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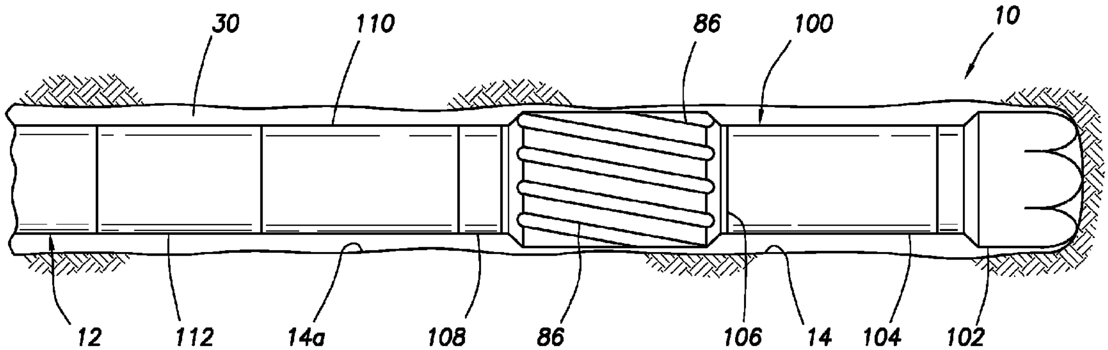

(57) Abrégé/Abstract:
A tubular string for use in a well can include a fluid motor and a tractor tool. The fluid motor can rotate the tractor tool in response to fluid flow through the fluid motor. Another tubular string can include a fluid motor, a gear reducer that reduces a rotational speed output of the fluid motor, and a tractor tool. The fluid motor and the gear reducer can rotate the tractor tool in response to fluid flow. Another tubular string can include a fluid motor, a tractor tool, and another fluid motor. One of the fluid motors can rotate with the tractor tool. A system for use in a subterranean wellbore can include a tool assembly. The tool assembly can include a fluid motor and a tractor tool. The tractor tool can be configured to engage a well surface in the wellbore and advance the tool assembly along the wellbore.

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(54) Title: DOWNHOLE TOOL ASSEMBLY ADVANCEMENT THROUGH WELLBORE

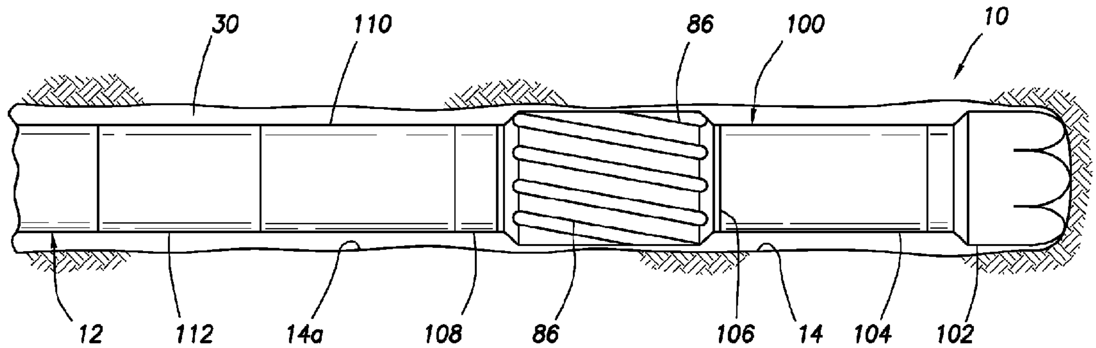

FIG. 12

(57) Abstract: A tubular string for use in a well can include a fluid motor and a tractor tool. The fluid motor can rotate the tractor tool in response to fluid flow through the fluid motor. Another tubular string can include a fluid motor, a gear reducer that reduces a rotational speed output of the fluid motor, and a tractor tool. The fluid motor and the gear reducer can rotate the tractor tool in response to fluid flow. Another tubular string can include a fluid motor, a tractor tool, and another fluid motor. One of the fluid motors can rotate with the tractor tool. A system for use in a subterranean wellbore can include a tool assembly. The tool assembly can include a fluid motor and a tractor tool. The tractor tool can be configured to engage a well surface in the wellbore and advance the tool assembly along the wellbore.

WO 2019/216922 A1

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DOWNHOLE TOOL ASSEMBLY ADVANCEMENT THROUGH WELLBORE

TECHNICAL FIELD

This disclosure relates generally to well tools and operations utilizing well tools in subterranean wells and, in at least one example described below, more particularly provides for advancement of a downhole tool assembly through a wellbore.

BACKGROUND

It is desirable in many different situations to displace a downhole tool assembly through a wellbore. For example, in a drilling operation, a drilling bottom hole assembly is advanced through a wellbore as the wellbore is being extended by the drilling. As another example, it can be advantageous to gradually advance a cleaning tool through a wellbore as the wellbore is being cleaned by the tool.

Therefore, it will be appreciated that improvements in the arts of designing, constructing and utilizing equipment to produce or facilitate displacement of well tools downhole are continually needed. Such improvements may be useful with any of a wide variety of different well tools and in a variety of different operations performed in wells.

SUMMARY

Accordingly, there is described a tubular string for use in a subterranean well, the tubular string comprising: a tool assembly including: a first fluid motor; and a tractor tool configured to advance the tool assembly through the well, and in which the first fluid motor rotates the tractor tool in response to fluid flow through the first fluid motor.

There is also described a tubular string for use in a subterranean well, the tubular string comprising: a tool assembly including: a first fluid motor; a gear reducer that reduces a rotational speed output of the first fluid motor; and a tractor tool configured to advance the tool assembly through the well, and in which the first fluid motor and the gear reducer rotate the tractor tool in response to fluid flow through the first fluid motor.

There is further described a tubular string for use in a subterranean well, the tubular string comprising: a tool assembly including: a first fluid motor; a tractor tool; and a second fluid motor, and in which the first fluid motor rotates the tractor tool and the second fluid motor.

There is further described a system for use in a subterranean wellbore, the system comprising: a tool assembly including: a first fluid motor; and a tractor tool, and in which the first fluid motor rotates the tractor tool in response to fluid flow through the first fluid motor, and in which the tractor tool is configured to engage a well surface in the wellbore and advance the tool assembly along the wellbore.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a representative partially cross-sectional view of an example of a well system and associated method which can embody principles of this disclosure.

FIG. 2 is a representative cross-sectional view of a rotary actuator assembly that may be used in the system and method of FIG. 1, and which may embody the principles of this disclosure.

FIG. 3 is a representative cross-sectional view of a gear reducer section of the rotary actuator assembly.

FIG. 4 is a representative cross-sectional view of a fluid motor of the rotary actuator assembly, taken along line 4-4 of FIG. 3.

FIG. 5 is a representative cross-sectional view of the gear reducer section, taken along line 5-5 of FIG. 3.

FIG. 6 is a representative cross-sectional view of the gear reducer section, taken along line 6-6 of FIG. 3.

FIG. 7 is a representative cross-sectional view of the gear reducer section, taken along line 7-7 of FIG. 3.

FIG. 8 is a representative cross-sectional view of an example of a bottom hole assembly comprising the rotary actuator assembly connected to a cleaning tool.

FIGS. 9A & B are representative side and cross-sectional views of an example of a lower section of the rotary actuator assembly.

FIGS. 10A & B are representative side and cross-sectional views of an example of a tractor embodiment of the rotary actuator assembly.

FIGS. 11A & B are representative cross-sectional views of an example of a bottom hole tool assembly comprising the rotary actuator assembly connected to a fluid motor and a drill bit.

FIG. 12 is a representative partially cross-sectional view of an example of a tool assembly in a drilling operation.

FIG. 13 is a representative partially cross-sectional view of another example of a tool assembly in a cleaning operation.

DETAILED DESCRIPTION

Representatively illustrated in FIG. 1 is a system 10 for use with a subterranean well, and an associated method, which can embody principles of this disclosure. However, it should be clearly understood that the system 10 and method are merely one example of an application of the principles of this disclosure in practice, and a wide variety of other examples are possible. Therefore, the scope of this disclosure is not limited at all to the details of the system 10 and method described herein and/or depicted in the drawings.

In the system 10 as depicted in FIG. 1, a tubular string 12 is deployed into a wellbore 14 lined with casing 16 and cement 18. The wellbore 14 in this example is generally vertical, but in other examples the wellbore could be horizontal, deviated or otherwise inclined relative to vertical. It is not necessary for the wellbore 14 to be cased or cemented in sections of the wellbore where the method is practiced.

The tubular string 12 in this example comprises coiled tubing, but in other examples the tubular string could be made up of separate tubing joints connected together by threaded connections, or other types of connections. The scope of this disclosure is not limited to use of any particular type of tubular string, tubing or other well equipment.

The tubing is “coiled” in that it is stored at surface on a spool or reel 20. An injector 22 and a blowout preventer stack 24 connected to a wellhead 26 may be used to convey the tubular string 12 into and out of the wellbore 14. A pump 28 may be used to apply pressure to an interior flow passage of the tubular string 12.

An annulus 30 is formed radially between the tubular string 12 and the casing 16 in the FIG. 1 example. In some situations, the annulus 30 can serve as a fluid passage for flowing fluid from the wellbore 14 to surface, for example, in drilling operations or other operations in which fluid is flowed into the wellbore via the tubular string 12.

The tubular string 12 in this example includes a combination of well tools 34, 36, 38, 40 connected together at a distal end of the tubular string. Typically, such a combination of well tools is referred to by those skilled in the art as a bottom hole assembly (BHA). However, it is not necessary for a combination of well tools incorporating the principles of this disclosure to be at or near a bottom of a hole or wellbore, or for any particular combination of well tools to be used, or for the well tools to be connected at a distal end of the tubular string. Thus, the scope of this disclosure is not limited at all to any of the details of the tubular string 12 or well tools 34, 36, 38, 40 as described herein or depicted in the drawings.

In the FIG. 1 example, the well tool 40 comprises a rotary actuator assembly with a fluid motor that produces rotation in response to fluid flow through the tubular string 12. Fluid can be pumped through an inner flow passage of the tubular string 12 (for example, using the pump 28), and through the rotary actuator assembly 40, in order to cause rotation of the well tools 34, 36 connected below the rotary actuator assembly. The well tool 38 could comprise an anchor or another type of anti-rotation device that functions to prevent reactive rotation or torque from being induced in the tubular string 12 above the rotary actuator assembly 40.

The fluid motor of the rotary actuator assembly 40 may be any type of fluid motor. For example, the fluid motor could be a positive displacement-type fluid motor, such as a Moineau progressive cavity pump. The scope of this disclosure is not limited to any particular type of fluid motor used in the rotary actuator assembly 40.

The well tools 34, 36 may be any type, number or combination of well tools. The well tools 34, 36 could include washing or other cleaning tools, drill bits, survey or logging equipment, perforating equipment, etc. In some examples, only a single well tool may be connected below the rotary actuator assembly 40. The scope of this disclosure is not limited to any particular well tool or well tools rotated by means of the rotary actuator assembly 40.

Referring additionally now to FIG. 2, a cross-sectional view of an example of the rotary actuator assembly 40 is representatively illustrated. In this example, the assembly 40 includes upper and lower connectors 42, 44 for connecting the assembly in the tubular string 12. However, the assembly 40 may be used in other tubular strings and in systems other than the system 10 of FIG. 1, in keeping with the principles of this disclosure.

When connected in the tubular string 12, the internal flow passage 46 of the tubular string extends longitudinally through the assembly 40. In this manner, a fluid 48 can be flowed through the flow passage 46 (such as, using the pump 28).

The assembly 40 includes a fluid motor 50 that produces rotation in response to the flow of the fluid 48 through the passage 46. In the FIG. 2 example, the fluid motor 50 is of the Moineau progressive cavity positive displacement-type, but other types of fluid motors may be used in other examples.

The fluid motor 50 includes a helically lobed rotor 52 positioned in an external stator 54. The stator 54 in this example has internal helical lobes formed in an elastomeric lining 54a secured in an outer tubular housing 54b.

In some examples, the fluid motor 50 lining 54a could be made of other types of materials, and the lining and the outer housing 54b are not necessarily separate components of the stator 54. For example, the lining 54a could be made of a metallic material or metal alloy, and/or the lining and housing 54b could be integrally formed as a single component. Thus, the scope of this disclosure is not limited to any particular details of the fluid motor 50 as described herein or depicted in the drawings.

The upper connector 42 has a downwardly extending (as viewed in FIG. 2) abutment 56 that prevents substantial upward displacement of the rotor 52. The rotor 52 is thereby maintained in operative engagement with the stator 54, so that the rotor rotates when the fluid 48 is flowed through the fluid motor 50.

Note that the rotor 52 also orbits relative to a central longitudinal axis 58 of the stator 54 with a displacement characterized by hypocyclic precessional motion, as is typical in Moineau-type fluid motors. As depicted in FIG. 2, the rotor 52 is off-center with respect to the longitudinal axis 58.

An externally toothed input gear 60 is rigidly connected at a bottom end of the rotor 52 during operation of the fluid motor 50. The gear 60 is rigidly connected to the rotor 52 in that no relative movement is permitted between the gear and the rotor. The gear 60 rotates with the rotor 52 and displaces with the same hypocyclic precessional motion as the rotor relative to the longitudinal axis 58. Although the gear 60 is depicted in FIG. 2 as being a separate component from the rotor 52, in other examples the gear and the rotor could be integrally formed as a single component.

The gear 60 is in engagement with an internally toothed output gear 62 formed in an upper end of a tubular shaft 64. Although the gear 62 and shaft 64 are depicted in FIG. 2 as being formed as a single component, they could in other examples be formed as separate rigidly connected components.

Note that the gear 62 and shaft 64 do not displace with the hypocyclic precessional motion of the rotor 52 and gear 60, but the gear 62 and shaft 64 do rotate about the longitudinal axis 58. However, the gear 62 and shaft 64 rotate at a slower rotational speed about the axis 58, as compared to the rotor 52 and gear 60, as described more fully below.

Rotation is transmitted from the shaft 64 to the lower connector 44 via additional tubular shafts 66, 68. The shafts 64, 66, 68 are supported by radial bearings 70 and thrust bearings 72. In other examples, all or some of the shafts 64, 66, 68 could be combined into an output shaft 74, which could comprise the multiple shafts 64, 66, 68 or a single integrally formed shaft.

Due to the unique arrangement of the gears 60, 62 in relation to the rotor 52 and output shaft 74, the lower connector 44 rotates at a slower rotational speed than the rotor 52. Thus, the gears 60, 62 provide for a “gear reduction” (an increased gear ratio) in the assembly 40. This reduced rotational speed of the lower connector 44 can be very beneficial in a variety of different well operations.

Referring additionally now to FIG. 3, an enlarged scale cross-sectional view of a gear reducer section 76 of the rotary actuator assembly 40 is representatively illustrated. FIGS. 5, 6 & 7 are representative cross-sectional views of the gear reducer section 76, taken along lines 5-5, 6-6 and 7-7 of FIG. 3, respectively. FIG. 4 is a representative cross-sectional view of the fluid motor 50, taken along line 4-4 of FIG. 3.

In FIG. 4, it may be seen that the rotor 52 in this example is provided with five external lobes 52a, and the stator 54 is provided with six internal lobes 54c (some of which are compressed by the rotor lobes 52a as viewed in FIG. 4). In Moineau-type fluid motors, the numbers of lobes on the rotor and the stator are unequal, and a ratio of the numbers of lobes influences a rotational speed of the rotor at a given flow rate. Any numbers of external and internal lobes 52a, 54c may be provided on the rotor 52 and stator 54, respectively, in keeping with the scope of this disclosure.

In FIG. 5, it may be seen that the gear 60 in this example is provided with six external teeth 60a, and the gear 62 is provided with seven internal teeth 62a. Different numbers of the teeth 60a, 62a may be used in other examples.

As mentioned above, the gear 60 rotates and precesses with the rotor 52. As a result, a central axis 78 of the gear 60 rotates about the longitudinal axis 58 (as indicated by the arrow 80 in FIG. 5). Thus, the gear 60 rotates about its central axis 78, and the axis 78 rotates about the longitudinal axis 58 when the rotor 52 rotates within the stator 54. Note that the central axis 78 is also a central longitudinal axis of the rotor 52 in this example (see FIG. 3).

Due to this unique configuration and motion of the gear 60, the cooperative arrangement of the engaged gears 60, 62 and the numbers of the teeth 60a, 62a, the gear 62 will rotate at a slower rotational speed as compared to the gear 60. The gear reduction ratio can be calculated using the following equation: $R = 1 - (N_I / N_O)$, in which R is the gear ratio, N_I is the number of input gear teeth 60a, and N_O is the number of output gear teeth 62a.

Using the present example ($N_I = 6$ and $N_O = 7$), the gear ratio R is ~0.14. Thus, the gear 62, output shaft 74 and lower connector 44 (and any well tool connected thereto) will rotate at a speed that is approximately 0.14 times the rotational speed of the rotor 52. Of course, other gear ratios may be used in other examples.

Relatively large voids exist between the gears 60, 62, so that the flow passage 46 extends through those gaps. In addition, the shaft 64 has openings 64a formed therein for flow of the fluid 48, so that the openings 64a form part of the passage 46.

Note that only a relatively small gap *G* exists between disengaged pairs of the teeth 60a, 62a. This prevents disengagement of the engaged teeth 60a, 62a opposite the gap *G* from the axis 78. Thus, at least one pair of the teeth 60a, 62a is positively engaged at all times, so that rotation and torque are consistently transmitted from the input gear 60 to the output gear 62.

In FIG. 6, it may be seen that an upper portion of a thrust bearing 82 (also see FIG. 3) is provided in the form of a flat disc 82a secured at a lower end of the gear 60. The disc 82a is made of a polished carbide material in this example, but other materials and other types of thrust bearings may be used in other examples.

In FIG. 7, it may be seen that a lower portion of the thrust bearing 82 is provided in the form of a flat disc 82b secured at an upper end of the shaft 64. The disc 82b is made of a polished carbide material in this example, similar to the disc 82a, but other materials and other types of thrust bearings may be used in other examples.

Referring additionally now to FIG. 8, an example use of the rotary actuator assembly 40 is representatively illustrated. In this example, the well tool 36 is connected to the lower connector 44. The well tool 36 comprises a wash tool with nozzles 84 for increasing a velocity of the fluid 48 flow and directing the flow outward, for example, to clean an interior of the casing 16 in the FIG. 1 system. Other types of washing or cleaning tools (such as casing scrapers, etc.) may be used in other examples.

It is desirable for the wash tool 36 to be rotated relatively slowly by the rotary actuator assembly 40 (in any event, slower than the rotor 52 rotates in response to the fluid 48 flow), so that the fluid 48 impinges longer on a given surface area to be cleaned. For at least this purpose, the gear reducer section 76 reduces the rotational speed of the lower connector 44 and the connected wash tool 36.

Referring additionally now to FIGS. 9A & B, side and cross-sectional views, respectively, of a lower section of another example of the assembly 40 are representatively illustrated. In these views, it may be seen that the output shaft 74 is separately formed from the lower connector 44, and a series of external helical threads 86 are formed on the lower connector.

The threads 86 are oriented so that, as the lower connector 44 rotates in response to flow of the fluid 48 through the passage 46, the threads urge the assembly 40 to advance through the wellbore 14 in the system 10 of FIG. 1. For example, the threads 86 could engage an interior surface of the casing 16 (or an inner wall of the wellbore 14 itself if the wellbore is uncased) and thereby “pull” the assembly 40 along the surface as the lower connector 44 rotates.

The threads 86 can extend radially outward past the remainder of the assembly 40, so that the threads positively engage the well surface (e.g., the interior surface of the casing 16 or an inner wall surface of the wellbore 14). In this example, the threads 86 operate to “screw” the assembly 40 into the wellbore 14.

Referring additionally now to FIGS. 10A & 10B, side and cross-sectional views, respectively, of another example of the assembly 40 are representatively illustrated. In this example, the threads 86 are not formed directly on the lower connector 44, but are instead formed on a separate outer sleeve 88 that is connected to the lower connector and extends upwardly over an exterior of the fluid motor 50 and gear reducer section 76.

As described above for the FIGS. 9A & B example, the configuration of FIGS. 10A & B can be used to urge the assembly 40 and the remainder of the tubular string 12 through the wellbore 14 in the FIG. 1 system 10 in response to flow of the fluid 48 through the passage 46. In this manner, the assembly 40 can function as a “tractor” to advance any connected equipment and tubulars through the wellbore 14, whether or not the wellbore is lined with the casing 16 and cement 18.

Referring additionally now to FIGS. 11A & B, another example of the assembly 40 connected to well tools 34, 36 is representatively illustrated. In this example, the well tool 36 comprises a fluid motor. The fluid motor 36 may be similar to the fluid motor 50, or it may be a different type of fluid motor. The fluid motor 36 in this example does not have a gear reducer section that receives an output of a rotor 90 of the fluid motor 36, but a gear reducer section could be provided, if desired.

The well tool 34 comprises a drill bit as depicted in FIG. 11B. The drill bit 34 may be used to extend the wellbore 14 in the FIG. 1 system 10, or it may be used for other purposes (for example, to initiate or start a lateral wellbore or sidetrack, or drill through a bridge plug). Other types of cutting devices (such as mills, etc.) may be used for the well tool 34 in other examples.

The fluid motor 36 rotates the drill bit 34 relatively rapidly in this example, in order to correspondingly rapidly drill the wellbore 14. Thus, the fluid motor 36 does not include the gear reducer section 76.

The assembly 40 is used to slowly rotate the fluid motor 36 and drill bit 34, in order to prevent sticking (e.g., “stiction,” static friction or differential sticking) of these components against the interior wall of the wellbore 14. The assembly 40 also rotates the lower connector 44 with the threads 86 thereon to help advance the tubular string 12 along the wellbore 14. This is particularly beneficial in horizontal or highly deviated wellbores. The threads 86, and the rotation of the fluid motor 36 with the drill bit 34, also help to clear drill cuttings and debris from around the bottom hole assembly.

Note that, with both of the fluid motors 36, 50 connected above the drill bit 34, the drill bit will rotate at a speed that is a sum of the rotational speed output of the fluid motor 36 and the rotational speed output of the fluid motor 50. One benefit of providing the gear reducer section 76 in the assembly 40 is that it prevents rotating the drill bit 34 too fast. However, the assembly 40 could be provided without the gear reducer section 76, if desired.

Referring additionally now to FIG. 12, an example of a tool assembly 100 is representatively illustrated. The tool assembly 100 may be used in the system 10 and method of FIG. 1, or it may be used in other systems and methods.

In the FIG. 12 example, the tool assembly 100 includes a cutting tool 102, a fluid motor 104, a tractor tool 106, a gear reducer 108, another fluid motor 110 and a vibratory tool 112. The tool assembly 100 is connected at a distal end of the tubular string 12 and is used to extend the wellbore 14, in this example.

The cutting tool 102 as depicted in FIG. 12 is a drill bit. The drill bit may be similar to the drill bit 34 depicted in FIG. 11B, or another type of drill bit may be used. In other examples, the cutting tool 102 could be a mill or another type of cutting tool. The scope of this disclosure is not limited to use of any particular type of cutting tool with the tool assembly 100.

The fluid motor 104 may be a turbine or Moineau-type mud motor or drill motor. The fluid motor 104 rotates the cutting tool 102 in response to flow of fluid (such as fluid 48, see FIGS. 11A & B) through the fluid motor. The fluid motor 104 may be similar to the fluid motor 36 depicted in FIG. 11B. However, the scope of this disclosure is not limited to use of any particular type of fluid motor with the tool assembly 100.

The tractor tool 106 as depicted in FIG. 12 has the external threads 86 thereon for engaging and advancing the tool assembly 100 along a well surface. In this example, the well surface is an inner wall surface 14a of the wellbore 14.

The tractor tool 106 may be similar to the lower connector 44 as depicted in FIGS. 9A & B, and in some examples including the outer sleeve 88 as depicted in FIGS. 10A & B. However, other configurations or types of tractor tools may be used, in keeping with the scope of this disclosure.

The gear reducer 108 reduces a rotational speed output of the fluid motor 110. The gear reducer 108 and the fluid motor 110 may be combined into a single assembly (such as, the rotary actuator assembly 40), with or without the tractor tool 106. Another example of a suitable fluid motor and gear reducer for use in the tool assembly 100 is described in US Patent No. 6336502.

The gear reducer 108 may be similar to the gear reducer section 76 described above. However, the scope of this disclosure is not limited to use of any particular type of gear reducer with the tool assembly 100.

The fluid motor 110 may be the same type of fluid motor as any of the fluid motors 36, 50, 104 described above, or it may be another type of fluid motor. If the fluid motor 110 is a Moineau-type fluid motor having a rotor that rotates relative to a stator, the rotor may be internal or external to the stator. The fluid motor 110 in the FIG. 12 example rotates the tractor tool 106, the fluid motor 104 and the cutting tool 102 in response to fluid flow through the fluid motor 110.

As mentioned above, the gear reducer 108 functions to reduce an output rotational speed of the fluid motor 110. In this manner, the tractor tool 106 is rotated at an appropriate speed to gradually advance the tool assembly 100 along the wellbore 14, and the cutting tool 102 is not rotated too fast for optimal drilling of the wellbore 14. Preferably, but not necessarily, a rotational output speed of the fluid motor 110 and gear reducer 108 is less than a rotational output speed of the fluid motor 104, as described above for the FIGS. 11A & B example.

Rotational output speeds of the fluid motors 104, 110 themselves may be the same for a given flow rate of the fluid 48 through the tool assembly 100 (not accounting for rotation of the fluid motor 104 by the fluid motor 110 and gear reducer 108). In some examples, the rotational output speeds of the fluid motors

104 may be different, and in such cases it is preferable (although not necessary) that the rotational output speed of the fluid motor 104 is greater than the rotational output speed of the fluid motor 110. In the FIG. 12 example, the rotational speed at an output of the gear reducer 108 (e.g., the rotational output speed of the fluid motor 110 as reduced by the gear reducer) is less than the rotational output speed of the fluid motor 104.

The vibratory tool 112 produces vibrations in response to the fluid flow through the tool assembly 100. The vibrations reduce “stiction,” static friction, differential sticking or other friction forces that inhibit motion of the tool assembly 100 along the wellbore surface 14a. This is particularly advantageous in longer horizontal or highly deviated wellbores. The vibratory tool 112 combined with the tractor tool 106 in the tool assembly 100 should enable drilling much farther in horizontal or highly deviated wellbores, but use of the tool assembly in such horizontal or highly deviated wellbores is not necessary in keeping with the principles of this disclosure.

A suitable vibratory tool for use as the vibratory tool 112 in the tool assembly 100 is the model XRV G3™ dynamic excitation tool marketed by Thru Tubing Solutions, Inc. of Oklahoma City, Oklahoma USA. However, the scope of this disclosure is not limited to use of any particular type of vibratory tool in the tool assembly 100, or to use of a vibratory tool at all.

Note that the tool assembly 100 is not necessarily used to drill a wellbore. In some examples (such as, if the cutting tool 102 is a mill, an under-reamer or another type of cutting tool), the tool assembly 100 could be used in a wellbore enlarging or casing cleanout operation, e.g., in casing or tubing to cut through a frac plug, bridge plug or other obstruction. The tool assembly 100 could include other, differently configured, or fewer or greater numbers of, tools. Thus, the scope of this disclosure is not limited to the tool assembly 100 configuration as depicted in FIG. 12 or described herein.

Referring additionally now to FIG. 13, another example of the tool assembly 100 is representatively illustrated. The FIG. 13 tool assembly 100 example may be used in the system 10 and method of FIG. 1, or it may be used with other systems and methods.

As depicted in FIG. 13, the tool assembly 100 includes the tractor tool 106, the gear reducer 108 and the fluid motor 110 connected to the tubular string 12. The cutting tool 102, fluid motor 104 and vibratory tool 112 are not included in the FIG. 13 tool assembly 100 example, but any of these tools could be included in other examples. In particular, the vibratory tool 112 could be used in the FIG. 13 tool assembly 100 to facilitate displacement of the tool assembly through long horizontal or highly deviated wellbores.

The FIG. 13 tool assembly 100 includes a cleaning tool 114 connected to the tractor tool 106. The cleaning tool 114 may be similar to the cleaning tool 36 depicted in FIG. 8. The cleaning tool 114 directs the fluid 48 outward at high flow rates, in order to clean a well surface, such as an interior surface 16a of the casing 16.

The fluid motor 110 and gear reducer 108 rotate the tractor tool 106 and the cleaning tool 114. Rotation of the tractor tool 106 helps to advance the tool assembly 100 along the casing 16, and rotation of the cleaning tool 114 helps to ensure that the fluid 48 impinges at high flow rates on all of the interior surface 16a around the cleaning tool.

The threads 86 on the tractor tool 106 engage the interior surface 16a. As the tractor tool 106 is rotated by the fluid motor 110 and gear reducer 108, the threads 86 grip and pull the tool assembly 100 and the tubular string 12 along the interior surface 16a. In some examples, the tractor tool 106 may be combined with the fluid motor 110 and gear reducer 108 (as in the rotary actuator assembly 40 described above), or any one or combination of these components could be separately provided.

Note that the cutting tool 102, fluid motor 104 and cleaning tool 114 depicted in FIGS. 12 & 13 are just a few examples of a wide variety of different well tools that may be advanced or displaced along a wellbore (or casing, liner or tubing in a wellbore) using the tractor tool 106. Other examples include (but are not limited to) perforators, shifting tools, flow control devices, etc. Thus, the scope of this disclosure is not limited to any particular well tool advanced or displaced along a wellbore using the tractor tool 106.

It may now be fully appreciated that the above disclosure provides significant advancements to the arts of designing, constructing and utilizing equipment to produce displacement of well tools downhole. In examples described above, the tractor tool 106 can be rotated by a fluid motor 104 downhole. The tractor tool 106 and fluid motor 104 can be components of the tool assembly 100, which is part of the tubular string 12. Rotation of the tractor tool 106 advances the tubular string 12 (including the tool assembly 100) along the wellbore 14.

The above disclosure provides to the art a tubular string 12 for use in a subterranean well. In one example, the tubular string 12 can comprise a tool assembly 100. The tool assembly 100 can include a first fluid motor 110 and a tractor tool 106. The first fluid motor 110 can rotate the tractor tool 106 in response to fluid 48 flow through the first fluid motor 110.

The tractor tool 106 may comprise one or more external threads 86. The threads 86 may extend radially outward relative to the first fluid motor 110, or radially outward past an outer housing 54b of the first fluid motor 110. The threads 86 may engage a well surface (such as the wellbore inner surface 14a or the casing interior surface 16a) external to the tractor tool 106.

The tool assembly 100 may include a gear reducer 108 that reduces a rotational speed output of the first fluid motor 110. The first fluid motor 110 may comprise a rotor 52 that displaces with hypocyclic precessional motion within a stator 54 in response to the fluid 48 flow through the first fluid motor 110. The gear reducer 108 may comprise an input gear 60 that is fixed relative to the rotor 52 and displaces with the hypocyclic precessional motion relative to an output gear 62.

The first fluid motor 110 may comprise a rotor 52 that rotates within a stator 54 in response to the fluid 48 flow through the first fluid motor 110, the rotor

52 having a central longitudinal axis 78 that rotates about a central longitudinal axis 58 of the stator 54. The gear reducer 108 may comprise an input gear 60 that rotates with the rotor 52 and displaces relative to an output gear 62, the input gear 60 having the same central longitudinal axis 78 as the rotor 52.

The tool assembly 100 may include a second fluid motor 104. The second fluid motor 104 may rotate with the tractor tool 106.

The tool assembly 100 may include a cutting tool 102. The second fluid motor 104 may be connected between the tractor tool 106 and the cutting tool 102.

The tool assembly 100 may include a cleaning tool 114. The cleaning tool 114 may rotate with the tractor tool 106.

The above disclosure also provides to the art another tubular string 12 for use in a subterranean well. In an example described above, the tubular string 12 can comprise a tool assembly 100 including a fluid motor 110, a gear reducer 108 that reduces a rotational speed output of the fluid motor 110, and a tractor tool 106. The fluid motor 110 and the gear reducer 108 rotate the tractor tool 106 in response to fluid 48 flow through the fluid motor 110.

Also described above is another example of a tubular string 12 for use in a subterranean well. In this example, the tubular string 12 comprises a tool assembly 100 including a first fluid motor 110, a tractor tool 106 and a second fluid motor 104. The second fluid motor 104 rotates with the tractor tool 106.

A system 10 for use in a subterranean wellbore 14 can include a tool assembly 100. The tool assembly 100 can include a fluid motor 110 and a tractor tool 106. The fluid motor 110 can rotate the tractor tool 106 in response to fluid 48 flow through the fluid motor 110. The tractor tool 106 can be configured to engage a well surface 14a, 16a in the wellbore 14 and advance the tool assembly 100 along the wellbore 14.

Although various examples have been described above, with each example having certain features, it should be understood that it is not necessary for a particular feature of one example to be used exclusively with that example.

Instead, any of the features described above and/or depicted in the drawings can be combined with any of the examples, in addition to or in substitution for any of the other features of those examples. One example's features are not mutually exclusive to another example's features. Instead, the scope of this disclosure encompasses any combination of any of the features.

Although each example described above includes a certain combination of features, it should be understood that it is not necessary for all features of an example to be used. Instead, any of the features described above can be used, without any other particular feature or features also being used.

It should be understood that the various embodiments described herein may be utilized in various orientations, such as inclined, inverted, horizontal, vertical, etc., and in various configurations, without departing from the principles of this disclosure. The embodiments are described merely as examples of useful applications of the principles of the disclosure, which is not limited to any specific details of these embodiments.

In the above description of the representative examples, directional terms (such as “above,” “below,” “upper,” “lower,” etc.) are used for convenience in referring to the accompanying drawings. However, it should be clearly understood that the scope of this disclosure is not limited to any particular directions described herein.

The terms “including,” “includes,” “comprising,” “comprises,” and similar terms are used in a non-limiting sense in this specification. For example, if a system, method, apparatus, device, etc., is described as “including” a certain feature or element, the system, method, apparatus, device, etc., can include that feature or element, and can also include other features or elements. Similarly, the term “comprises” is considered to mean “comprises, but is not limited to.”

Of course, a person skilled in the art would, upon a careful consideration of the above description of representative embodiments of the disclosure, readily appreciate that many modifications, additions, substitutions, deletions, and other changes may be made to the specific embodiments, and such changes are contemplated by the principles of this disclosure. For example, structures disclosed as being separately formed can, in other examples, be integrally formed and *vice versa*. Accordingly, the foregoing detailed description is to be clearly understood as being given by way of illustration and example only, the spirit and scope of the invention being limited solely by the appended claims and their equivalents.

EMBODIMENTS IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A tubular string for use in a subterranean well, the tubular string comprising:

a tool assembly including:

a first fluid motor; and

a tractor tool configured to advance the tool assembly through the well, and

in which the first fluid motor rotates the tractor tool in response to fluid flow through the first fluid motor.

2. The tubular string of claim 1, in which the tractor tool comprises one or more external threads.

3. The tubular string of claim 2, in which the threads extend radially outward relative to the first fluid motor.

4. The tubular string of claim 2, in which the threads extend radially outward past an outer housing of the first fluid motor.

5. The tubular string of claim 2, in which the threads engage a well surface external to the tractor tool.

Date Reçue/Date Received 2021-06-10

6. The tubular string of claim 1, in which the tool assembly further includes a gear reducer that reduces a rotational speed output of the first fluid motor.

7. The tubular string of claim 6, in which the first fluid motor comprises a rotor that displaces with hypocyclic precessional motion within a stator in response to the fluid flow through the first fluid motor, and in which the gear reducer comprises an input gear that is fixed relative to the rotor and displaces with the hypocyclic precessional motion relative to an output gear.

8. The tubular string of claim 6, in which the first fluid motor comprises a rotor that rotates within a stator in response to the fluid flow through the first fluid motor, the rotor having a central longitudinal axis that rotates about a central longitudinal axis of the stator, and in which the gear reducer comprises an input gear that rotates with the rotor and displaces relative to an output gear, and the input gear having the same central longitudinal axis as the rotor.

9. The tubular string of claim 1, in which the tool assembly further includes a second fluid motor, and in which the second fluid motor rotates with the tractor tool.

10. The tubular string of claim 9, in which the tool assembly further includes a cutting tool, and in which the second fluid motor is connected between the tractor tool and the cutting tool.

11. The tubular string of claim 1, in which the tool assembly further includes a cleaning tool, and in which the cleaning tool rotates with the tractor tool.

Date Reçue/Date Received 2021-06-10

12. A tubular string for use in a subterranean well, the tubular string comprising:

a tool assembly including:

a first fluid motor;

a gear reducer that reduces a rotational speed output of the first fluid motor; and

a tractor tool configured to advance the tool assembly through the well, and

in which the first fluid motor and the gear reducer rotate the tractor tool in response to fluid flow through the first fluid motor.

13. The tubular string of claim 12, in which the tractor tool comprises one or more external threads.

14. The tubular string of claim 13, in which the threads extend radially outward relative to the first fluid motor.

15. The tubular string of claim 13, in which the threads extend radially outward past an outer housing of the first fluid motor.

16. The tubular string of claim 13, in which the threads engage a well surface external to the tractor tool.

Date Reçue/Date Received 2021-06-10

17. The tubular string of claim 12, in which the first fluid motor comprises a rotor that displaces with hypocyclic precessional motion within a stator in response to the fluid flow through the first fluid motor, and in which the gear reducer comprises an input gear that is fixed relative to the rotor and displaces with the hypocyclic precessional motion relative to an output gear.

18. The tubular string of claim 12, in which the first fluid motor comprises a rotor that rotates within a stator in response to the fluid flow through the first fluid motor, the rotor having a central longitudinal axis that rotates about a central longitudinal axis of the stator, and in which the gear reducer comprises an input gear that rotates with the rotor and displaces relative to an output gear, and the input gear having the same central longitudinal axis as the rotor.

19. The tubular string of claim 12, in which the tool assembly further includes a second fluid motor, and in which the second fluid motor rotates with the tractor tool.

20. The tubular string of claim 19, in which the tool assembly further includes a cutting tool, and in which the second fluid motor is connected between the tractor tool and the cutting tool.

21. The tubular string of claim 12, in which the tool assembly further includes a cleaning tool, and in which the cleaning tool rotates with the tractor tool.

22. A tubular string for use in a subterranean well, the tubular string comprising:

Date Reçue/Date Received 2021-06-10

a tool assembly including:

a first fluid motor;

a tractor tool; and

a second fluid motor, and

in which the first fluid motor rotates the tractor tool and the second fluid motor.

23. The tubular string of claim 22, in which the first fluid motor rotates the tractor tool and the second fluid motor in response to fluid flow through the first fluid motor.

24. The tubular string of claim 22, in which the tractor tool comprises one or more external threads.

25. The tubular string of claim 24, in which the threads extend radially outward relative to the first fluid motor.

26. The tubular string of claim 24, in which the threads extend radially outward past an outer housing of the first fluid motor.

27. The tubular string of claim 24, in which the threads engage a well surface external to the tractor tool.

28. The tubular string of claim 22, in which the tool assembly further includes a gear reducer that reduces a rotational speed output of the first fluid motor.

Date Reçue/Date Received 2021-06-10

29. The tubular string of claim 28, in which the first fluid motor comprises a rotor that displaces with hypocyclic precessional motion within a stator in response to fluid flow through the first fluid motor, and in which the gear reducer comprises an input gear that is fixed relative to the rotor and displaces with the hypocyclic precessional motion relative to an output gear.

30. The tubular string of claim 28, in which the first fluid motor comprises a rotor that rotates within a stator in response to fluid flow through the first fluid motor, the rotor having a central longitudinal axis that rotates about a central longitudinal axis of the stator, and in which the gear reducer comprises an input gear that rotates with the rotor and displaces relative to an output gear, and the input gear having the same central longitudinal axis as the rotor.

31. The tubular string of claim 22, in which the tool assembly further includes a cutting tool, and in which the second fluid motor is connected between the tractor tool and the cutting tool.

32. A system for use in a subterranean wellbore, the system comprising:

a tool assembly including:

a first fluid motor; and

a tractor tool, and

in which the first fluid motor rotates the tractor tool in response to fluid flow through the first fluid motor, and in which the tractor tool is configured to engage a well surface in the wellbore and advance the tool assembly along the wellbore.

Date Reçue/Date Received 2021-06-10

33. The system of claim 32, in which the tractor tool comprises one or more external threads.

34. The system of claim 33, in which the threads extend radially outward relative to the first fluid motor.

35. The system of claim 33, in which the threads extend radially outward past an outer housing of the first fluid motor.

36. The system of claim 33, in which the threads engage the well surface external to the tractor tool.

37. The system of claim 32, in which the tool assembly further includes a gear reducer that reduces a rotational speed output of the first fluid motor.

38. The system of claim 37, in which the first fluid motor comprises a rotor that displaces with hypocyclic precessional motion within a stator in response to the fluid flow through the first fluid motor, and in which the gear reducer comprises an input gear that is fixed relative to the rotor and displaces with the hypocyclic precessional motion relative to an output gear.

39. The system of claim 37, in which the first fluid motor comprises a rotor that rotates within a stator in response to the fluid flow through the first fluid motor, the rotor having a central longitudinal axis that rotates about a central longitudinal axis of the stator, and in which the gear reducer comprises an input gear that rotates

Date Reçue/Date Received 2021-06-10

with the rotor and displaces relative to an output gear, and the input gear having the same central longitudinal axis as the rotor.

40. The system of claim 32, in which the tool assembly further includes a second fluid motor, and in which the second fluid motor rotates with the tractor tool.

41. The system of claim 40, in which the tool assembly further includes a cutting tool, and in which the second fluid motor is connected between the tractor tool and the cutting tool.

42. The system of claim 32, in which the tool assembly further includes a cleaning tool, and in which the cleaning tool rotates with the tractor tool.

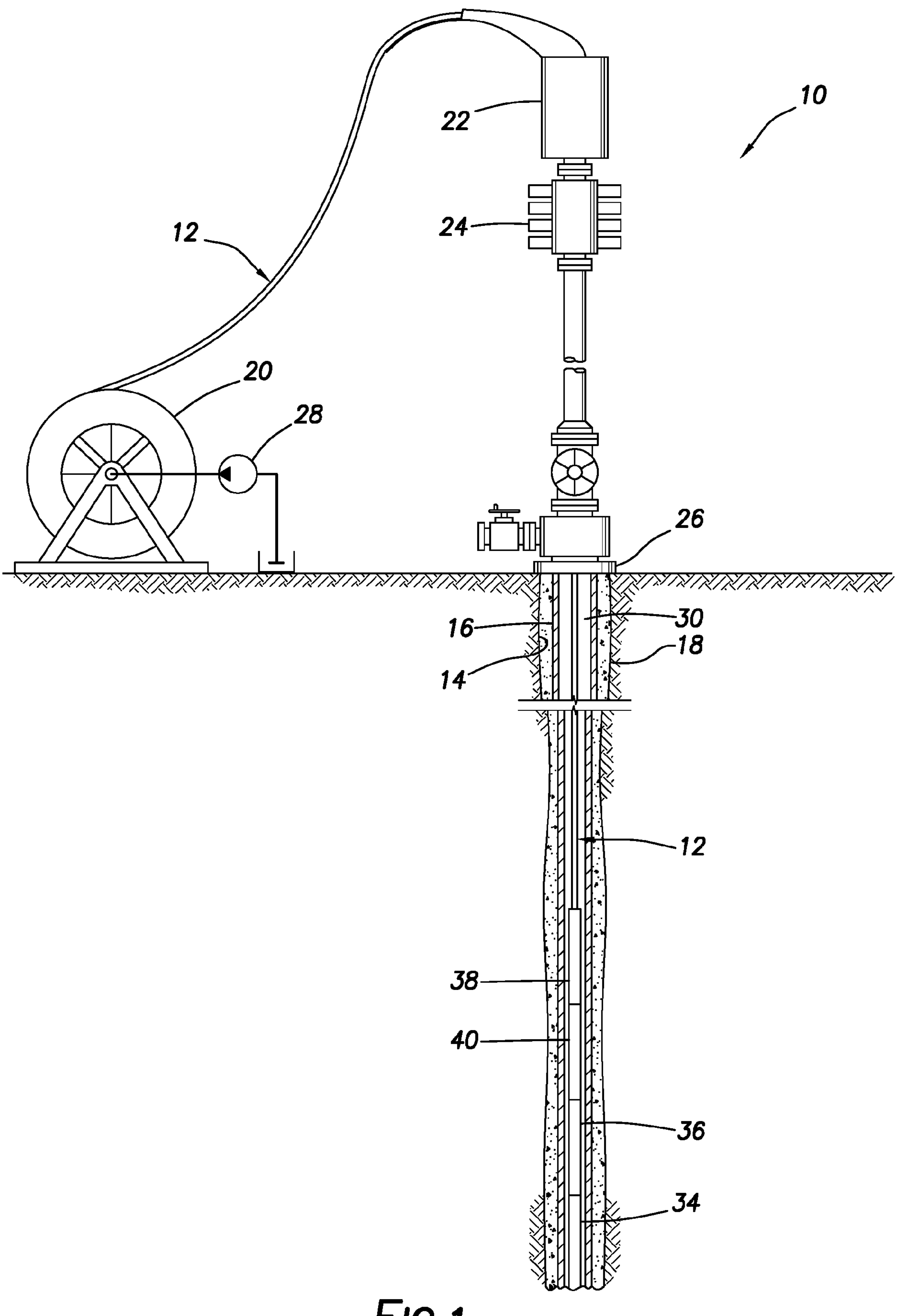

FIG.1

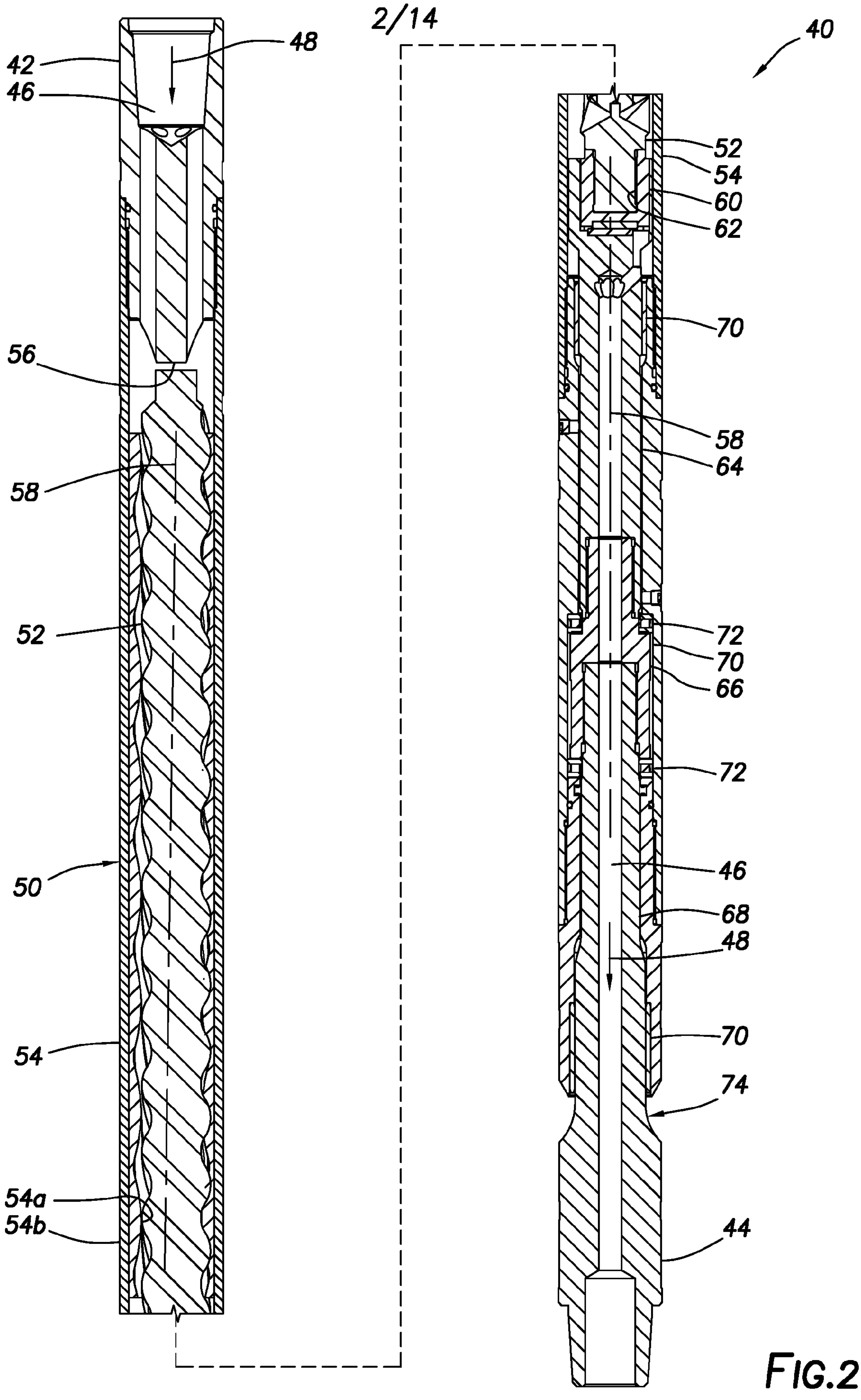
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FIG.2

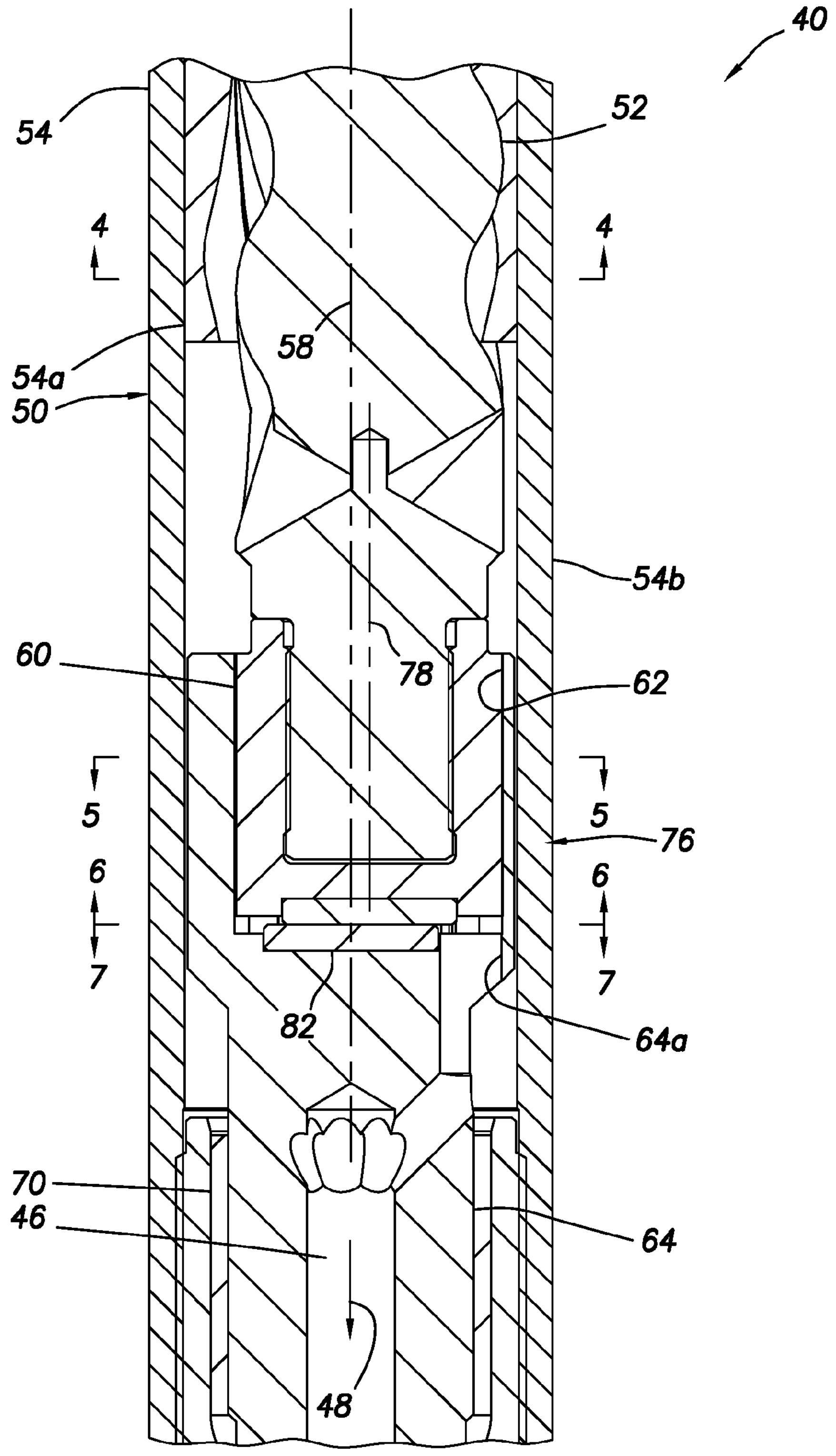

FIG.3

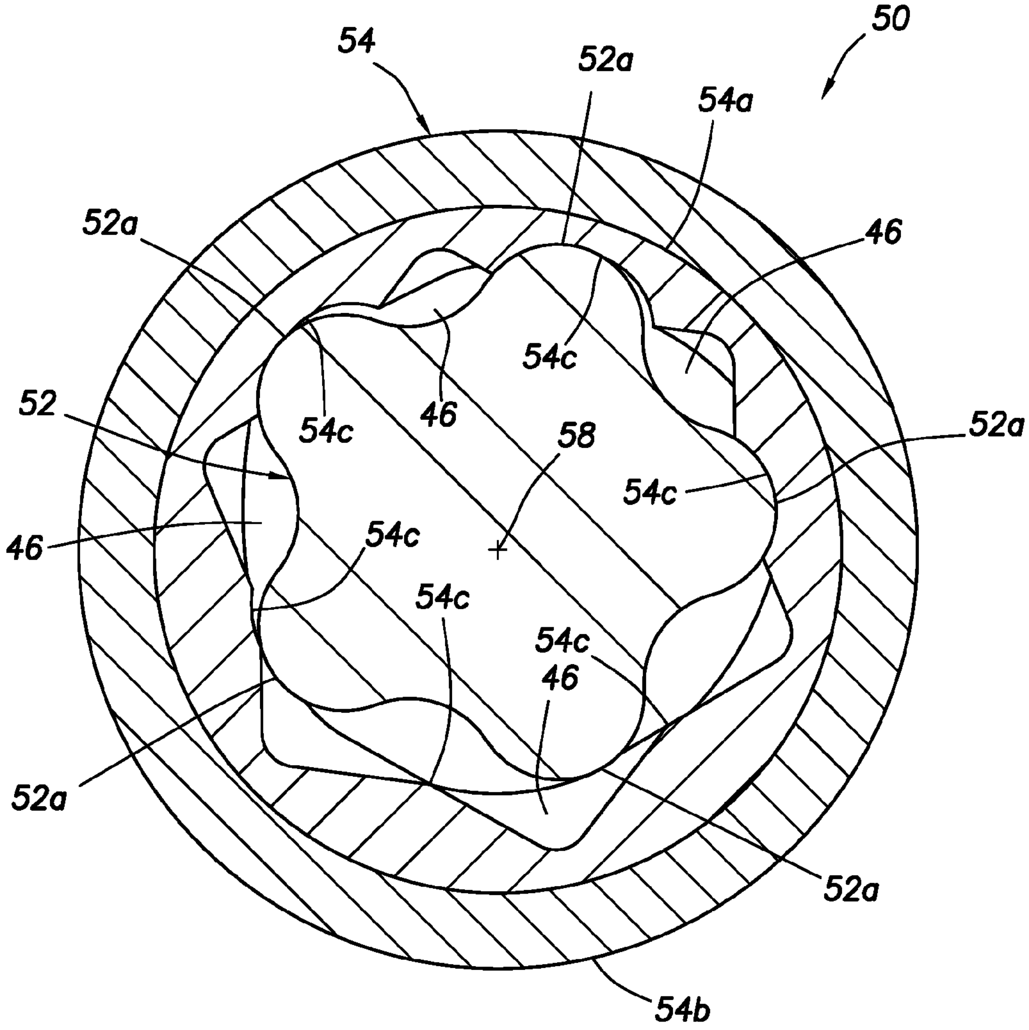
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FIG.4

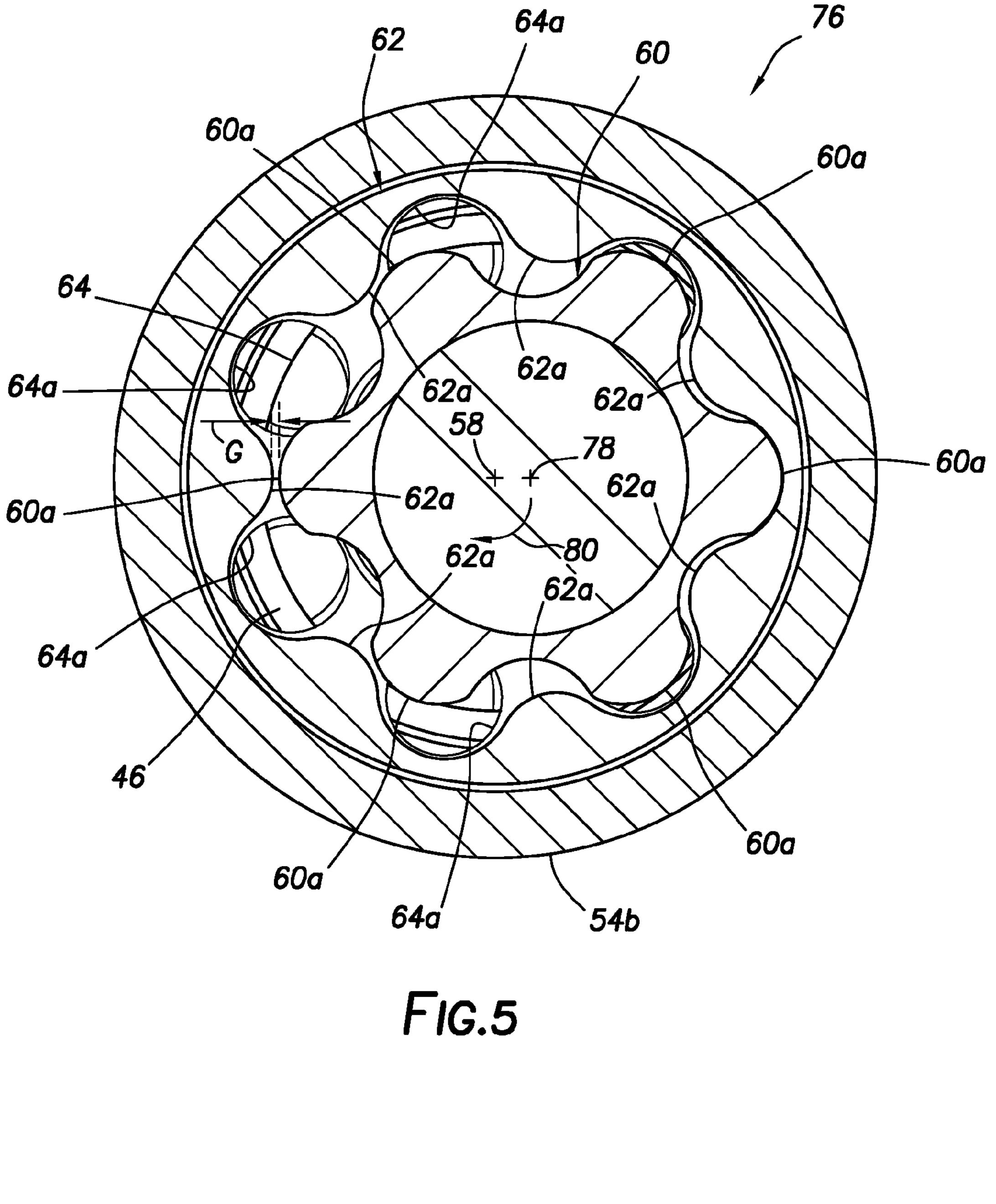
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FIG.5

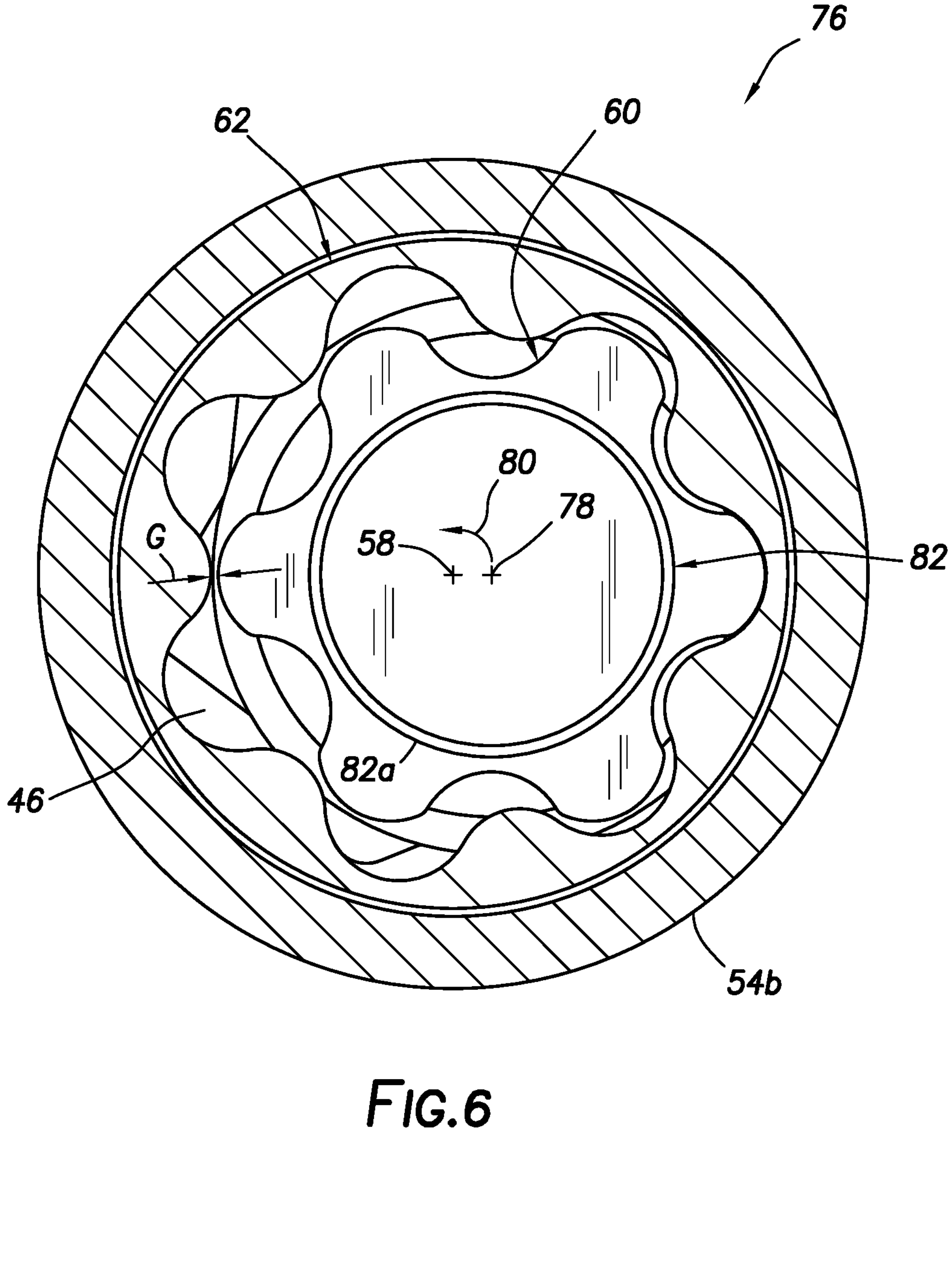

FIG.6

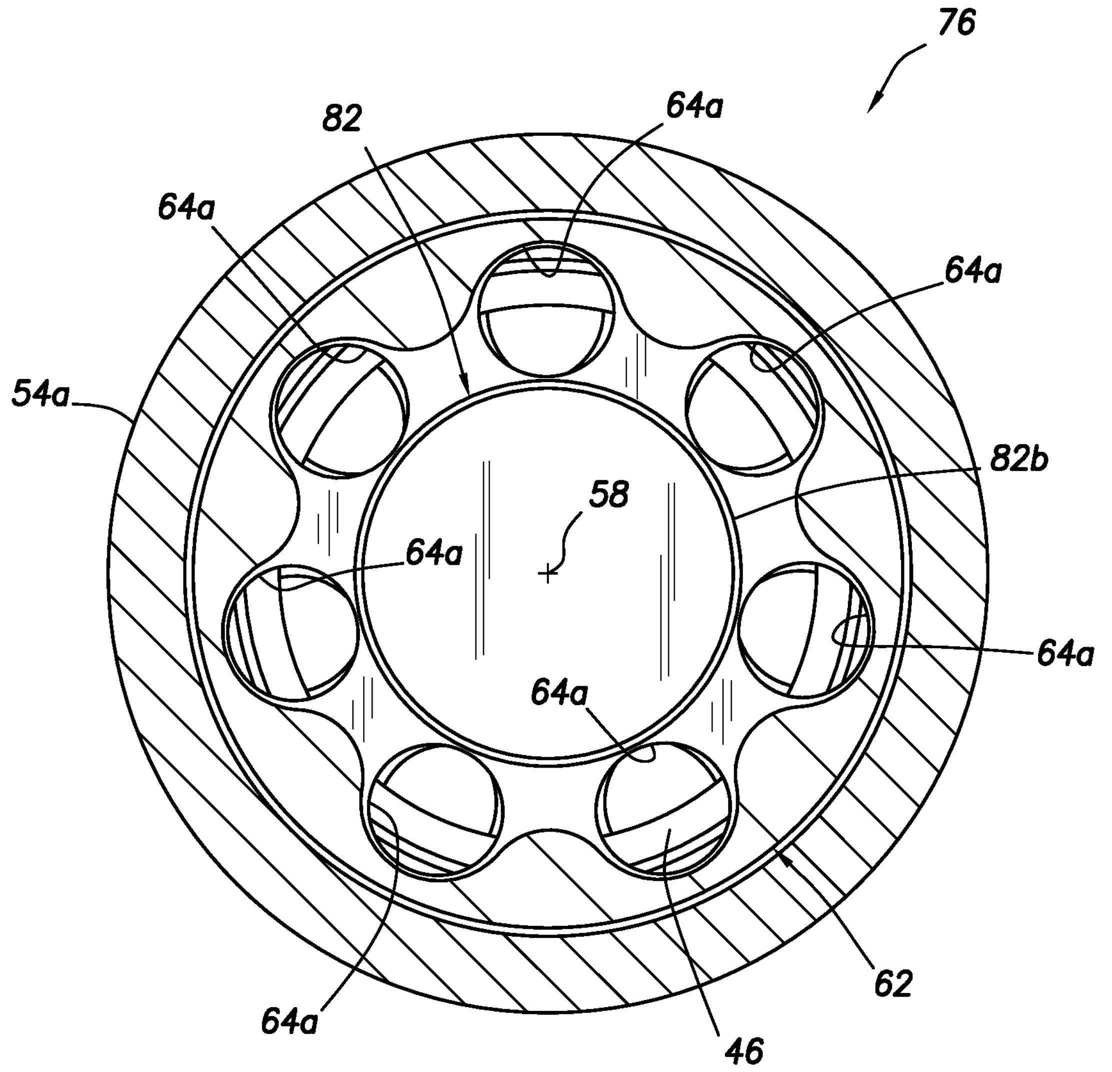

FIG.7

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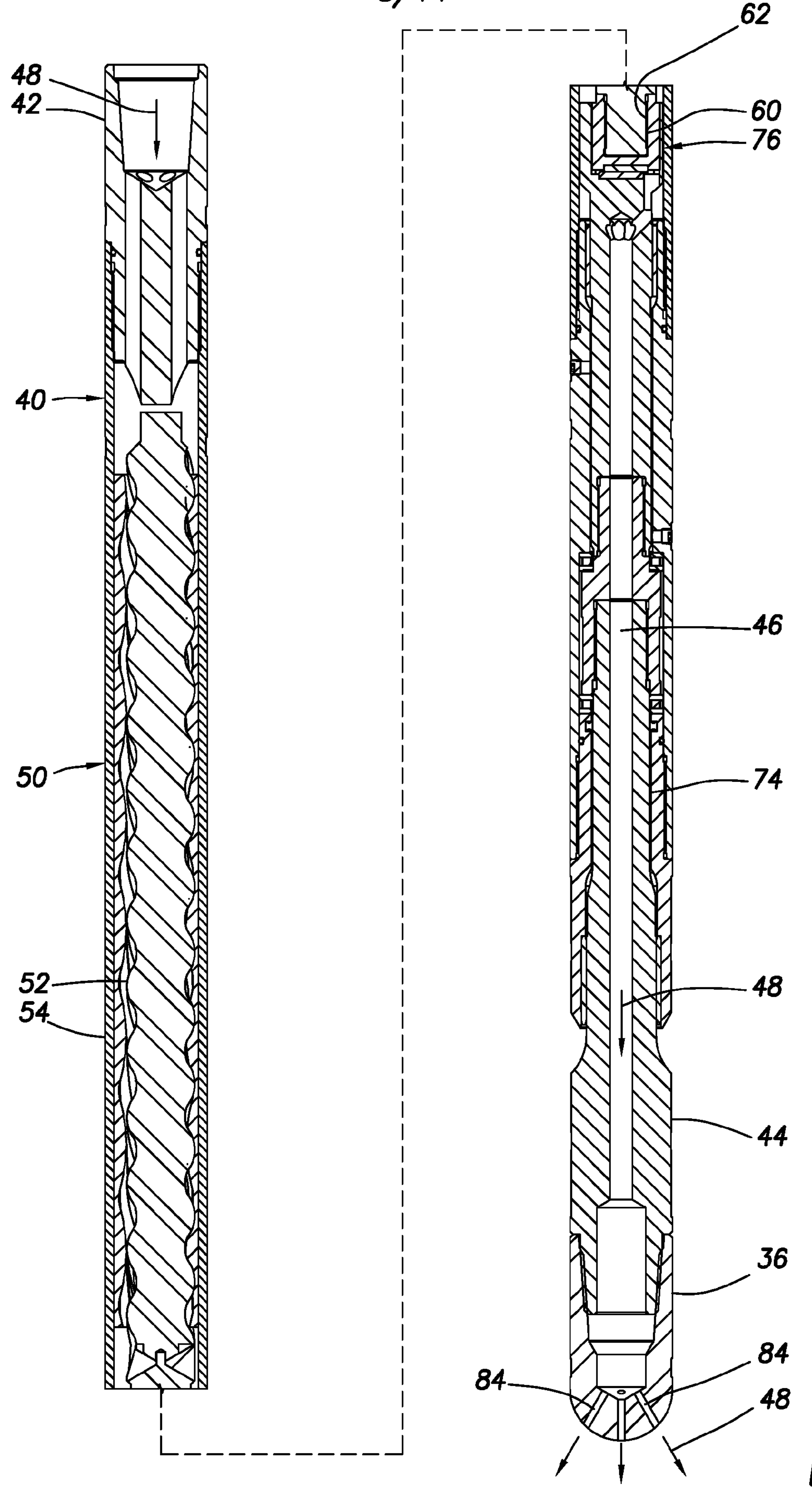


FIG.8

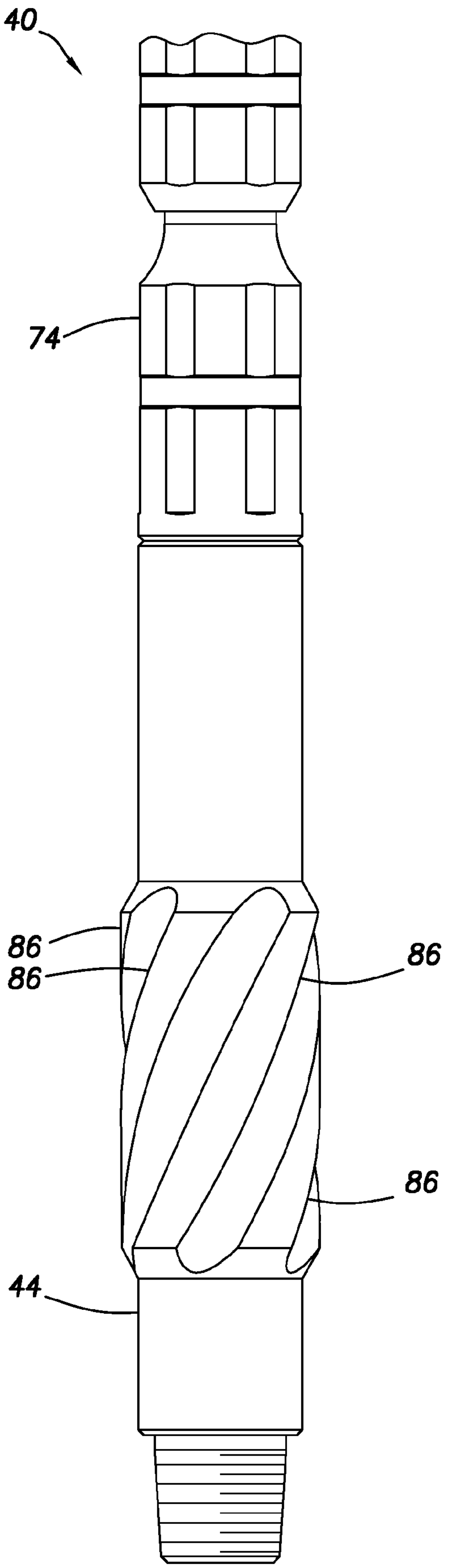


FIG.9A

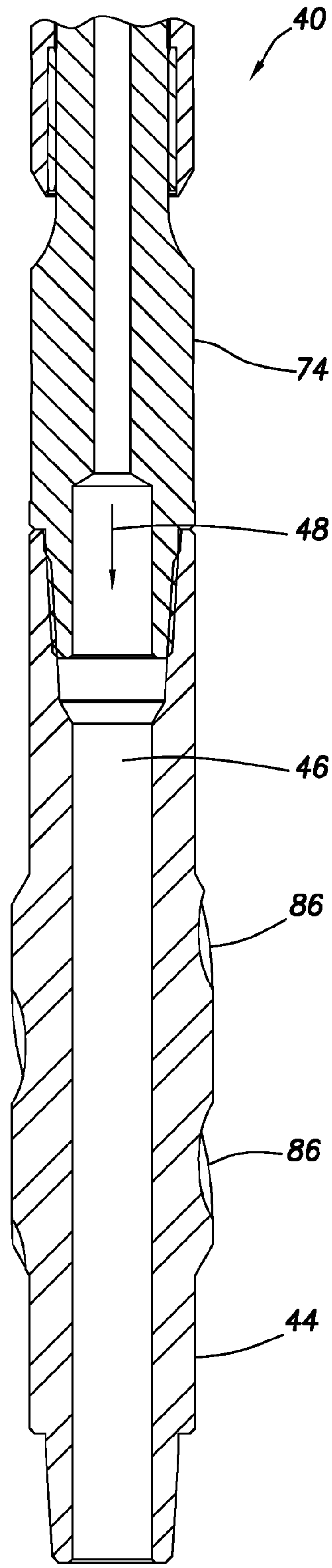


FIG.9B

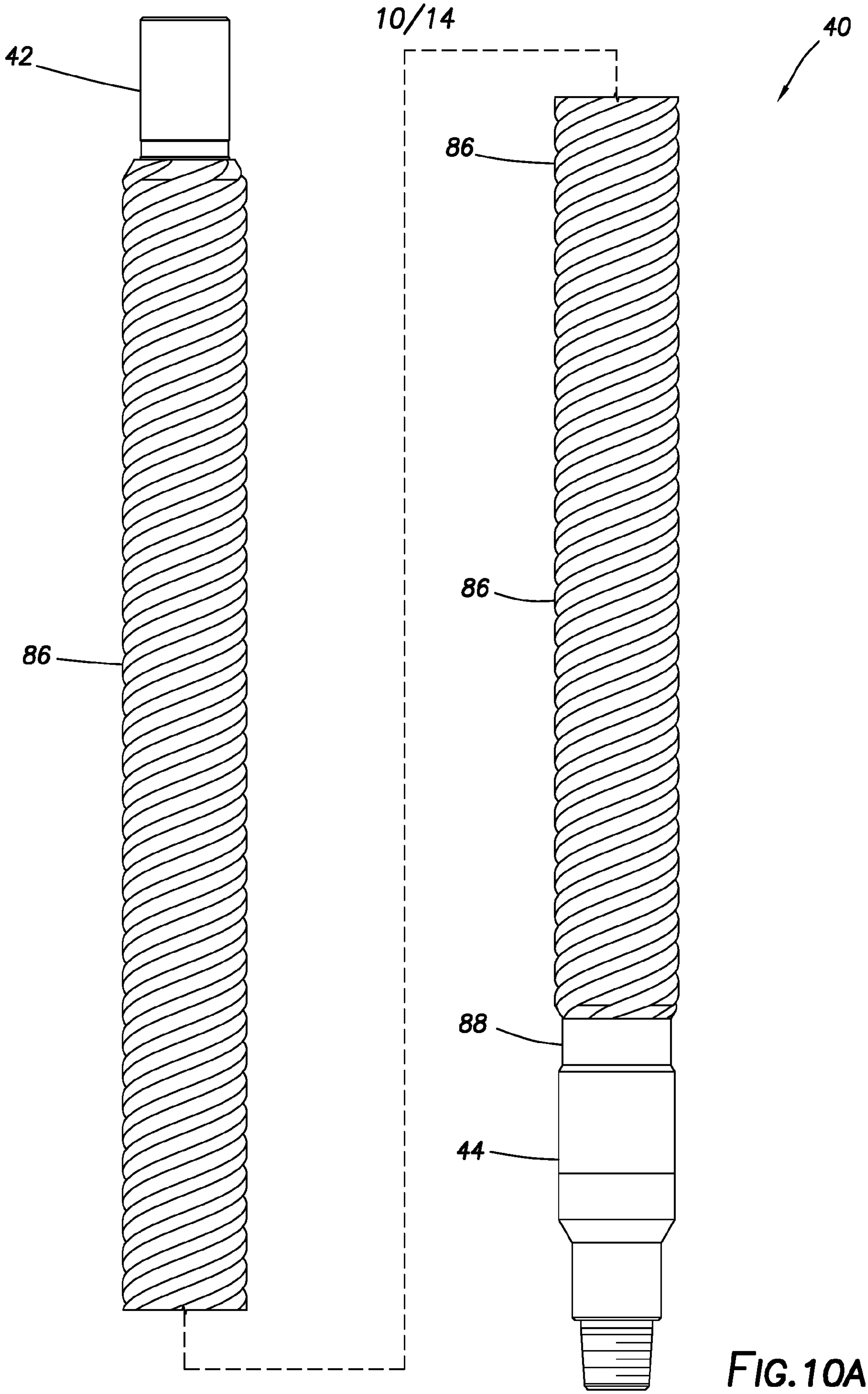


FIG.10A

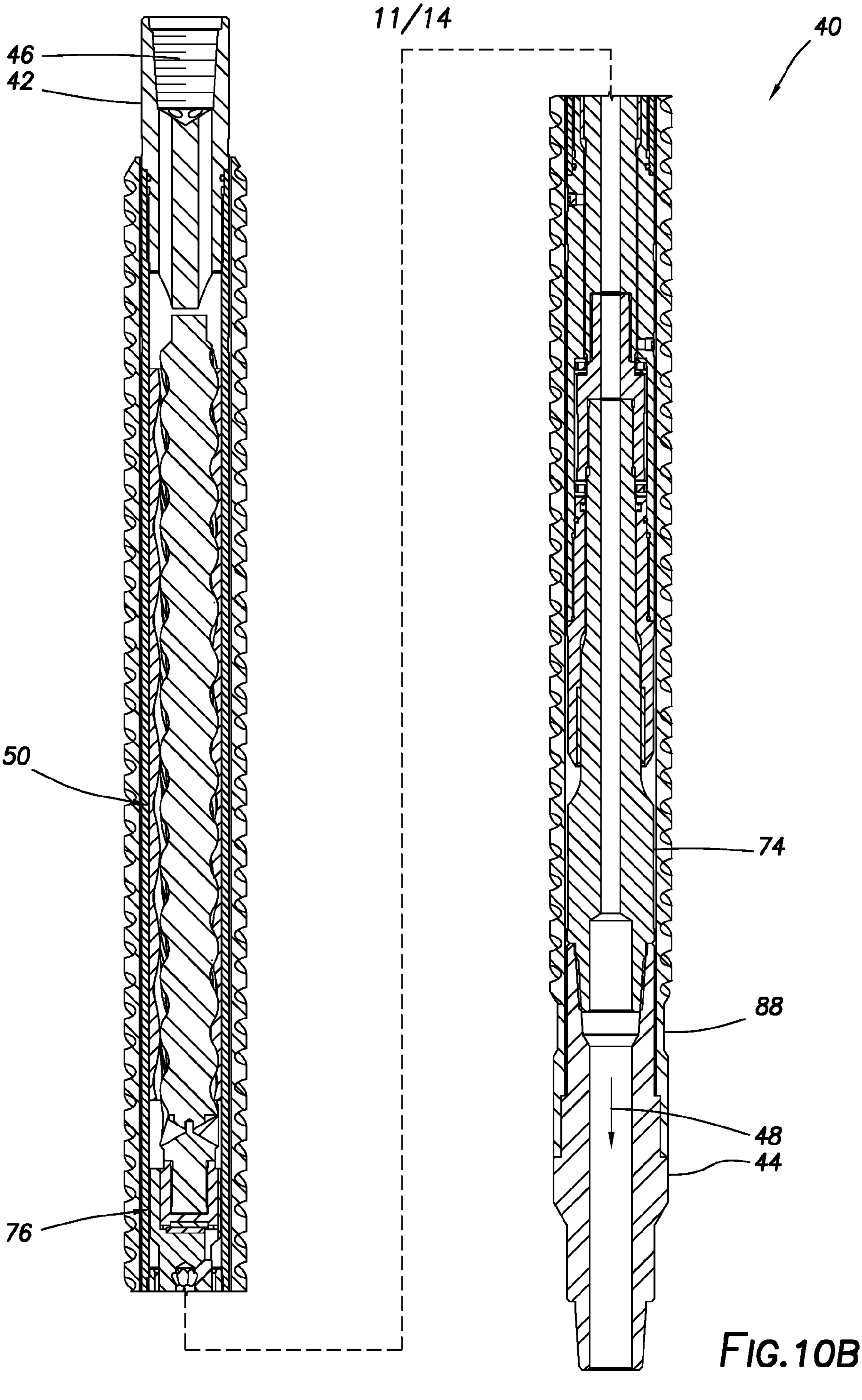


FIG.10B

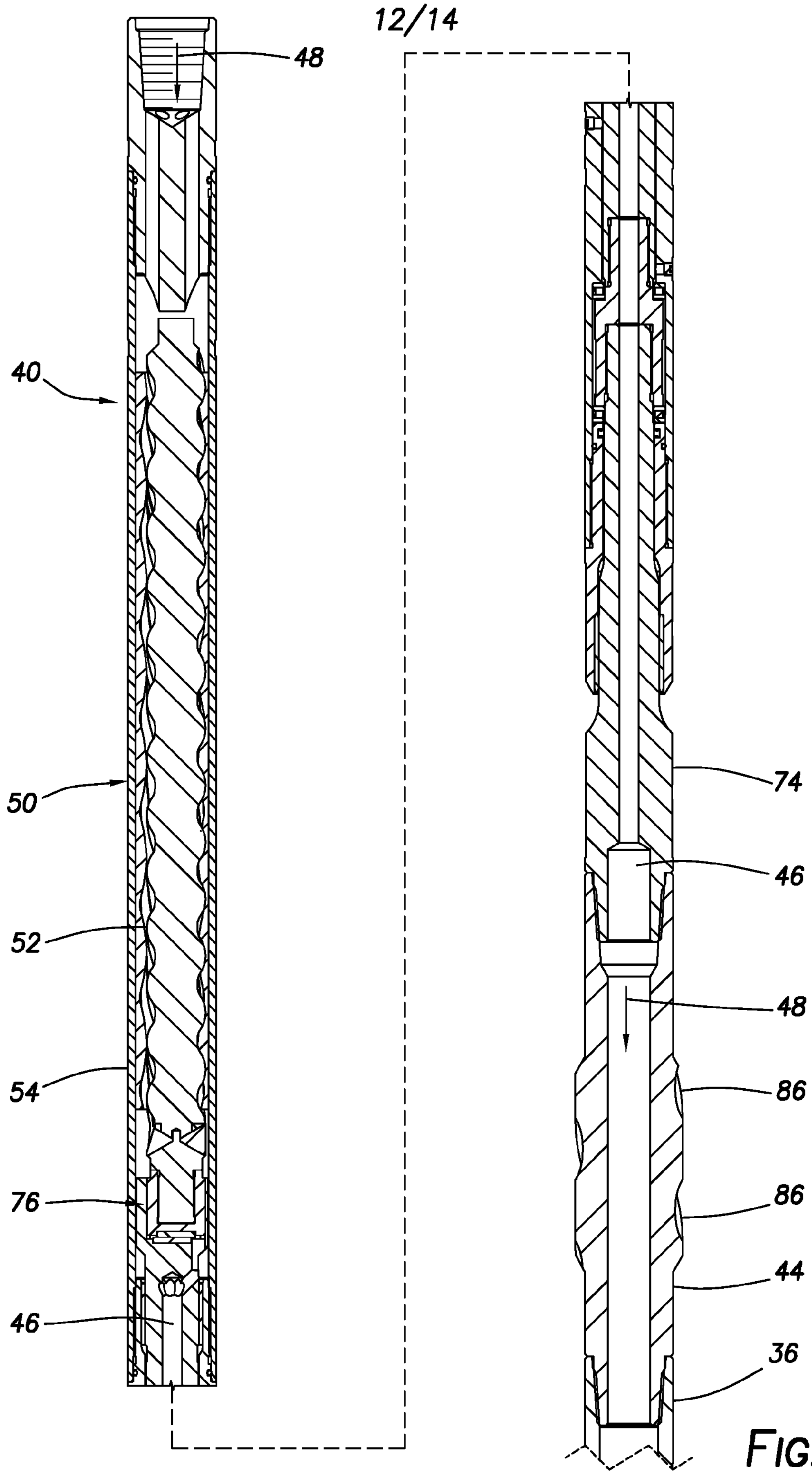


FIG.11A

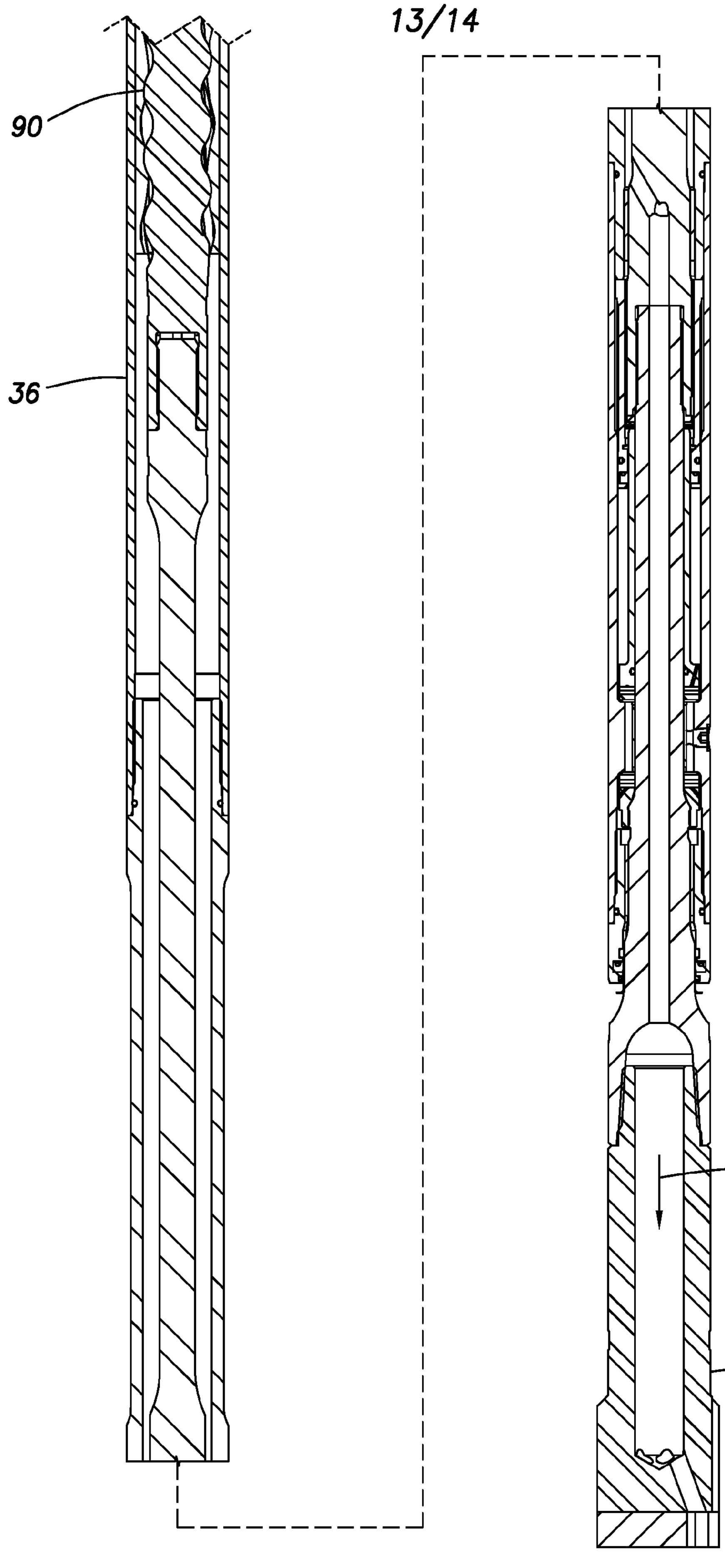
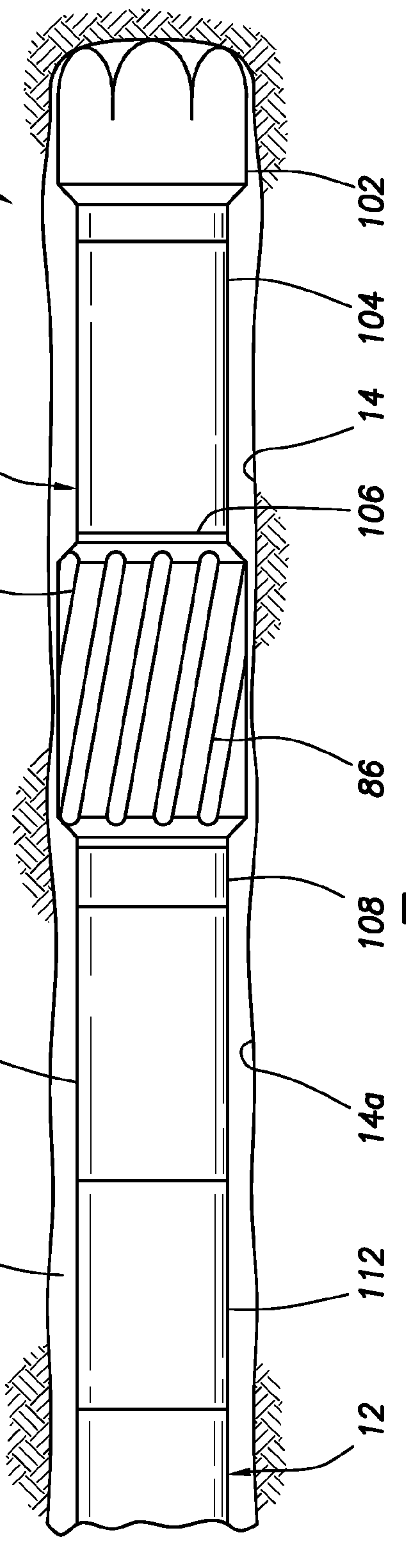


FIG.11B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14a
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112
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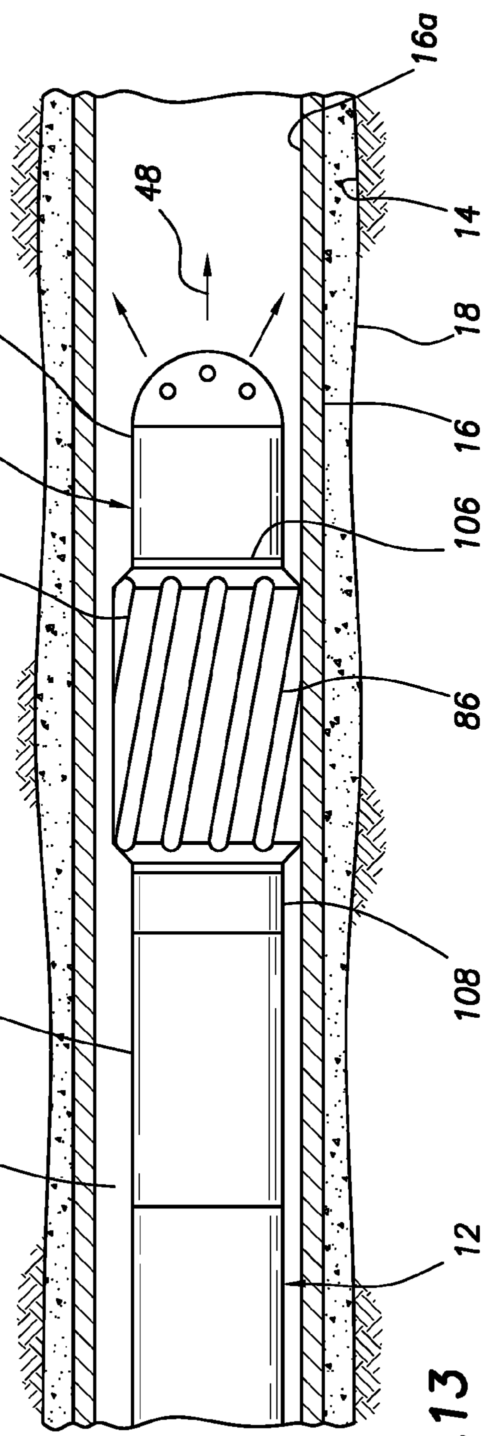
FIG.12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14
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18
100
16
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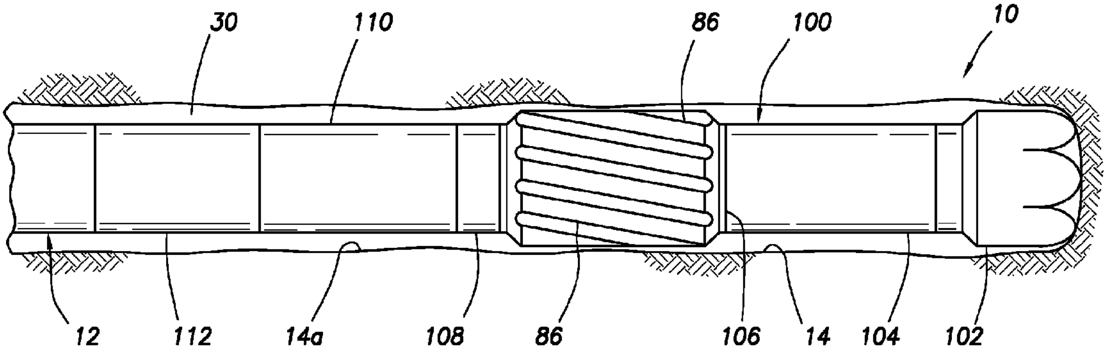
86
86
108
110
30
12

FIG.13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