereby incorporated by reference herein.

FIELD OF THE INVENTION

[0002] The present invention relates to a hole opener particularly suited for use with a horizontal directional drilling rig.

BACKGROUND

[0003] Some types of hole openers used with horizontal directional drilling rigs include lubrication systems for providing lubricant to a roller cutter of the hole opener. In these hole openers, the roller cutter rotates relative to a connecting body affixed to a drill string of the hole opener. In prior lubrication systems, lubricant is passed through a duct of the connecting body without adjusting for lubricant conditions such as temperature and pressure. In other prior lubrication systems, pressure of lubricant in the connecting body is regulated with a pressure compensator system relying on exterior (typically hydrostatic) forces which oppose pressure of lubricant in the hole opener.

SUMMARY OF THE INVENTION

[0004] The present invention provides, in one aspect, a hole opener configured for use with a drilling rig, the hole opener comprising a shaft configured for rotation by the horizontal directional drilling rig, a body coupled to the shaft for rotation with the shaft, a cutter coupled to the body for rotation relative to the body, and a lubrication system at least partially located within the body, the lubrication system operable to supply a lubricant to the cutter. The lubrication system includes a duct in the body and a pressure regulator that increases and

decreases a volume of the duct in response to a change in pressure of the lubricant to regulate a pressure of the lubricant in the duct.

[0005] The present invention provides, in another independent aspect, a hole opener configured for use with a drilling rig, the hole opener comprising a shaft configured for rotation by the horizontal directional drilling rig, a body coupled to the shaft for rotation with the shaft, a cutter coupled to the body for rotation relative to the body, and a lubrication system at least partially located within the body, the lubrication system operable to supply a lubricant to the cutter. The lubrication system includes a duct in the body, a first lubricant outlet in fluid communication with the duct and a second lubricant outlet in fluid communication with the duct.

[0006] The present invention provides, in another independent aspect, a hole opener configured for use with a drilling rig, the hole opener comprising a shaft configured for rotation by the horizontal directional drilling rig, a body removably coupled to the shaft for rotation with the shaft, a cutter removably coupled to the body for rotation relative to the body, and a lubrication system at least partially located within the body, the lubrication system operable to supply a lubricant to the cutter. The lubrication system includes a duct in the body, and a pressure regulator that increases and decreases a volume of the duct in response to a change in pressure of the lubricant to regulate a pressure of the lubricant in the duct.

[0007] Other features and aspects of the invention will become apparent by consideration of the following detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Fig. 1 is a perspective view of a hole opener according to one embodiment of the invention.

[0009] FIG. 1A is an exploded perspective view of the hole opener of Fig. 1.

[0010] Fig. 2 is a side view of the hole opener of Fig. 1.

[0011] Fig. 3 is a perspective view of a roller cutter assembly of the hole opener of Fig. 1.

[0012] Fig. 4 is a cross-sectional view of a portion of the roller cutter assembly of Fig. 3 taken along line 4-4 of Fig. 3.

[0013] Fig. 5 is an enlarged view of a portion of Fig. 4 with a pressure regulator in a first position.

[0014] FIG. 5A is an enlarged view of a portion of FIG. 5 with the pressure regulator in the first position.

[0015] Fig. 6 is an enlarged view of the portion of Fig 4 shown in Fig. 5 with the pressure regulator in a second position.

[0016] Fig. 7 diagrammatically illustrates a horizontal drilling rig configured for use with the hole opener of Fig. 1.

[0017] Before any embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The invention is capable of other embodiments and of being practiced or of being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting.

DETAILED DESCRIPTION

[0018] Fig. 1 illustrates a hole opener or reamer 10. The hole opener 10 is particularly suited for use with a horizontal directional drilling rig 8 (Fig. 7) for creating underground bores. The underground bores are used for utilities, including water lines, sewer lines, gas lines, electrical conduits, communication lines or conduits, direct buried electrical wires, and the like. Although the hole opener 10 is particularly suited for use with a horizontal directional drilling rig, in other embodiments, the hole opener 10 can be configured for use with other types of drilling rigs.

[0019] As shown in FIG. 7, a number of components are used in horizontal direction drilling. Such components may include, but are not limited to, the drill rig 8, extension rods 100, a crane 104 for moving extension rods 100 onto and off of the drill rig 8, a control trailer 108 where an

operator controls the drilling operation of the drill rig 8, a mud rig 112 for holding cuttings from the drill rig 8, and a power unit 116 providing power to the drill rig 8, mud rig 112, and control trailer 108.

[0020] In the cutting operation, extension rods 100 are moved by the crane 104 onto the drill rig 8. The extension rods 100 are translated through a hole 102 to be reamed to the opposite end (not shown) of the hole 102, with additional extension rods 100 being added to the extension rods 100 within the hole 102 as the extension rods 100 are translated through the hole 102. The extension rods 100 are attached to the hole opener 10 to fit within the hole 102. An operator in the control trailer 108 supplies power through the power unit 116 to the drill rig 8 to rotate the hole opener 10, and translate the hole opener 10 along a cutting path of the hole 102. In some embodiments, the cutting path of the hole 102 is directed towards the drill rig 8, and the hole opener 10 is pulled through the hole 102. In this embodiment, the crane 104 lifts extension rods 100 from the drill rig 8 as they are translated out of the hole 102. Alternatively, the cutting path of the hole 102 can be directed away from the drill rig 8, and the hole opener 10 is pushed through the hole 102 by the drill rig 8. In this alternative embodiment, the crane 104 lifts extension rods 100 to apply them to the drill rig 8 as they are needed to further translate the hole opener 10 through the hole 102. During drilling, cuttings from within the hole 102 created by the hole opener 10 are excavated into the mud rig 112 for removal from the reamed hole 102.

[0021] The illustrated hole opener 10 includes a shaft 12, a first cutting assembly 14 coupled to the shaft 12 for rotation with the shaft 12, and a second cutting assembly 16 coupled to the shaft 12 for rotation with the shaft 12. The shaft 12 includes a first end 18 and a second end 20 and a longitudinal shaft axis 22 that extends centrally through the shaft 12. An aperture 24 is formed into each of the first end 18 and the second end 20 of the shaft 12. The apertures 24 are configured (e.g., threaded connection, pin connection, etc.) to mate with extension rods or drive rods 6 (Fig. 7) to connect the hole opener 10 to a drilling rig, such as the horizontal directional drilling rig 8 described above. Rotation of the extension rods by the drilling rig rotates the shaft 12 about shaft axis 22, which rotates the cutting assemblies 14, 16 to perform the underground boring or drilling operation.

[0022] The first cutting assembly 14 is coupled to the shaft 12 between the first end 18 and the second cutting assembly 16. The first cutting assembly 14 is tapered. That is, the first cutting assembly 14 has a radius 26 (Fig. 2) measured from the shaft axis 22 that increases in a direction from the first end 18 toward the second end 20 of the shaft 12. The first cutting assembly 14 includes a plurality of blades 28 spaced evenly around the shaft axis 22. The blades 28 each include a plurality of cutters or chisels 30. In one embodiment, the cutters 30 are welded to the blades 28 and the cutters 30 can be removed when worn or dull and replaced by welding new cutters 30 to the blades 28. In the illustrated embodiment, the hole opener 10 is pushed or pulled underground in the direction of arrow 32 in Fig. 2 while the hole opener 10 rotates about the shaft axis 22. The tapered first cutting assembly 14 increases the diameter of the underground bore as the hole opener 10 travels in the direction of arrow 32.

[0023] The second cutting assembly 16 is coupled to the shaft 12 between the first cutting assembly 14 and the second end 20 of the shaft 12. The second cutting assembly 16 further increases the diameter of the underground bore after the first cutting assembly 14. The second cutting assembly 16 includes a gauge ring 36, saddles 38, and roller cutter assemblies 40. The gauge ring 36 is fixed to the shaft 12 for rotation with the shaft 12. The gauge ring 36 includes a plurality of saddle recesses 42 spaced evenly around the shaft axis 22. A saddle 38 is received in each of the saddle recesses 42 and the saddle recesses 42 of the gauge ring 36 evenly space the saddles 38 around the shaft axis 22. The saddles 38 are coupled to the shaft 12 and the gauge ring 36 so that the saddles 38 rotate with the shaft about the shaft axis 22. In one embodiment, the saddles 38 are coupled to the shaft 12 using a keyed connection.

[0024] A roller cutter assembly 40 is slidably received in each of the saddles 38 so that the roller cutter assemblies 40 rotate with the shaft 12 about the shaft axis 22. Each roller cutter assembly 40 includes a body or leg 46 and a cutter 48. The following description refers to a single roller cutter assembly 40, it being understood that all of the illustrated roller cutter assemblies 40 are essentially the same. Referring to Figs. 3 and 4, the cutter 48 is coupled to the body 46 such that the cutter 48 can rotate relative to the body about a cutter axis 50. In the illustrated embodiment, the cutter 48 is generally cone shaped and includes a plurality of chisels or blades 52. In the illustrated embodiment, the cutter 48 is removably coupled to the body 46 so that the cutter 48 can be removed and replaced when the blades 52 are worn or dull.

[0025] FIG. 1 illustrates an exploded view of the hole opener 10 with one of the saddles 38 removed from the gauge ring 36, one of the roller cutter assemblies 40 removed from the saddle, and one of the cutters 38 removed from the roller assembly 40.

[0026] Referring to Fig. 4, the body 46 includes a hub 54. The cutter axis 50 is generally defined by the hub 54, and is transverse to a body axis 55 generally defined by the body 46. The body axis 55 defined by the body 46 is parallel with the shaft axis 22 of the shaft 12. The cutter axis 50 of the hub 54 is angled relative to the body axis 55 defined by the body 46 such that the cutter axis 50 of the hub 54 points towards the shaft axis 22. The cutter 48 is rotationally coupled to the body 46 at the hub 54 so that the cutter 48 can rotate about the cutter axis 50 relative to the hub 54. The hub 54 includes a bearing recess or race 58 that extends around the cutter axis 50. Rollers or balls 60 are located between the cutter 48 and the body 46 in the race 58 to facilitate rotation of the cutter 48 relative to the body 46 about the cutter axis 50.

[0027] The body 46 further includes a lubrication system 64 for the cutter 48. The lubrication system 64 provides lubricant (e.g., oil, grease, etc.) to the hub 54 and the rollers 60 to lubricate the interface between the cutter 48 and the body 46. The lubrication system 64 includes lubricant ducts 66 and a pressure regulator 68 that are internal to the body 46. A lubricant fitting 70 (e.g., grease nipple, Zerk fitting, Alemite fitting, etc.) is in fluid communication with the ducts 66, and the fitting 70 is exposed to the exterior of the body 46. A supply of lubricant is removably coupled to the fitting 70 to periodically provide lubricant into the ducts 66. Periodically, it is preferred that new and/or additional lubricant is added to the ducts 66. The ducts 66 include lubricant outlets 72. The lubricant outlets 72 are generally located on the hub 54 where the cutter 48 is rotationally supported on the body 46. Lubricant exits the ducts 66 through the outlets 72 to provide lubrication to the interface between the cutter 48 and the body 46. The lubrication system 64 is housed substantially within the roller cutter assembly 40.

[0028] Referring to Figs. 5-6, the body 46 includes a bore 74 that receives the pressure regulator 68. The illustrated bore 74 has a slightly larger diameter than the adjacent duct 66 such that a shoulder or stop 76 is formed at the interface between bore 74 and the adjacent duct 66. The illustrated pressure regulator 68 includes a biasing member 78 and a piston 80. In the illustrated embodiment, the biasing member 78 is a coil spring 78. The coil spring 78 biases the

piston 80 in the direction of the arrow 82 in Fig. 6. A plug 84 is received in the bore 74 to close the bore 74. The plug 84 is positioned such that the spring 78 pushes against the plug 84. The plug 84 includes a recess 86 that receives the spring 78 to properly position the spring 84 and to aid in assembly. The plug 84 further includes a seal 87. The seal 87 reduces the chance that any lubricant would exit the duct 66 via the bore 74. In the illustrated embodiment, a snap ring 88 retains the plug 84 in position in the bore 74.

[0029] The piston 80 is sized to slide within the bore 74 yet inhibit lubricant from passing from the adjacent duct 66 past the piston 80 toward the spring 78. The piston 80 includes seals 90, such as high lubricity seals, that seal the interface between the piston 80 and the bore 74. The spring 78 pushes and moves the piston 80 in the bore 74 until the piston 80 contacts the stop or shoulder 76. The motion of the piston 80 is restricted within the bore 74 between the shoulder 76 and the plug 84. The bore 74 is offset from and runs parallel to the body axis 55. Additionally, the bore 74 is offset from and runs parallel to the shaft axis 22.

[0030] The piston 80 operates on forces which come from within the roller cutter assembly 40. The piston 80 realizes a pressure force from the lubricant in the ducts 66 acting towards the plug 84. The piston 80 also realizes a spring force from the spring 78 acting away from the plug 84. Relative amounts of the pressure force and spring force determine whether the piston 80 remains in a position, or moves in a direction towards or away from the plug 84 to increase or decrease the volume of the ducts 66. The piston 80 may realize other forces such as frictional forces, gravitational forces, and normal forces. Operationally, the piston moves as a result of the difference between relative amounts of the pressure force and the spring force, and does not require other forces exterior to the cutter assembly 40 to operate.

[0031] In operation, referring to Figs. 2 - 4, the hole opener 10 is rotated about the shaft axis 22 by a drilling rig while the rig also pushes or pulls the hole opener 10 in the direction of arrow 32. This movement causes the cutters 48 of the roller cutter assemblies 40 to rotate about the cutter axis 50 to further assist in creating the underground bore. The rotation of the cutters 48 creates friction that increases the temperature of the lubricant in the ducts 66 (Figs. 4 - 6) that provide lubrication for the cutter 48 at the hub 54. In hole openers without variable volume pressure regulators, and considering the ducts 66 as a closed system, increasing the temperature

of the lubricant in the ducts 66 increases the pressure of the lubricant in the ducts 66. This increased pressure of the lubricant in the ducts 66 forces an undesirable amount of lubricant out of the ducts 66 through the outlets 72. In contrast, the described pressure regulator 68 reduces the change in pressure caused by increased temperature of the lubricant. As the lubricant pressure begins to increase beyond a desired level, the increased pressure pushes the piston 80 in the direction of arrow 92 (Fig. 5) against the bias of the spring 78. This movement of the piston 80 in the direction of arrow 92 increases the volume of the ducts 66, which reduces the pressure increase caused by the increased temperature of the lubricant. As previously described, the piston 80 moves to expand the ducts 66 until the force of the spring 78 matches the pressure force of the lubricant pushing the piston 80 against the spring 78.

[0032] Lubricant is continuously exhausted from the outlets 72 during operation, decreasing the volume of lubricant within the ducts 66. As a result of a lesser volume of lubricant being held in the expanded duct 66 or as a result of a change in the surroundings, the lubricant temperature decreases. As the lubricant temperature decreases, the spring 78 pushes the piston 80 back in the direction of arrow 82 (Fig. 6) to decrease the volume of the ducts 66 and regulate the lubricant pressure. As the lubricant temperature changes, so does the pressure inside the ducts 66 and the automatic movement of the piston 80 regulates and stabilizes the lubricant pressure and the amount of lubricant that is supplied to the cutter 48 via the lubricant outlets 72.

[0033] Also during the drilling operation, a drilling fluid or mud, such as bentonite clay, is injected into the underground bore to remove cut material and stabilize the bore. As the depth of the bore (i.e., distance from the surface) increases, so does the depth of the drilling fluid. As the depth of the drilling fluid increases, the fluid pressure on the hole opener 10 also increases. Increasing fluid pressure external to the hole opener 10 increases the pressure at the lubricant outlets 72 (Fig. 4). As discussed above, the spring 78 pushes the piston 80 in the direction of arrow 82. Therefore, in a manner similar to temperature change discussed above, the pressure regulator 68 regulates or stabilizes the lubricant pressure inside the ducts 66 as pressure caused by the drilling fluid increases or decreases.

[0034] Accordingly, the pressure regulator 68 provides, among other things, a mechanical system that automatically regulates lubricant pressure in the ducts 66 to control the amount of lubricant that is supplied to the cutter 48.

[0035] Various features of the invention are set forth in the following claims.

CLAIMS

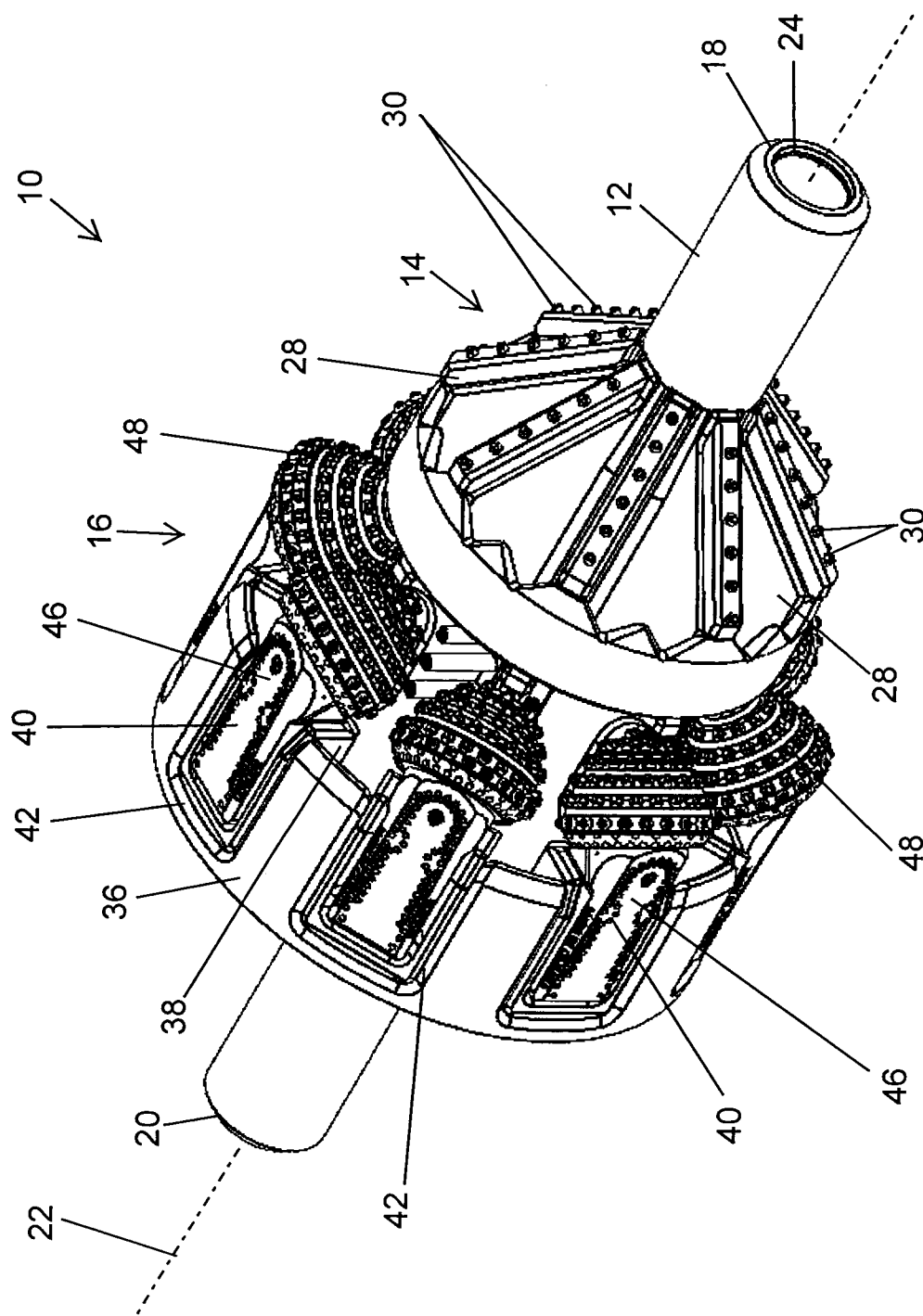
1. A hole opener configured for use with a drilling rig, the hole opener comprising:
a shaft configured for rotation by the horizontal directional drilling rig;
a body coupled to the shaft for rotation with the shaft;
a cutter coupled to the body for rotation relative to the body; and
a lubrication system at least partially located within the body, the lubrication system operable to supply a lubricant to the cutter, the lubrication system including,
a duct in the body, and
a pressure regulator that increases and decreases a volume of the duct in response to a change in pressure of the lubricant to regulate a pressure of the lubricant in the duct.
2. The hole opener of claim 1, wherein the pressure regulator includes a biasing member and a piston.
3. The hole opener of claim 2, wherein the biasing member provides a biasing force at least partially opposing a pressure force of lubricant in the duct.
4. The hole opener of claim 2, wherein the piston moves along a path parallel to an axis of rotation of the shaft to expand or contract the volume of the duct based on the pressure of the lubricant.
5. The hole opener of claim 1, wherein the pressure regulator automatically increases and decreases the volume of the duct mechanically.
6. The hole opener of claim 2, wherein the piston is sized for slidable engagement within a bore adjacent the duct, the bore having a greater diameter than the duct.
7. The hole opener of claim 6, wherein the piston is sized to engage a shoulder formed at the interface of the bore and the duct.

8. The hole opener of claim 2, wherein the biasing member engages the piston and a plug at an end of the bore opposite the duct.

9. The hole opener of claim 2, wherein the piston includes a seal which interfaces with the bore to prevent lubricant from passing from the duct and past the piston, and the plug includes a seal to prevent lubricant from exiting the bore.

10. A hole opener configured for use with a drilling rig, the hole opener comprising:
 - a shaft configured for rotation by the horizontal directional drilling rig;
 - a body coupled to the shaft for rotation with the shaft;
 - a cutter coupled to the body for rotation relative to the body; and
 - a lubrication system at least partially located within the body, the lubrication system operable to supply a lubricant to the cutter, the lubrication system including,
 - a duct in the body,
 - a first lubricant outlet in fluid communication with the duct, and
 - a second lubricant outlet in fluid communication with the duct.
11. The hole opener of claim 10, wherein the lubrication system further comprises a lubrication inlet in fluid communication with the duct.
12. The hole opener of claim 11, wherein the lubrication inlet is one of a group consisting of a grease nipple, Zerk fitting, or an Alemite fitting.
13. The hole opener of claim 11, wherein a lubrication supply outlet is removably coupled to the lubrication inlet to supply lubricant to the duct.
14. The hole opener of claim 10, wherein the first lubrication outlet provides lubricant to rollers located between the cutter and the body to facilitate rotation of the cutter relative to the body.
15. The hole opener of claim 10, wherein at least one of the first lubrication outlet and the second lubrication outlet provides lubricant directly to the cutter to facilitate rotation of the cutter relative to the body.

16. A hole opener configured for use with a drilling rig, the hole opener comprising:
a shaft configured for rotation by the horizontal directional drilling rig;
a body removably coupled to the shaft for rotation with the shaft;
a cutter removably coupled to the body for rotation relative to the body; and
a lubrication system at least partially located within the body, the lubrication system operable to supply a lubricant to the cutter, the lubrication system including,
a duct in the body, and
a pressure regulator that increases and decreases a volume of the duct in response to a change in pressure of the lubricant to regulate a pressure of the lubricant in the duct.
17. The hole opener of claim 16, wherein the shaft further comprises a recess capable of removably engaging the body.
18. The hole opener of claim 17, wherein the body is slidably received in the recess of the shaft.
19. The hole opener of claim 16, further comprising an additional cutter removably coupled to the shaft.
20. The hole opener of claim 19, wherein the additional cutter can be removed and replaced by welding a new additional cutter to the shaft when the additional cutter is worn or dull.



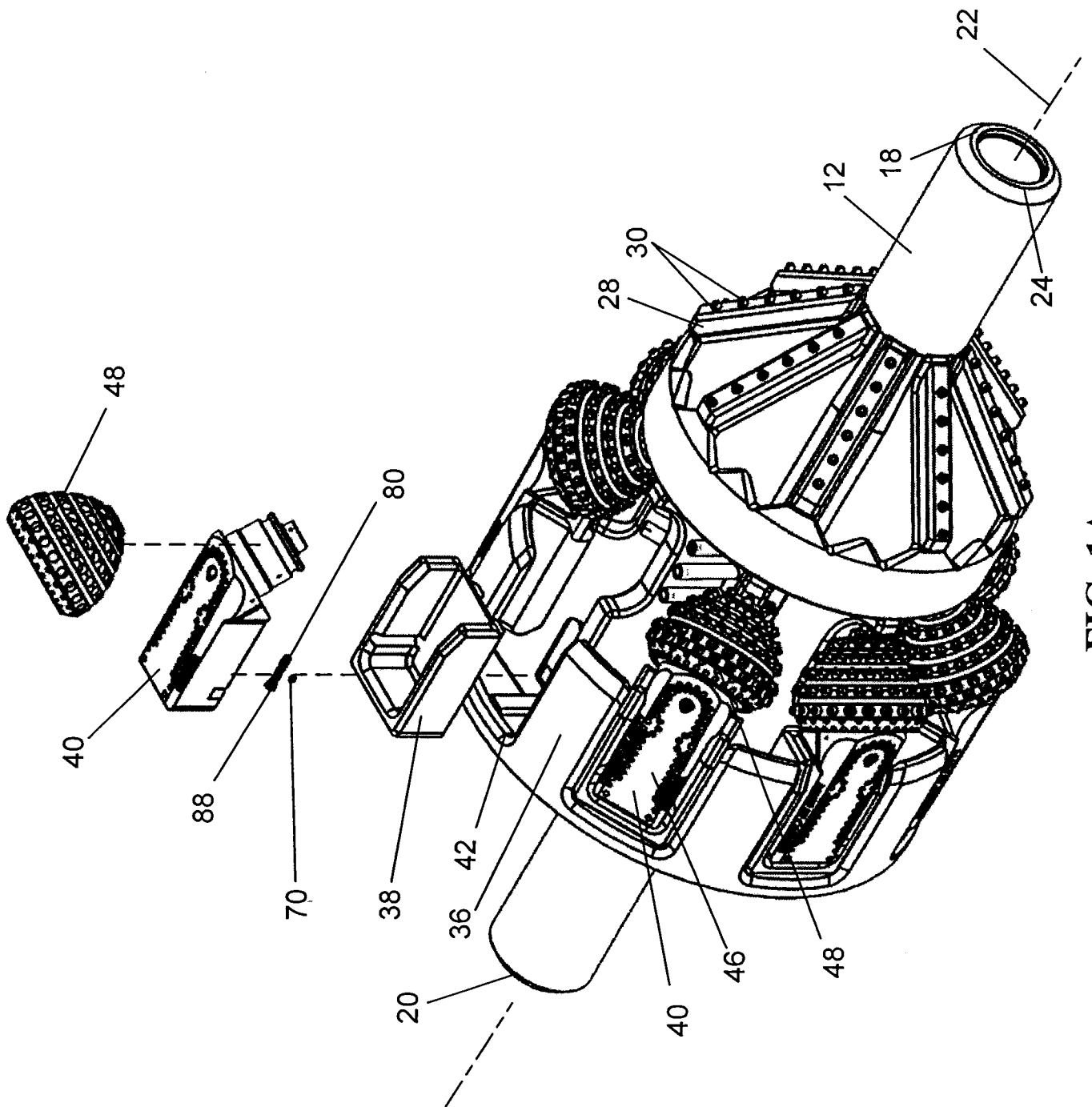


FIG. 1A

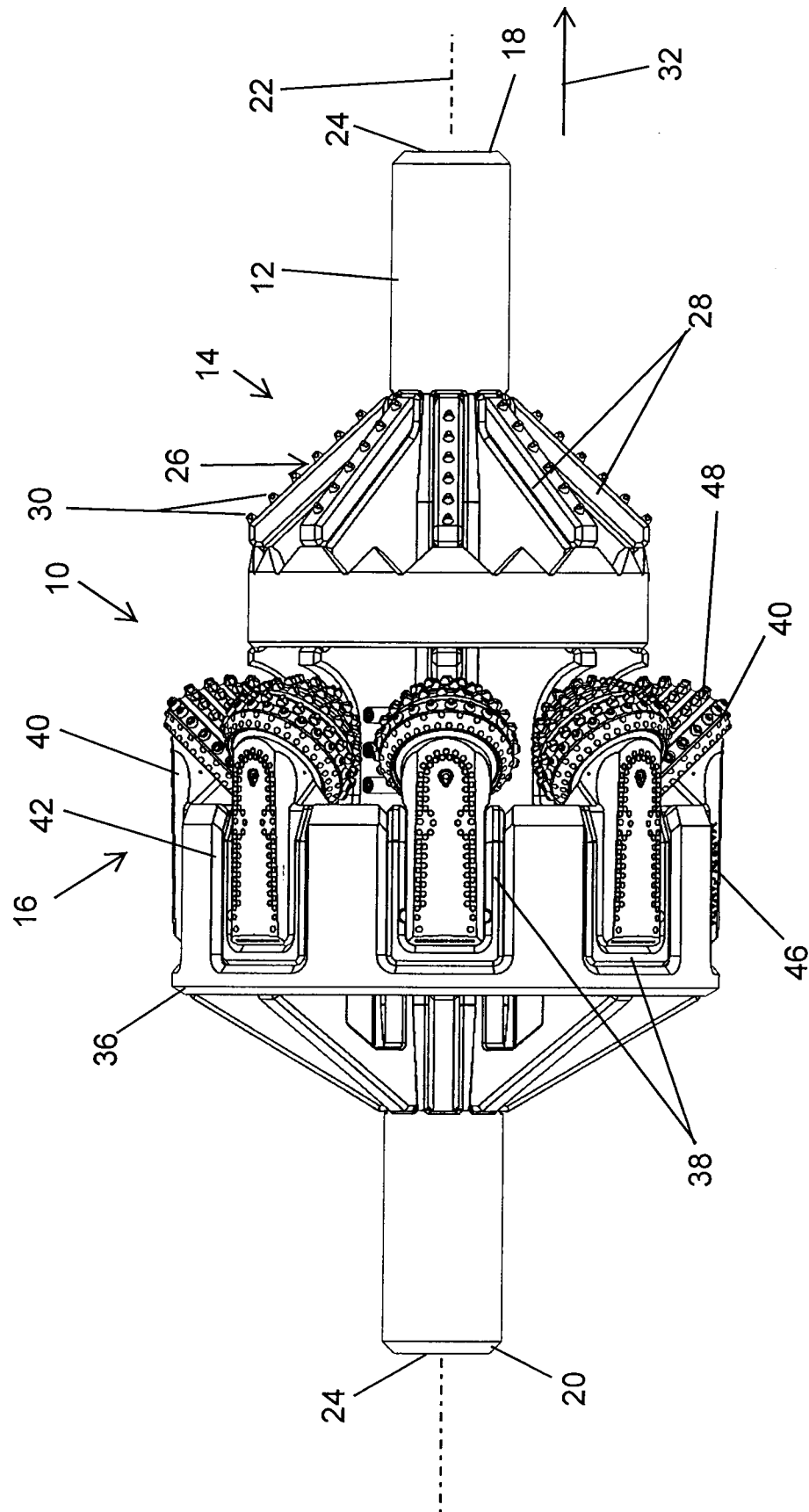


FIG. 2

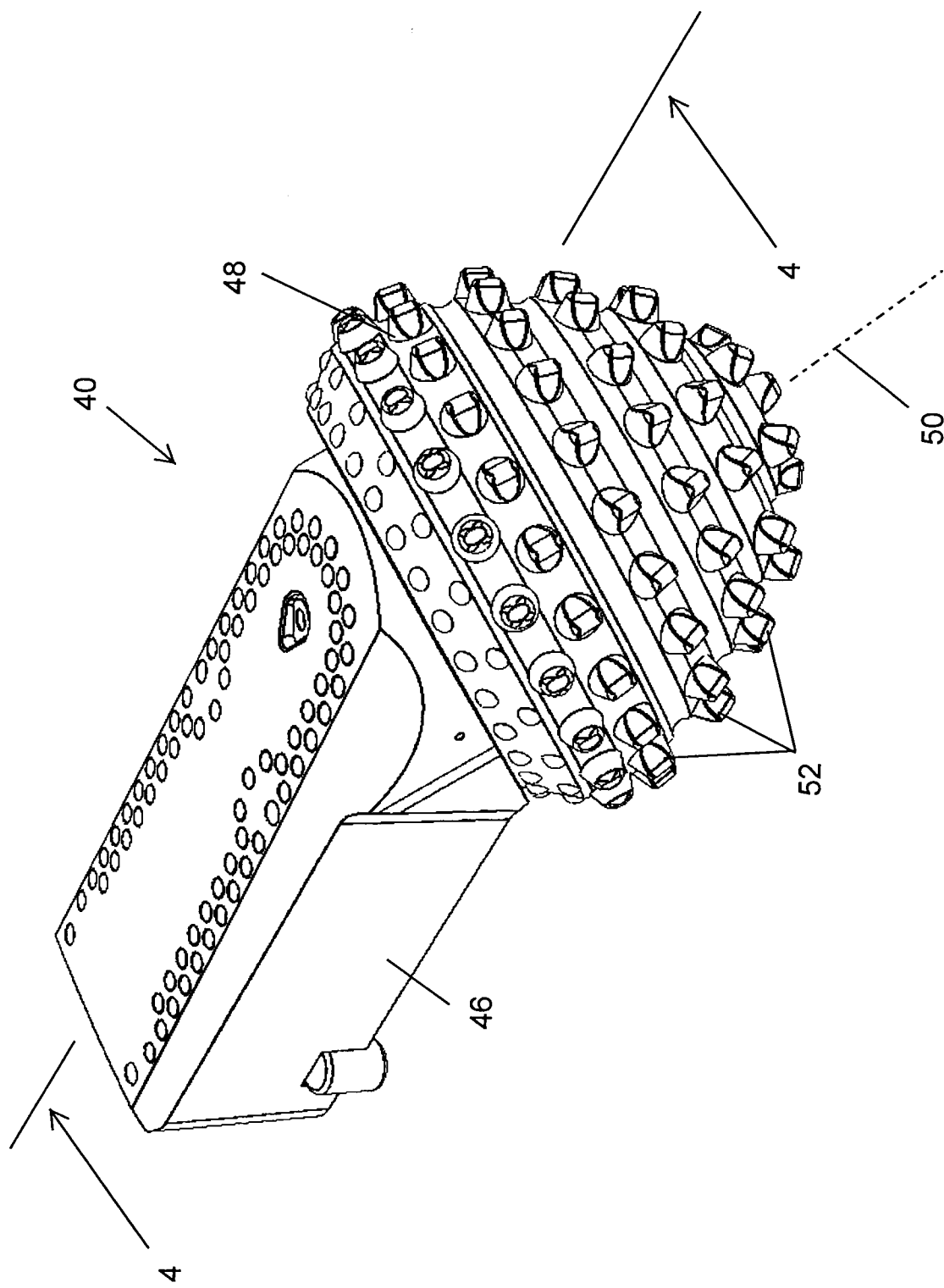
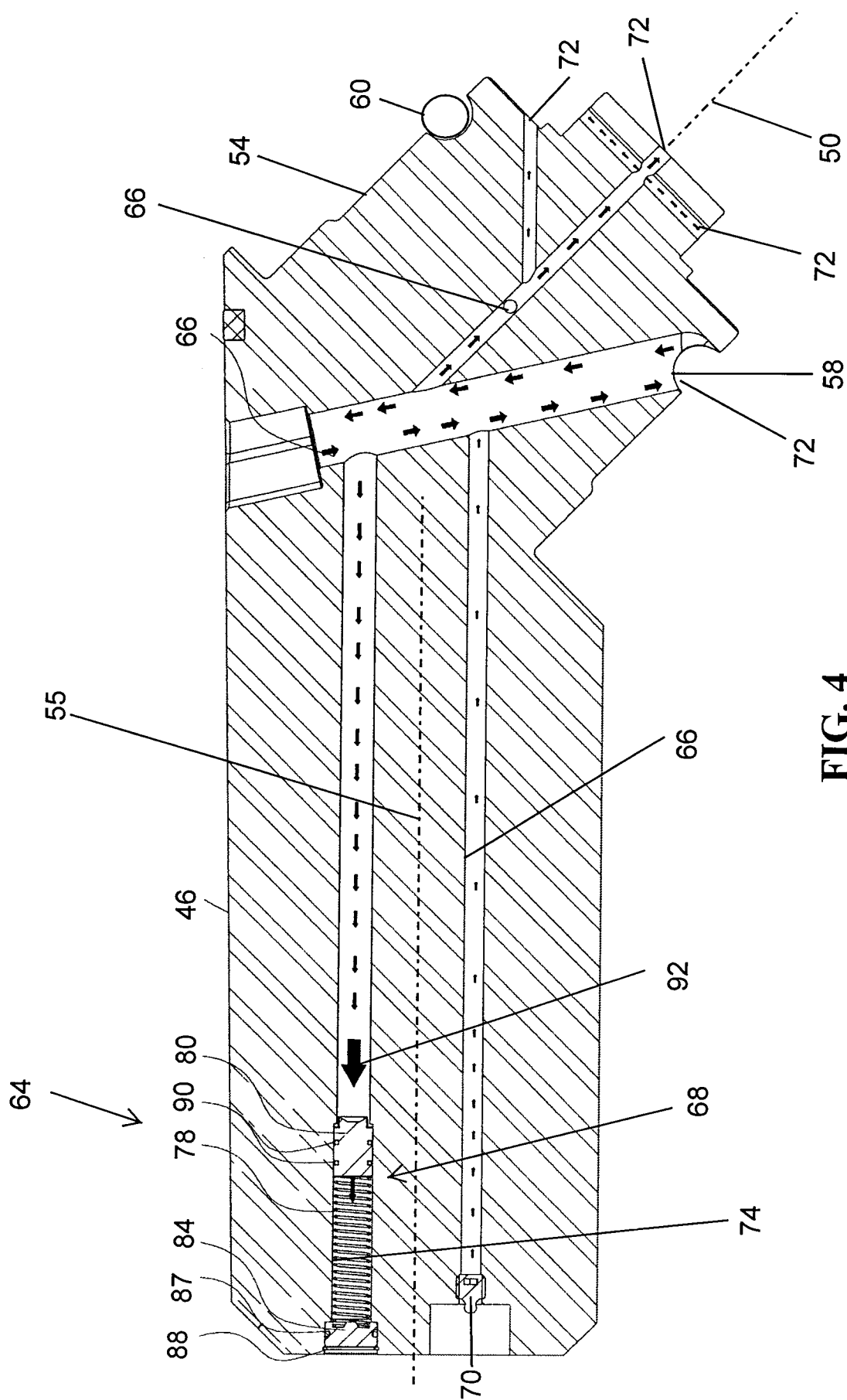


FIG. 3



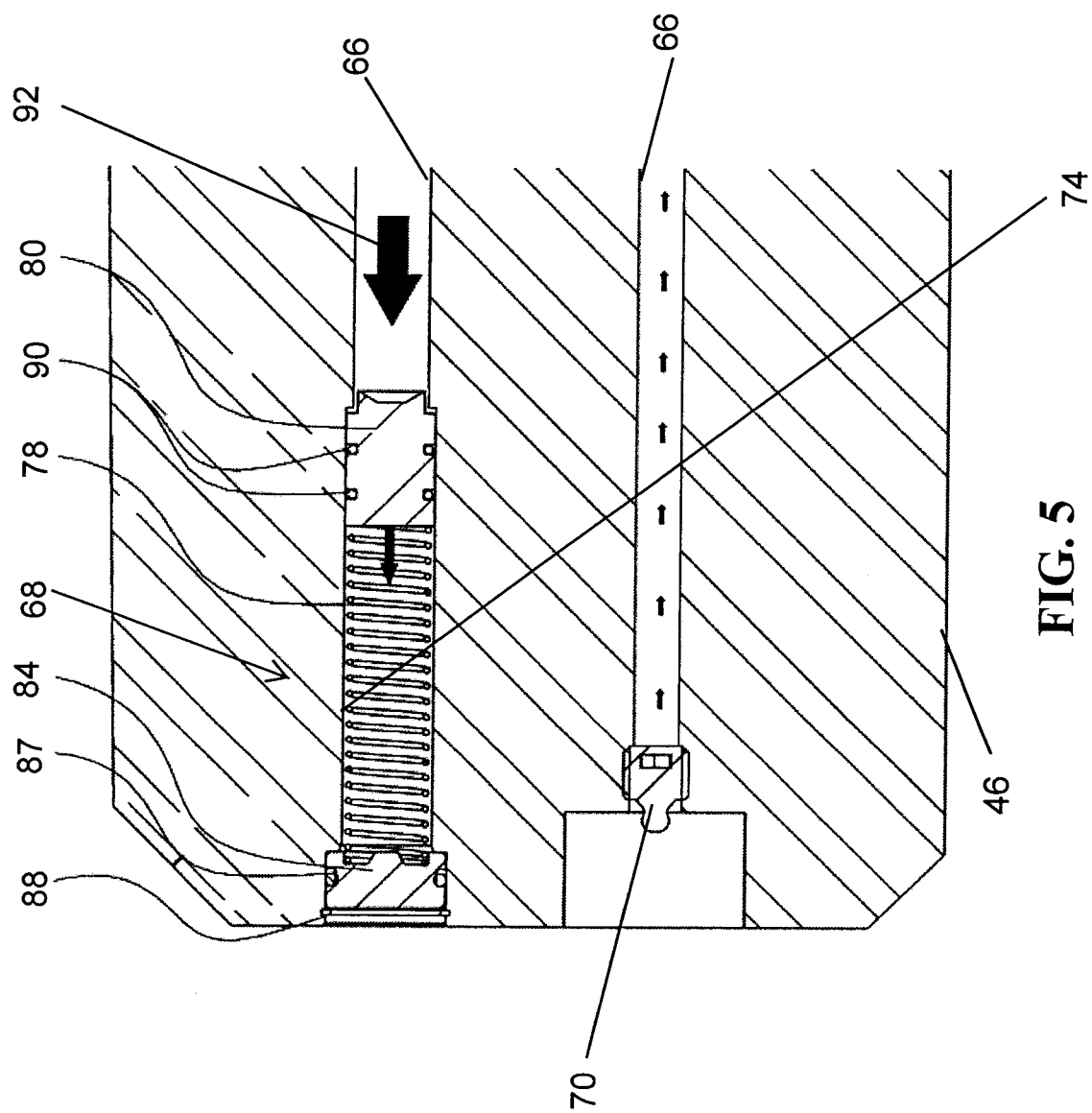


FIG. 5

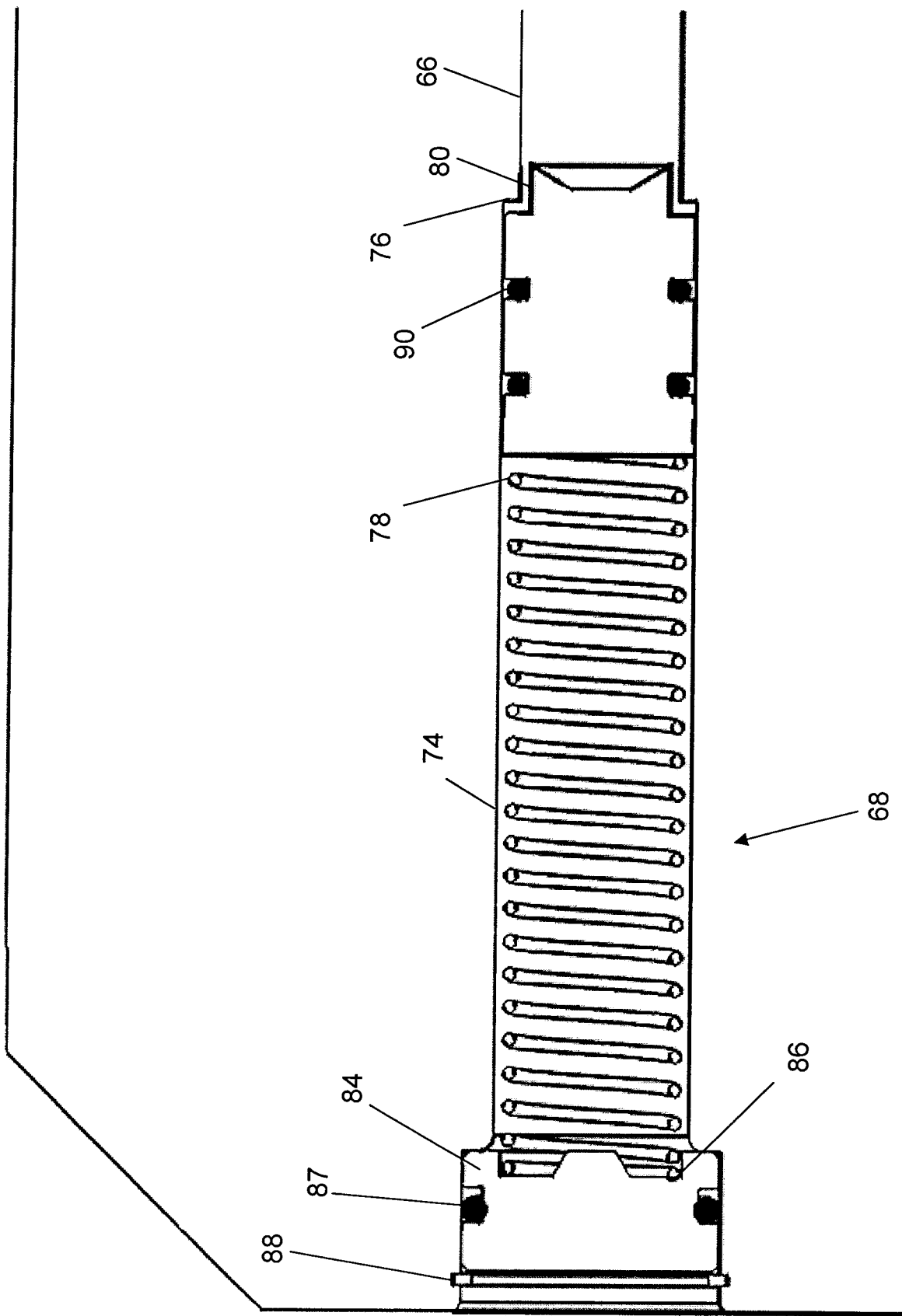


FIG. 5A

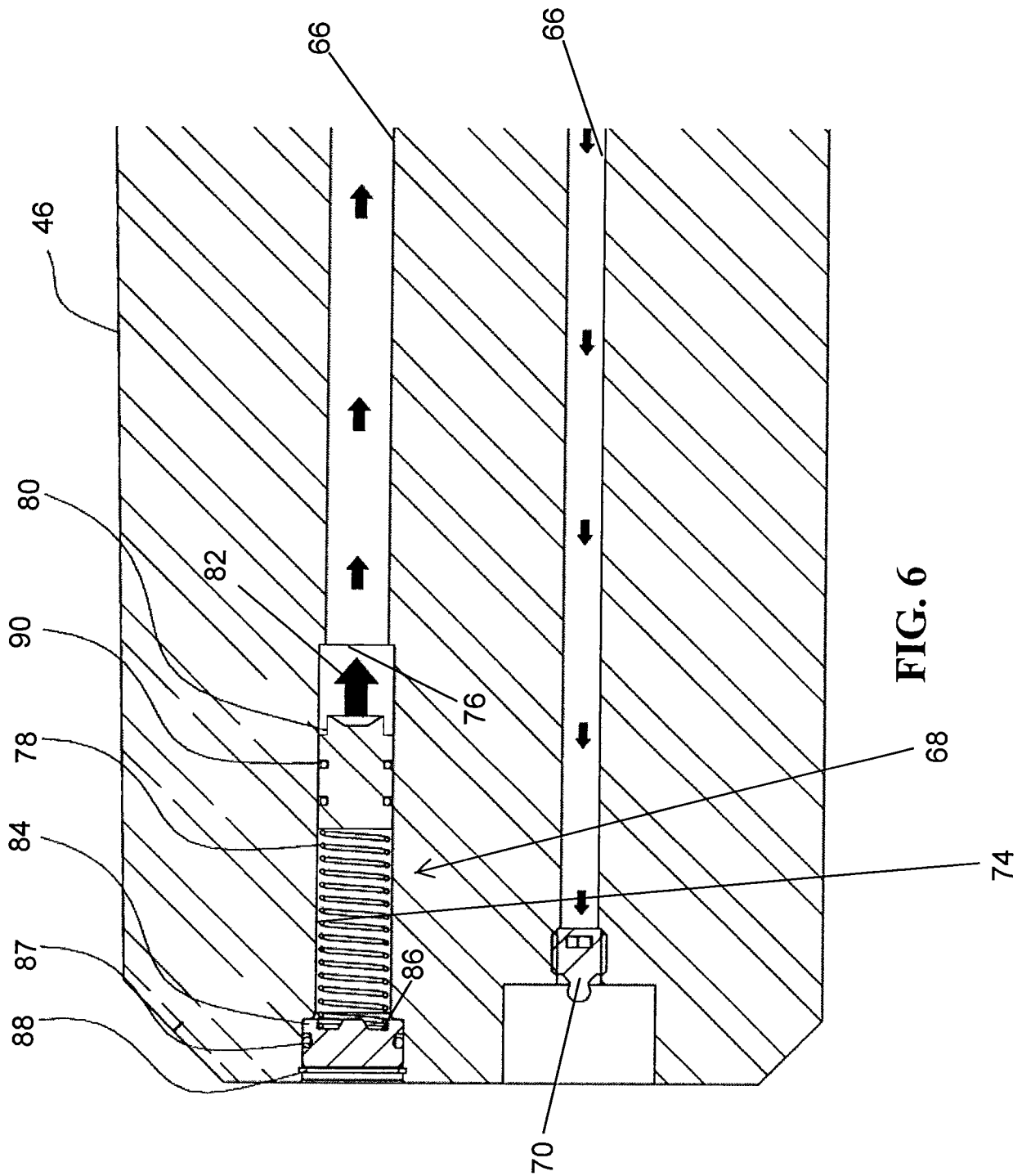


FIG. 6

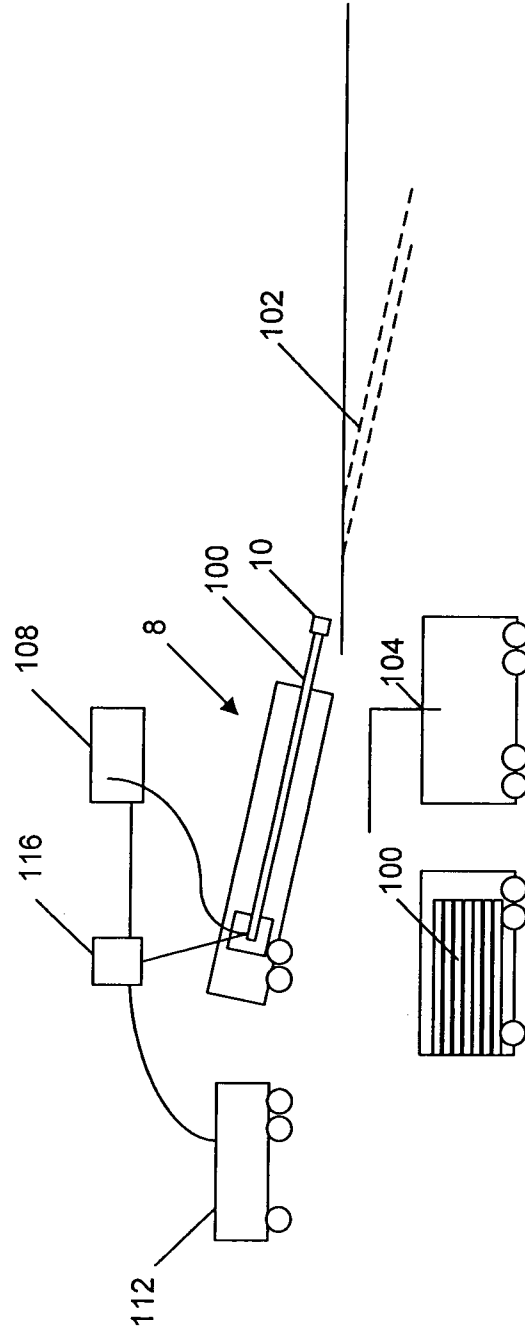
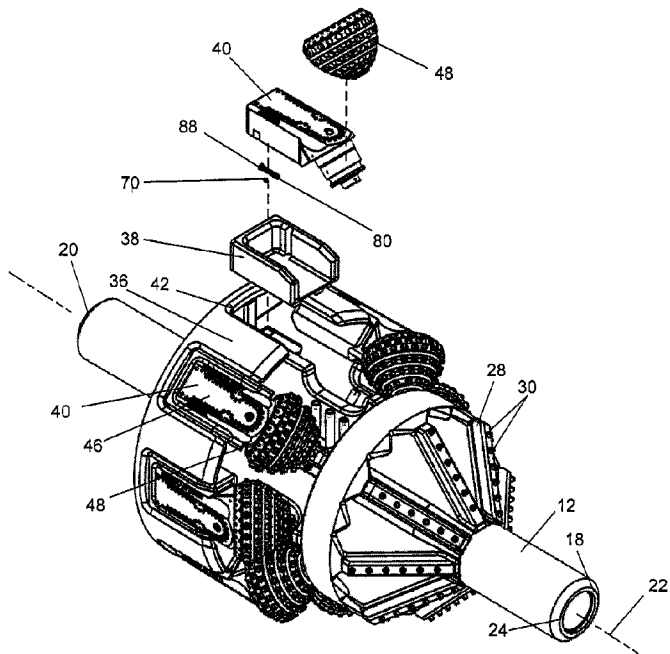


FIG. 7



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