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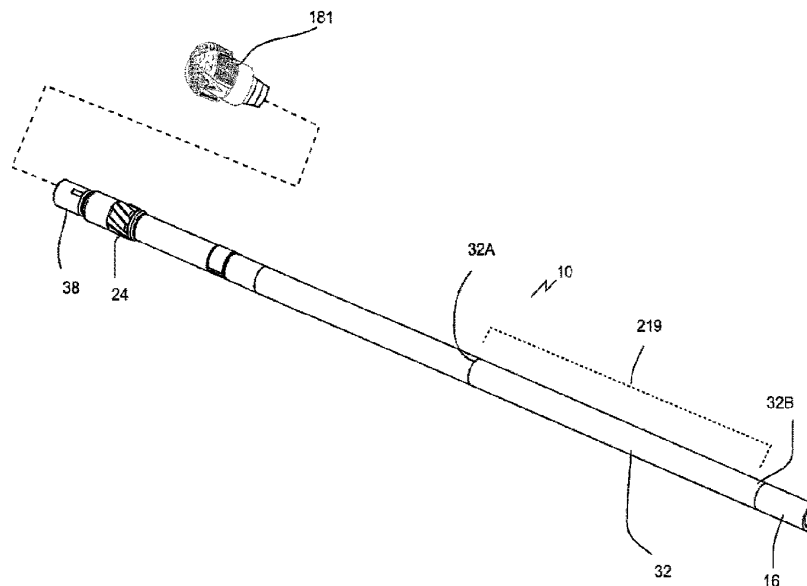
(72) **Inventeurs/Inventors:**

PEARSON, ALLAN, CA;
LUCHAK, MARK, CA;
SCHEMING, OXANA, CA;
OSATCHUK, MATT, CA;
VENABLES, ERIN, CA;
NKWOCHA, CHIMERE, CA;
SAMUEL, GEOFF, CA;
KJELLBOTN, PETER, CA

(73) **Propriétaire/Owner:**

(54) **Titre : OUTILS DE FOND DE TROU A SECTIONS DE CAVITE PROGRESSIVES, ET METHODES D'UTILISATION ET
ASSEMBLAGE ASSOCIEES**

(54) **Title: DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND RELATED METHODS OF USE AND ASSEMBLY**



(57) **Abrégé/Abstract:**

Various downhole tools, such as drilling motors, drilling tools, reamer tools, casing reamer shoes, and related methods of installation, assembly and use. Casing reamer shoes and drilling reamers or motors may have internal impellers, progressive cavity pumps, hollow rotors and other parts, universal joints, and other features. A progressive cavity section may have a rotor and a stator. Rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, may be rigid during use. The stator contacting surfaces and the rotor contacting surfaces may be made of metal. After the casing is run, the casing is cemented and the reamer shoe drilled out.

(73) **Propriétaires(suite)/Owners(continued):**CROSSBERRY HOLDINGS LIMITED, GB

(74) **Agent:** NISSEN, ROBERT A.

1. A downhole tool comprising:
 - a progressive cavity section with a stator and a rotor;
 - in which the stator is formed from a single integral block of material, and the stator has a length of at least fifty inches defined between axial ends of the stator;
 - in which rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid and do not flex when in use at downhole temperatures;
 - in which the stator contacting surfaces and the rotor contacting surfaces are made of metal;
 - in which the stator is formed by electrochemical machining (ECM) to structure the rotor contacting surfaces of the stator to achieve a sufficiently narrow clearance or negative interference fit with the rotor to form an efficient pumping seal without seizing the progressive cavity section in use; and
 - in which the rotor contacting surfaces of the stator have been heat treated for increased surface hardness.
2. The downhole tool of claim 1 in which the progressive cavity section is connected to rotate a reamer part of a casing reamer shoe.
3. The downhole tool according to any one of claim 1 - 2 in which the progressive cavity section is connected to rotate a drill bit.
4. The downhole tool according to any one of claim 1 - 3 in which the length of the stator is at least eighty inches defined between the axial ends of the stator.
5. The downhole tool of claim 4 in which the length of the stator is at least one hundred and fifty inches defined between the axial ends of the stator.
6. The downhole tool of claim 5 in which the length of the stator is at least three hundred inches defined between the axial ends of the stator.

7. The downhole tool according to any one of claim 1- 6 in which the rotor is formed by electrochemical machining (ECM).
8. The downhole tool according to any one of claim 1 - 7 in which the stator contacting surfaces of the rotor have been heat treated for increased surface hardness.
9. The downhole tool according to any one of claim 1 - 8 in which the rotor contacting surfaces of the stator and the stator contacting surfaces of the rotor have been heat treated with nitriding for increased surface hardness.
10. A method comprising:
 - positioning the downhole tool according to any one of claim 1 - 9 in a well; and
 - pumping fluid to operate the progressive cavity section to rotate the rotor relative to the stator.
11. A method comprising:
 - forming a stator from a single integral block of material, in which the stator has a length of at least fifty inches defined between axial ends of the stator;
 - assembling a downhole tool by inserting a rotor into the stator;
 - in which rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid and do not flex when in use at downhole temperatures;
 - in which the stator contacting surfaces and the rotor contacting surfaces are made of metal;
 - in which the stator is formed by electrochemical machining (ECM) to structure the rotor contacting surfaces of the stator to achieve a sufficiently narrow clearance or negative interference fit with the rotor to form an efficient pumping seal without seizing a progressive cavity section in use; and
 - in which forming comprises heat treating the rotor contacting surfaces of the stator to increase surface hardness.

12. The method of claim 11 in which the stator and the rotor within the downhole tool form the progressive cavity power section connected to rotate a reamer part of a casing reamer shoe.
13. The method according to any one of claim 11 - 12 in which the stator and the rotor within the downhole tool form the progressive cavity power section connected to rotate a drill bit.
14. The method according to any one of claim 11 - 13 in which the length of the stator is at least eighty inches defined between the axial ends of the stator.
15. The method of claim 14 in which the length of the stator is at least one hundred and fifty inches defined between the axial ends of the stator.
16. The method of claim 15 in which the length of the stator is at least three hundred inches defined between the axial ends of the stator.
17. The method according to any one of claim 11 - 16 in which the rotor is formed by electrochemical machining (ECM).
18. The method according to any one of claim 11 - 17 in which the stator contacting surfaces of the rotor have been heat treated to increase surface hardness.
19. The method according to any one of claim 11 - 18 in which the rotor contacting surfaces of the stator and the stator contacting surfaces of the rotor have been heat treated with nitriding to increase surface hardness.

DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND RELATED METHODS OF USE AND ASSEMBLY

TECHNICAL FIELD

[0001] This document relates to downhole tools with progressive cavity sections, and related methods of use and assembly.

BACKGROUND

[0002] Progressive cavity sections, such as power sections and pumps are used in downhole tools, particularly in drilling and production applications. Casing reamer shoes have been used with a progressive cavity power section to achieve a reaming function. Multi-part stators are known, as are non-elastomeric stators. Counter-weighted, hollow stators are known. Drilling motors and other drilling tools use progressive cavity sections. United States patent nos. 6,241,494, 4,764,094, 5,221,197, United States patent publication nos. 2010/0032170 and 2010/0038142, and French patent no. 2,349,729 provide some examples of such tools.

SUMMARY

[0003] A downhole tool is disclosed comprising: a progressive cavity section with a stator and a rotor; and in which the stator, the rotor, or the stator and the rotor are formed by electrochemical machining (ECM).

[0004] A method is disclosed comprising: forming a stator, a rotor, or the stator and the rotor by electrochemical machining (ECM); and forming a downhole tool by inserting the rotor into the stator.

[0005] A downhole tool is disclosed comprising: a progressive cavity section with a stator and a rotor; and in which the stator is formed from a single integral block of material, and the stator has a length of at least fifty inches defined between axial ends of the stator.

[0006] A method is disclosed comprising: forming a stator from a single integral block of material, in which the stator has a length of at least fifty inches defined between axial ends of the stator; and assembling a downhole tool by inserting a rotor into the stator.

[0007] A downhole tool is disclosed comprising: a progressive cavity section with a stator and a rotor; and in which the stator is formed by plural axial stator sections connected end to end, and adjacent axial stator sections, of the plural axial stator sections, are connected by dowels.

[0008] A method is disclosed comprising: forming a stator by connecting plural axial stator sections together end to end using dowels between the plural axial stator sections; and assembling a downhole tool by inserting a rotor into the stator.

[0009] A downhole tool is disclosed comprising: a progressive cavity section with a stator and a rotor; and in which the stator is formed by three dimensional printing.

[0010] A method is disclosed comprising: forming a stator by three dimensional printing; and assembling a downhole tool by inserting a rotor into the stator.

[0011] A method is disclosed comprising: forming a hollow rotor sleeve; forming a stator by three dimensional printing; and inserting the hollow rotor sleeve into the stator to form a progressive cavity section.

[0012] A downhole reamer tool is disclosed, comprising: a tubular body defining an interior passageway between an uphole end and a downhole end of the tubular body; and a reamer part mounted to the tubular body between the uphole end and the downhole end, the reamer part being mounted to rotate, relative to the tubular body, around a circumferential path about an outer-facing surface of the tubular body upon application of fluid flow within the interior passageway.

[0013] A method is also disclosed comprising: positioning a tubing string downhole in a well, the tubing string including a reamer tool; and pumping fluid through the tubing string to rotate a reamer part, of the reamer tool, relative to an uphole end tubing connector and a downhole end tubing connector of the reamer tool.

[0014] A casing reamer shoe is also disclosed comprising: a progressive cavity section with a stator and a rotor; a reamer part mounted to be rotated by the stator or the rotor; and in which the rotor is formed by a hollow helically lobed sleeve.

[0015] A method is also disclosed comprising: positioning a casing string downhole in a well, with a downhole end of the casing string mounting a casing reamer shoe; and pumping fluid through the casing string to operate a progressive cavity section of the casing

reamer shoe to rotate a reamer part of the casing reamer shoe, in which a rotor of the progressive cavity section is formed by a hollow helically lobed sleeve.

[0016] A downhole reamer tool is also disclosed comprising: a progressive cavity section with a stator and a rotor, with the rotor having an uphole end tubing connector, and the stator mounted to rotate relative to the rotor upon application of fluid flow between the rotor and the stator; and a reamer part mounted to be rotated by the stator.

[0017] A casing or drill string with a downhole reamer tool is also disclosed.

[0018] A method is also disclosed comprising: positioning a tubing string downhole in a well, with the tubing string mounting a downhole reamer tool; and pumping fluid through the tubing string to operate a progressive cavity section, which has a stator and a rotor, with a reamer part connected to rotate relative to the stator, in which pumping fluid causes the stator and reamer part to rotate relative to the tubing string and the rotor.

[0019] A casing reamer shoe comprising: a tubular body with an uphole end tubing connector defining an interior passageway; a reamer part mounted to rotate relative to the tubular body at a first speed under fluid flow in the interior passageway; and a nose mounted to rotate relative to the tubular body at a second speed under fluid flow in the interior passageway, the first speed being different than the second speed.

[0020] A method is also disclosed comprising: positioning a casing string downhole in a well, with a downhole end of the casing string mounting a casing reamer shoe; and pumping fluid through the casing string to rotate a reamer part and a nose, both of the casing reamer shoe, at a first speed and a second speed, relative to an uphole end tubing connector of the casing reamer shoe, with the first speed being different than the second speed.

[0021] A casing reamer shoe is also disclosed comprising: a tubular body; the tubular body having a progressive cavity section with a stator and a rotor; a reamer part connected to be rotated by the stator or rotor; and a universal joint connected between the reamer part and the rotor, or between the rotor and a bearing on the tubular body, the universal joint being structured to convert eccentric motion of the rotor into concentric motion.

[0022] A method is also disclosed comprising: positioning a casing string downhole in a well, with a downhole end of the casing string mounting a casing reamer shoe; and pumping fluid through the casing string to operate a progressive cavity section of the casing

reamer shoe to rotate a reamer part, in which a universal joint connects between the reamer part and a rotor of the progressive cavity section, or between the rotor and a bearing on the casing reamer shoe, the universal joint being structured to convert eccentric motion of the rotor into concentric motion.

[0023] A downhole reamer tool is also disclosed comprising: a tubular body with an uphole end tubing connector defining an interior passageway; a reamer part mounted to rotate relative to the tubular body; an impeller mounted within the tubular body and connected to rotate the reamer part; and the interior passageway having a plurality of radial passageways that direct fluid through the interior passageway in a radial direction against the impeller to drive the impeller and rotate the reamer part.

[0024] A method is also disclosed comprising: positioning a tubing string downhole in a well, with the tubing string mounting a downhole reamer tool; and pumping fluid through the tubing string to direct fluid through a plurality of radial passageways in a radial direction against an impeller, of the downhole reamer tool, to drive the impeller and rotate the reamer part, relative to the downhole reamer tool.

[0025] A method is also disclosed comprising: forming a hollow rotor sleeve; forming a stator by three dimensional printing; and inserting the hollow rotor sleeve into the stator to form a progressive cavity section.

[0026] A casing reamer shoe is disclosed comprising: a progressive cavity section with a stator and a rotor; a reamer part mounted to be rotated by the stator or the rotor; and in which rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid during use.

[0027] A casing reamer shoe comprising: a progressive cavity section with a stator and a rotor; a reamer part mounted to be rotated by the stator or the rotor; and in which the stator is formed by plural axial stator sections connected end to end, and adjacent axial stator sections, of the plural axial stator sections, are connected by dowels.

[0028] After drilling is completed for a particular section of a well, casing may be put down the hole to create a smooth interior bore through which additional work may be completed. However, the hole may not be perfect and often includes defects that can stop the casing from going all the way down. Accordingly, a reamer tool, the operating tip of which

is usually called a shoe, may be put towards the bottom to ream out the hole as the casing slides down. In one non-limiting embodiment, there is a reamer system, device, and/or mandrel assembly that is, advantageously, a low-cost system that attaches to any of a great variety of shoes (e.g. float shoe, reamer shoe, guide shoe) from a variety of manufacturers. Such a system may include an internal/central axle that rotates inside a housing and/or includes a pin-down connection (e.g. pin to pin, box-pin) to couple to a shoe so it can connect to any tool/shoe. The internal axle may spin when fluid is pumped through the mandrel assembly and spins a sub that is connected to the shoe which therefore also spins. The internal axle and/or other centrally positioned parts may comprise of an aluminum and/or zinc alloy (or other material that may be drilled through rather easily, since the mandrel assembly is generally left at a bottom of the hole when the casing is finished being installed). There may be a power section, such as an internal corkscrew shaped set of blades/lobes that cause the internal axle to rotate and thus cause the tool to rotate when fluid is pumped through the housing that contains the corkscrew.

[0029] A reaming power assembly is disclosed, comprising: a) an inner mandrel having spiral lobes disposed on an outer surface thereof; b) an outer mandrel disposed around the inner mandrel and having spiral lobes disposed on an inner surface of the outer mandrel; and c) a spacing between the outer surface of the inner mandrel and the inner surface of the outer mandrel through which fluid may be pumped to generate torque therebetween; wherein at least one of the inner and outer mandrel is free to rotate.

[0030] A reaming tool is disclosed functionally coupled to an end of the assembly such that torque therefrom may be used to rotate the reaming tool.

[0031] A reaming device is disclosed comprising: a) a hollow inner mandrel having spiral lobes disposed on an outer surface thereof; b) an outer mandrel disposed around the inner mandrel and having spiral lobes disposed on an inner surface of the outer mandrel; and c) a spacing between the outer surface of the inner mandrel and the inner surface of the outer mandrel through which fluid may be pumped to generate torque therebetween; wherein at least one of the inner and outer mandrel is free to rotate; wherein the outer mandrel has a number of spiral lobes equal to the number of spiral lobes of the inner mandrel plus one.

[0032] A stabilized accentuated reamer is disclosed, comprising: a) a power section having a rotor and a stator; b) a stator outer housing having a bladed profile; and c) a drill string.

[0033] A reaming system is disclosed, comprising: a) an inner mandrel having spiral lobes disposed on an outer surface thereof; wherein the inner mandrel is hollow; wherein the hollow of the inner mandrel is sized large enough to freely pass a standard drill bit therethrough; b) an outer mandrel disposed around the inner mandrel and having spiral lobes disposed on an inner surface of the outer mandrel; c) a spacing between the outer surface of the inner mandrel and the inner surface of the outer mandrel through which fluid may be pumped to generate torque therebetween; wherein at least one of the inner and outer mandrel is free to rotate; wherein the outer mandrel has a number of spiral lobes equal to the number of spiral lobes of the inner mandrel plus one; wherein one of the inner and outer mandrel is nonrotatably coupled to an end of a casing and the other is non-rotatably coupled to a bit or shoe; d) an upper flow diverter that diverts fluid flow from a center region of the reaming assembly to the spacing between the inner and outer mandrels; e) a lower flow diverter that diverts fluid flow from the spacing between the inner and outer mandrels to a center region of the reaming assembly; f) an upper and lower bearing assemblies rotatably coupled between the inner and outer mandrels; g) an elongated tubular housing, including: g1) a first end having a fluid inlet aperture; g2) a second end, opposite the first end, having a fluid outlet aperture; and g3) a coupling structure at the first end of the housing that selectably mates with a bottom end of a casing tube; h) a first bearing pack disposed circumferentially about the first end of the housing; i) a reaming tool functionally coupled to the inner mandrel or outer mandrel such that torque therefrom rotates the reaming tool; and j) a casing tube coupled to the housing.

[0034] In various embodiments, there may be included any one or more of the following features: Rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid. The stator contacting surfaces and the rotor contacting surfaces are made of metal. Rotor contacting surfaces of the stator are defined by an elastomeric coating within the stator. The progressive cavity section is connected to rotate a reamer part of a casing reamer shoe. The progressive cavity section is connected to rotate a drill bit. The drill bit

may be a polycrystalline diamond compact (PDC) or rotary drill bit. The stator has a length of at least fifty inches defined between axial ends of the stator. The stator has a length of at least fifty inches defined between axial ends of the stator. The stator has a length of at least eighty inches defined between axial ends of the stator. The stator has a length of at least one hundred and fifty inches defined between axial ends of the stator. The stator has a length of at least three hundred inches defined between axial ends of the stator. The stator is formed by ECM. Forming the stator, rotor, or the stator and the rotor by ECM further comprises advancing a cutting tool into or over a workpiece along an axis of the workpiece, with a sidewall of the cutting tool having a helically lobed profile, in which advancing is carried out while: an electrical field is established across a gap defined by the sidewall of the cutting tool and a sidewall of the workpiece; an electrolytic solution flows through the gap; and the cutting tool rotates about the axis such that the sidewall of the workpiece takes on a shape that is the inverse of the helically lobed profile of the sidewall of the cutting tool. Securing the dowels between adjacent plural axial stator sections using adhesive. Sliding an outer sleeve around the stator to form an interference fit between the stator and the outer sleeve. A progressive cavity power section with a stator and a rotor, with the progressive cavity power section connected to rotate the reamer part. The reamer part is mounted or formed on an external part of the stator, and the stator is connected to rotate relative to the tubular body. The rotor is fixed in relation to the uphole end and the downhole end of the tubular body. The interior passageway is connected to a fluid inlet of the progressive cavity section; and the interior passageway includes a power section bypass between an uphole end and a downhole end of the progressive cavity power section. The power section bypass is coaxial with the tubular body. The fluid inlet comprises a plurality of radial passageways that direct fluid through the interior passageway in a radial direction. The plurality of radial passageways comprise a plurality of diverter ports, which are angularly spaced from one another about a reamer tool axis, in which the diverter ports are oriented to have decreasing distance from the downhole end of the tubular body when moving from an entry to an exit of each of the plurality of diverter ports. The interior passageway is connected to a fluid outlet of the progressive cavity section. The fluid outlet and the fluid inlet are defined through the rotor. The reamer part is mounted on respective bearings at an uphole end and a downhole

end of the reamer part. The respective bearings comprise bearing packs. The respective bearings are exposed to fluid within the interior passageway during use. Rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid during use. The stator contacting surfaces and the rotor contacting surfaces are made of metal. The stator is formed by plural axial stator sections connected end to end. Adjacent axial stator sections, of the plural axial stator sections, are connected by dowels. Adhesive securing the dowels between adjacent axial stator sections. The plural axial stator sections are held together within an outer sleeve, with an interference fit between the plural axial stator sections and the outer sleeve. The stator is formed as a single piece by three dimensional printing. Respective tubing connectors at the uphole end and the downhole end of the tubular body. The reamer part comprises one or more of reamer blades and polycrystalline diamond cutters. The reamer part comprises reamer blades configured to act as stabilizer blades to center the downhole reamer tool within a well. The reamer part comprises a sleeve mounted coaxial with the tubular body. A casing or drill string comprising the reamer tool. The tubing string is a drilling string or a casing string. The tubing string is a drilling string. The drilling string comprises a fluid-actuated drilling motor and a drill bit, both located in a downhole direction relative to the reamer tool, and in which pumping fluid through the tubing string causes the fluid-actuated drilling motor to rotate the drill bit relative to the reamer tool. The tubing string remains angularly stationary while pumping fluid to rotate the reamer part. A hollow interior, defined by the hollow helically lobed sleeve, is closed. A wall within the hollow interior. Opposed axial ends of the hollow helically lobed sleeve are blocked by respective end walls. An uphole facing surface of the wall is striated. Rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid during use. The stator contacting surfaces and the rotor contacting surfaces are made of metal. The stator is formed by plural axial stator sections connected end to end. Adjacent axial stator sections, of the plural axial stator sections, are connected by dowels. Adhesive securing the dowels between adjacent axial stator sections. The plural axial stator sections are held together within an outer sleeve, with an interference fit between the plural axial stator sections and the outer sleeve. An inner diameter of the hollow helically lobed sleeve is sized to be commensurate with an inner diameter of the casing. A hollow interior, defined by the hollow helically lobed sleeve, is

closed. Pumping cement through the casing reamer shoe and up an annulus defined between the well and the casing string. Drilling out the casing reamer shoe. An uphole facing surface of the tool is striated. A stator of the progressive cavity section is formed by plural axial stator sections connected end to end. Prior to positioning the casing string downhole, assembling the casing reamer shoe by connecting adjacent axial stator sections, of the plural axial stator sections, with dowels. Assembling further comprises using an adhesive to glue the dowels between adjacent axial stator sections. Assembling further comprises sliding an outer sleeve around the plural axial stator sections, to form an interference fit between the plural axial stator sections and the outer sleeve. Sliding is carried out while one or both of a) the plural axial stator sections are cooled below, and b) the outer sleeve is heated above, room temperature. An inner diameter of the hollow helically lobed sleeve is sized to be commensurate with an inner diameter of casing of the casing string. Forming a casing reamer shoe, and further comprising a nose forming a downhole end of the casing reamer shoe, in which the stator is connected to rotate the nose. The casing reamer shoe defines an interior passageway that supplies fluid to the progressive cavity section and to outlet ports within the nose. The outlet ports include outlet ports directed in one or both of axial and radial directions. A tubular body defining the uphole end tubing connector and mounting the rotor; and a stabilizer mounted to the tubular body. A universal joint connected between the rotor and a bearing on the tubular body, the universal joint being structured to convert eccentric motion of the rotor into concentric motion. A first motor connected to rotate the nose relative to the tubular body; and a second motor connected to rotate the reamer part relative to the tubular body. The first motor comprises a progressive cavity section with a stator and a rotor; and the second motor comprises an impeller. The stator is connected to the tubular body, and the rotor is connected to rotate the nose. The interior passageway has a plurality of radial passageways that direct fluid in a radial direction against the impeller to drive the impeller and rotate the reamer part. A progressive cavity section with a stator and a rotor, in which the stator or the rotor is connected to rotate the reamer part or the nose. An impeller connected to rotate the reamer part or the nose. The first speed is faster than the second speed. The nose is structured as one or both a drill bit or a reamer. The interior passageway is connected to supply fluid to outlet ports within the nose. The outlet ports include outlet ports directed in

one or both of axial and radial directions. Pumping fluid to operate a progressive cavity section of the casing reamer shoe to rotate one or both the reamer part and the nose. Pumping fluid further comprises pumping fluid to operate an impeller to rotate one or both the reamer part and the nose. Pumping fluid further comprises supplying fluid to outlet ports within the nose to spray jets of fluid into the well from the nose. The first speed is faster than the second speed. The cooperating circumferential arrays of splines mesh via a circumferential array of pins. Each pin, of the circumferential array of pins, is tapered with decreasing radius from a central portion to each axial end of the pin. The cooperating circumferential arrays of splines comprise a radially-outward facing array of splines and a radially-inward facing array of splines. The cooperating circumferential arrays of splines are located at or near a first axial end of the shaft; and the shaft connects to the reaming part, or to a bearing on the tubular body, via a second set of cooperating circumferential arrays of splines, which are located at or near a second axial end of the shaft. The shaft is a hollow shaft sleeve. A hollow interior, defined by the hollow shaft sleeve, is closed. The universal joint is connected between the reamer part and the rotor. The universal joint is connected between the rotor and a bearing on the tubular body. The rotor is formed by a hollow helically lobed sleeve. The impeller comprises a circumferential array of fins on a radially inward facing surface of a sleeve that mounts the impeller to the tubular body. The circumferential array of fins are oriented parallel with an axis of the downhole reamer tool. The plurality of radial passageways are defined by slots in respective axial faces of each of a plurality of ring plates stacked axially one on the other. Each slot is curved or angled to eject fluid at non-zero angles relative to a radius defined by the respective ring plate and passing through a fluid exit end of the slot. The plurality of ring plates are stacked around a cylindrical wall of and coaxial with a collar, in which the plurality of radial passageways are defined from a central bore of the collar through the cylindrical wall of the collar. A pair of flanges, secured to or formed by the collar, compress the plurality of ring plates on the collar. An uphole flange of the pair of flanges connects to the tubular body. The cylindrical wall has an out-of-round circumferential profile that meshes with a corresponding inner circumferential profile of the plurality of ring plates. The out-of-round circumferential profile is polygonal. The impeller is connected to rotate the nose. The nose comprises one or more of blades and

polycrystalline diamond cutters. The tubular body further comprises a progressive cavity section connected to rotate the nose independent of the rotation of the reamer part by the impeller. A wire brush scraper on an external surface of the downhole reamer tool. The progressive cavity section is connected to rotate a reamer part of a casing reamer shoe. The outer mandrel has a number of spiral lobes equal to the number of spiral lobes of the inner mandrel plus one. One of the inner and outer mandrel is non-rotatably coupled to an end of a casing and the other is non-rotatably coupled to a bit or shoe. An upper flow diverter that diverts fluid flow from a center region of the reaming assembly to the spacing between the inner and outer mandrels. A lower flow diverter that diverts fluid flow from the spacing between the inner and outer mandrels to a center region of the reaming assembly. The inner mandrel is hollow. The hollow of the inner mandrel is sized large enough to freely pass a standard drill bit therethrough. Upper and lower bearing assemblies rotatably coupled between the inner and outer mandrels. A) an elongated tubular housing, including: a1) a first end having a fluid inlet aperture; a2) a second end, opposite the first end, having a fluid outlet aperture; and a3) a coupling structure at the first end of the housing that selectably mates with a bottom end of a casing tube. A casing tube coupled to the housing. One of the inner and outer mandrel is non-rotatably coupled to an end of a casing and the other is non-rotatably coupled to a bit or shoe. An upper flow diverter that diverts fluid flow from a center region of the reaming assembly to the spacing between the inner and outer mandrels. A lower flow diverter that diverts fluid flow from the spacing between the inner and outer mandrels to a center 5 region of the reaming assembly. The hollow of the inner mandrel is sized large enough to freely pass a standard drill bit therethrough. Upper and lower bearing assemblies rotatably coupled between the inner and outer mandrels. A) an elongated tubular housing, including: a1) a first end having a fluid inlet aperture; a2) a second end, opposite the first end, having a fluid outlet aperture; and a3) a coupling structure at the first end of the housing that selectably mates with a bottom end of a casing tube; b) a first bearing pack disposed circumferentially about the first end of the housing; and c) a reaming tool functionally coupled to the motor. A casing tube coupled to the housing.

[0035] These and other aspects of the device and method are set out in the claims, which are incorporated here by reference.

BRIEF DESCRIPTION OF THE FIGURES

- [0036] Embodiments will now be described with reference to the figures, in which like reference characters denote like elements, by way of example, and in which:
- [0037] Fig. 1 is a perspective view of a downhole reamer tool with a progressive cavity power section.
- [0038] Figs. 2A and 2B collectively form a cross-section view of the downhole reamer tool of Fig. 1.
- [0039] Fig. 3 is an exploded perspective view of the downhole reamer tool of Fig. 1.
- [0040] Fig. 4 is a perspective view of a casing reamer shoe with an impeller-powered reamer.
- [0041] Figs. 5A and 5B are front and rear perspective views, respectively, of a discharge ring plate of the casing reamer shoe of Fig. 4.
- [0042] Fig. 6 is an exploded perspective view of the casing reamer shoe of Fig. 4.
- [0043] Fig. 7 is a cross-section view of the casing reamer shoe of Fig. 4.
- [0044] Fig. 8 is a section view taken along the 8-8 section lines of Fig. 7.
- [0045] Fig. 9 is a section view taken along the 9-9 section lines of Fig. 7.
- [0046] Fig. 10 is a perspective view of a further embodiment of a casing reamer shoe an impeller-powered reamer.
- [0047] Fig. 11A is a section view taken along section lines 11A-11A of Fig. 10.
- [0048] Fig. 11B is a section view taken along section lines 11B-11B of Fig. 10.
- [0049] Fig. 12 is a perspective view of a discharge ring plate of the casing reamer shoe in Fig. 10.
- [0050] Fig. 13 is a cross-section view of the casing reamer shoe of Fig. 10.
- [0051] Fig. 14 is an exploded perspective view of the casing reamer shoe of Fig. 10.
- [0052] Fig. 15 is a perspective view of a further embodiment of a casing reamer shoe with a progressive cavity power section and an impeller-powered reamer.
- [0053] Figs. 16A, 16B and 16C collectively form a cross-section view of casing reamer shoe of Fig. 15.
- [0054] Fig. 17 is an exploded perspective view of the casing reamer shoe of Fig. 15.

[0055] Fig. 18 is a perspective view of a further embodiment of a casing reamer shoe with a progressive cavity power section.

[0056] Figs. 19A and 19B collectively form a cross-section view of the casing reamer shoe of Fig. 18.

[0057] Fig. 19C is close up side elevation view of a drive pin from the universal joint of the embodiment of Fig. 19A.

[0058] Fig. 20 is an exploded perspective view of the casing reamer shoe of Fig. 18.

[0059] Fig. 21 is a perspective view of a further embodiment of a casing reamer shoe with a progressive cavity power section.

[0060] Figs. 22A and 22B collectively form a cross-section view of the casing reamer shoe of Fig. 21.

[0061] Fig. 23 is an exploded perspective view of the casing reamer shoe of Fig. 21 with a progressive cavity power section.

[0062] Fig. 24 is a perspective view of a further embodiment of a casing reamer shoe with a progressive cavity power section.

[0063] Figs. 24A and 24B are enlarged detail perspective views of portions, circled in dashed lines, of the illustration of casing reamer shoe of Fig. 24.

[0064] Fig. 25 is a cross-section view through the upper flow diverter of the casing reamer shoe of Fig. 24.

[0065] Fig. 26 is a section view taken along the 26-26 section lines of Fig. 24.

[0066] Fig. 27 is a perspective view of a further embodiment of a casing reamer shoe.

[0067] Fig. 28 is a side elevation view of a casing reamer shoe in use in horizontal well.

[0068] Fig. 29 is a perspective view of a further embodiment of a casing reamer shoe with an impeller-powered reamer and a casing scraper wire brush.

[0069] Figs. 30A and 30B collectively form a cross-section view of the casing reamer shoe of Fig. 29.

[0070] Fig. 31 is a perspective view of a further embodiment of a casing reamer shoe with a progressive cavity power section.

[0071] Figs. 32A and 32B collectively form a cross-section view of the casing reamer shoe of Fig. 31.

[0072] Fig. 33 is an exploded perspective view of the casing reamer shoe of Fig. 31 with a progressive cavity power section.

[0073] Figs. 34A and 34B collectively form a cross-section view of the casing reamer shoe of Fig. 35.

[0074] Fig. 35 is an exploded perspective view of a further embodiment of a casing reamer shoe with a progressive cavity power section.

[0075] Fig. 36 is a schematic view, partially in section, of an electrochemical machining method used to form a stator.

[0076] Fig. 37 is a schematic view, partially in section, of a three dimensional printing method used to form a stator.

[0077] Fig. 38 is a perspective exploded view of a drilling motor and a drill bit.

[0078] Figs. 39A-C collectively form a cross-section view of the drilling motor of Fig. 38.

DETAILED DESCRIPTION

[0079] Immaterial modifications may be made to the embodiments described here without departing from what is covered by the claims.

[0080] In a typical power section of a positive displacement fluid motor used in drilling a wellbore that traverses subterranean hydrocarbon bearing formations, power generation is based upon the Moineau pump principle. In this type of motor design, a stator and rotor assembly converts the hydraulic energy of a pressurized circulating fluid to the mechanical energy of a rotating shaft. The rotor and stator are typically of a helically lobed design, with the rotor and stator having a corresponding helically lobed profile with plural helical lobes. The rotor is generally formed from steel or another suitable metal having one less lobe than the stator, which is typically lined with an elastomer layer.

[0081] In general, the power section may be categorized based upon the number of lobes and effective stages. The rotor and stator lobes may have a helical configuration defining plural stages, with each stage equating to the linear distance of a full wrap of the

stator helix. The rotor and stator lobes and helix angles may be selected such that the rotor and stator seal at discrete intervals, which results in the creation of axial fluid chambers or cavities that are filled by the pressurized circulating fluid. The action of the pressurized circulating fluid causes the rotor to rotate and precess within the stator. Motor power characteristics are generally a function of the number of lobes, lobe geometry, helix angle and number of effective stages. Motor output torque is directly proportional to the differential pressure developed across the rotor and stator. In drilling operations, bit rotation speed is directly proportional to the circulating fluid flow rate between the rotor and stator.

[0082] Progressive cavity sections, such as pumps or motors, or used in downhole contexts other than drilling. For example, a progressive cavity pump may be used at the end of a sucker rod string in a production well. Similarly, cutting and servicing tools, as well as well perforating and stimulation tools may incorporate progressive cavity sections.

[0083] A reamer is a type of rotary cutting tool used to clean and in some cases enlarge the size of a previously formed hole, generally to leave the sides of the hole sufficiently smooth for later purposes. The process of cleaning or enlarging the hole may be called reaming. Reamers take many forms and may be designed for use as a hand tool or in a machine tool, such as a milling machine or drill press, in drilling system for drilling for oil, and/or in other earth drilling contexts, and others. In the context of drilling for oil, immediately after a hole is drilled, the hole may lack a clean, smooth profile suitable for casing.

[0084] Drilling may alter the characteristics of the surrounding formation and produce a void with respect to pressure, and water content. In some cases chemical interactions may occur by exposure of materials surrounding the hole to the air. Further, natural layering, fissures, and fracture lines may react differently to the hole than the surrounding material. Accordingly, such newly-drilled holes may end up with discontinuities that make it difficult to operate the hole as desired. Reamer systems may be used in such and other contexts to make the sides of the hole sufficiently smooth for continued operation. Also, in completion operations reaming is followed with installation of a casing string that prevents further distortion of the surrounding material from intruding on the working portion of the hole.

[0085] Casing may refer to steel pipe that is landed within the well and cemented in place during wellbore construction in order to stabilize the wellbore. The casing string may be made up of a plurality of casing sections, which are threaded together and collectively extend from the surface to a landing point within an open hole. The base of the casing string may contain a shoe, which may operate as one or more of a reamer, guide, or float shoe. Once in position the casing may be cemented in place. Once casing is installed, the wellbore may be further extended by drilling through the casing shoe using a drill bit of a relatively smaller inner diameter than the diameter of the casing that is drilled through. Once drilling is complete, a subsequent casing string is run from surface to extend from the bottom of the previous casing string to the bottom of the further drilled open hole. Once installed, the subsequent casing string is cemented in place. The process can be repeated to further extend the wellbore, leading to a situation where the wellbore thus comprises a series of concentric casing strings of gradually decreasing inner diameter extending to great depths and distances within the formation.

[0086] Casing is usually selected to have an outer diameter that is commensurate with an open hole diameter. A float shoe may be used to guide the casing toward the center of the hole to minimize the impact of rock ledges or washouts in obstructing the travel of the casing string as the casing is run into the wellbore. The float shoe functions to assist in cementing operations, and may be constructed of a drillable material to permit the float shoe to be drilled through if the well is to be deepened beyond the casing landing point. If a casing string gets snagged on an obstruction in the well, the entire string may become jammed, holding up the completion operation and requiring extensive and expensive intervention operations. A reamer thus works synergistically with the running of a casing string to obliterate and remove obstructions in the wellbore, improving ease of casing travel through the well, reducing the chance of a stuck casing string, and all the while cleaning and polishing the wellbore to prepare same for cementing and completion. The nature of a reamer shoe as a reamer usually means that the reamer is wider than or equal to the outer diameter (OD) of the casing string, and thus difficult or impossible to remove from the well if run into the well with a casing string. Thus, a casing reamer shoe may be left at the bottom of the hole and drilled out if required.

[0087] Reaming a deviated well, such as a horizontal well, may present additional challenges relative to a vertical well. For example, it may be a challenge to slide a string of mandrels, pipes and others, inside the dogleg or toe part of the hole, as the weight of such units may rest against the side of the hole, creating friction. Such friction may increase the difficulty to advance a drill or reamer during horizontal operation, and may increase the chance of a casing string getting stuck or otherwise hung up prior to landing.

[0088] Referring to Fig. 28, a method of using a downhole tool 10, such as a reamer tool as shown, to cut the final size and finish of a horizontal drill hole is illustrated. Generally, a reamer tool will not make the original hole, but instead, will enlarge and/or clean or otherwise smooth the interior wall of a previously drilled or bored hole. In some cases, the reamer tools disclosed here may be used as part of a drilling operation, however. The illustrated reamer tool 10 may be supported at a downhole end of a casing 172, which is supported by a suitable rig structure such as a derrick 170. The reamer tool 10 may be disposed within a well bore 176. The derrick 170 may include suitable structure and devices to operate the reamer tool 10 and to permit the incremental addition of casing sections to the casing string as the reamer tool 10 works its way in a downhole direction through the wellbore 176. The reamer tool 10 may advantageously allow for the wellbore 176 to be reamed and lined with a casing 172 for future production and stimulation operations.

[0089] Referring to Fig. 28, derrick 170 may comprise a lifting device such as a guyed mast, for example a gin pole, which may be articulated over a load by adjusting its guys. The term derrick may include the framework supporting a drilling apparatus in an oil well drilling or completion rig. The illustrated derrick comprises a crown block 178. The illustrated crown block 178 may be functionally coupled to a traveling block 180 that travels vertically within the derrick 170. A crown block may form a stationary section of a block and tackle system that contains a set of pulleys or sheaves through which the drill line 182 (wire rope) may be threaded and positioned opposite and above traveling block 180. Traveling block 180 is the freely moving section of a block and tackle system that contains a set of pulleys or sheaves through which the drill line (wire rope) may be threaded and positioned opposite (and under) the crown block (the stationary section). The combination of the traveling block 180, crown block 178 and wire rope drill line 182 may produce the ability

to lift string weights in the hundreds of thousands of pounds. On larger drilling rigs, when raising and lowering derrick 170, line tensions over a million pounds are not unusual.

[0090] Referring to Fig. 28, the rig may comprise sufficient surface pumping equipment to operate the fluid-actuated reamer tool 10. Derrick 170 may comprise a motor 184 or other power source that may be used to operate one or more pumps, winches, drills, and/or the like and combinations thereof. The motor 184 may be used to pump fluid through the casing 172 and through reamer tool 10 to cause the reamer tool 10 to rotate at high speeds and with sufficient torque to effectively ream the hole or wellbore 176.

[0091] Derrick 170 may also include a blowout preventer 186 functionally coupled around a top of the wellbore 176. The blowout preventer 186 may comprise a large, specialized valve or similar mechanical device, usually installed redundantly in stacks, used to seal, control and monitor an oil and gas well. Blowout preventers were developed to cope with extreme erratic pressures and uncontrolled flow (formation kick) emanating from a well reservoir during drilling. A kick may lead to a potentially catastrophic event known as a blowout. In addition to controlling the down hole (occurring in the drilled hole) pressure and the flow of oil and gas, a blowout preventer is intended to prevent tubing (e.g. drill pipe and well casing), tools and drilling fluid from being blown out of the wellbore (also known as the bore hole, the hole leading to the reservoir) when a blowout threatens. A blowout preventer improves the safety of crew, rig (the equipment system used to drill a wellbore) and environment, and are used in the monitoring and maintenance of well integrity. Blowout preventers are intended to provide fail-safety to the systems that include them.

[0092] Referring to Fig. 28, the reamer tool 10 may be coupled to the bottom or downhole end of the casing 172 in a variety of suitable manners, including but not limited to mating threads, snap-fits, friction fitting, adhesives, bolts, and the like and combinations thereof. The reamer tool 10 may function with or as a shoe, which is the operating component that interfaces with the interior of the hole to be reamed and abrades away material, thereby reaming the hole. The shoe may include protrusions that, when the shoe spins, impact with non-cylindrical regions of the interior of the hole and thereby abrade the same making such regions smoother and increasing the effective interior diameter of the same so that the casing can follow behind the shoe without getting stuck.

[0093] **The STAR - Stabilized Accentuated Reamer**

[0094] Referring to Figs. 1 and 2A-B, a downhole reamer tool 10 is depicted comprising a reamer part 14 and a tubular body 12. An interior passageway 160 may be defined between a downhole end 40 and an uphole end 42 of tubular body 12. Reamer part 14 may mount to tubular body 12 between the uphole end 42 and the downhole end 40, for example at a location where axial ends 14C, 14D, of the reamer part 14, and in the example shown axial ends 32A, 32B of the stator 32, are spaced from both ends 40 and 42 of body 12. Referring to Figs. 1, 2A-B, and 3, reamer part 14 may be mounted to rotate, relative to the tubular body 12, for example around an outer circumferential path, such as path 13 (Fig. 1), about an outer-facing surface 200 of the tubular body 12. Figs. 2A-B, reamer part 14 may rotate upon application of fluid flow within interior passageway 160 of the tubular body 12. Fluid flow may comprise the flow of drilling fluid or other suitable fluids, such as water or invert, through at least a portion of tool 10 from uphole end 42 to downhole end 40.

[0095] Referring to Fig. 1, reamer part 14 may be mounted in a suitable fashion to rotate relative to tubular body 12. Reamer part 14 may be mounted to rotate via a suitable mechanism such as bearings (for example ball bearings, slide bearings, thrust bearings, or bearing surfaces), parts comprising sacrificial material, and others. Tubular body 12 may comprise tubing connectors 37 and 39 at the downhole end 40 and the uphole end 42, respectively. Tubing connectors 37 and 39, such as threaded pin and box ends as shown, may connect to part of the tubing string, such as casing string 173 or drilling string, including tools that make up the string. During use, body 12 may remain angularly stationary, while reamer part 14 may rotate relative to body 12, under fluid flow. In cases where body 12 is rotating, for example if the tubing string is rotating, body 12 may rotate at a relatively faster rate relative to tubular body 12 than the tubing string. Reamer part 24 may mount to a motor housing sleeve 26 and in the example shown housing sleeve 26 rotates with reamer part 24.

[0096] Referring to Fig. 1, the exterior of tool 10 may comprise a suitable reamer part 14. For example, a bladed profile with helical reamer blades 28 extending radially outwardly from a maximum outer diameter (OD) of the casing, tool or drill string may be used. The relative rotation caused by the fluid pumped through the interior passageway 160 may cause the reamer blades 28 to rotate and thereby ream the hole about the location of the

tool within the drill hole. Reamer blades 28 may be configured to act as stabilizer blades when the reamer part 14 is not rotating, to center tool 10 within the drill hole or well.

[0097] Referring to Fig. 2A, a motor 15, such as a mud motor or progressive cavity power section (PC motor), may be connected to rotate the reamer part 14. PC motor 15 may use fluid flow to create rotational motion, in the power section 17, and such motion may be transferred to the reamer part 14. The power section 17 of PC motor 15 may comprise an outer mandrel such as a stator 32 and an inner mandrel such as rotor 36.

[0098] Referring to Fig. 2A and 3, in some cases, the outer mandrel comprises a stator 32, and the inner mandrel comprises a rotor 36. Rotor 36 may comprise helical lobes 41 that extend from an exterior surface of rotor 36. Stator 32 may comprise opposing helical lobes 33 that extend from an interior surface of stator 32 that faces helical lobes 41 of the rotor 36 after assembly. There may be a region between the rotor 36 and the stator 32 that is spaced and shaped to permit fluid to flow between from one axial end of the PC motor 15 to the other. The spiral lobes 33, 41 may be mismatched such that they rotate against each other when fluid is pumped through the space between them and generate vibration (notation) as one rotates past the other. When the number of nodes on the rotor is one less than the number of nodes on the stator, the rotation may induce a vibration to reamer tool 10 and may help tool 10 overcome frictional forces and assist the blades 28 on an exterior of the stator 32 to cut through earth or rock. Motor 15 may comprise any suitable fluid-moving motor or pump. In some cases, PC motor 15 operates by rotating the outer mandrel relative to the inner mandrel, while in other cases, PC motor 15 rotates the inner mandrel relative to the outer mandrel. Lobe differentials, such as two or more lobes on the stator than on the rotor, may be used.

[0099] Referring to Figs 2 and 3, stator 32 may have a suitable shape. Stator 32 may be formed by plural axial stator sections connected end to end. Stator 32 may comprise adjacent stator housing sections 32'-32'''. Stator housings 32'-32''' may comprise an aperture or plurality of apertures 155 each sized to fit a single dowel 34. Dowels 34 may connect and fix one stator housing sections 32'-32''' to one or more of adjacent stator housing sections 32'-32'''. The plural axial housing sections 32'-32'''. Dowels may be

secured to stator housing sections 32'-32''' by adhesive, such as LOCTITE™ or another suitable adhesive.

[00100] Referring to Fig. 3, the plural axial housing sections 32'-32''' may be connected end to end. The plural axial stator sections 32'-32''' may be held together within an outer sleeve 46, which holds the sections by a suitable mechanism, such as an interference fit between the plural axial stator sections 32'-32''' and the outer motor sleeve 46. The interference fit may be sufficiently tight to transmit torque during use between stator 32 and reamer part 14. In some cases a zero or positive interference fit may be used. Assembly of stator sections 32'-32''' may comprise sliding the outer motor sleeve 46 around the plural axial stator sections 32'-32''', to form the interference fit. Sliding may be carried out while one or both of a) the plural axial stator sections are cooled below, and b) the outer motor sleeve is heated above, room temperature. For example, dry ice may be loaded within sections 32'-32''' after connection by dowels, and the sleeve 46 may be heated with a torch or other suitable mechanism. Next, the stator 32 may be hoisted in the air by a lifting mechanism such as a crane, and lowered into the sleeve 46. Upon returning to room temperature, the parts contract and expand and grip one another. At room temperature it may be impossible to physically separate the stator 32 and sleeve 46.

[00101] Referring to Fig. 3, rotor contacting surfaces 188 of the stator 32, and stator contacting surfaces 190 of the rotor 36, may comprise rigid material, such as metal. Rigid includes non-elastomeric materials, and materials that do not flex when in use at downhole temperatures. Sealing may be achieved by carefully machining the surfaces 188 and 190 to achieve a sufficiently narrow clearance / negative interference fit to form an efficient pumping seal without seizing the unit. In some cases one or more of surfaces 188 and 190 are treated or coated to protect and increase the longevity of the tool 10. The coating may be a bearing material with a coefficient of kinetic friction that is less than or equal to 0.2 in relation to steel. The bearing material may have a coefficient of kinetic friction that is less than 0.1, in relation to steel. Other bearing materials with higher coefficients of friction may be used. The bearing material may comprise a non-metal. The bearing material may comprise one or both nylon or ultra-high-molecular-weight polyethylene. The coating on one or more surfaces 188 and 190 may be applied to a thickness that will not change the rigid

characteristics of each surface, so that the surfaces 188 and 190 still act as a metal on metal seal. An appropriate thickness, for example a thin coating with a diameter of 1/100 thousandth of an inch may be used, although thicknesses greater or smaller may be used. The coating may be applied by spraying on one or more surfaces 188 and 190. The coating may be cured in an oven to set. The coating may reduce or prevent corrosion, for example if an anti-corrosion agent is used. In some cases, anti-corrosion paint, such as a polytetrafluoroethylene-based paint, may be applied either alone or in combination with the coating. The coating may act as lubrication during operation of stator 32 and rotor 36. In some cases, surface 188 and/or surface 190 comprise an elastomeric material, such as rubber.

[00102] Referring to Figs. 2A-B, during use, fluid, such as drilling fluid, may be pumped from an uphole end 42 through the motor 15 to and out the downhole end 40. Motor 15 may comprise a fluid inlet 150 connected to the interior passageway 160. Fluid may pass through interior passageway 160, which in some cases extends from uphole end 42 through the uphole facing end 36A of rotor 36 to the fluid inlet 150. Fluid inlet 150 may provide an access point for fluid to travel to the helical lobes 33 and 41 of the motor 15. Fluid inlet 150 may comprise a plurality of diverter ports 151. Diverter ports 151 may be angularly spaced from one another about a reamer tool axis 153. Diverter ports 151 may be oriented to have decreasing distance from downhole end 42 when moving from an entry 151' to an exit 151'' of each of the plurality of diverter ports 151. Interior passageway 160 may comprise a motor bypass 148 that diverts a portion of the fluid from traveling to fluid inlet 150 and onto the power section 177. Motor bypass 148 may be defined by rotor 36. In some cases motor bypass 148 is coaxial with the tubular body 12. Fluid may exit from the power section 17 via a fluid outlet 15 of the motor 15. Fluid outlet 157 may direct fluid flow from the space between the stator 32 and rotor 36 to the interior passageway 160. Fluid outlet 157 may comprise a plurality of diverter ports 159, that are angularly spaced from one another about axis 153, in which ports 159 are oriented to have increasing distance from downhole end 42 when moving from an entry 159' to an exit 159'' of each of the plurality of diverter ports 159.

[00103] Referring to Figs. 2A-B and 3, reamer part 14 may mount to the tubular body 12 via suitable bearings, such as bearing pack 149, roller or slide bearings. Rotor 36 may

comprise bearing packs 149 that rotatably couple the rotor 36 to the stator 32. Bearing packs 149 may be replaced with any coupling structure that allows for rotational coupling, including but not limited to: ball bearings, roller bearings, ball thrust bearings, roller thrust bearings, tapered roller bearings, magnetic bearings, linear bearings, anti-friction bearings, rotary bearings, telescopic bearings, rotary unions, and the like and combinations thereof. tool 10 may be completely sealed from wellbore fluids and pressure, such that fluid does not exit the exterior of the tool 10, but instead is restricted to flow-through. Bearing pack 149 may comprise sealing ring 22A that seals between the rotor and the stator. Sealing ring 22A may provide a dynamic seal, which is a seal that maintains a seal during rotation of stator 32 and reamer housing sleeve 26. During rotation, pack 149 may be exposed to circulated fluid within the interior passageway 160. Circulated fluid may be used to cool the bearings by the sealing mechanism. Sealing ring may define teeth or fins 21 that interlock with opposing, complimentary teeth 19 defined by an end cap 18A. End cap 18A and seal ring 22A may rotate with the stator 32. A corresponding bearing pack 149 may be located on either end of the motor 15. Pack 149 may comprise outer load collar 20A and inner load collar 24A that distribute the load from a tubing string, such as a casing string or drill string, to the rotor 36. Pack 149 may be a plurality of bearing assemblies that secure axial ends of rotor 36 to the uphole end 42 and downhole end 40 of the tubular body 12. The plurality of bearing assemblies may have matching parts, such as end caps 18A, 18B, seal rings 22A, 22B, outer load collars 20A, 20B, inner load collars 24A, 24B and others. Other mechanisms of securing rotor 36 to uphole end 42 and downhole end 40 may be used, such as an induced fit between complimentary features, adhesive, such as LOCTITE™, and others.

[00104] Referring to Fig 3, reamer part 14 may be mounted or formed on an external part of stator 32. Reamer part 14 may comprise a sleeve, such as a sleeve formed by reamer housing sleeve 26. Reamer housing sleeve 26 may be mounted coaxial with the tubular body 12. Reamer part 14 and reamer housing sleeve 26 may be secured to rotate with stator 32 during operation of PC motor 15.

[00105] Referring to Fig. 1, reamer tool 10 may be configured for use in an oilfield application, for example as a drilling enhancement or for drilling applications. Reamer tool 10 may be used in drilling through unstable ground conditions. In the process of drilling,

reamer tool 10 may be carried down casing pipe to the hole to protect the wall to achieve drilling work. Reamer part 14 may comprise one or more of reamer blades 28 and polycrystalline diamond cutters 30. Reamer tool 10 may include a rotor and a stator rotatably coupled to each other (e.g. by operation of the illustrated pair of bearing packs disposed between the rotor and stator near opposite ends of tool 10), wherein the stator envelopes the rotor. As used herein, neither “rotor” nor “stator” implies rotational movement or fixed positioning.

[00106] Tool 10 may be coupled to a drill string used to drill earth/rock, such as but not limited to for drilling oil wells. Tool 10 may couple between sections of a tubing string, such as a casing or drilling string, such that fluid that is pumped through the string goes through tool 10 as well. The rotor 36 may be fixedly coupled to coupling subs 38, 16 at each ends 40, 42, respectively to allow the tool 10 to couple to the tubing string between segments of such. The tubing string, including tool 10, may be positioned downhole in a well and fluid may be pumped through the tubing string to rotate the reamer part 14. The drilling string may comprise a fluid-actuated drilling motor 15 and a drill bit (not pictured), both located in a downhole direction relative to the tool 10. Pumping fluid through the tubing string may cause motor 15 to rotate the drill bit relative to tool 10. While pumping fluid, the tubing string may remain angularly stationary to rotate the reamer part. Tool 10 may be used in a casing application as well.

[00107] The fluid may be diverted from the core of the drill string to a region between the rotor 36 and stator 32 of tool 10. In such a region, the fluid causes the rotor 36 and stator 32 to rotate relative to each other (generally only one will rotate and the other stays in fixed angular relation to the rest of the string). The rotor 36 and stator 32 are attached to the string in such a way as to cause the rotational force created by the pumped drilling fluid to be applied only to the stator 32, thereby causing it to rotate. The stator housing sections 32'-32'' may comprise a bladed profile that may be beveled unto the base pipe OD to ensure that the leading edge is less aggressive and the ensuing cutting action and torque generated is gradual. This profile is both upward directional and downward directional since it is designed to be used to ream both downwards and upwards (forwards and backwards, for horizontal drilling/reaming).

[00108] Tool 10 may be used for horizontal drilling, as the friction between the drill string and the bottom arc of the drill hole (where the drill string rests because of gravity) may be a tremendous friction force to overcome. This may make the horizontal well more difficult to drill, especially when the hole shifts, swells, cracks, fills-in, etc. Rotating the reamer tool 10 without having to rotate the whole drill string may improve the efficiency and utility of tool 10 in horizontal wells.

[00109] The illustrated tools 10 may be suited for rigs with sufficient hydraulic power to drill but where torque limitations on either surface equipment or string components or both, limit string rotation to combat hole problems. Example hole problems include tight spots, swelling shales and/or wellbore collapse, where traditionally, the solution would have required backreaming. The illustrated tools 10 may allow the drilling team to ream regions having such problems without requiring. The reamer tools 10 disclosed here may be used to ream a hole as it is being drilled.

[00110] The STAR Stabilized accentuated reamer tool 10 may actuate with circulation. When fluid is circulated up to the threshold flow rate, the external sleeve starts to rotate clockwise looking downwards. Such rotation is irrespective of the rotation of the drill string. The stabilized accentuated reamer is self torque-generating due to the associated hydraulic power section that generates both torque and rotation. This family of tools may enable a drilling team to ream in and out of hole without string rotation making it a suitable reaming solution for tight spots, hole pack-offs, swelling shales, and all manner of wellbore instability related issues. Due to its unique internal power generation this tool may contribute lesser torque to the string in drilling mode than regular reamers or stabilizers.

[00111] String rotation may be used to increase the available torque at the stabilized accentuated reamer for rock destruction and deformation. Due to its offset dynamics and harmonics (i.e. vibration during operation) tool 10 is expected to reduce stick slip or drill string vibrations. The stabilized accentuated reamer may be bored in the centre (i.e. include a narrowed core between the two diversion channels that allows fluid to pass either through the core or the diversion channels) to ensure better signal transfer for telemetry systems that require to communicate using the internal fluid medium in the drill string.

[00112] Tool 10 may act as a conventional stabilizer as well as a reamer. According to one embodiment of the invention, there is a tool 10 stabilizer with reaming functions for drilling applications. The reaming stabilizer may be hydraulically powered without a need for the string to rotate. The stabilizer allows a user to ream out the hole as the user goes down. In addition, if the casing or drilling string gets stuck, the user may activate the stabilizer to back up and ream along the way up. The stabilizer may be cheaper, doesn't lose the drill string, faster, more convenient, is easier to use, and less likely to get stuck. According to one embodiment of the invention, there is a tool 10 stabilizing accentuated reamer including a sealed motor section (i.e. no fluid going in or out of the string), a reaming stabilizer having an outer surface with multiple bearing packs, a flow diversion channel, a lobe (allows for the rotation), a stator with one more lobe than the rotor (stator is the outside component and the rotor is the internal component, even though the rotor would typically be the one that moves and in this case the rotor does not move at all), and a narrowed central bore.

[00113] According to one embodiment of the invention, there is a tool 10 stabilizing accentuated reamer that fits between sections of the drilling string and attaches to them the same way the drilling string sections attached to each other. The rotor attaches to the string adapters. The stator may be coupled to the rotor via sealed bearing packs and is disposed around the rotor. The flow diversion channels do not block flow of the fluid through the center but instead allow for flow to also go between the stator and rotor and thereby interact to cause rotation of the stator. The exterior surface of the stator has stabilizing geometry and reaming geometry so that it simultaneously performs both functions. According to one embodiment of the invention, there is a tool 10 stabilizing accentuated reamer including a sealed motor section (i.e. no fluid going in or out of the string) (may have sealable ports), a reaming stabilizer including an outer surface (e.g. hard facing, tungsten carbide inserts, any cutting surface, laser cladding, diamond impregnated, etc.), a plurality of multiple bearing packs (e.g. 2, 3, 4, 5, 6+, sealed, upward and downward acting bearings, ball bearings, radial bearings, friction, etc.), a plurality of flow diversion channels (e.g. multiple, center bore is there to allow for telemetry signals, center bore is narrowed), a plurality of lobes that allow

for the rotation (e.g. wherein the external array of lobes has one more lobe than the internal), and a stator with one more lobes than the rotor.

[00114] In operation, the drill team assembles the drill string as drilling occurs, and in doing so includes the tool 10 between two segments of the drill string. The tool 10 reams the hole as it is drilled and the drill string may be pushed/pulled as desired to engage the drill bit and the tool 10 in positions as needed and as appropriate. Telemetry signals may be transmitted through the drilling fluid through the drill string and may pass through the tool 10 without interference from the tool 10.

[00115] **The Hydra**

[00116] Referring to Figs. 4 and 7, a downhole reamer tool 10 is illustrated having a tubular body 12, a reamer part 14, and an impeller 58. The reamer part 14 may be mounted to rotate relative to the body 12. The impeller 58 may be mounted within the tubular body 12 and connected to rotate the reamer part 14. Referring to Figs. 6 and 7, the interior passageway 160 may have a plurality of radial passageways, such as apertures 55, that direct fluid through the interior passageway 160 in a radial direction 167 (Fig. 7) against the impeller 58 to drive the impeller 58 and rotate the reamer part 14.

[00117] Referring to Figs. 6-8, the impeller 58 may take a suitable shape. Referring to Figs. 7-8, a radially-inward facing surface 58A of a sleeve 59 of the impeller 58 may comprise a circumferential array of fins 58B. The sleeve 59 may mount the impeller 58 to the tubular body 12. The circumferential array of fins 58B may be oriented parallel with an axis 61 of the downhole reamer tool 10. Other orientations may be used, including orientations where fins 58B form a helix that wraps at least partially around surface 58A. In the example shown, with fins 58B parallel to axis 61, fluid flow expelled in radial directions against fins 58B imparts a circumferential torque upon fins 58B, causing fins 58B to spin.

[00118] Referring to Figs. 7-8, the radial passageways to impeller 58 may be formed by slots 57 in plates 56. The plurality of radial passageways may be at least partially defined by slots 57 in respective axial faces 57A of each of a plurality of ring plates 56 that are stacked axially one on the other. In the example shown, slots 57 are formed on one axial face 57A per plate 56, although in other cases slots 57 may be formed on opposing faces 57A. Each slot may have a suitable shape, for example slots 57 may be curved or angled to eject

fluid along an ejection path 71B at a nonzero angle 71 relative to a radius 71A, which is defined by the respective ring plate 56 and passes through a fluid exit end 71C of the slot 57. In the example shown, the orientation, size, and number of slots 57 in each plate 56 is selected to balance fluid momentum and ejection direction, to minimize vibration inducement by operation of impeller 58. In the example shown, all slots 57 are identical to provide symmetry and to maximize torque imparted upon impeller 58. Each slot 57 may align to receive fluid flow from a respective aperture 55 from an inner mandrel collar 54. The use of a plurality of plates 56 with slots 57 stacked one on the other creates a structural that acts as a single unit but without the demands of machining same if such were machined from a single block of material. Each plate 56 may be individually machined or otherwise fabricated with complex slots that may be impossible to form within a solid block.

[00119] Referring to Figs. 7 and 8, the plates 56 may be mounted in a suitable fashion within the tool 10. In the example shown the plurality of ring plates 56 are stacked around a cylindrical wall 54A of and coaxial with a collar 54. The plurality of radial passageways, including apertures 55, may be defined from a central bore 166 of the collar 54 through the cylindrical wall 54A of the collar 54. Referring to Fig. 8, the cylindrical wall 54A may have an out-of-round circumferential profile, such as a polygonal profile 54C, that meshes with a corresponding inner circumferential profile, such as a polygonal profile 56B, of the plurality of ring plates 56. Matching torque transfer profiles permit the parts to rotate together, and facilitate drill out.

[00120] Referring to Figs. 6 and 7, the plates 56 may mount on the collar 54 via a suitable mechanism. For example, a pair of flanges, 53A and 53B, secured to or formed by the collar 54, may compress the plurality of ring plates 56 on the collar 54. In the example shown, flange 53A is formed as part of collar 54, while flange 54B is part of a static mandrel 60 that is threaded or press fit to an uphole end of collar 54. The flange 54B effectively forms an uphole flange of the pair of flanges 53A, 53B, and connects to the tubular body 12, in this case indirectly via mandrel 60.

[00121] Referring to Figs. 6, 7, and 9, the reamer tool 10 may form a casing shoe reamer, with a nose 48. The nose 48 may be structured as one or both a drill bit or a reamer. In the example shown, the nose 48 functions in a drill bit capacity. For example, the lipstick-

style nose 48 defines one or more blades or bladed edges 48B that are positioned to act upon debris directly axially in the path of the nose 48 to pulverize and clear same out of the path of the tool 10. In other cases a reaming blade or other device may be mounted to a peripheral part of nose 48.

[00122] Referring to Figs. 6 and 7, drilling and cleaning action may also be achieved using outlet ports 72 in the nose 48. Interior passageway 160 may connect from the impeller 58 to the outlet ports 72, to produce fluid jets during use that act to remove, pulverize, and wash out debris in the wellbore. Referring to Fig. 7, the outlet ports 72 may include outlet ports directed in one or both of axial direction, in the case of port 72A, and radial directions, in the case of port 72B.

[00123] Referring to Figs. 6 and 7, the impeller 58 may be connected to rotate the nose 48, for example if nose 48 is threaded or press fitted to radial bearing 52, which threads or is press fit to reamer housing 50, which is mounted to rotate with impeller 58 relative to tubular body 12, in this case top sub 70. Top sub 70 may define an uphole tubing connector 37, and may mount via bearings 66A and 66B to a dynamic sleeve 68, which threads or is press fit to reamer housing 50. The top sub 70 may thread or press fit to a static sleeve 64, which connects via radial set screws 62 to static mandrel 60. In some cases, instead of or in addition to set screws 62, one or more locking split rings may be used within grooves that align during make up between sleeves 64 and 60. In one case during assembly the sleeve 60 is press fit into sub 70, sleeves 68 and 64 are then connected to sub 70, and as sleeve 64 is connected to sub 70, sleeve 64 positions the split ring or rings within the aligned grooves to mate sleeves 60 and 64. An uphole facing surface of the tool 10, for example surface 60A of static mandrel 60, may be striated, with striations 60B, or may be otherwise contoured to improve drillability. Reaming part 14 may be mounted to reamer housing 50.

[00124] Referring to Fig. 7, in use, the tool 10, which may be a casing shoe reamer as shown, may connect to a downhole end of a casing string. Fluid may pass down the casing string bore, and into passageway 160, passing into central bore 166 of collar 54, where the fluid is then diverted radially outward through apertures 55. From apertures 55, the fluid passes into slots 57, and is channeled radially outward to strike against fins 58B of impeller 58, causing impeller 58 to rotate. The rotation of the impeller 58 causes housing 50, reamer

part 14, and nose 48 to rotate. Referring to Figs. 7 and 9, fluid that exits a downhole end 58D of impeller 58 passes radially outward via outlet ports 73 into the wellbore, and radially inward into nose 48 via axial ports 52A in radial bearing 52. Fluid entering the hollow nose 48 is then ejected outward into the wellbore via ports 72. Fluid ejected out into the wellbore acts to pulverize and entrain debris, creating a swirling vortex along with the rotation of the nose 48 and reamer part 14, to lift debris up off the well bottom and carry same to surface. The reaming action of the reamer part 14 acts to smooth and enlarge the wellbore, preparing same for installation of the casing string. An impeller may permit the tool 10 to achieve high rpm in a relatively axially short span of space.

[00125] Referring to Figs. 10-13 and 29, 30A, and 30B, two other embodiments of impeller-powered reamer tools 10 are illustrated. Referring to Fig. 10, the tool 10 illustrated has many of the same features as tool 10 from Fig. 4. However, the nose 48 is configured to act as a reamer, with reamer blades 47. In addition, the reamer part 14 comprises relatively long, straight blades 49. Referring to Fig. 12, each plate 56 has six slots 57 instead of the three slots 57 found on the plates 56 of the embodiment of Fig. 4. Referring to Figs. 29, 30A, and 30B, the embodiment of Fig. 10 is illustrated with the addition of a wire brush scraper sub 75 between the nose 48 and the reamer housing 50. The scraper sub 75 acts as a casing scraper to polish the wellbore, and may include a plurality of brushes 75A on an external surface of the sub 75.

[00126] **The Hydra Hybrid**

[00127] Referring to Fig. 15, a further embodiment of a downhole reamer tool 10 is illustrated. The tool 10 has the ability to rotate the reamer part 14 and the nose 48 at different speed relative to the tubular body 12. Referring to Figs. 16A-C and 17, the tool 10 also comprises a progressive cavity power section 15 connected to rotate the nose 48, the reamer part 14, or both. In the example shown the motor 15 is connected to rotate the nose 48 independent of the rotation of the reamer part 14 by the impeller 58.

[00128] Referring to Figs. 16A-C, reamer part 14 and nose 48 may be mounted to rotate at different speeds relative to the tubular body 12, in this case top sub 98 and stator 32. The reamer part 14 may be mounted to rotate relative to the tubular body 12 at a first speed under fluid flow in the interior passageway 160. The nose 48 may be mounted to rotate

relative to the tubular body 12 at a second speed under fluid flow in the interior passageway 160. The first speed may be different, for example faster, than the second speed. The example shown provides relatively higher torque and rpm than the embodiments of Fig. 4 and 10.

[00129] Referring to Figs. 16A-C and 17, the tool 10 may incorporate plural motors to plural parts. For example, a first motor, such as PC motor 15, may be connected to rotate the nose 48 relative to the tubular body 12. Also, a second motor, such as impeller 58, may be connected to rotate the reamer part 14 relative to the tubular body 12. The PC motor 15 may comprise a stator 32 and a rotor 36. The stator 32 may be connected to the tubular body 12, for example rotationally fixed to the tubular body 12 as shown. The rotor 36 may be connected to rotate the nose 48. In other cases the stator 32 may rotate the reamer part 14 and the rotor 36 may be rotationally fixed to body 12. In some cases the PC motor 15 is connected to rotate the reamer part 14, while the impeller 58 is connected to rotate the nose 48. The nose 48 may comprise one or more of blades 47 and polycrystalline diamond cutters (not shown).

[00130] Referring to Figs. 16A-C and 17, the tool 10 may have various parts. A top sub 98 may define an uphole tubing connector 37 at uphole end 42. The top sub 98 may be threaded or press fitted to the stator 32, which may be made of plural or a single stator sections (a single piece is illustrated). The stator 32 is threaded or press fitted to a drive housing 96, which houses a drive shaft 94, which transfers torque from rotor 36 to a mandrel such as a drive adapter 92. Drive housing 96 may thread or press fit to a drive adapter sub 90, which mounts the drive adapter 92 via bearings 66B and 66C, and threads or is press fit to static sleeve 86. Bearings 66D and 66B mount dynamic sleeve 88, which connects via threading or press fit to reamer housing 50.

[00131] Referring to Fig. 16A, 16B and 17, rotor contacting surfaces 188 of the stator 32, and stator contacting surfaces 190 of the rotor 36, may comprise rigid material, such as metal. In some cases one or more of surfaces 188 and 190 may be treated or coated. An example treating method includes laser treatment. The coating may be a bearing material with a coefficient of kinetic friction that is less than or equal to 0.2 in relation to steel. The bearing material may have a coefficient of kinetic friction that is less than 0.1, in relation to

steel. The bearing material may comprise a non-metal. The bearing material may comprise one or both nylon or ultra-high-molecular-weight polyethylene. In other cases, surface 188 and/or surface 190 comprise an elastomeric material, such as rubber.

[00132] In use, when the casing string is downhole in a well, fluid is pumped through the casing string into an uphole portion 160A of the interior passageway 160. Fluid enters a fluid inlet 161 at an uphole end of the motor 15, travelling in a downhole direction through the motor 15 while imparting torque upon the rotor 36. The rotation of rotor 36 causes the nose 48 to rotate. Fluid travels around drive shaft 94, and passes via radially inward ports 95 into central bore 160B in drive adapter 92. Fluid then travels through bore 166 in collar 54, passing through apertures 55 and slots 57 to strike and rotate the impeller 58, causing reamer part 14 to rotate for reaming action. Fluid then travels into the wellbore via exit ports 73 in reamer housing 50, and while some fluid passes radially inward into nose 48 via ports 160C, Once in the rotating nose 48, fluid may exit via a variety of fluid outlet ports 72, jetting out at various angles to assist in drilling, reaming, and debris clean out to surface.

[00133] **MRS - Motorized Reamer Shoe**

[00134] Referring to Figs. 18-27, several embodiments of a reamer tool 10 are illustrated, with reamer parts 14 powered by a PC motor 15. Referring to Figs. 19A and 24, embodiments are shown where the stator 32 rotates relative to a stationary rotor 36, thereby rotating the reamer part 14. Referring to Figs. 19A, 22A, and 24, all embodiments incorporate a universal joint to convert eccentric rotor 36 motion into concentric motion to reduce vibration and increase tool 10 effectiveness. Referring to Figs. 19A and 22A, embodiments are shown with a hollow helically lobed sleeve rotor 36. Tools 10 may be used in suitable applications, such as deep water or deep well applications, as well as conventional wells.

[00135] Referring to Figs 19A-19B, and 20 an embodiment is shown where the stator 32 rotates relative to the rotor 36. The stator 32 may be mounted to rotate relative to the rotor 36 upon application of fluid flow between the rotor 36 and the stator 32. The reamer part 14 may be mounted to be rotated by the stator 32. The rotor 36 may be connected, for example rotationally fixed to the tubular body 12, for example by press fit or an uphole end 36A of rotor 36 threading to a rotor adapter 110, which mates with a drive shaft 124, which

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mates with a drive adapter 144, which threads or press fits to a bearing shaft 132, which threads or press fits to a casing adapter / top sub 140. A downhole end 36B of the rotor 36 may form a free cantilevered end. The stator 32 may be mounted to rotate relative to top sub 140, which defines an uphole tubing connector 37, by an uphole end 32A of stator 32 threading or press fitting to a stator adapter 108, which threads or press fits to an end cap 128, which mounts upon bearing shaft 132 via bearings 66 and 130. A downhole end 32B of stator 32 threads or press fits to reamer housing 50, which mounts reamer part 14 and reamer blades 47.

[00136] Referring to Figs. 19A-B, the tool 10 may form a casing reamer shoe. A nose 48 may form a downhole end 40 of the casing reamer shoe, and the stator 32 may be connected to rotate the nose 48. In use the tubing or casing string may be positioned downhole in a well. Fluid may be pumped through the casing string to operate the progressive cavity power section 15, in which pumping fluid causes the stator 32 and reamer parts 14A and 14B to rotate relative to the string and the rotor 36. In use, fluid enters a portion 160A of the interior passageway 160 via connector 37, is redirected through the PC motor 15, where the stator 32 is actuated to rotate, and the fluid exits the downhole end 32B of the PC motor 15 into a central bore 160B of the reamer housing 50, where the fluid then exits the reamer tool 10 via one or outlet ports 72 within the nose 48, for example ports 72A pointed in an axial direction, and ports 72B pointed in a radial direction. One or more outlet ports 72 may comprise a nozzle 77 fitted and rated to create a fluid jet of controlled characteristics upon exit. A stabilizer 141, which includes a centralizer, may be present on top sub 140.

[00137] Referring to Figs. 19A-B and 20, the rotor 36 may be mounted to a universal joint for correcting eccentricity of rotation of rotor 36. A universal joint includes a coupling that can transmit rotary motion by a shaft over a range of angles. The universal joint 79 may be connected between the rotor 36 and a bearing, such as bearing shaft 132 mounted on ball bearings 130 and 66, on the tubular body, in this case top sub 140. The universal joint 79 may be structured to convert eccentric motion of the rotor 36 into concentric motion. Referring to Figs. 22A-B, an example is shown where the universal joint 79 is connected between the reamer part 14 and the rotor 36.

[00138] Referring to Figs. 19A-B and 20, the universal joint 79 may comprise a drive shaft 124. The shaft 124 may be mounted for rotation within the tubular body 12. The shaft 124 and the rotor 36 may mate via cooperating circumferential arrays of splines 124A and 125A, for example which mesh via a circumferential array of pins 116A. The cooperating circumferential arrays of splines may comprise a radially-outward facing array of splines 124B, for example mounted on the drive shaft 124, and a radially-inward facing array of splines 125A, for example mounted on the rotor 36, or in this case on a rotor adapter 110 that threads or press fits to an uphole end 36A of the rotor 36.

[00139] A pin and splined connection can be tailored to provide the required degree of conversion from eccentricity to concentricity. Referring to Fig. 19C, each pin 116A, of the circumferential array of pins 116A, may be tapered with decreasing radius from a central portion 117C to each axial end 117A and 117B of the pin 116A. In the example shown the pin 116A is beveled at each end 117A, and 117B. The shape used permits the pin 116A to tip axially forward and backward, while still retaining a meshing connection with the splines. Such allows the shaft 124 and adapter 110 to translate radially and pivot relative to one another. Pins 116A may be made of rigid material that does not deform under the relatively high temperatures experienced downhole. Rubberless or other metal on metal embodiments of the progressive cavity sections disclosed here may be used in high temperature downhole applications.

[00140] Referring to Figs. 19A-B and 20, a second set of splines and pins may be present. The cooperating circumferential arrays of splines 124A, 125A may be located at or near a first axial end 129A of the shaft 124. The shaft 124 may connect to a bearing, in this case bearing shaft 132 mounted to ball bearings 130 and 66, on the tubular body 12, via a second set of cooperating circumferential arrays of splines 124B, 125B. The second set of splines may be located at or near a second axial end 129B of the shaft 124. A second array of pins 116B may cooperate with splines 124B, 125B. Splines 124B, 125B, and pins 116B may have the same characteristics as splines 124A, 125A, and pins 116A, respectively.

[00141] Referring to Fig. 22A-B, an example is shown where the drive shaft 124 and spline-pin universal joint 79 is located between the rotor 36, in this case a downhole end 36B of rotor 36, and the reaming part 14. Specifically, the downhole end 36B threads or press fits

to a rotor adapter 110, which mates with drive shaft 124 via a spline and pin connection as above, and drive shaft 124 mates with a drive adapter 144 via a second spline and pin connection. Adapter 144 threads or press fits to bearing shaft 132, which threads or press fits into reamer housing 50, which mounts reamer part 14 and nose 48.

[00142] Referring to Figs. 19A-B and 20, each set of splines may be protected by a respective drive boot, in this case boots 122A and 122B, which mount via split rings 120A and 120B, and thrust seat caps 112A, 112B, to the rotor adapter 110 and the drive adapter 144, respectively. The thrust seat caps 112A, 112B form caps that secure the split rings 120A and 120B and keep the boots 122A and 122B in position around shaft 124 to protection the spline and pin connections clean from fluids. Such structures also help to contain lubricating fluid, such as grease from washing out of the spline and pin connections. A port 219 and an NPT threaded plug 221 may be used for grease injection in each of adaptors 110 and 144. Each of adaptors 110 and 144 may have a pair of plugs 221 and ports 219, one to permit venting while the other is filled.

[00143] Referring to Figs. 31-33, a further embodiment of a reamer tool 10 is illustrated. In the example shown, a drive shaft 124 is used to act as a universal joint 79 between the rotor 36 and the bearings 138 and 66. The drive shaft 124 may also be used on the downhole end of the rotor 36 similar to the embodiment of Fig. 21. The axial ends 129A and 129B of the shaft 124 may be press fit with rotor adapter 110 and drive adapter 144. The drive shaft 124 may be made of a resilient metal, which bends elastically during use to convert eccentricity to concentricity, for example titanium and other suitable metals. The drive shaft 124 may thus form a flex-shaft.

[00144] Referring to Figs. 34A, 34B and 35, a further embodiment of a reamer tool 10 is illustrated. In the example shown, a drive shaft 124 is used in a form that combines ideas from the splines of the embodiment of Fig. 19A, with the pinless design of Fig. 31. In the example the spline sets 124A-125A and 124B-125B mate directly in a gear to gear fashion. Referring to Figs. 34A-B and 35, the spline-spline connection may be structured to permit radial translation and pivoting between parts, similar to the type of movement permitted by the beveled drive pins 116A. The splines 124A may be tapered with decreasing distance from a central portion 119C to each axial end 119A and 119B of each spline 124A, 124B.

The shape used permits the drive shaft 124 to tip axially forward and backward, while still retaining a meshing connection with the splines. Such allows the shaft 124 and adapter 110 to translate radially and pivot relative to one another. Boots 122A and 122B may also be used.

[00145] Referring to Figs. 19A-B, the drive shaft 124 may be a hollow shaft sleeve as shown. A hollow interior 131, defined by the hollow shaft sleeve, may be closed, for example by end caps 118A, B secured within respective drive caps 114A, 114B. A hollow drive shaft may reduce the weight of the tool 10, and also may assist in drilling out the tool 10 when sacrificed at the bottom of a casing string. The inner diameter 133 may be selected to be commensurate with an inner diameter 173A of the casing 172 being run with tool 10.

[00146] Referring to Figs. 19A-B, in use a casing string 173 may be positioned downhole in a well. Fluid may be pumped through the casing string 173 and into an uphole portion 160A of interior passageway 160. Fluid may pass drive shaft 124 around an annulus defined between the drive shaft 124 and the stator adapter 108, by moving through radial ports 135 in drive adapter 144, passing around the shaft 124, and entering the PC motor 15. The fluid flow through motor 15 causes the stator 32 or rotor 36 (in this case the stator 32) to rotate, and the universal joint 79 acts to convert eccentric motion of the rotor 36, relative to the stator 32, into concentric motion, thus reducing vibration, which may deleteriously affect reaming operation. Fluid passing through motor 15 in a downhole direction then moves into bore 160B and out the ports 72 in the nose 48 as previously discussed above. Referring to Figs. 19A and 22B, uphole and downhole facing surfaces 137 and 139, respectively, may be structured, for example striated as shown, to improve drillability. In the example shown an surface 137 defines a striated uphole entry to bearing shaft 132, to permit a drill bit to be able to grip and drill through the shaft 132 and the interior contents of the tool 10.

[00147] Referring to Figs. 19A-B and 20, the rotor 36 may form a hollow helically lobed sleeve as shown. The rotor 36 may define a hollow interior 36C, which may be closed against fluid passage, for example via one or more walls. In the example shown opposed axial ends 36A and 36B of the hollow helically lobed sleeve are blocked by respective end walls, namely provided by rotor adapter 110 and rotor plug 104. An uphole facing surface of the wall may be striated. A casing 172 may be connected, for example directly as shown, or

indirectly through intermediary parts or tools, to the downhole reamer tool 10. An inner diameter 36D of the hollow helically lobed sleeve of rotor 36 may be sized to be commensurate with, for example equal to, an inner diameter 173A of the casing 172. In some cases nominal deviations between diameters 36D and 173A may be present. For example the diameter 36D may be larger than the diameter 173A, or smaller, for example equal to the drift ID of the casing. A smaller diameter 36D may be acceptable at the bottom of the well, if no further sections will be drilled, or if only a limited number of sections are to be drilled and the diameter 36D still permits sufficient play for such sections and casing to pass through. If the diameter 36D is too small, milling tools may be required to mill out the excess diameter, and such milling tools may require an extra trip in and out of the well to position and retrieve such tools.

[00148] Referring to Fig. 28, once the casing string is landed in the desired position, the casing 172 may be cemented in place. To accomplish such cement may be pumped down the internal bore of the casing 172, to the casing reamer tool 10, out the outlet ports 72 in the tool 10, and up the annulus defined between the well and the casing string 173. The tool 10 may be structured as a guide or float shoe, and may have a one-way valve to prevent backflow of cement. Upon setting of the cement, casing reamer tool may be drilled out by running a drill bit 181 at the end of a drill string 185 to the tool 10, and operating the drill bit 181 to drill out an axial passage in the tool 10. Once drilled out, the drill bit 181 continues on downhole to create and extend the well bore by adding a new section of well bore.

[00149] Referring to Figs. 21-23, a modification of the embodiment of Fig. 18 is illustrated. Referring to Figs. 22A and 22B, in the example shown, fluid is pumped into a portion 160A of the interior passageway 160, passing into the motor 15, and causing the rotor 36 to rotate, turn the drive shaft 124, and turn the reamer part 14 and nose 48. Fluid then continues down the internal annulus of the tool 10 between the drive shaft 124 and a static sleeve 142, passing through radial ports 143 in drive adapter 144 and entering a bore 160B of bearing shaft 132, exiting the nose 48 via fluid ports 72. Once the casing is landed the casing may be cemented in place and the tool 10 may be drilled through and the wellbore continued in a downhole direction.

[00150] Referring to Figs. 24, 24A, 24B, 25, 26, and 27, a further embodiment of a downhole reamer tool 10, such as a casing reamer shoe as shown, is illustrated. In the example shown fluid enters through the uphole end 42 into the portion 160A of interior passageway 160. The fluid passes through radial ports 135 into the motor 15. Upper and lower bearing assemblies 223 and 225 may be used. The reaming tool 10 may agitate a drill string or casing string by generating a shock-wave due to the rotation of the tool. This extends the reach of the casing 50 by creating agitation. In some extended reach wells (e.g. horizontal wells that are longer than the vertical section of the well) the tool 10 may run the casing 50 further than normally would be possible without extra hydraulic or mechanical evacuation. The torque produced may allow the tool 10 to drill with a casing bit. The tool 10 may replace a jetting assembly in deep water operations.

[00151] Referring to Figs. 36 and 39A-C, an electrochemical machining (ECM) method and resulting downhole tool 10 are illustrated. Referring to Fig. 36, in a first stage the stator is formed by ECM. Electrochemical machining (ECM) is a method of removing metal by an electrochemical process. It may be used for working extremely hard materials or materials that are difficult to machine using conventional methods. ECM may be used to cut small or odd-shaped angles, intricate contours or cavities in hard and exotic metals, such as titanium aluminides, and high nickel, cobalt, and rhenium alloys. Both external and internal geometries can be machined.

[00152] ECM may be characterized as “reverse electroplating” in that it removes material instead of adding it. An ECM cutting tool is guided along the desired path close to the workpiece but without touching the workpiece. High metal removal rates are possible with ECM, with no thermal or mechanical stresses being transferred to the part, and mirror surface finishes can be achieved.

[00153] In the ECM process, a cathode (tool) is advanced into an anode (workpiece). A pressurized electrolyte is injected at a set temperature to the area being cut. The feed rate may be the same as the rate of liquefaction of the material. The gap between the tool and the workpiece may vary, for example within 80 - 800 micrometers or 0.003 - 0.030 inches, or other suitable distances smaller or greater. As electrons cross the gap, material from the workpiece is dissolved and the tool forms the desired shape in the workpiece according to

the shape of the cutting tool. The electrolytic fluid carries away the metal hydroxide formed in the process.

[00154] Referring to Fig. 36, the stator 32 may be made via ECM. A power supply 214 may be connected to a metal block or tube 202, which forms a workpiece, and a shaping tool such as cutting tool 204, for example to pass current between the metal tube 202 and the shaping tool 204. The power supply 214 may thus establish an electrical field across gap 221 defined by the outer sidewall 225 of the cutting tool 204 and an inner sidewall 227 of the workpiece or tube 202. The metal tube 202 may form an anode. The shaping tool 204 may form a cathode.

[00155] The shaping tool 204 may have a tool head 208 positioned adjacent a surface 220 of the shaping tool 204, for example defining a gap between the tool head 208 and the surface 220, with surface 220 being eroded and retreating as the tool head 208 advances. An electrolyte 210 or other suitable conductive fluid may be injected and continually flowed through the gap 221 between the tool head 208 and the surface 220. The electrolyte 210 may be supplied to the shaping tool 204 from a suitable reservoir 203 via one or more of a pump 240 and a fluid line 216, for example that extends through the interior of the shaping tool 204. The electrolyte 210 may exit the shaping tool 204 via a nozzle 218, for example defined within the tool head 208 of the shaping tool 204, and upon exit the electrolyte comes into contact with the tube 202. Once the electrolyte passes the gap 221 and absorbs metal from the tube 202, the now-metal-carrying electrolyte may flow into a further reservoir 211, where the fluid may be recycled back into the supply reservoir 203, for example via a recovery line 213. The fluid may be filtered or treated prior to re-entering reservoir 203. In some cases spent fluid is discarded. A cooling circuit may be provided to manage temperature changes in the electrolyte fluid during the process.

[00156] During the ECM process the shaping tool 204 may be rotated and advanced around and along, respectively, an axis 209 of the metal tube 202, for example in a direction 222, via a suitable actuator 212 such as a linear actuator or hydraulic arm. Extension of the shaping tool 204 towards the surface 220 may cause release or removal of material from the metal tube 202.

[00157] Outer sidewall 225 of the cutting tool 204 may have a suitable shape such as a helically lobed profile as shown. Extension and rotation of the shaping tool 204 into the tube 202 advances the surface 220 and erodes material in the interior of the metal tube 202 to form helical lobes that are contoured into an inner surface 206 of the metal tube 202. The cutting tool 204 may rotate about the axis 209 such that the inner sidewall 227 of the workpiece or tube 202 takes on a shape that is the inverse of the helically lobed profile of the outer sidewall 225 of the cutting tool 204. Movement, for example advancement, extension, retraction, and / or rotation, of the shaping tool 204 may follow a preset path or pattern determined by a controller 258. The rotation and advancement of the tool 204 may follow the profile lines of the helical lobes of the tool 204, to ensure that the tube 202 takes on the same helically lobed profile. The controller 258 and the actuator 212 may be connected to one or more of the power supply 214, actuator 212, and pump 240 via respective control lines 244, 242, and 245. In some cases variations of ECM may be used, such as electrical discharge machining (EDM), or other processes that involve selective erosion of the interior surfaces of the workpiece to achieve the desired interior shape.

[00158] Referring to Figs. 38 and 39A-C, a drilling motor tool 10 is illustrated. The tool 10 may be formed by ECM or another suitable method. ECM may permit a suitable stator 32 to be formed from a single integral block of material such as tube 202 (Fig. 36). A single integral block of material may be initially a suitable unbroken shape such as a cylinder, although the block could have a solid or hollow core, and could be other than cylindrically shaped, such as shaped like a rectangular box. Further machining after ECM may be carried out to finalize the shape of the stator 32. ECM may permit extended lengths of integral stator sections to be made, for example stator sections may be made with an axial length 219 (Fig. 38) of at least fifty and in some cases fifty, eighty, one hundred fifty, and three hundred inches or more, defined between axial ends 32A and 32B of the stator. The resulting stator may have no break lines or transition points such as weld lines or abutting ends of adjacent sections connected by connectors such as dowels. Instead, the stator may have a continuous unbroken profile from axial end to axial end. The axial ends 32A and 32B may refer in some cases to the start and end points of the helically lobed profile. By contrast conventional computer numerical control (CNC) methods using a lathe and mill may only be

able to create a stator section of thirty six inches or less. The length of a tool 10 produced by ECM may be limited by the axial length of the cutting tool 202, with such axial length capable of being tailored to achieve the desired stator length, and hence in theory any length of stator 32 may be created. In other cases the rotor, or both the rotor and the stator, may be formed using ECM. In cases where the rotor is formed by ECM, the inner sidewall of the cutting tool may be shaped with a helically lobed profile, so that the cutting tool rotates about the axis such that the sidewall of the workpiece takes on a shape that is the inverse of the helically lobed profile of the inner sidewall of the cutting tool.

[00159] In some cases the resulting stator formed may be connected with adjacent stators as sections to form a larger stator. In the example shown the entire motor 15 is formed by a single stator 32, in which a corresponding rotor 36 is inserted to assemble the motor 15. Rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, may be rigid, for example metal, for further example the same type of metal or different metals as one another. In other cases an elastomeric coating such as rubber may be placed, for example lined with corresponding helically lobed shape, on the inner sidewall 227 of the stator 32. Referring to Figs. 28 and 38, once formed and assembled, the tool 10 may be used in a downhole operation by positioning the tool 10 in a well bore 176, and pumping fluid to operate the progressive cavity section to rotate the rotor relative to the stator. In the example shown the tool 10 may be connected to or incorporate a drill bit 181, such that the rotor 36 is connected to rotate the drill bit 181 under fluid pressure to drill the well. Referring to Figs. 39A-C, the tool 10 assembled may incorporate various suitable features, such as uphole and downhole tubing connectors 39 and 37, respectively, bearings 128, reamers 24, a drive shaft 94, and top and bottom subs 16 and 38, respectively.

[00160] Methods may be used other than ECM to form a stator 32 out of a single integral block of material. Referring to Fig. 37, for example, three-dimensional printing may be used. Three-dimensional (3D) printing, also known as a form of additive manufacturing (AM), refers to processes used to create a three-dimensional object in which layers of material are formed under computer control to create an object. Objects may be of almost any shape or geometry and may be produced using digital model data from a 3D model or another electronic data source such as an Additive Manufacturing File (AMF) file.

Stereolithography (STL) is one of the most common file types that 3D printers can read. Thus, unlike material removed from a stock in a conventional machining process, 3D printing or AM builds a three-dimensional object from computer-aided design (CAD) model or AMF file by successively adding material layer by layer.

[00161] In some cases the stator 32 may be formed as a single piece. For example the stator 32 may be formed as a single piece by three dimensional printing. Layers of metal may be added until the desired shape is achieved. The resulting stator may be used in a rubberless, rigid contact surface application as described elsewhere in this document. A hollow rotor sleeve may be inserted into the stator to form a progressive cavity power section. In other cases a single piece stator may be made by other suitable methods, such as electrochemical machining, or one piece CNC machining.

[00162] Referring to Fig. 37, the stator 32 may be made via a 3D printer 224. The 3D printer 224 may comprise a structural frame 232 upon which actuators and workpieces are mounted. Frame 232 may comprise a set of guide rails 230 mounted to the structural frame 232, a printing head 234 mounted to the guide rails 230, for example to slide in opposed directions along arrows 250 and in directions into and out of the page to provide freedom of movement in a plane 251, which in the example shown is a horizontal plane. A nozzle 228 may be mounted to the printing head 234. Printing material 226 may be supplied from a reservoir 252 to the printing head 234 and ejected onto a substrate such as platform 236 via the nozzle 228, for example to form the stator 32. The platform 236 may be raised and lowered via an actuator 248 such as in opposed directions 260, for example to facilitate addition of the printing material 226 to the platform 236. Actuators that do not require rails may be used, for example robotic arms may be used as actuators. The printing head 234, the actuator 248, and the container 252 may be connected to a controller 238 via respective control lines 254, 262, and 246. Once completed and cured, a rotor may be inserted into the stator 32 to assemble the tool 10.

[00163] Referring to Figs. 2A, 2B, and 3, stators 32 may be made by other suitable methods such as using dowels 34. A progressive cavity section may be produced with a stator 32 and a rotor 36, in which the stator is formed by plural axial stator sections, such as sections 32'-32''' connected end to end. Adjacent axial stator sections, of the plural axial

stator sections, may be connected by dowels 36 as before. Dowels may refer to pegs as shown in Fig. 3 that are separate and independent to sections 32'-32''', or dowels may refer to pegs that are integral with one of the stator sections and extend out into engagement with an adjacent section in use. Adhesive and other techniques may be used as described elsewhere in this document. Dowels may be used to construct any suitable downhole tool incorporating a progressive cavity section.

[00164] The techniques, methods, and processes described here may be used to make and use various downhole tools, from drilling motors, to reamers, to rotary steerables, stimulation tools, pulsation tools, and others.

[00165] The stator 32, rotor 36, or both, may be subjected to various surface treatments to improve performance, for example to increase physical properties. Such treatments may include varying the coefficient of friction, surface hardness, metal porosity, and residual surface stresses. Processes may include heat treatments such as laser hardening, nitriding, carborizing, or boronizing, to modify surface hardness. Teflon, or ceramic coating, or polishing, may be used or carried out to reduce friction. Surface coating processes such as a chrome overlay, carbide overlay, physical vapor deposition, chemical vapor deposition, or high velocity oxygen fuel (HVOF) processes may be used.

[00166] The tool 10 may be used in a drilling application. In such cases the tool 10 may be ran with a drilling rig outfitted to drill with casing. The nose 48 of the tool 10 may be of similar construction as a typical drill bit, for example with cutting structures impregnated into a metal matrix. After drilling the well, and after the casing has been cemented in place, the tool 10 may be drilled out. In some cases the nose 48 may need to be milled out by a milling tool due to the hardness of material of the nose 48. Milling may require an extra run to bring the milling tool down the well, to the nose 48 and back up the well again, to change out the milling bit into a drill bit. In some cases a casing while drilling application may be carried out while drilling a vertical well, although the embodiments here are not limited to vertical wells. To drill a directional or horizontal well the tool 10 may have an adjustable housing, and may use a directional measurement (MWD - measuring while drilling) system. In some cases a non-magnetic environment may be needed with certain MWD technology. In other cases a gyro may be used with a drilling application.

[00167] The reamer tool 10 may be considered to be a mandrel assembly, with an inner mandrel and an outer mandrel. The tool 10 may be coupled to the bottom end of the casing in a variety of manners, including but not limited to mating threads, press fits, snap-fits, friction fitting, adhesives, bolts, and the like and combinations thereof. The tool 10 may grip a shoe, which is the operating component that interfaces with the interior of the hole to be reamed and abrades away material, thereby reaming the hole. The shoe may include protrusions that, when the shoe spins, impact with non-smooth regions of the interior of the hole and thereby abrade the same making such regions more smooth and increasing the effective interior diameter of the same so that the casing can follow behind without getting stuck. After the drilling is completed for a particular section of a hole, the operator may put casing down the hole to create a smooth interior bore through which additional work may be completed.

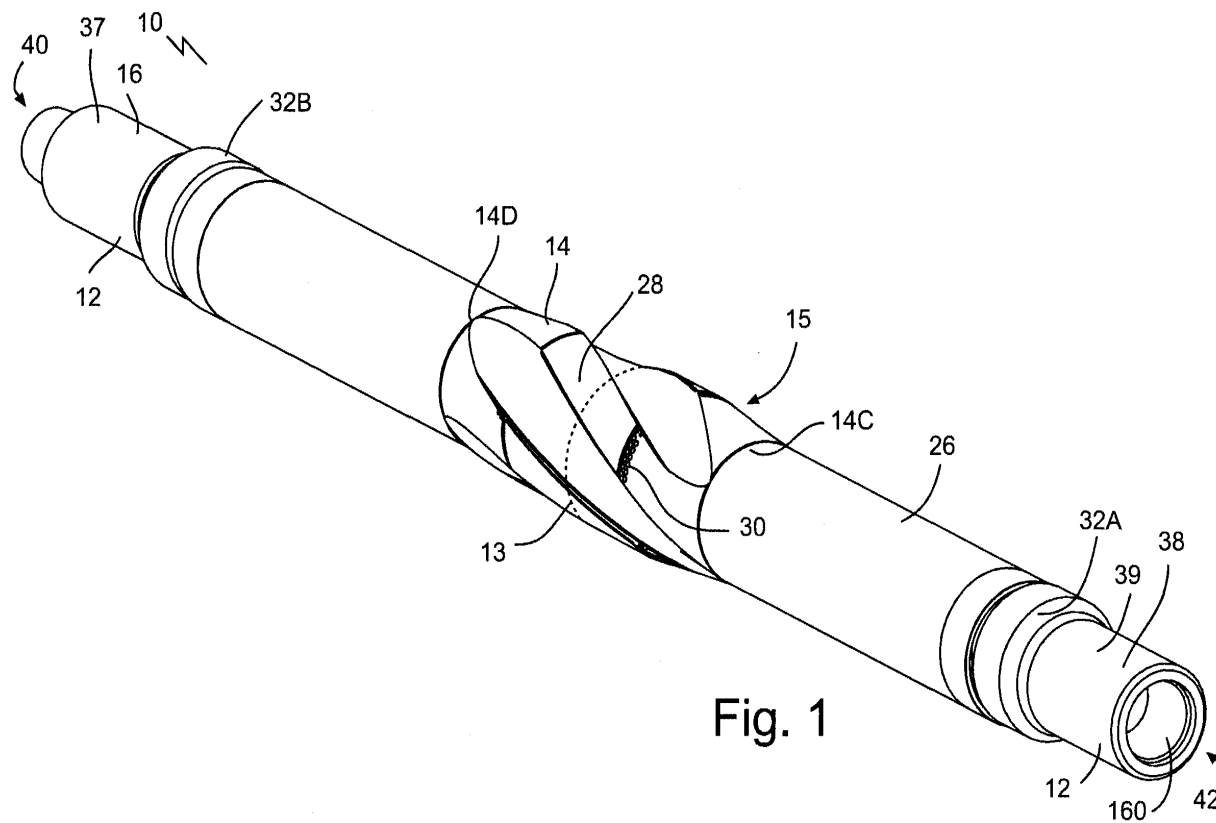
[00168] However, the hole is generally not perfect and often includes defects that can stop the casing from going all the way down. Accordingly, it is desirable to put a reaming tool, the operating tip of which is usually called a shoe, towards the bottom to ream out the hole as the casing slides down. In one non-limiting embodiment, there is a reaming system, device, and/or mandrel assembly that is, advantageously, a low cost system that attaches to or includes one of a great variety of shoes (e.g. float shoe, reamer shoe, guide shoe) from a variety of manufacturers. The tool 10 may include an internal/central axle that rotates inside a housing and/or includes a pin-down connection (e.g. pin to pin, box-pin) to couple to a shoe so it can connect to any tool/shoe. The internal axle spins when fluid is pumped through the mandrel assembly and spins a sub that is connected to the shoe which therefore also spins. The internal axle and/or other centrally positioned parts may be of an aluminum, bronze, brass, and/or zinc alloy (or other material that may be drilled through rather easily, since the mandrel assembly is generally left at a bottom of the hole when the casing is finished being installed).

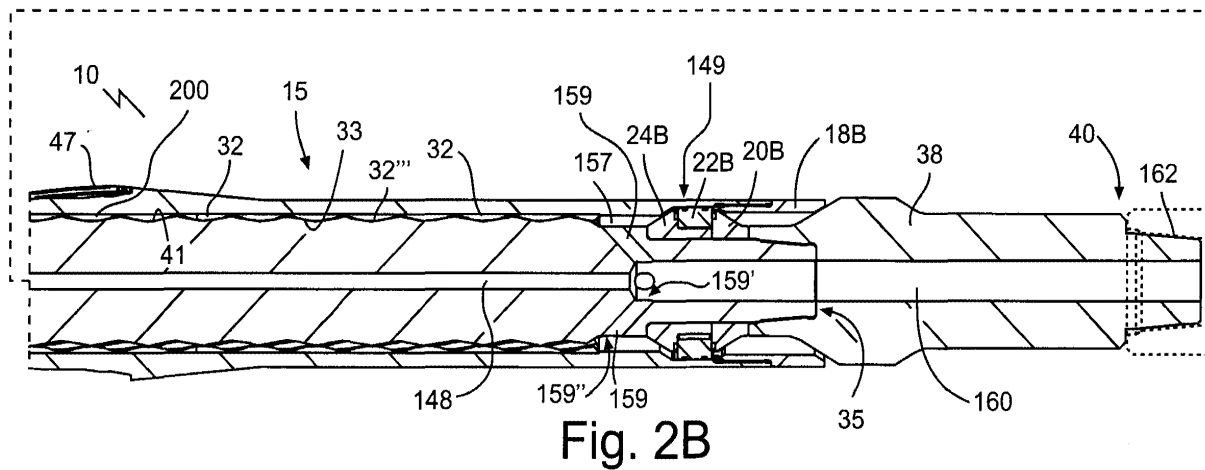
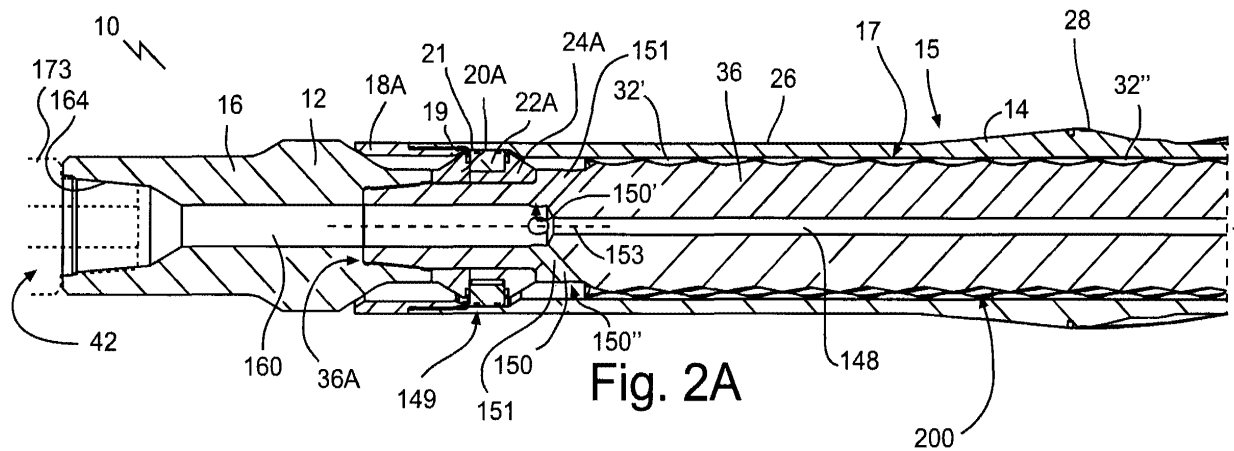
[00169] Additionally, although the figures illustrate an outer mandrel with a certain number of spiral lobes on an interior thereof, a different number of lobes and/or lobes of different slopes, curvatures, sizes, shapes and the like may be present. Finally, it is envisioned that the components of the device may be constructed of a variety of materials,

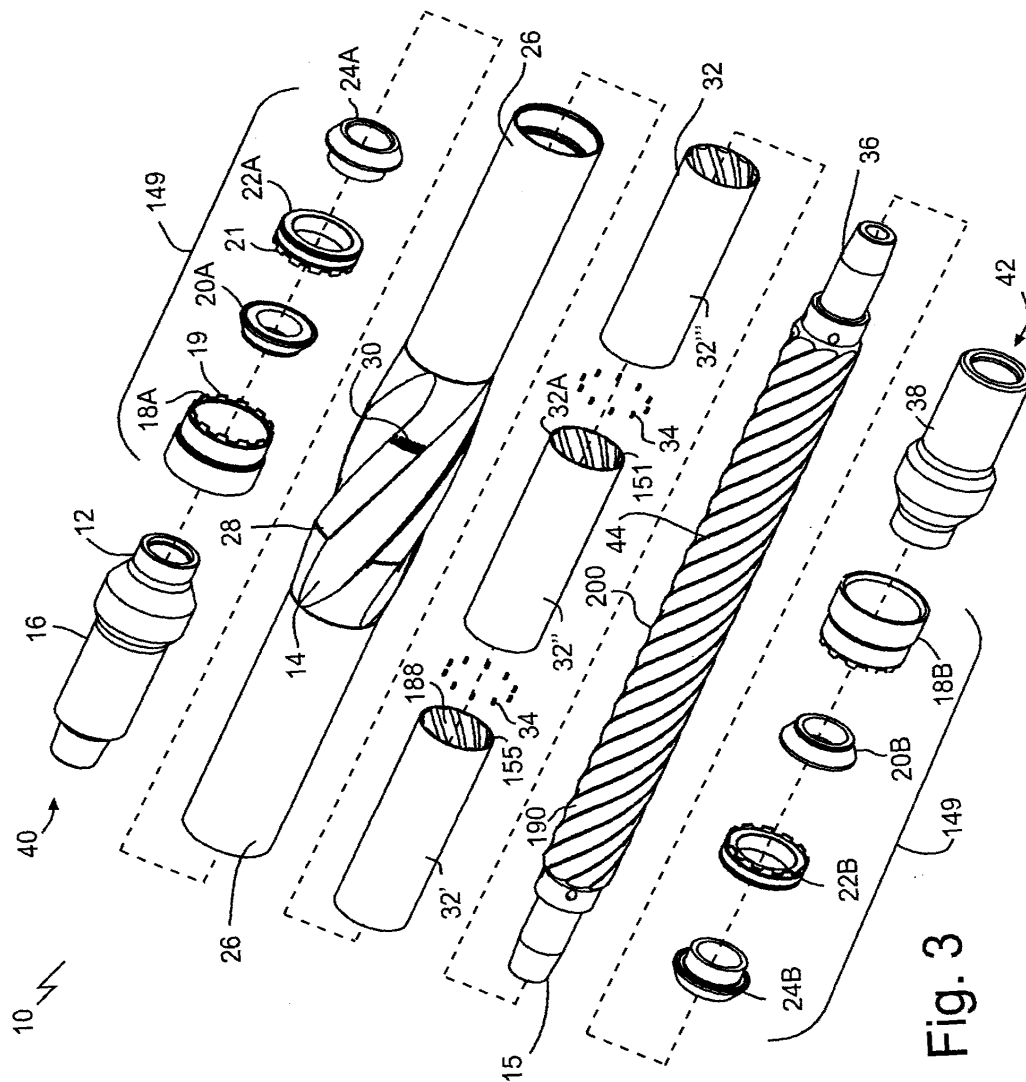
including but not limited to metals (both drillable and not), plastics, ceramics, composites and the like and combinations thereof. Parts may be made up of more than one part connected together, for example a housing may be made of plural sleeves of material threaded or press fitted together to form one unit. Blades include helical blades. A magnet tool may be used in an uphole direction of the casing brush or other embodiments of tool 10 to assist in collectively large metallic debris.

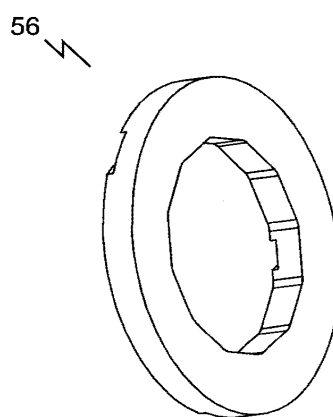
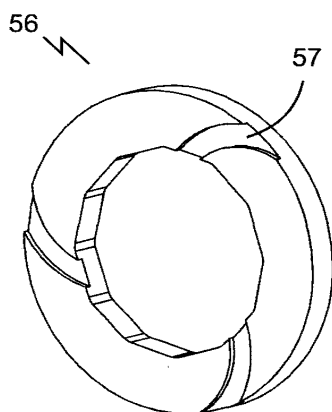
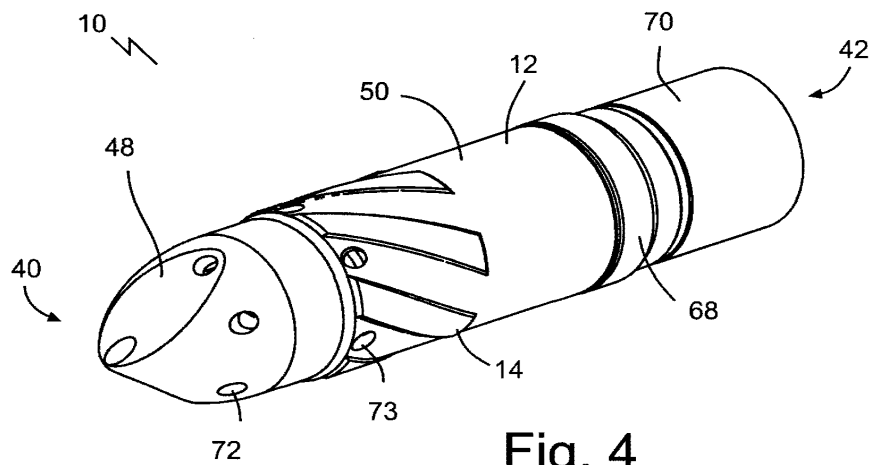
[00170] Parts or components of tool 10 may be connected to one another and other parts of a tubing string by any suitable method, including mating threads, press fits, snap-fits, friction fitting, adhesives, bolts, bearings, and the like and combinations thereof. Points of dynamic contact may be coated with one or more of an anti-corrosion agent and a slip agent. Tools 10 may be used in suitable applications, such as deep water or deep well applications, as well as conventional wells. In some cases stators or rotors may be made with forty inches of axial length or more.

[00171] In the claims, the word “comprising” is used in its inclusive sense and does not exclude other elements being present. The indefinite articles “a” and “an” before a claim feature do not exclude more than one of the feature being present. Each one of the individual features described here may be used in one or more embodiments and is not, by virtue only of being described here, to be construed as essential to all embodiments as defined by the claims.









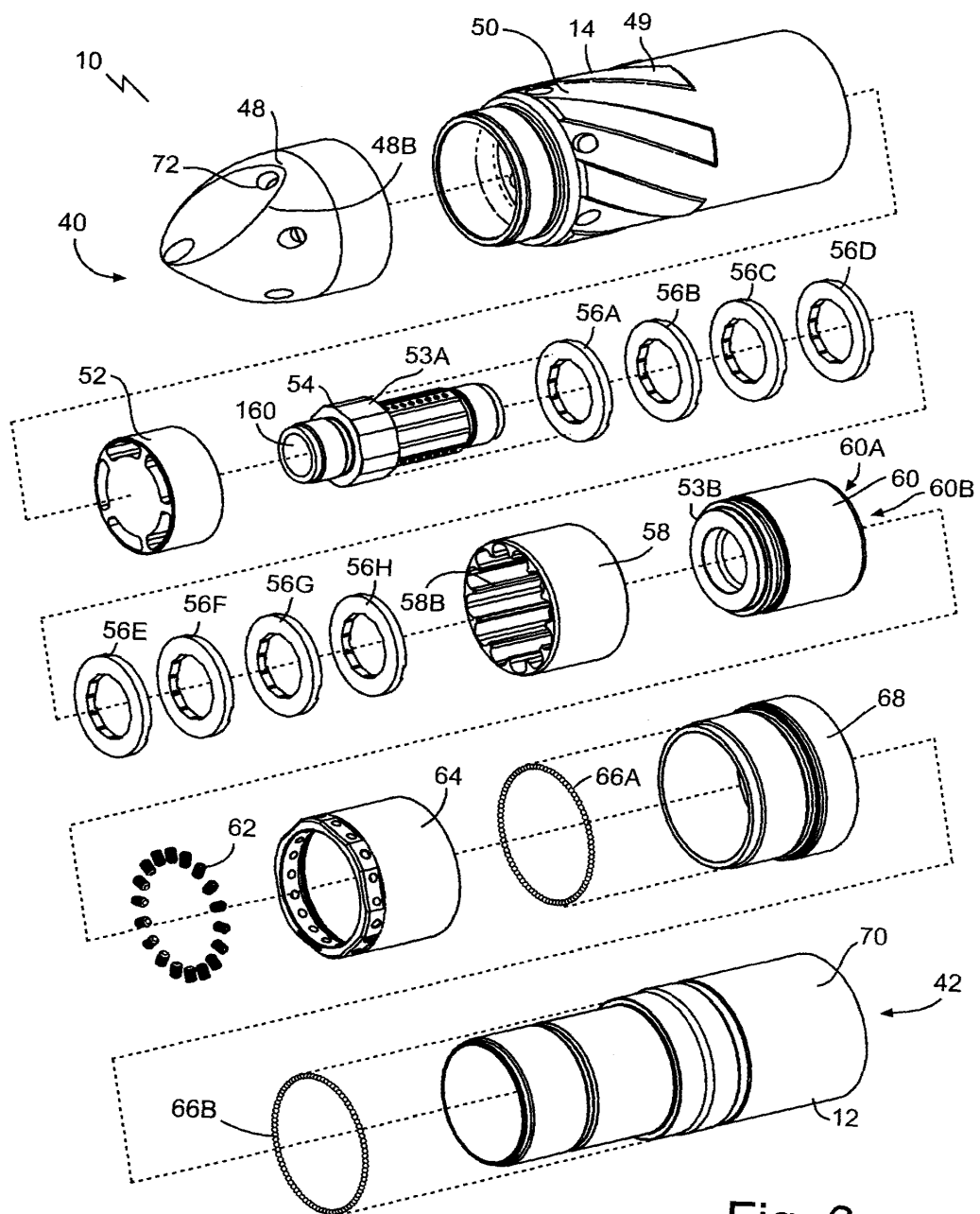


Fig. 6

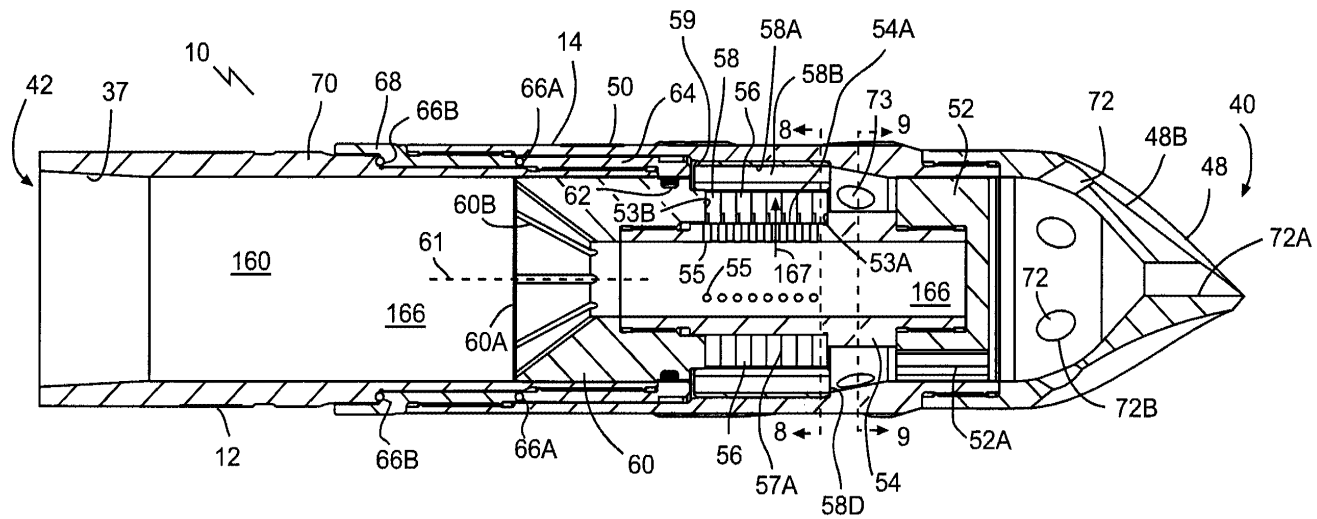


Fig. 7

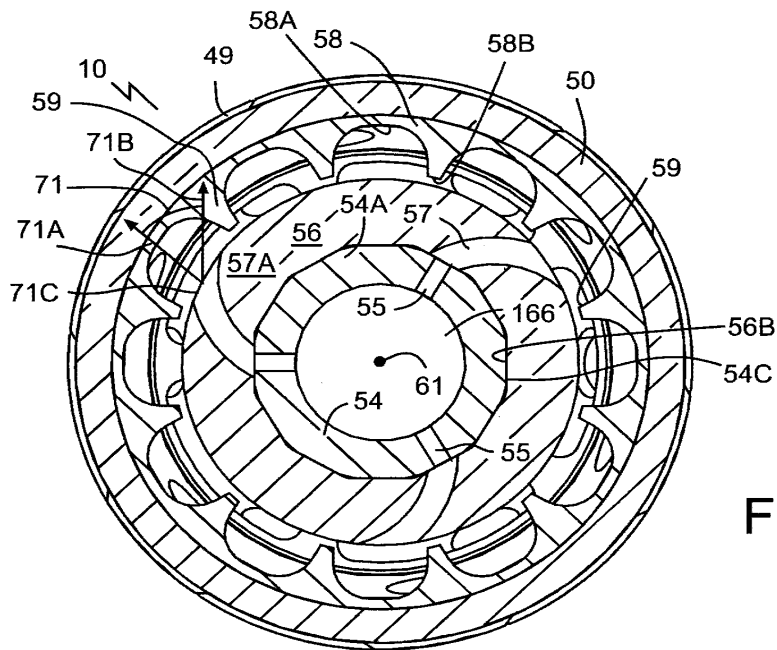


Fig. 8

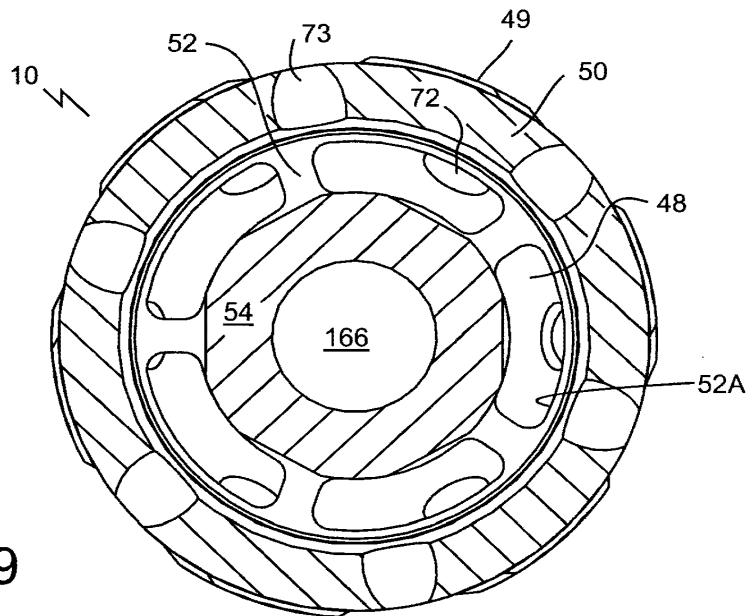


Fig. 9

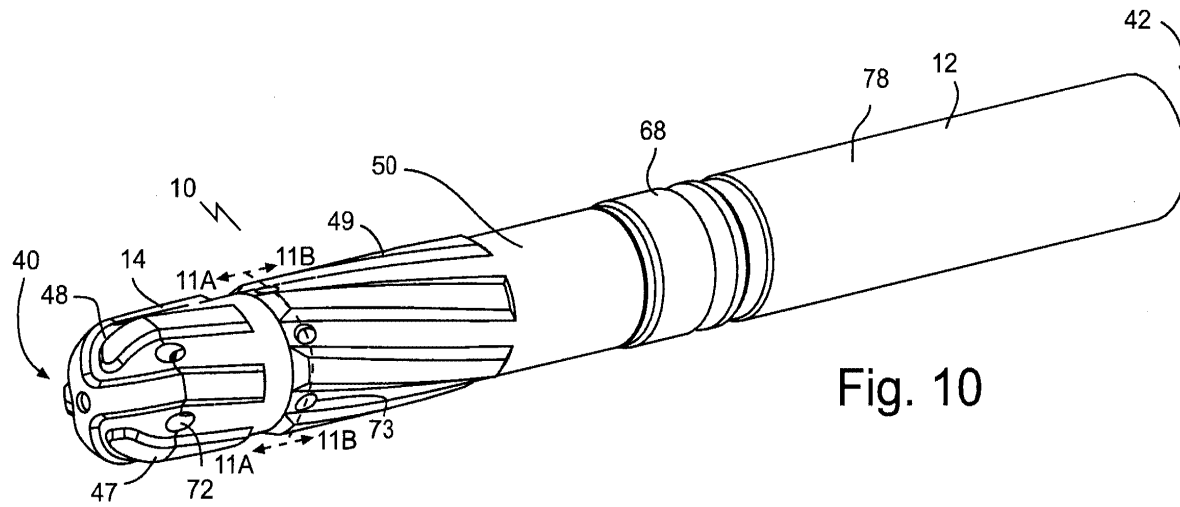


Fig. 10

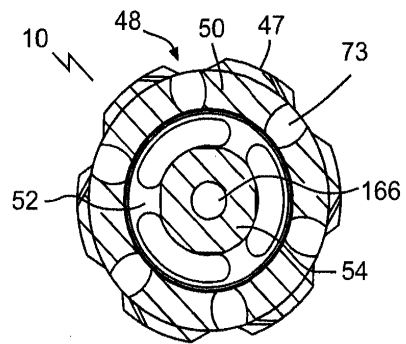


Fig. 11A

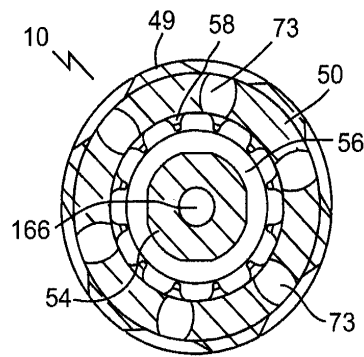


Fig. 11B

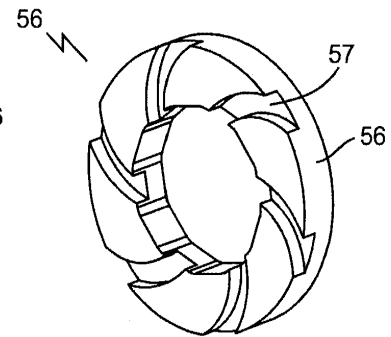


Fig. 12

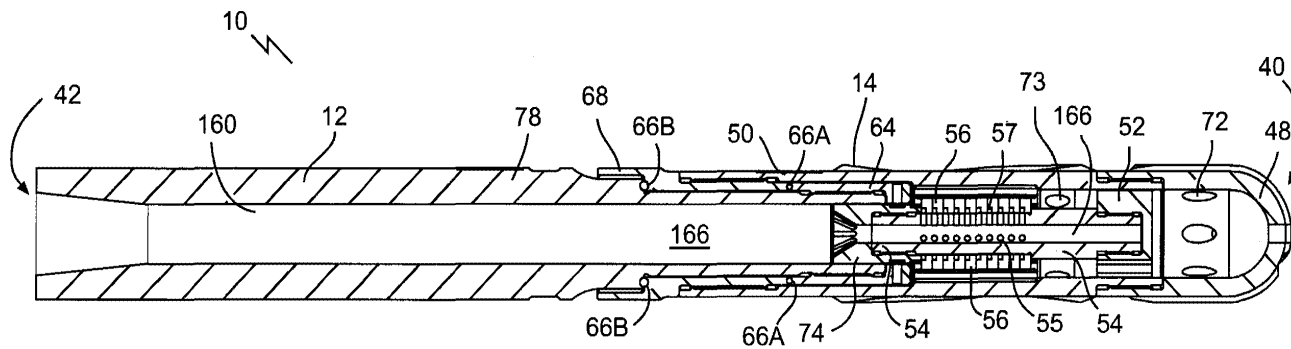


Fig. 13

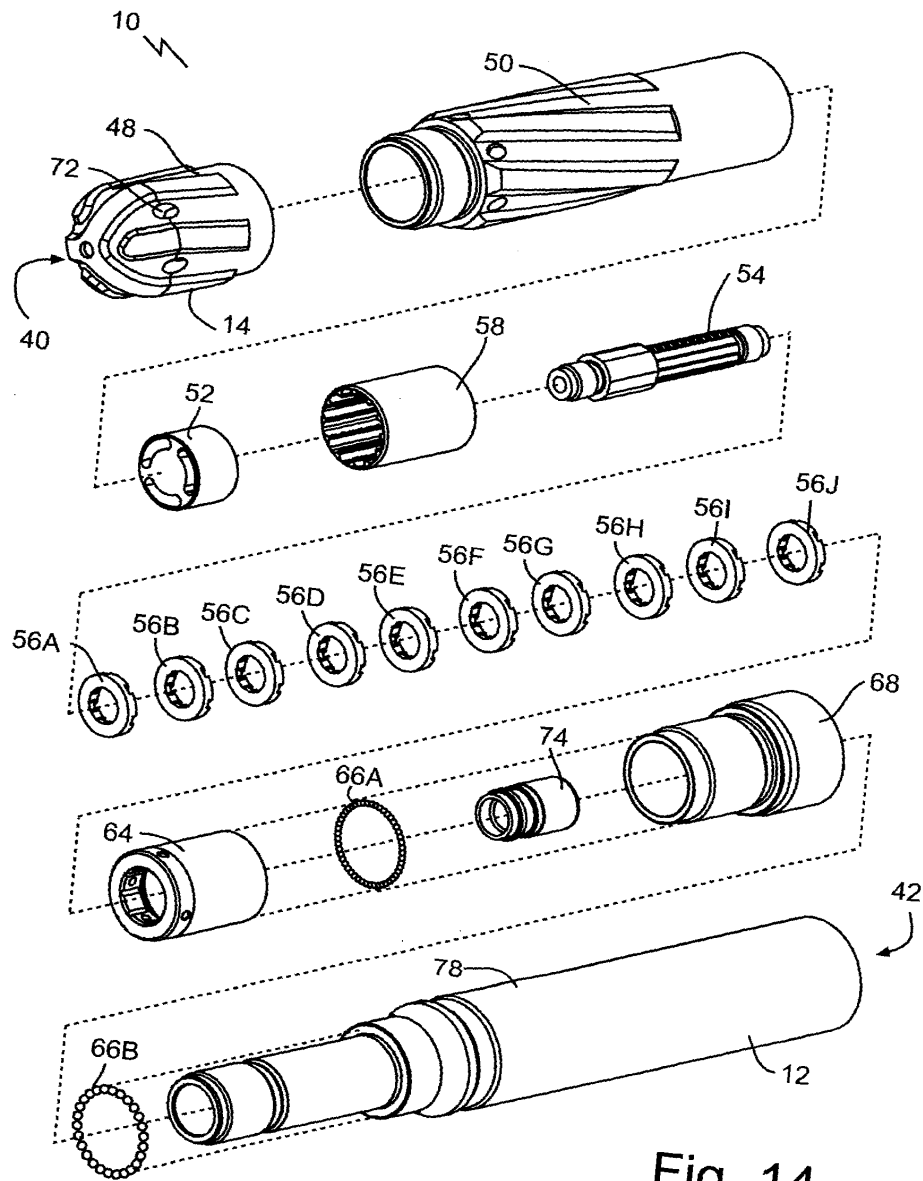


Fig. 14

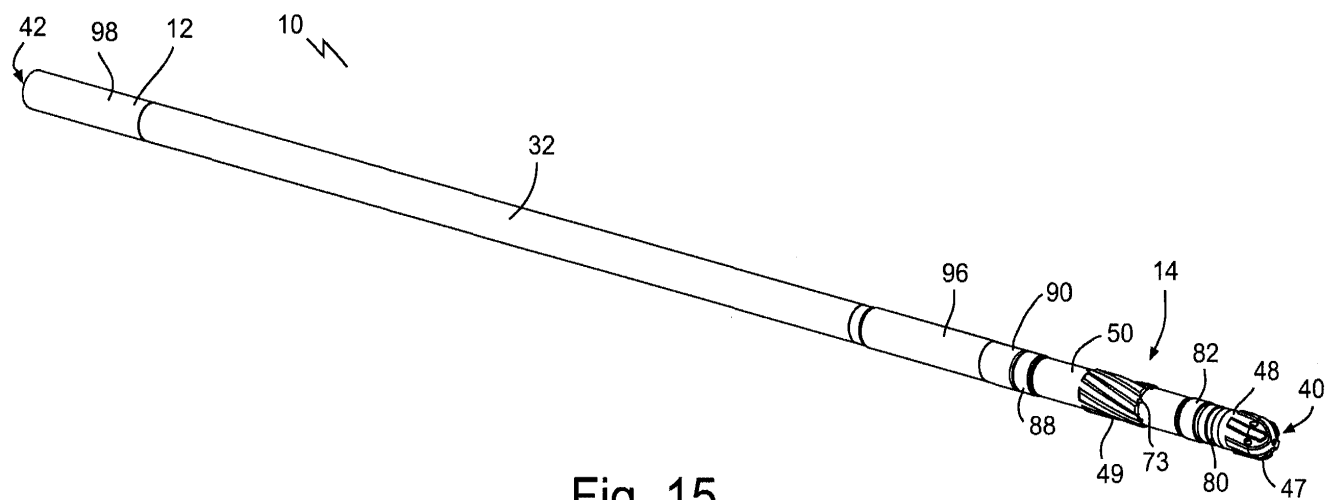
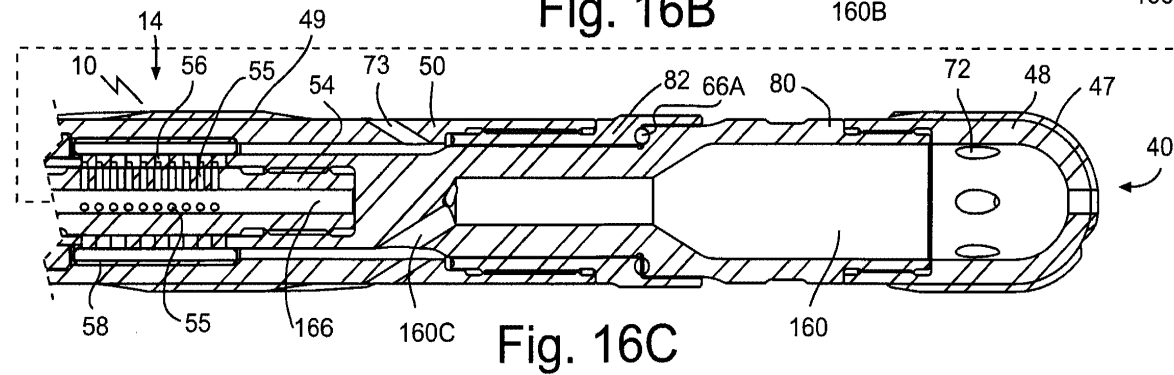
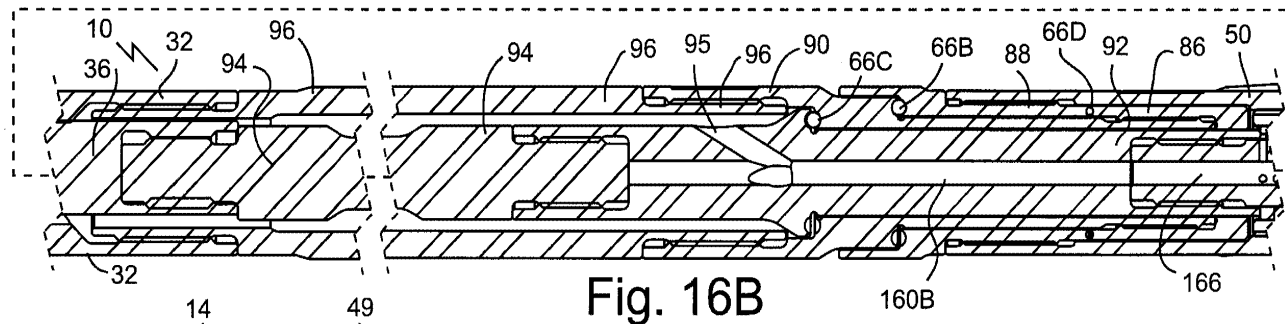
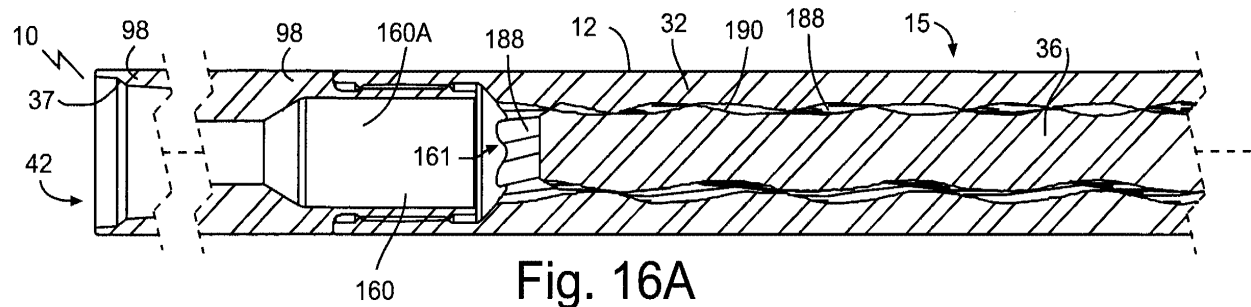
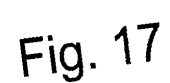


Fig. 15





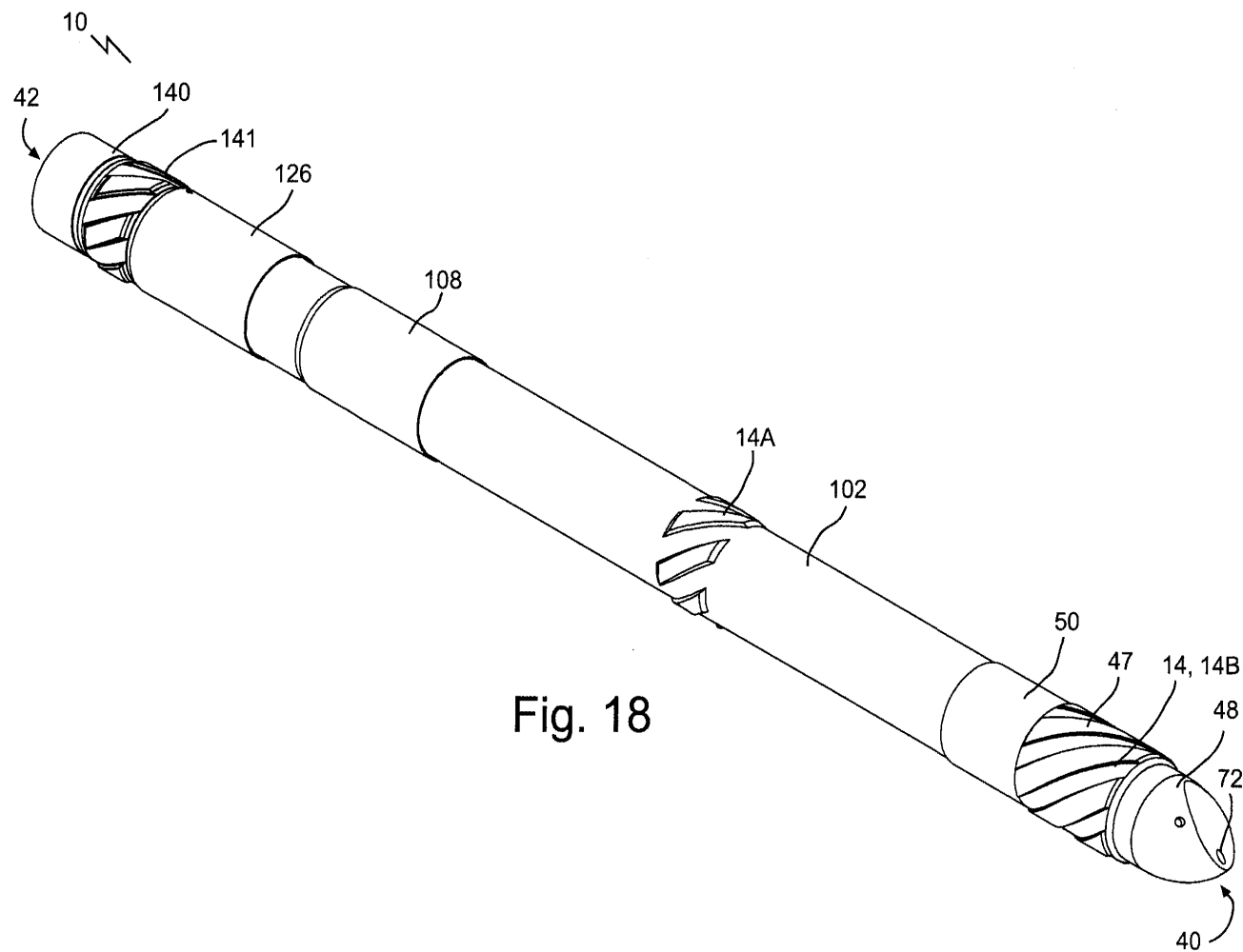
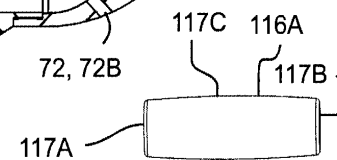
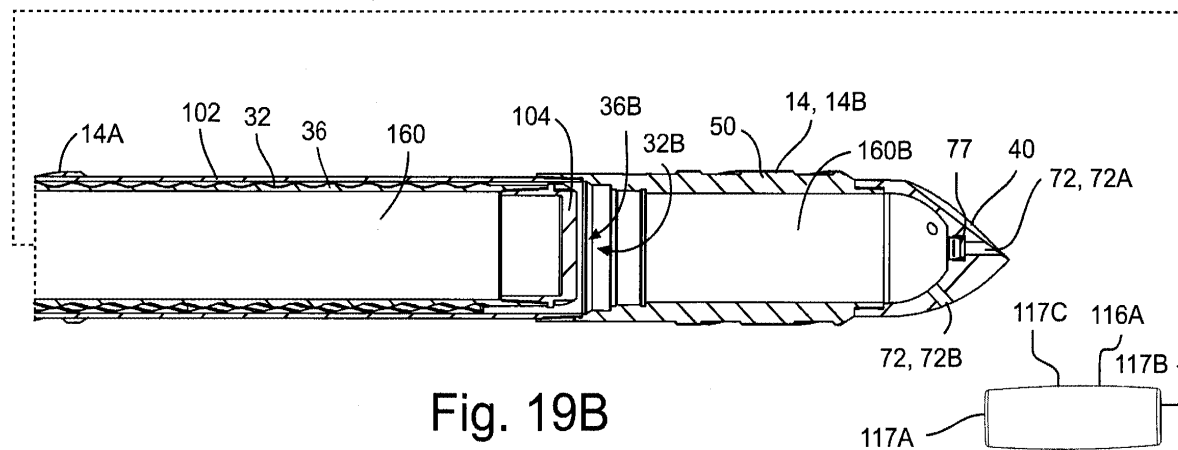
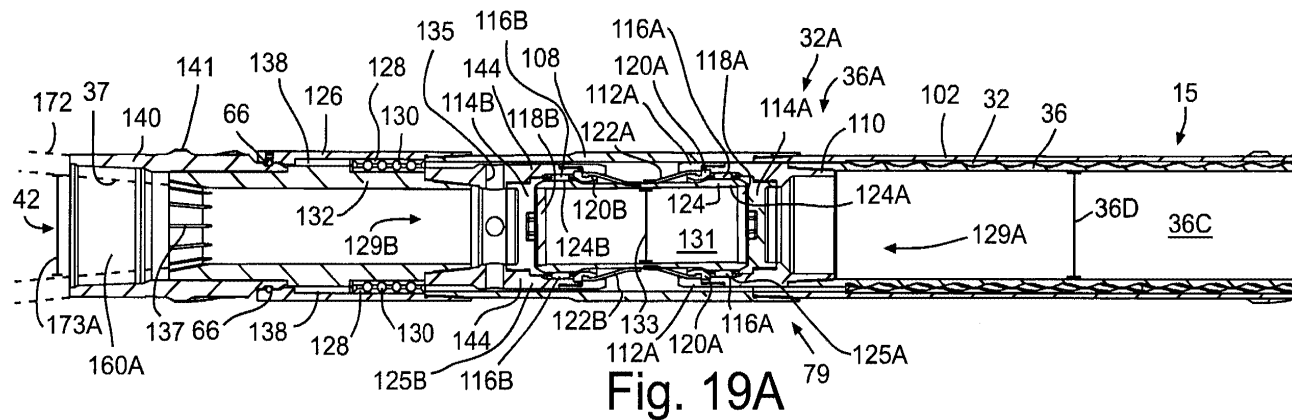


Fig. 18



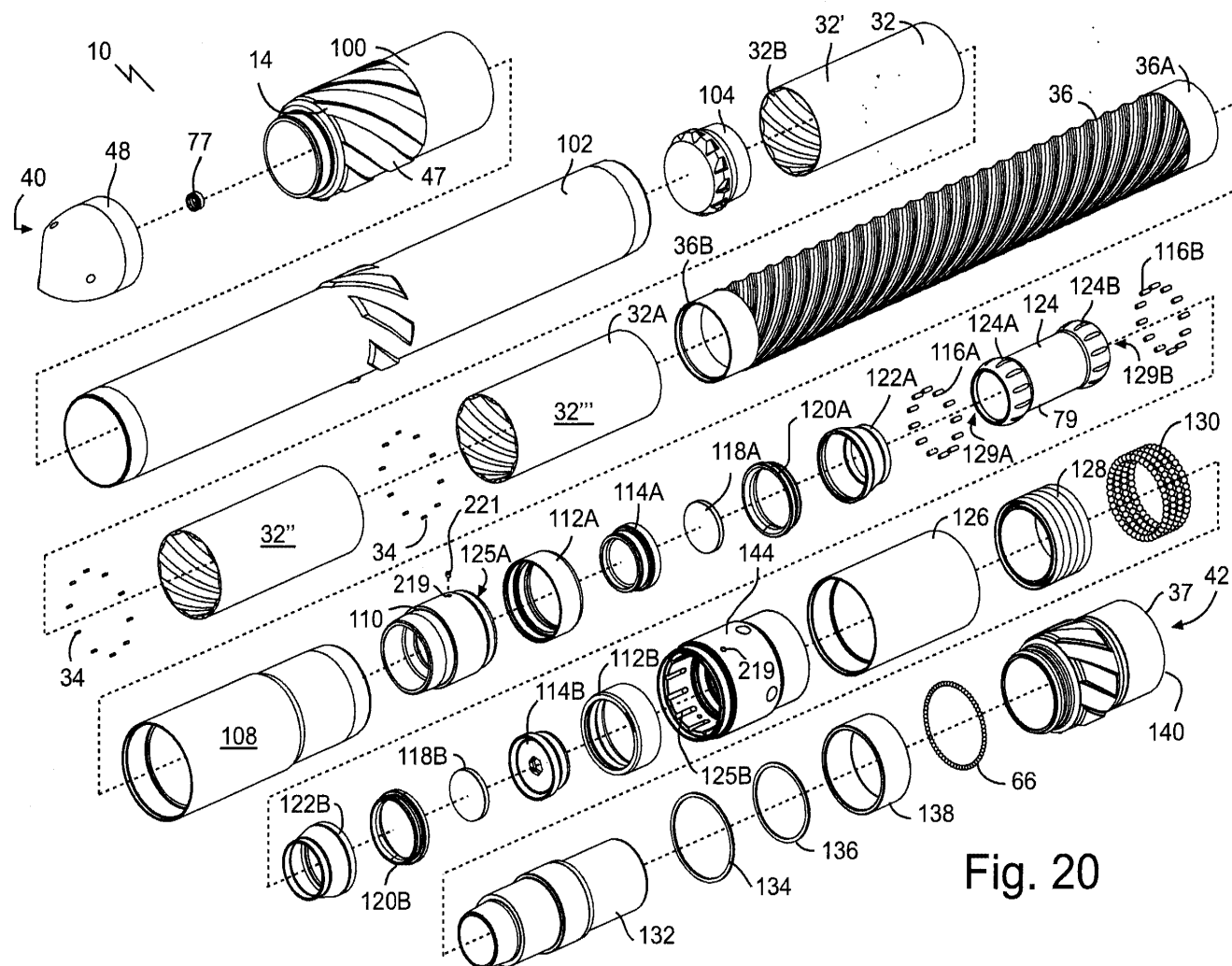


Fig. 20

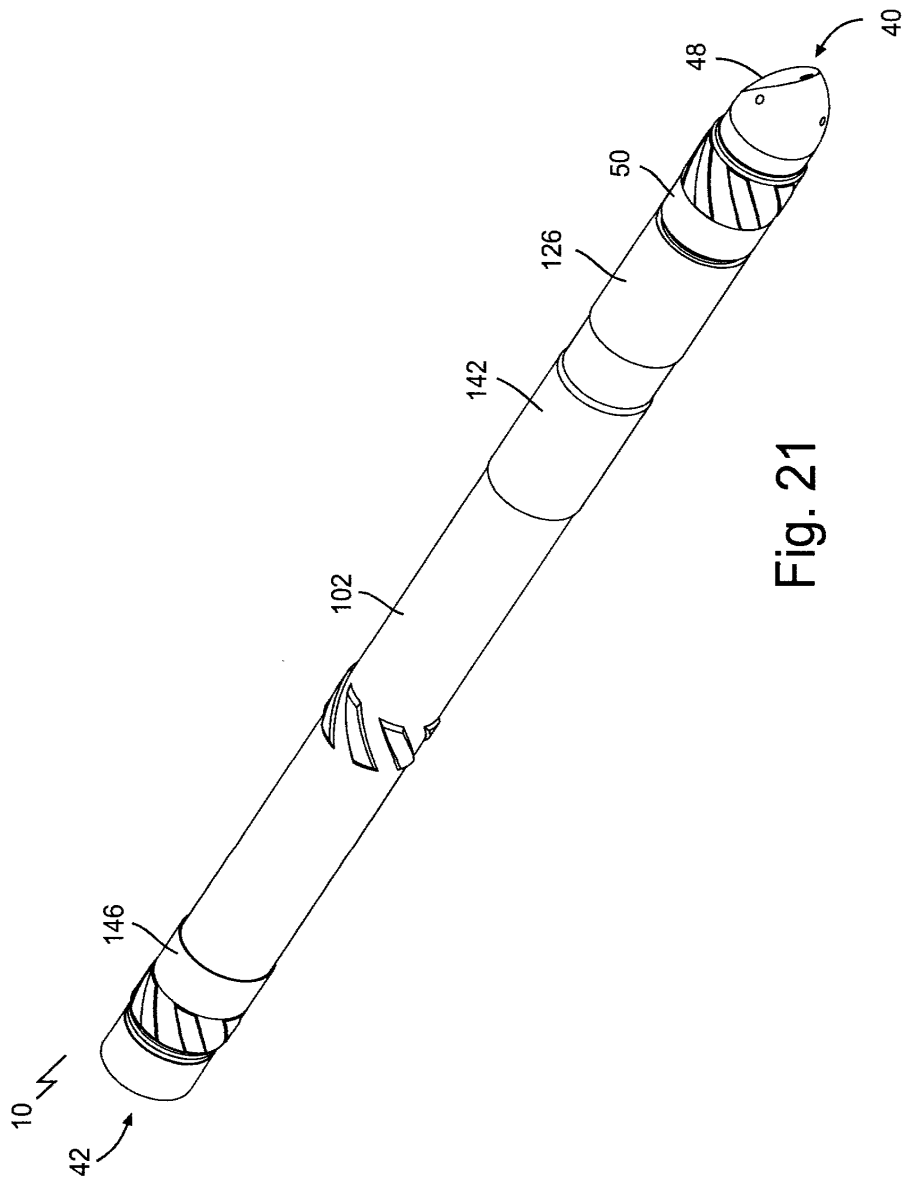


Fig. 21

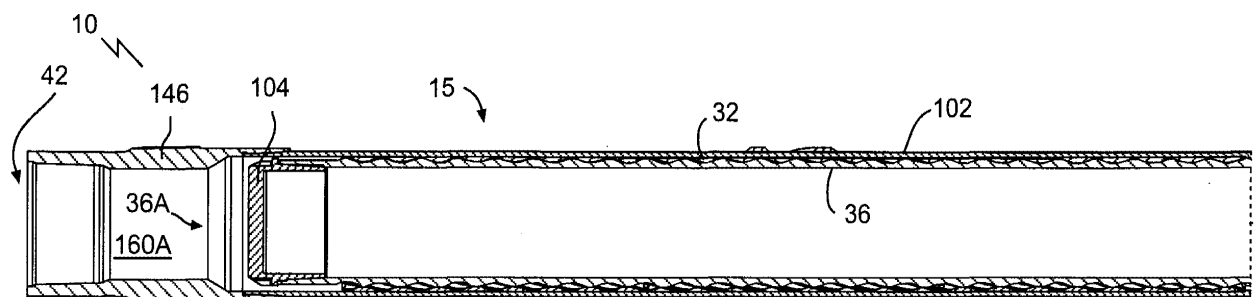


Fig. 22A

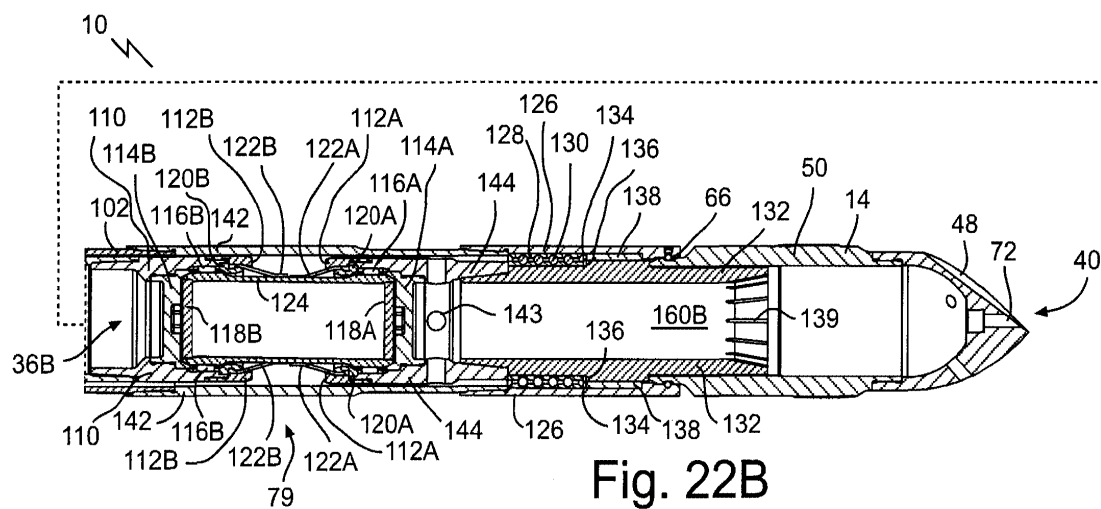
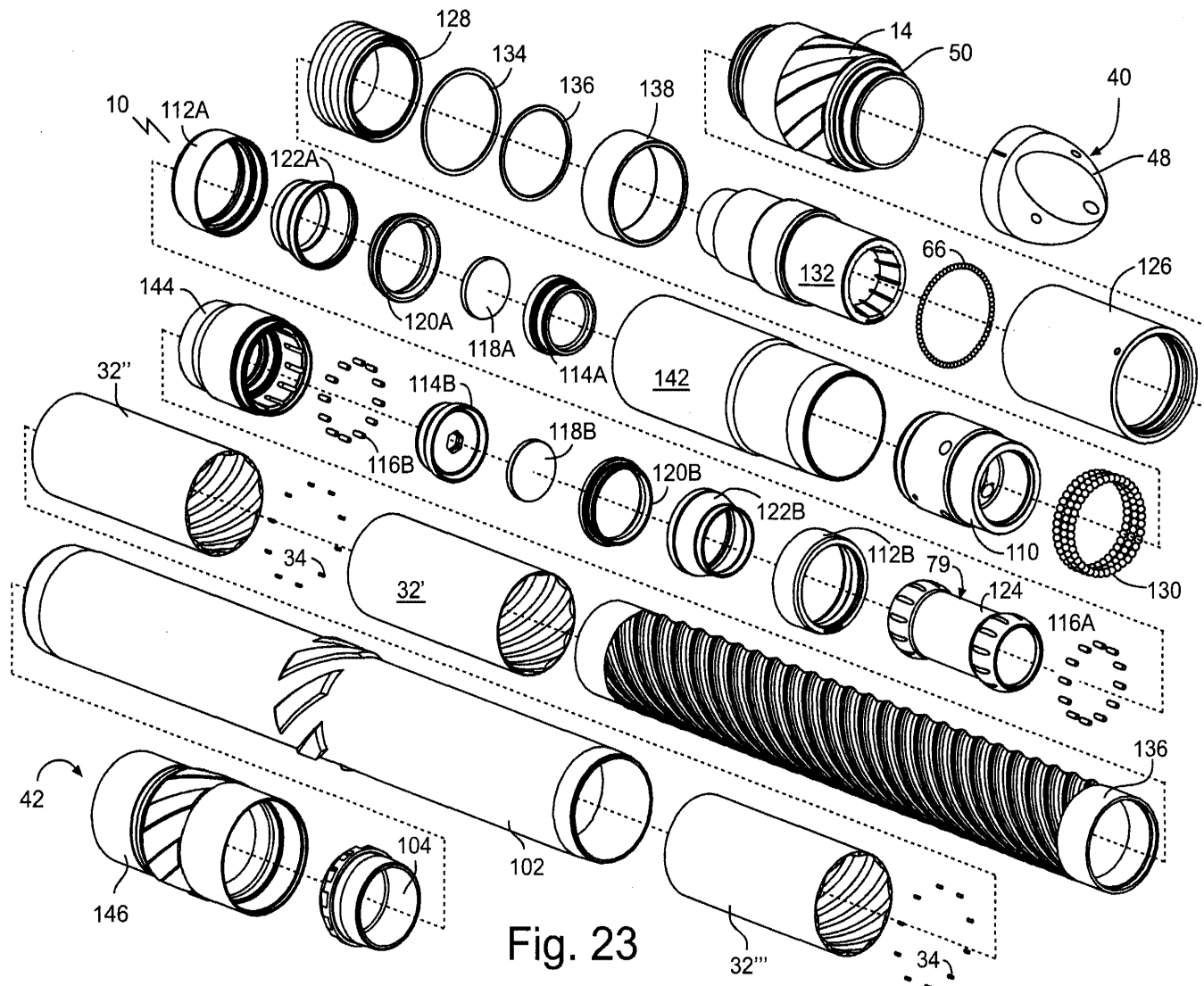
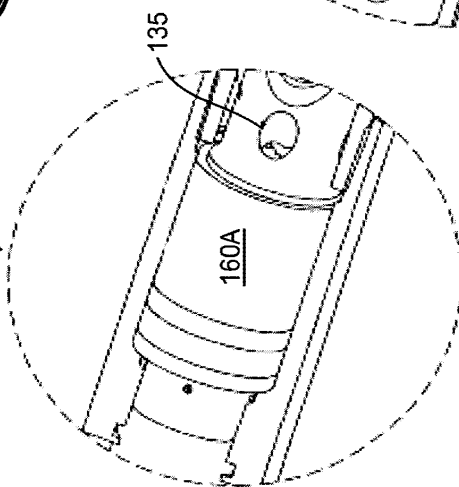
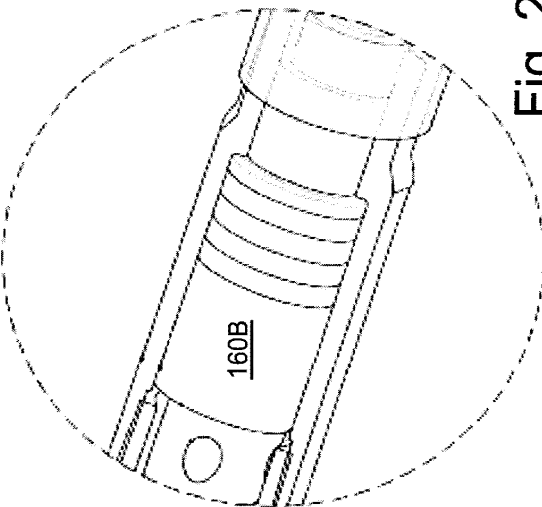
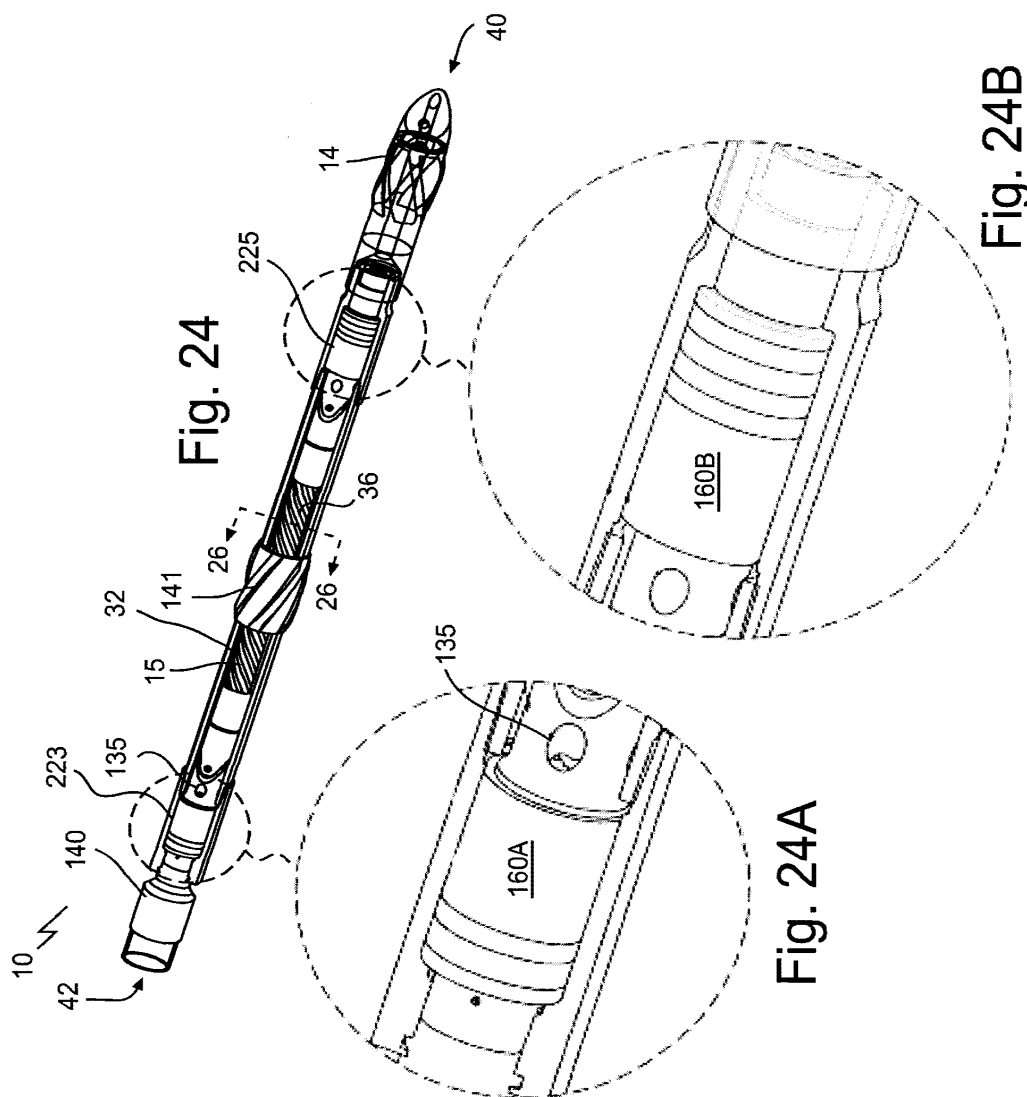


Fig. 22B





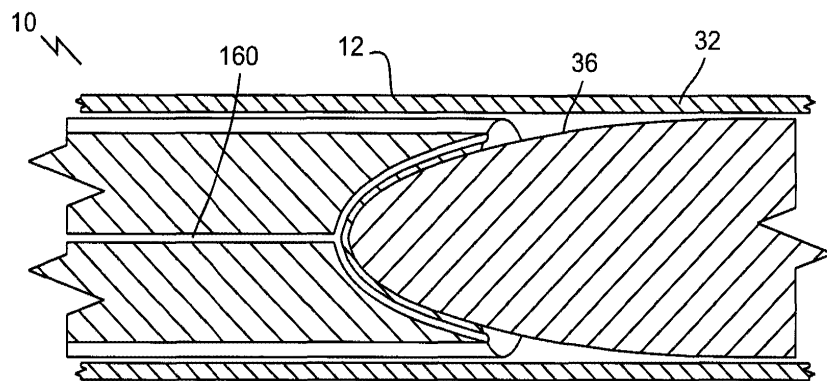


Fig. 25

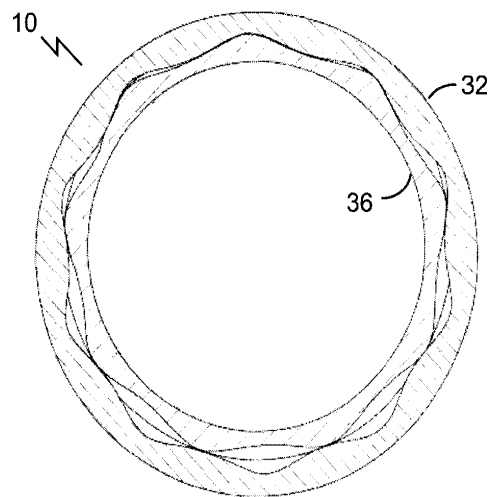


Fig. 26

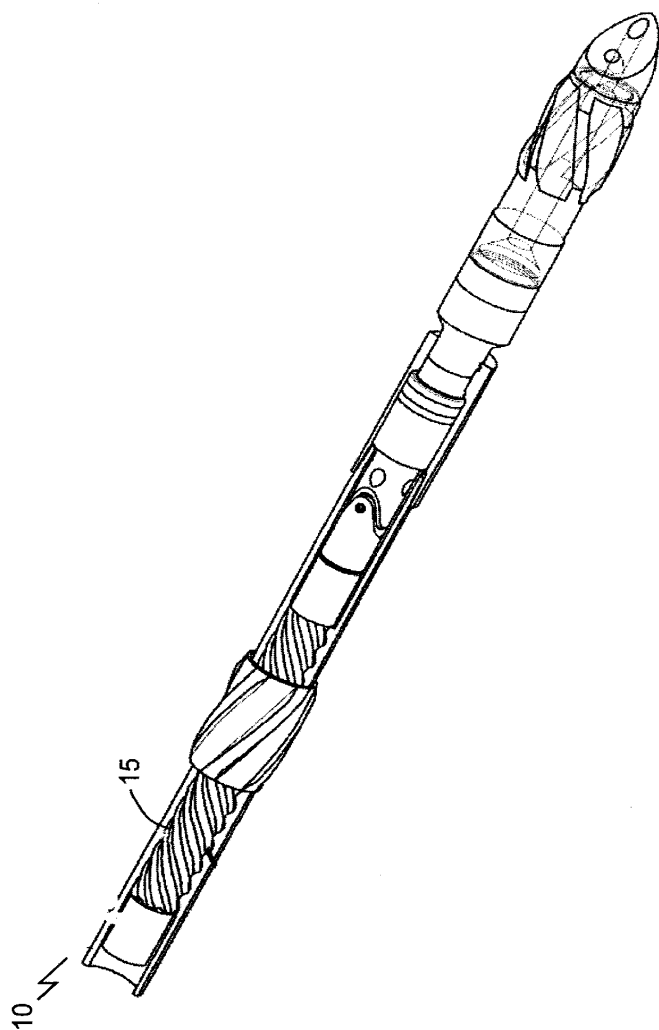


Fig. 27

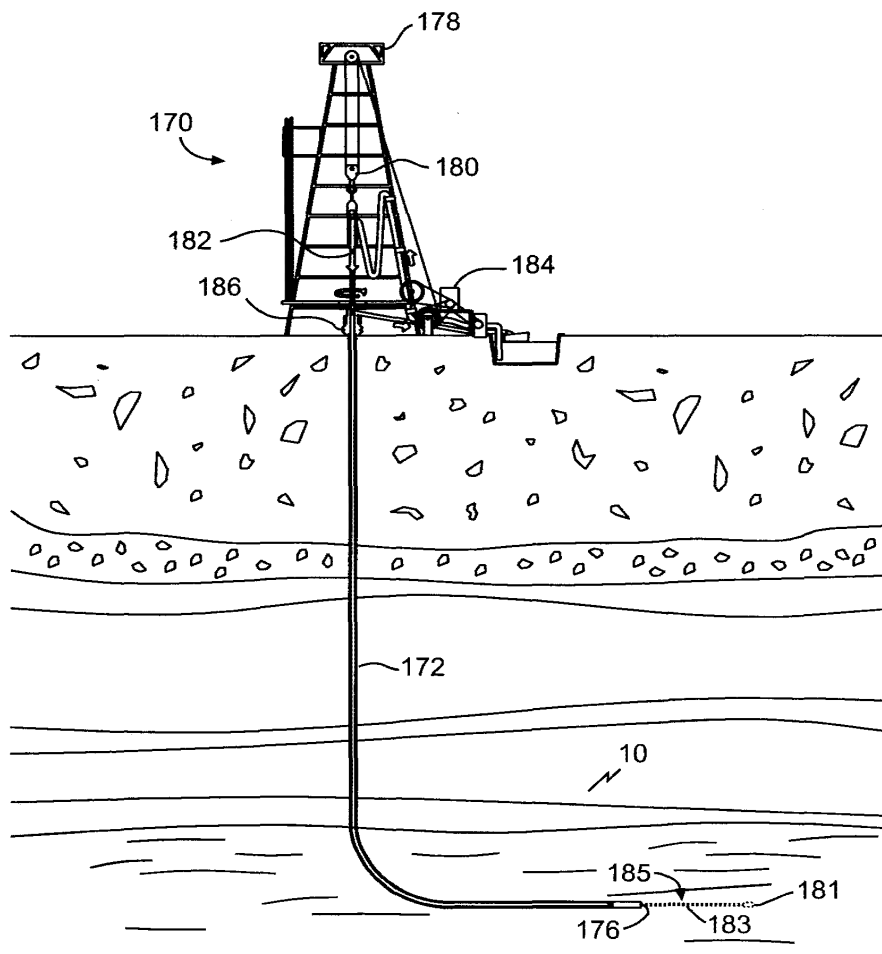


Fig. 28

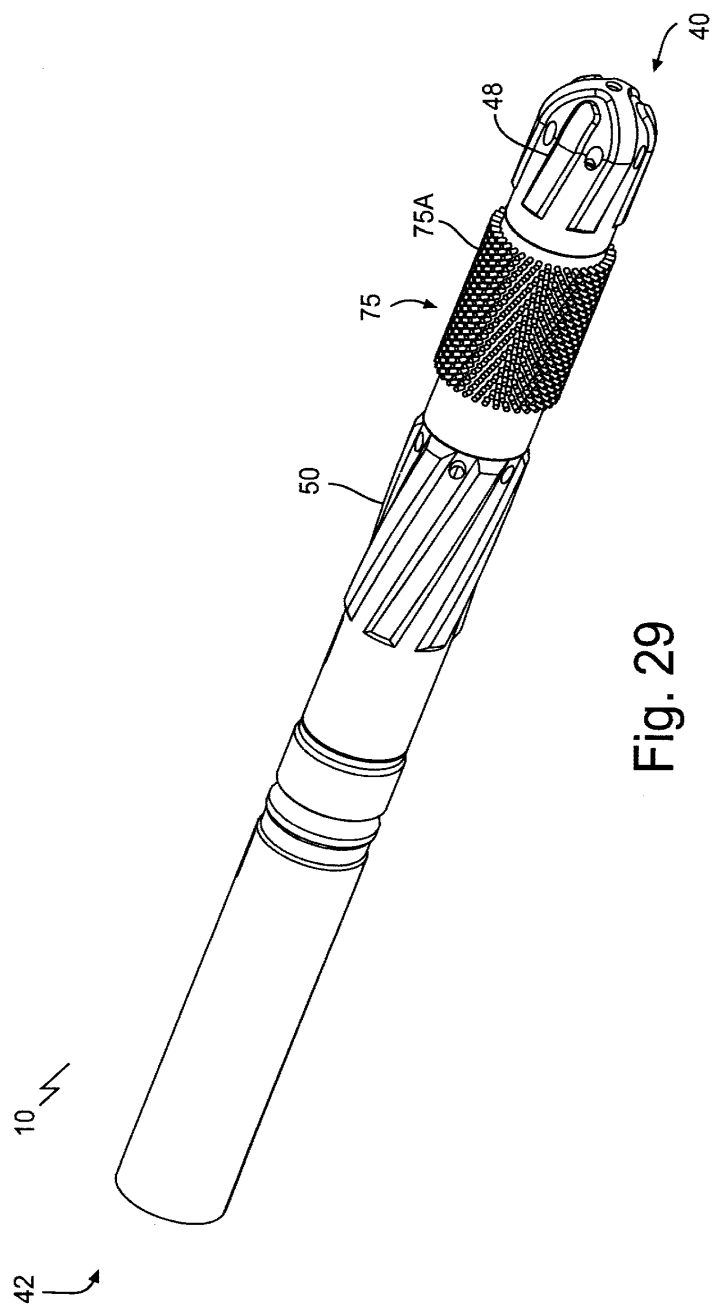


Fig. 29

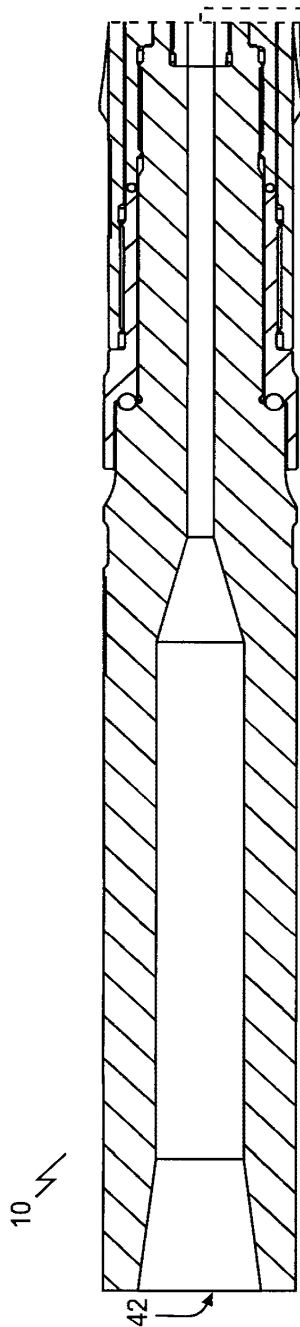


Fig. 30A

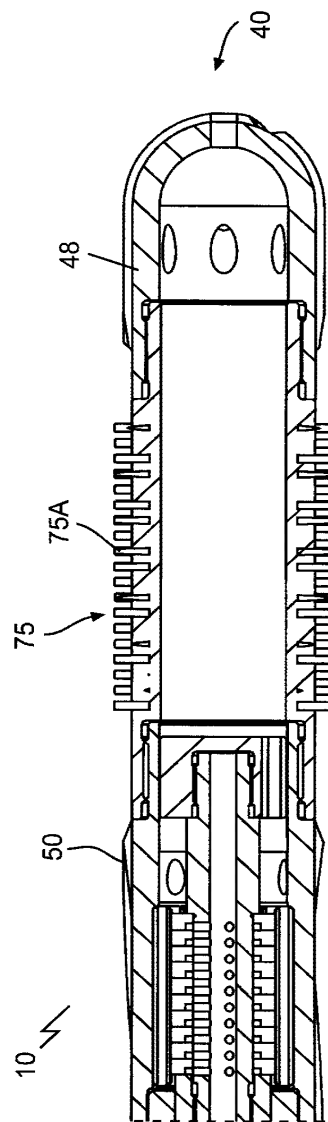


Fig. 30B

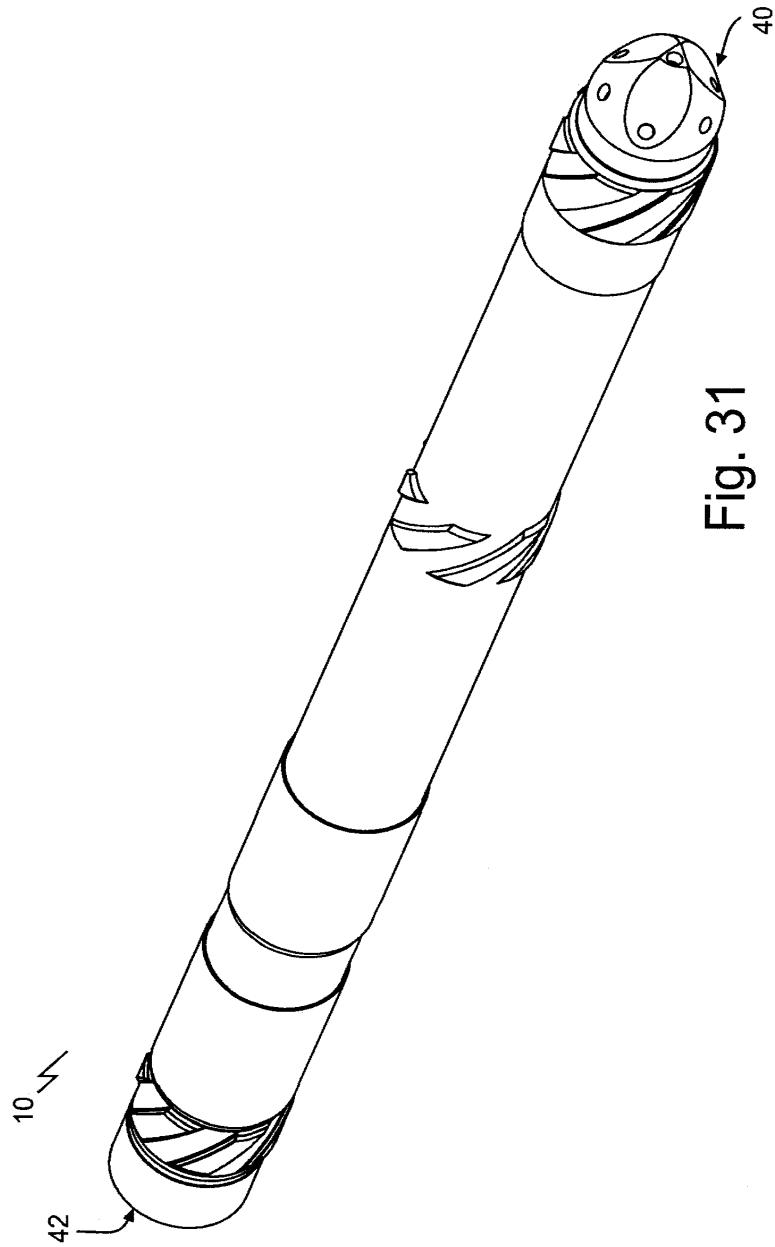


Fig. 31

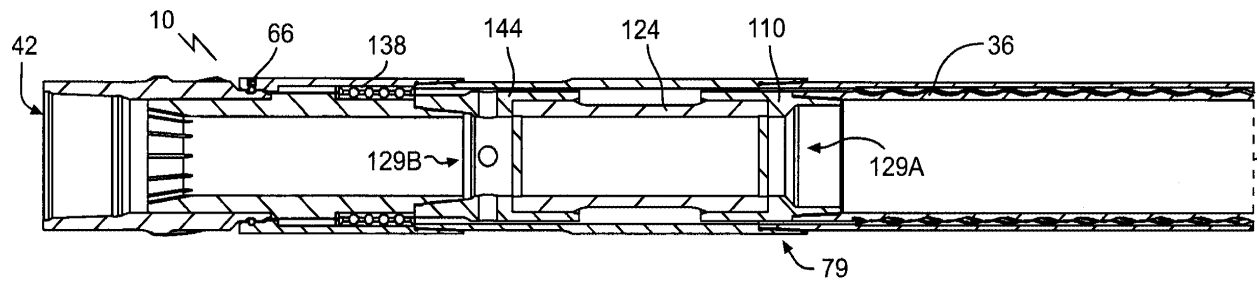


Fig. 32A

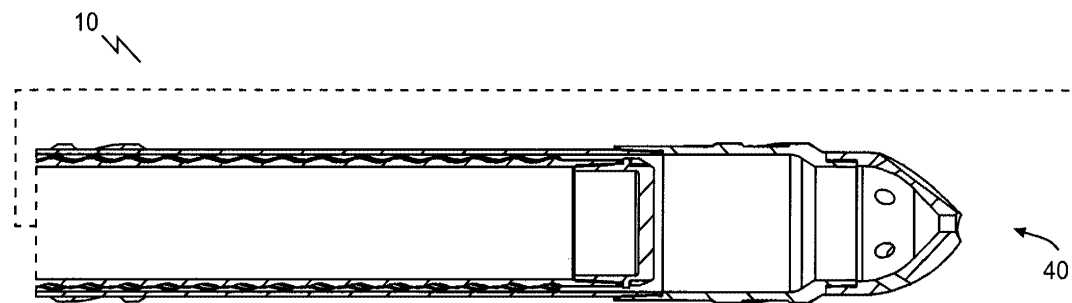


Fig. 32B

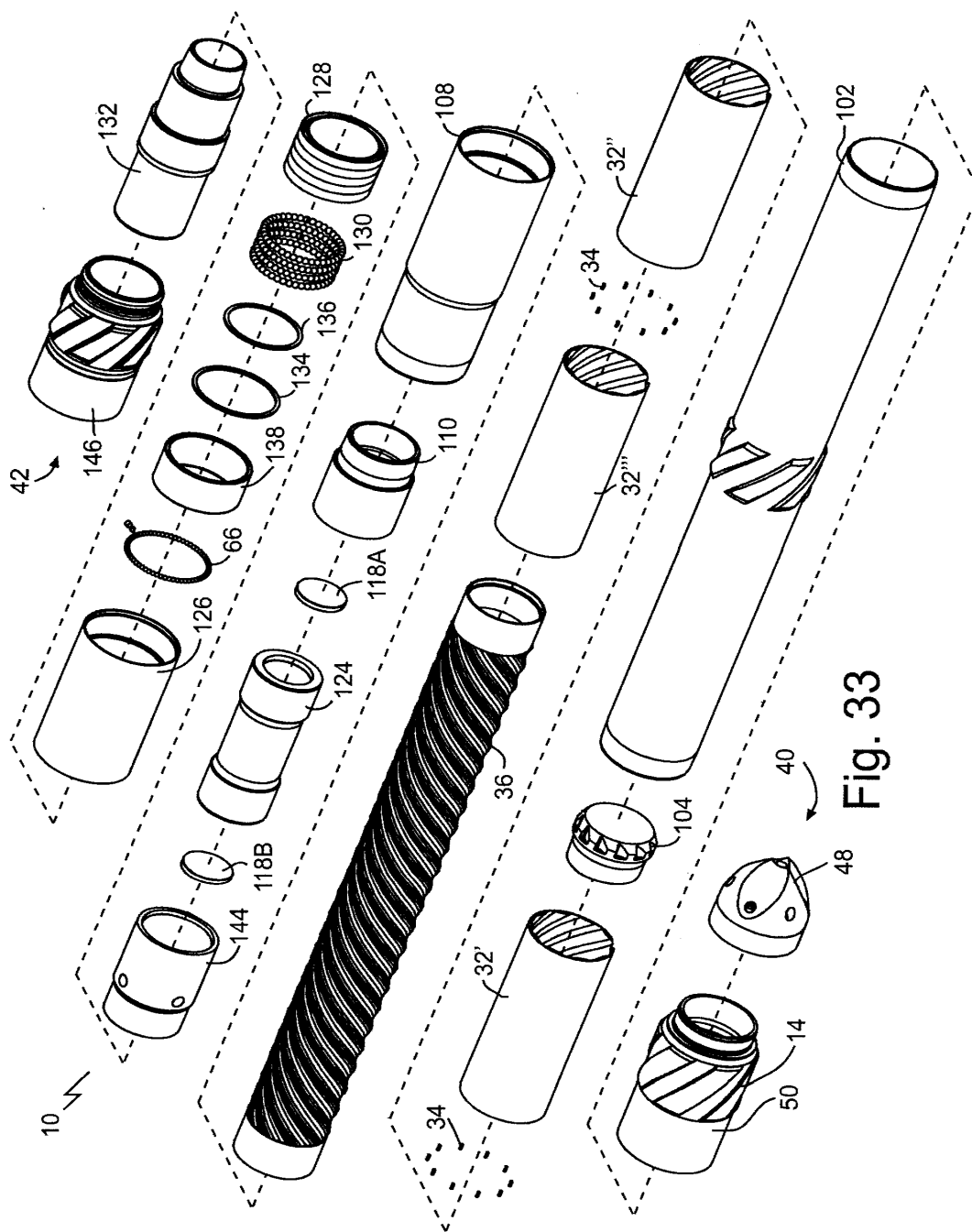


Fig. 33

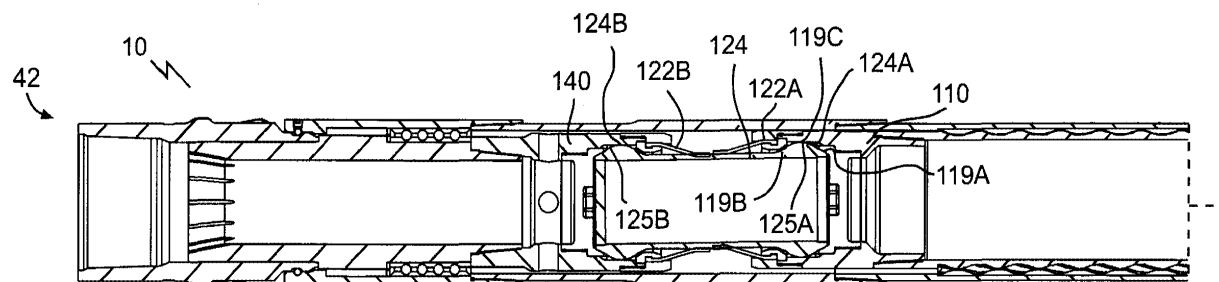


Fig. 34A

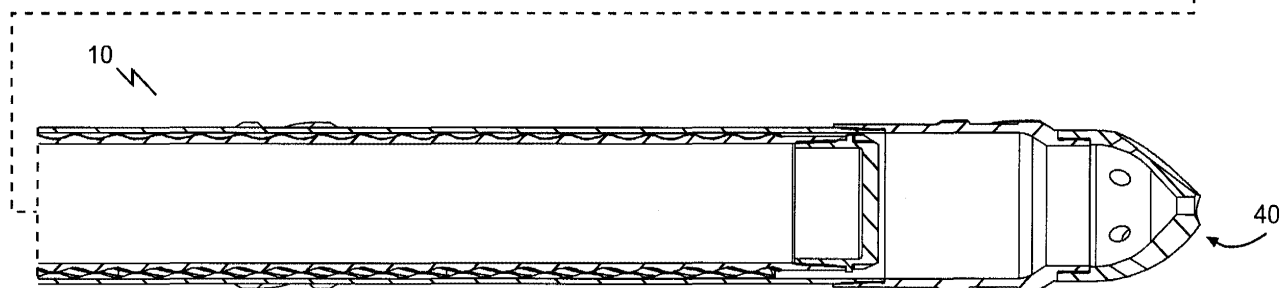


Fig. 34B

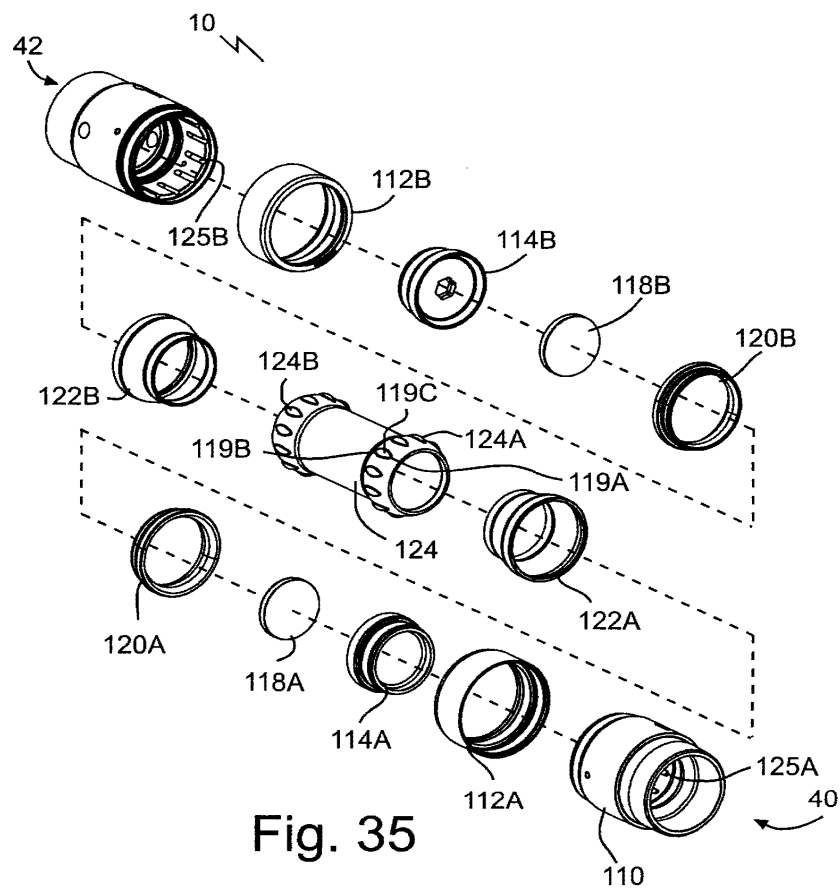


Fig. 35

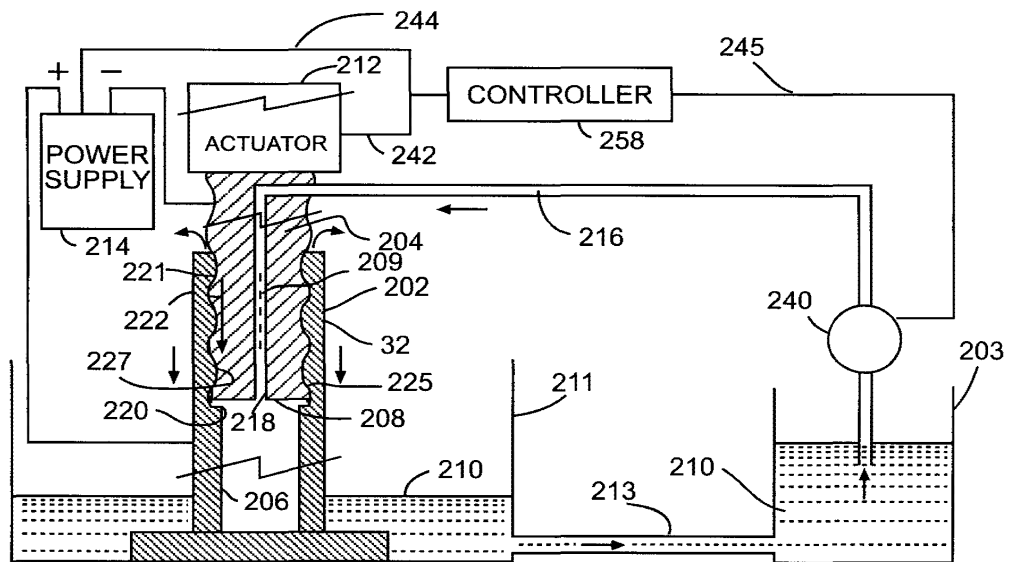


Fig. 36

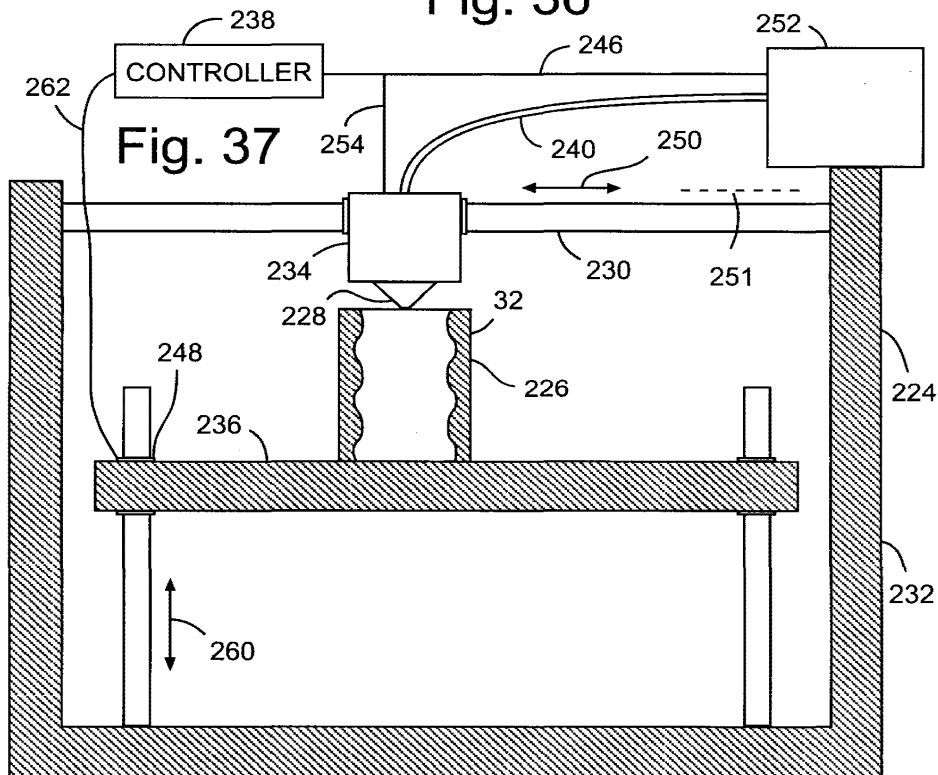


Fig. 37

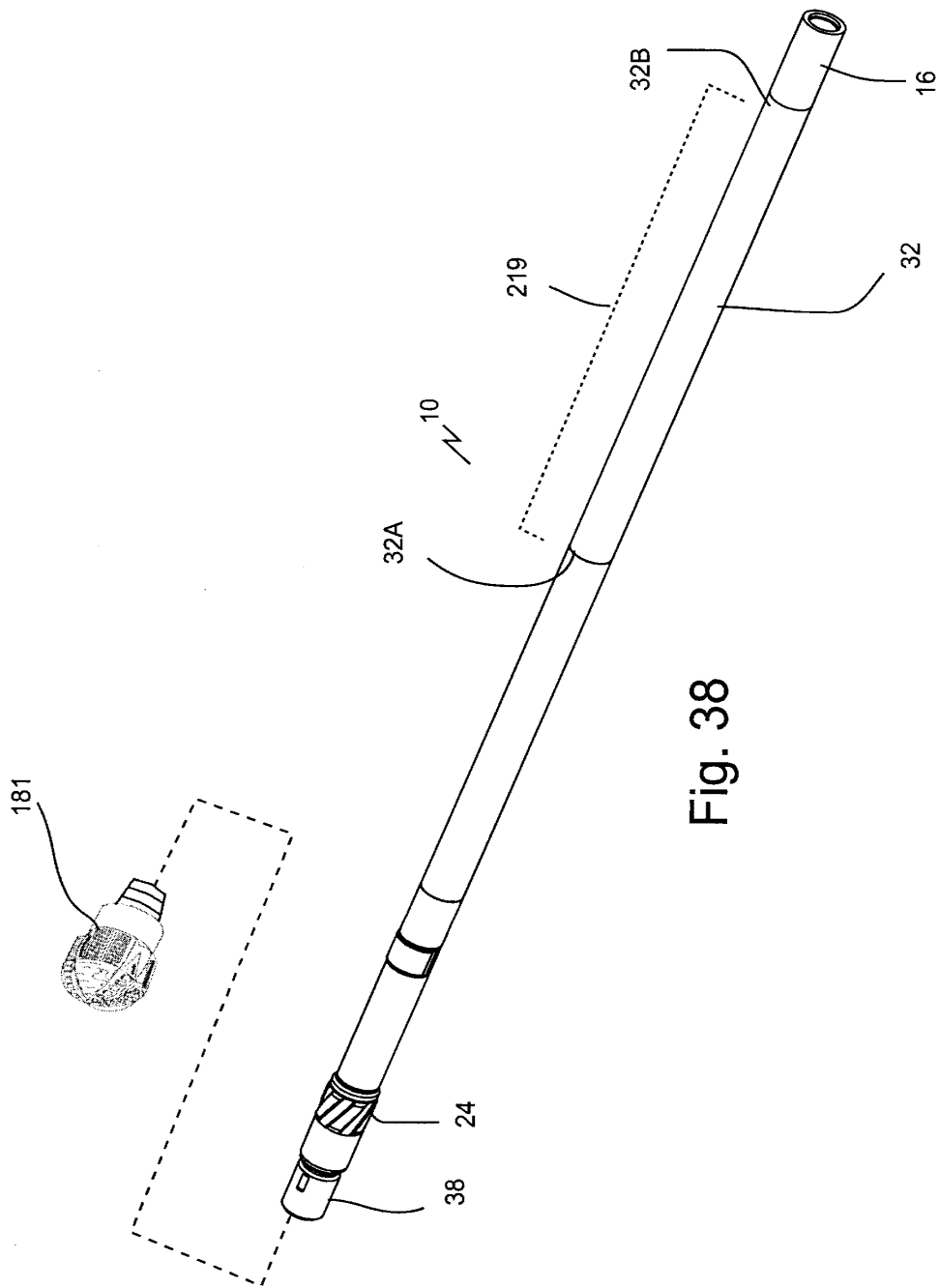
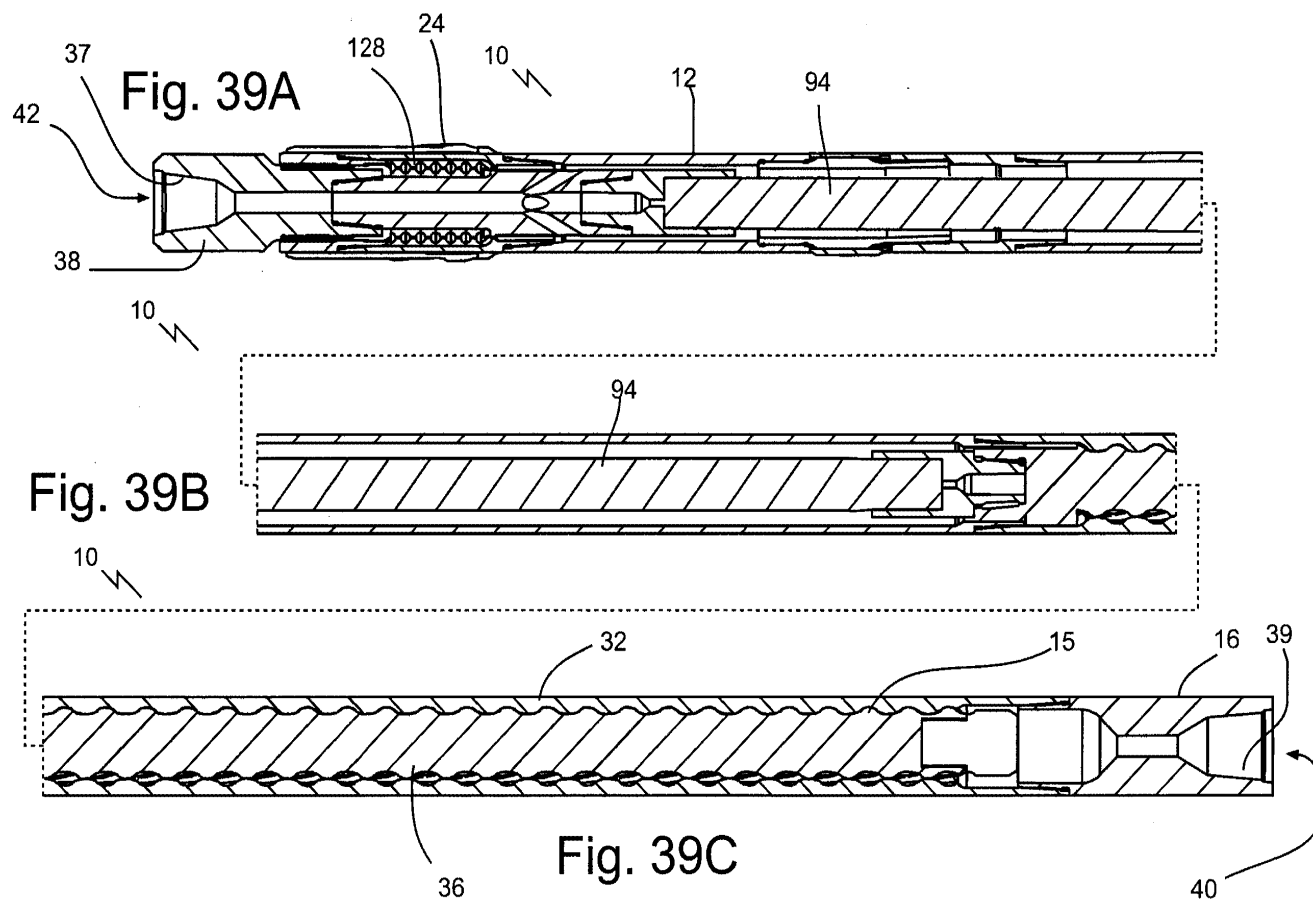


Fig. 38



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

1. A downhole tool comprising:
a progressive cavity section with a stator and a rotor; and
in which the stator, rotor, or stator and rotor are formed by electrochemical
machining (ECM).
2. The downhole tool of claim 1 in which rotor contacting surfaces of the stator, and
stator contacting surfaces of the rotor, are rigid.
3. The downhole tool of claim 2 in which the stator contacting surfaces and the rotor
contacting surfaces are made of metal.
4. The downhole tool of claim 1 in which rotor contacting surfaces of the stator are
defined by an elastomeric coating within the stator.
5. The downhole tool of claim 1 - 4 in which the progressive cavity section is connected
to rotate a reamer part of a casing reamer shoe.
6. The downhole tool of claim 1 - 4 in which the progressive cavity section is connected
to rotate a drill bit.
7. The downhole tool of any one of claim 1 - 6 in which the stator has a length of at
least eighty inches defined between axial ends of the stator.
8. The downhole tool of claim 7 in which the stator has a length of at least one hundred
and fifty inches defined between axial ends of the stator.

9. The downhole tool of claim 8 in which the stator has a length of at least three hundred inches defined between axial ends of the stator.
10. The downhole tool of any one of claim 1 - 9 in which the stator is formed by ECM.
11. A method comprising:
 - positioning the downhole tool of any one of claim 1 - 10 in a well; and
 - pumping fluid to operate the progressive cavity section to rotate the rotor relative to the stator.
12. A method comprising:
 - forming a stator, rotor, or stator and rotor by electrochemical machining (ECM); and
 - forming a downhole tool by inserting the rotor into the stator.
13. The method of claim 12 in which within the downhole tool, rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid.
14. The method of claim 13 in which the stator contacting surfaces and the rotor contacting surfaces are made of metal.
15. The method of claim 12 in which rotor contacting surfaces of the stator are defined by an elastomeric coating within the stator.
16. The method of claim 12 - 15 in which the stator and the rotor within the downhole tool form a progressive cavity power section connected to rotate a reamer part of a casing reamer shoe.
17. The method of claim 12 - 15 in which the stator and the rotor within the downhole tool form a progressive cavity power section connected to rotate a drill bit.

18. The method of any one of claim 12 - 17 in which the stator has a length of at least eighty inches defined between axial ends of the stator.
19. The method of claim 18 in which the stator has a length of at least one hundred and fifty inches defined between axial ends of the stator.
20. The method of claim 19 in which the stator has a length of at least three hundred inches defined between axial ends of the stator.
21. The method of any one of claim 12 - 20 in which forming the stator or rotor by ECM further comprises advancing a cutting tool into or over a workpiece along an axis of the workpiece, with a sidewall of the cutting tool having a helically lobed profile, in which advancing is carried out while:
- an electrical field is established across a gap defined by the sidewall of the cutting tool and a sidewall of the workpiece;
 - an electrolytic solution flows through the gap; and
 - the cutting tool rotates about the axis such that the sidewall of the workpiece takes on a shape that is the inverse of the helically lobed profile of the sidewall of the cutting tool.
22. The method of any one of claim 12 - 20 in which the stator is formed by ECM.
23. A downhole tool comprising:
- a progressive cavity section with a stator and a rotor; and
 - in which the stator is formed from a single integral block of material, and the stator has a length of at least fifty inches defined between axial ends of the stator.
24. The downhole tool of claim 23 in which rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid.

25. The downhole tool of claim 24 in which the stator contacting surfaces and the rotor contacting surfaces are made of metal.

26. The downhole tool of claim 23 in which rotor contacting surfaces of the stator are defined by an elastomeric coating within the stator.

27. The downhole tool of claim 23 - 26 in which the progressive cavity section is connected to rotate a reamer part of a casing reamer shoe.

28. The downhole tool of claim 23 - 26 in which the progressive cavity section is connected to rotate a drill bit.

29. The downhole tool of any one of claim 23 - 28 in which the stator has a length of at least eighty inches defined between axial ends of the stator.

30. The downhole tool of claim 29 in which the stator has a length of at least one hundred and fifty inches defined between axial ends of the stator.

31. The downhole tool of claim 30 in which the stator has a length of at least three hundred inches defined between axial ends of the stator.

32. A method comprising:
positioning the downhole tool of any one of claim 23 - 31 in a well; and
pumping fluid to operate the progressive cavity section to rotate the rotor relative to the stator.

33. A method comprising:
forming a stator from a single integral block of material, in which the stator has a length of at least fifty inches defined between axial ends of the stator; and
assembling a downhole tool by inserting a rotor into the stator.

34. The method of claim 33 in which within the downhole tool, rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid.

35. The method of claim 34 in which the stator contacting surfaces and the rotor contacting surfaces are made of metal.

36. The method of claim 33 in which rotor contacting surfaces of the stator are defined by an elastomeric coating within the stator.

37. The method of claim 33 - 36 in which the stator and the rotor within the downhole tool form a progressive cavity power section connected to rotate a reamer part of a casing reamer shoe.

38. The method of claim 33 - 36 in which the stator and the rotor within the downhole tool form a progressive cavity power section connected to rotate a drill bit.

39. The method of any one of claim 33 - 38 in which the stator has a length of at least eighty inches defined between axial ends of the stator,

40. The method of claim 39 in which the stator has a length of at least one hundred and fifty inches defined between axial ends of the stator.

41. The method of claim 40 in which the stator has a length of at least three hundred inches defined between axial ends of the stator.

42. A downhole tool comprising:
a progressive cavity section with a stator and a rotor; and
in which the stator is formed by plural axial stator sections connected end to end, and adjacent axial stator sections, of the plural axial stator sections, are connected by dowels.

43. The downhole tool of claim 42 further comprising adhesive securing the dowels between adjacent axial stator sections.
44. The downhole tool of any one of claim 42- 181 in which rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid.
45. The downhole tool of claim 44 in which the stator contacting surfaces and the rotor contacting surfaces are made of metal.
46. A method comprising:
positioning the downhole tool of any one of claim 42 - 45 in a well; and
pumping fluid to operate the progressive cavity section to rotate the rotor relative to the stator.
47. A method comprising:
forming a stator by connecting plural axial stator sections together in an end to end using dowels between the plural axial stator sections; and
assembling a downhole tool by inserting a rotor into the stator.
48. The method of claim 47 in which forming the stator further comprises gluing the dowels between adjacent plural axial stator sections using adhesive.
49. The method of any one of claim 47 - 48 further comprising sliding an outer sleeve around the stator to form an interference fit between the stator and the outer sleeve.
50. The method of claim 49 in which sliding is carried out while one or both of a) the stator is cooled below, and b) the outer sleeve is heated above, room temperature.

51. The method of any one of claim 47 - 50 in which within the downhole tool, rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid.
52. The method of claim 51 in which the stator contacting surfaces and the rotor contacting surfaces are made of metal.
53. A downhole tool comprising:
a progressive cavity section with a stator and a rotor; and
in which the stator is formed by three dimensional printing.
54. A method comprising:
forming a stator by three dimensional printing; and
assembling a downhole tool by inserting a rotor into the stator.
55. A method comprising:
forming a hollow rotor sleeve;
forming a stator by three dimensional printing; and
inserting the hollow rotor sleeve into the stator to form a progressive cavity section.
56. A downhole reamer tool, comprising:
a tubular body defining an interior passageway between an uphole end and a downhole end of the tubular body; and
a reamer part mounted to the tubular body between the uphole end and the downhole end, the reamer part being mounted to rotate, relative to the tubular body, around a circumferential path about an outer-facing surface of the tubular body upon application of fluid flow within the interior passageway.
57. The downhole reamer tool of claim 56 further comprising a progressive cavity section with a stator and a rotor, with the progressive cavity section connected to rotate the reamer part.

58. The downhole reamer tool of claim 57 in which the reamer part is mounted or formed on an external part of the stator, and the stator is connected to rotate relative to the tubular body.

59. The downhole reamer tool of claim 58 in which the rotor is fixed in relation to the uphole end and the downhole end of the tubular body.

60. The downhole reamer tool of any one of claim 57 - 59 in which:
the interior passageway is connected to a fluid inlet of the progressive cavity section;
and
the interior passageway includes a motor bypass between an uphole end and a downhole end of the progressive cavity section.

61. The downhole reamer tool of claim 60 in which the motor bypass is coaxial with the tubular body.

62. The downhole reamer tool of any one of claim 60 - 61 in which the fluid inlet comprises a plurality of radial passageways that direct fluid through the interior passageway in a radial direction.

63. The downhole reamer tool of claim 62 in which the plurality of radial passageways comprise a plurality of diverter ports, which are angularly spaced from one another about a reamer tool axis, in which the diverter ports are oriented to have decreasing distance from the downhole end of the tubular body when moving from an entry to an exit of each of the plurality of diverter ports.

64. The reamer tool of any one of claim 60 - 63 in which the interior passageway is connected to a fluid outlet of the progressive cavity section.

65. The reamer tool of claim 64 in which the fluid outlet and the fluid inlet are defined through the rotor.
66. The downhole reamer tool of any one of claim 57 - 65 in which the reamer part is mounted on respective bearings at an uphole end and a downhole end of the reamer part.
67. The downhole reamer tool of claim 66 in which the respective bearings comprise bearing packs.
68. The downhole reamer tool of any one of claim 66 - 67 in which the respective bearings are exposed to fluid within the interior passageway during use.
69. The downhole reamer tool of any one of claim 57 - 68 in which rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid during use.
70. The downhole reamer tool of claim 69 in which the stator contacting surfaces and the rotor contacting surfaces are made of metal.
71. The downhole reamer tool of any one of claim 57 - 70 in which the stator is formed by plural axial stator sections connected end to end.
72. The downhole reamer tool of claim 71 in which adjacent axial stator sections, of the plural axial stator sections, are connected by dowels.
73. The downhole reamer tool of claim 72 further comprising adhesive securing the dowels between adjacent axial stator sections.
74. The downhole reamer tool of any one of claim 71 - 73 in which the plural axial stator sections are held together within an outer sleeve, with an interference fit between the plural axial stator sections and the outer sleeve.

75. The downhole reamer tool of any one of claim 57 - 70 in which the stator is formed as a single piece by three dimensional printing.
76. The downhole reamer tool of any one of claim 56 - 75 further comprising respective tubing connectors at the uphole end and the downhole end of the tubular body.
77. The downhole reamer tool of any one of claim 56 - 76 in which the reamer part comprises one or more of reamer blades and polycrystalline diamond cutters.
78. The downhole reamer tool of claim 72 in which the reamer part comprises reamer blades configured to act as stabilizer blades to center the downhole reamer tool within a well.
79. The downhole reamer tool of any one of claim 56 - 73 in which the reamer part comprises a sleeve mounted coaxial with the tubular body.
80. A casing or drill string comprising the reamer tool of any one of claim 56 - 79.
81. A method comprising:
positioning a tubing string downhole in a well, the tubing string including a reamer tool; and
pumping fluid through the tubing string to rotate a reamer part, of the reamer tool, relative to an uphole end tubing connector and a downhole end tubing connector of the reamer tool.
82. The method of claim 81 in which the tubing string is a drilling string or a casing string.
83. The method of claim 82 in which the tubing string is a drilling string.

84. The method of claim 83 in which the drilling string comprises a fluid-actuated drilling motor and a drill bit, both located in a downhole direction relative to the reamer tool, and in which pumping fluid through the tubing string causes the fluid-actuated drilling motor to rotate the drill bit relative to the reamer tool.

85. The method of any one of claim 81 - 84 in which the tubing string remains angularly stationary while pumping fluid to rotate the reamer part.

86. The method of any one of claim 81 - 85 in which the reamer tool comprises the reamer tool of any one of claim 56 - 79.

87. A casing reamer shoe comprising:
a progressive cavity section with a stator and a rotor;
a reamer part mounted to be rotated by the stator or the rotor; and
in which the rotor is formed by a hollow helically lobed sleeve.

88. The casing reamer shoe of claim 87 in which a hollow interior, defined by the hollow helically lobed sleeve, is closed.

89. The casing reamer shoe of claim 88 further comprising a wall within the hollow interior.

90. The casing reamer shoe of any one of claim 88 - 89 in which opposed axial ends of the hollow helically lobed sleeve are blocked by respective end walls.

91. The casing reamer shoe of any one of claim 89 - 90 in which an uphole facing surface of the wall is striated.

92. The casing reamer shoe of any one of claim 87 - 91 in which rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid during use.

93. The casing reamer shoe of claim 92 in which the stator contacting surfaces and the rotor contacting surfaces are made of metal.
94. The casing reamer shoe of any one of claim 87 - 93 in which the stator is formed by plural axial stator sections connected end to end.
95. The casing reamer shoe of claim 94 in which adjacent axial stator sections, of the plural axial stator sections, are connected by dowels.
96. The casing reamer shoe of claim 95 further comprising adhesive securing the dowels between adjacent axial stator sections.
97. The casing reamer shoe of any one of claim 94 - 96 in which the plural axial stator sections are held together within an outer sleeve, with an interference fit between the plural axial stator sections and the outer sleeve.
98. A casing string comprising casing connected to the downhole reamer shoe of any one of claim 87 - 97, in which an inner diameter of the hollow helically lobed sleeve is sized to be commensurate with an inner diameter of the casing.
99. A method comprising:
positioning a casing string downhole in a well, with a downhole end of the casing string mounting a casing reamer shoe; and
pumping fluid through the casing string to operate a progressive cavity section of the casing reamer shoe to rotate a reamer part of the casing reamer shoe, in which a rotor of the progressive cavity section is formed by a hollow helically lobed sleeve.
100. The method of claim 99 in which a hollow interior, defined by the hollow helically lobed sleeve, is closed.

101. The method of any one of claim 99 - 100 further comprising pumping cement through the casing reamer shoe and up an annulus defined between the well and the casing string.
102. The method of claim 101 further comprising drilling out the casing reamer shoe.
103. The method of claim 102 in which an uphole facing surface of the casing reamer shoe is striated.
104. The method of any one of claim 99 - 103 in which a stator of the progressive cavity section is formed by plural axial stator sections connected end to end.
105. The method of claim 104 further comprising, prior to positioning the casing string downhole, assembling the casing reamer shoe by connecting adjacent axial stator sections, of the plural axial stator sections, with dowels.
106. The method of claim 105 in which assembling further comprises using an adhesive to glue the dowels between adjacent axial stator sections.
107. The method of any one of claim 105 - 106 in which assembling further comprises sliding an outer sleeve around the plural axial stator sections, to form an interference fit between the plural axial stator sections and the outer sleeve.
108. The method of claim 107 in which sliding is carried out while one or both of a) the plural axial stator sections are cooled below, and b) the outer sleeve is heated above, room temperature.

109. The method of any one of claim 99 - 108 in which an inner diameter of the hollow helically lobed sleeve is sized to be commensurate with an inner diameter of casing of the casing string.

110. A downhole reamer tool comprising:
a progressive cavity section with a stator and a rotor, with the rotor having an uphole end tubing connector, and the stator mounted to rotate relative to the rotor upon application of fluid flow between the rotor and the stator; and
a reamer part mounted to be rotated by the stator.

111. The downhole reamer tool of claim 110 forming a casing reamer shoe, and further comprising a nose forming a downhole end of the casing reamer shoe, in which the stator is connected to rotate the nose.

112. The downhole reamer tool of claim 111 in which the casing reamer shoe defines an interior passageway that supplies fluid to the progressive cavity section and to outlet ports within the nose.

113. The downhole reamer tool of claim 112 in which the outlet ports include outlet ports directed in one or both of axial and radial directions.

114. The downhole reamer tool of any one of claim 110 - 113 in which the rotor is formed by a hollow helically lobed sleeve.

115. The downhole reamer tool of any one of claim 110 - 114 further comprising:
a tubular body defining the uphole end tubing connector and mounting the rotor; and
a stabilizer mounted to the tubular body.

116. The downhole reamer tool of any one of claim 110 - 115 further comprising a universal joint connected between the rotor and a bearing on the tubular body, the universal joint being structured to convert eccentric motion of the rotor into concentric motion.

117. The downhole reamer tool of any one of claim 110 - 116 in which rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid during use.

118. The downhole reamer tool of claim 117 in which the stator contacting surfaces and the rotor contacting surfaces are made of metal.

119. A casing or drill string comprising the downhole reamer tool of any one of claim 110 - 118.

120. A method comprising:
positioning a tubing string downhole in a well, with the tubing string mounting a downhole reamer tool; and
pumping fluid through the tubing string to operate a progressive cavity section, which has a stator and a rotor, with a reamer part connected to rotate relative to the stator, in which pumping fluid causes the stator and reamer part to rotate relative to the tubing string and the rotor.

121. A casing reamer shoe comprising:
a tubular body with an uphole end tubing connector defining an interior passageway;
a reamer part mounted to rotate relative to the tubular body at a first speed under fluid flow in the interior passageway; and
a nose mounted to rotate relative to the tubular body at a second speed under fluid flow in the interior passageway, the first speed being different than the second speed.

122. The casing reamer shoe of claim 121 further comprising:
a first motor connected to rotate the nose relative to the tubular body; and

a second motor connected to rotate the reamer part relative to the tubular body.

123. The casing reamer shoe of claim 122 in which:
the first motor comprises a progressive cavity section with a stator and a rotor; and
the second motor comprises an impeller.
124. The casing reamer shoe of claim 123 in which the stator is connected to the tubular body, and the rotor is connected to rotate the nose.
125. The casing reamer shoe of any one of claim 123 - 124 in which the interior passageway has a plurality of radial passageways that direct fluid in a radial direction against the impeller to drive the impeller and rotate the reamer part.
126. The casing reamer shoe of claim 121 further comprising a progressive cavity section with a stator and a rotor, in which the stator or the rotor is connected to rotate the reamer part or the nose.
127. The casing reamer shoe of any one of claim 121 and 126 further comprising an impeller connected to rotate the reamer part or the nose.
128. The casing reamer shoe of any one of claim 122 - 127 in which the first speed is faster than the second speed.
129. The casing reamer shoe of any one of claim 121 - 128 in which the nose is structured as one or both a drill bit or a reamer.
130. The casing reamer shoe of claim 129 in which the interior passageway is connected to supply fluid to outlet ports within the nose.

131. The casing reamer shoe of claim 130 in which the outlet ports include outlet ports directed in one or both of axial and radial directions.
132. The casing reamer shoe of any one of claim 123 - 131 in which rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid during use.
133. The casing reamer shoe of claim 132 in which the stator contacting surfaces and the rotor contacting surfaces are made of metal.
134. A method comprising:
positioning a casing string downhole in a well, with a downhole end of the casing string mounting a casing reamer shoe; and
pumping fluid through the casing string to rotate a reamer part and a nose, both of the casing reamer shoe, at a first speed and a second speed, relative to an uphole end tubing connector of the casing reamer shoe, with the first speed being different than the second speed.
135. The method of claim 134 in which pumping fluid further comprises pumping fluid to operate a progressive cavity section of the casing reamer shoe to rotate one or both the reamer part and the nose.
136. The method of any one of claim 134 - 135 in which pumping fluid further comprises pumping fluid to operate an impeller to rotate one or both the reamer part and the nose.
137. The method of any one of claim 134 - 136 in which pumping fluid further comprises supplying fluid to outlet ports within the nose to spray jets of fluid into the well from the nose.
138. The method of any one of claim 134 - 137 in which the first speed is faster than the second speed.

139. A casing reamer shoe comprising:
a tubular body;
the tubular body having a progressive cavity section with a stator and a rotor;
a reamer part connected to be rotated by the stator or rotor; and
a universal joint connected between the reamer part and the rotor, or between the rotor and a bearing on the tubular body, the universal joint being structured to convert eccentric motion of the rotor into concentric motion.
140. The casing reamer shoe of claim 139 in which:
the universal joint comprises a shaft mounted for rotation within the tubular body;
and
the shaft and the rotor mate via cooperating circumferential arrays of splines.
141. The casing reamer shoe of claim 140 in which the cooperating circumferential arrays of splines mesh via a circumferential array of pins.
142. The casing reamer shoe of claim 141 in which each pin, of the circumferential array of pins, is tapered with decreasing radius from a central portion to each axial end of the pin.
143. The casing reamer shoe of any one of claim 140 - 142 in which the cooperating circumferential arrays of splines comprise a radially-outward facing array of splines and a radially-inward facing array of splines.
144. The casing reamer shoe of any one of claim 140 - 143 in which:
the cooperating circumferential arrays of splines are located at or near a first axial end of the shaft; and
the shaft connects to the reaming part, or to a bearing on the tubular body, via a second set of cooperating circumferential arrays of splines, which are located at or near a second axial end of the shaft.

145. The casing reamer shoe of any one of claim 140 - 144 in which the shaft is a hollow shaft sleeve.
146. The casing reamer shoe of claim 145 in which a hollow interior, defined by the hollow shaft sleeve, is closed.
147. The casing reamer shoe of any one of claim 139 - 146 in which the universal joint is connected between the reamer part and the rotor.
148. The casing reamer shoe of any one of claim 139 - 147 in which the universal joint is connected between the rotor and a bearing on the tubular body.
149. The casing reamer shoe of any one of claim 139 - 148 in which the rotor is formed by a hollow helically lobed sleeve.
150. The casing reamer shoe of any one of claim 139 - 149 in which rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid during use.
151. The casing reamer shoe of claim 150 in which the stator contacting surfaces and the rotor contacting surfaces are made of metal.
152. The casing reamer shoe of any one of claim 139 - 151 in which the stator is formed by plural axial stator sections connected end to end.
153. The casing reamer shoe of claim 152 in which the plural axial stator sections are held together within an outer sleeve, with an interference fit between the plural axial stator sections and the outer sleeve.
154. A method comprising:

positioning a casing string downhole in a well, with a downhole end of the casing string mounting a casing reamer shoe; and

pumping fluid through the casing string to operate a progressive cavity section of the casing reamer shoe to rotate a reamer part, in which a universal joint connects between the reamer part and a rotor of the progressive cavity section, or between the rotor and a bearing on the casing reamer shoe, the universal joint being structured to convert eccentric motion of the rotor into concentric motion.

155. A downhole reamer tool comprising:

a tubular body with an uphole end tubing connector defining an interior passageway;

a reamer part mounted to rotate relative to the tubular body;

an impeller mounted within the tubular body and connected to rotate the reamer part;

and

the interior passageway having a plurality of radial passageways that direct fluid through the interior passageway in a radial direction against the impeller to drive the impeller and rotate the reamer part.

156. The downhole reamer tool of claim 155 in which the impeller comprises a circumferential array of fins on a radially inward facing surface of a sleeve that mounts the impeller to the tubular body.

157. The downhole reamer tool of claim 156 in which the circumferential array of fins are oriented parallel with an axis of the downhole reamer tool.

158. The downhole reamer tool of any one of claim 155 - 157 in which the plurality of radial passageways are defined by slots in respective axial faces of each of a plurality of ring plates stacked axially one on the other.

159. The downhole reamer tool of claim 158 in which each slot is curved or angled to eject fluid at non-zero angles relative to a radius defined by the respective ring plate and passing through a fluid exit end of the slot.

160. The downhole reamer tool of any one of claim 158 - 159 in which the plurality of ring plates are stacked around a cylindrical wall of and coaxial with a collar, in which the plurality of radial passageways are defined from a central bore of the collar through the cylindrical wall of the collar.

161. The downhole reamer tool of claim 160 in which a pair of flanges, secured to or formed by the collar, compress the plurality of ring plates on the collar.

162. The downhole reamer tool of claim 161 in which an uphole flange of the pair of flanges connects to the tubular body.

163. The downhole reamer tool of any one of claim 160 - 162 in which the cylindrical wall has an out-of-round circumferential profile that meshes with a corresponding inner circumferential profile of the plurality of ring plates.

164. The downhole reamer tool of claim 163 in which the out-of-round circumferential profile is polygonal.

165. The downhole reamer tool of any one of claim 155 - 164 forming a casing reamer shoe with a nose that is structured as one or both a drill bit or a reamer.

166. The downhole reamer tool of claim 165 in which the interior passageway extends from the impeller to outlet ports in the nose.

167. The downhole reamer tool of any one of claim 165 - 166 in which the impeller is connected to rotate the nose.

168. The downhole reamer tool of any one of claim 165 - 167 in which the nose comprises one or more of blades and polycrystalline diamond cutters.

169. The downhole reamer tool of any one of claim 165 - 168 in which the tubular body further comprises a progressive cavity section connected to rotate the nose independent of the rotation of the reamer part by the impeller.

170. The downhole reamer tool of claim 169 in which:
the progressive cavity section comprises a rotor and a stator; and
rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid during use.

171. The downhole reamer tool of claim 170 in which the stator contacting surfaces and the rotor contacting surfaces are made of metal.

172. The downhole reamer tool of any one of claim 155 - 171 further comprising a wire brush scraper on an external surface of the downhole reamer tool.

173. A casing or drill string comprising the downhole reamer tool of any one of claim 156 - 172.

174. A method comprising:
positioning a tubing string downhole in a well, with the tubing string mounting a downhole reamer tool; and
pumping fluid through the tubing string to direct fluid through a plurality of radial passageways in a radial direction against an impeller, of the downhole reamer tool, to drive the impeller and rotate the reamer part, relative to the downhole reamer tool.

175. A casing reamer shoe comprising:

a progressive cavity section with a stator and a rotor;
a reamer part mounted to be rotated by the stator or the rotor; and
in which rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid during use.

176. The casing reamer tool of claim 175 in which rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid during use.

177. The casing reamer tool of claim 176 in which the stator contacting surfaces and the rotor contacting surfaces are made of metal.

ABSTRACT OF THE DISCLOSURE

Various downhole tools, such as drilling motors, drilling tools, reamer tools, casing reamer shoes, and related methods of installation, assembly and use. Casing reamer shoes and drilling reamers or motors may have internal impellers, progressive cavity pumps, hollow rotors and other parts, universal joints, and other features. A progressive cavity section may have a rotor and a stator. Rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, may be rigid during use. The stator contacting surfaces and the rotor contacting surfaces may be made of metal. After the casing is run, the casing is cemented and the reamer shoe drilled out.



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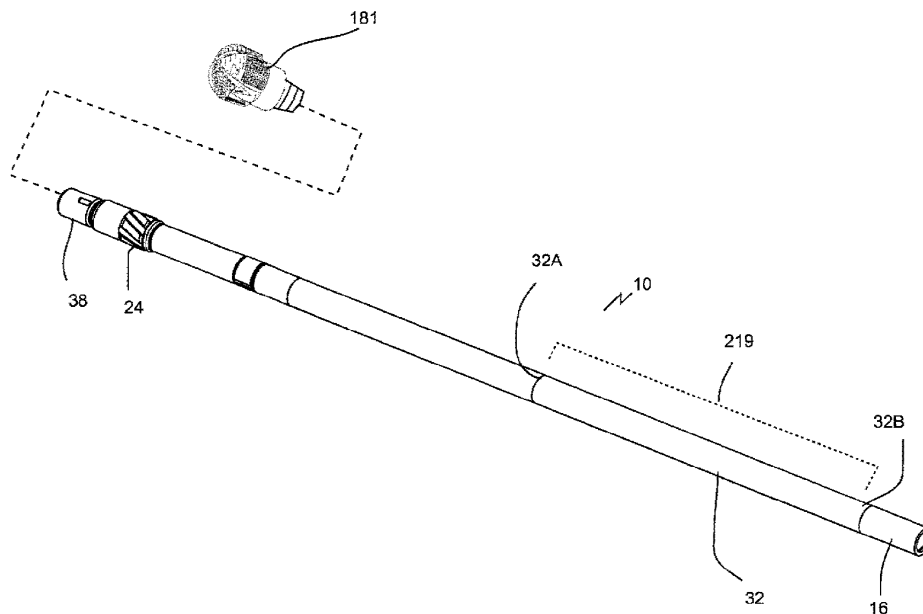
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(71) Demandeur/Applicant:
INFOCUS ENERGY SERVICES INC., CA

(72) Inventeurs/Inventors:
PEARSON, ALLAN, CA;
LUCHAK, MARK, CA;
SCHEMING, OXANA, CA;
OSATCHUK, MATT, CA;
VENABLES, ERIN, CA;
NKWOCHA, CHIMERE, CA;
SAMUEL, GEOFF, CA;

(54) Titre : OUTILS DE FOND DE TROU A SECTIONS DE CAVITE PROGRESSIVES, ET METHODES D-UTILISATION
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(54) Title: DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND RELATED METHODS OF USE AND
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(57) Abrégé/Abstract:

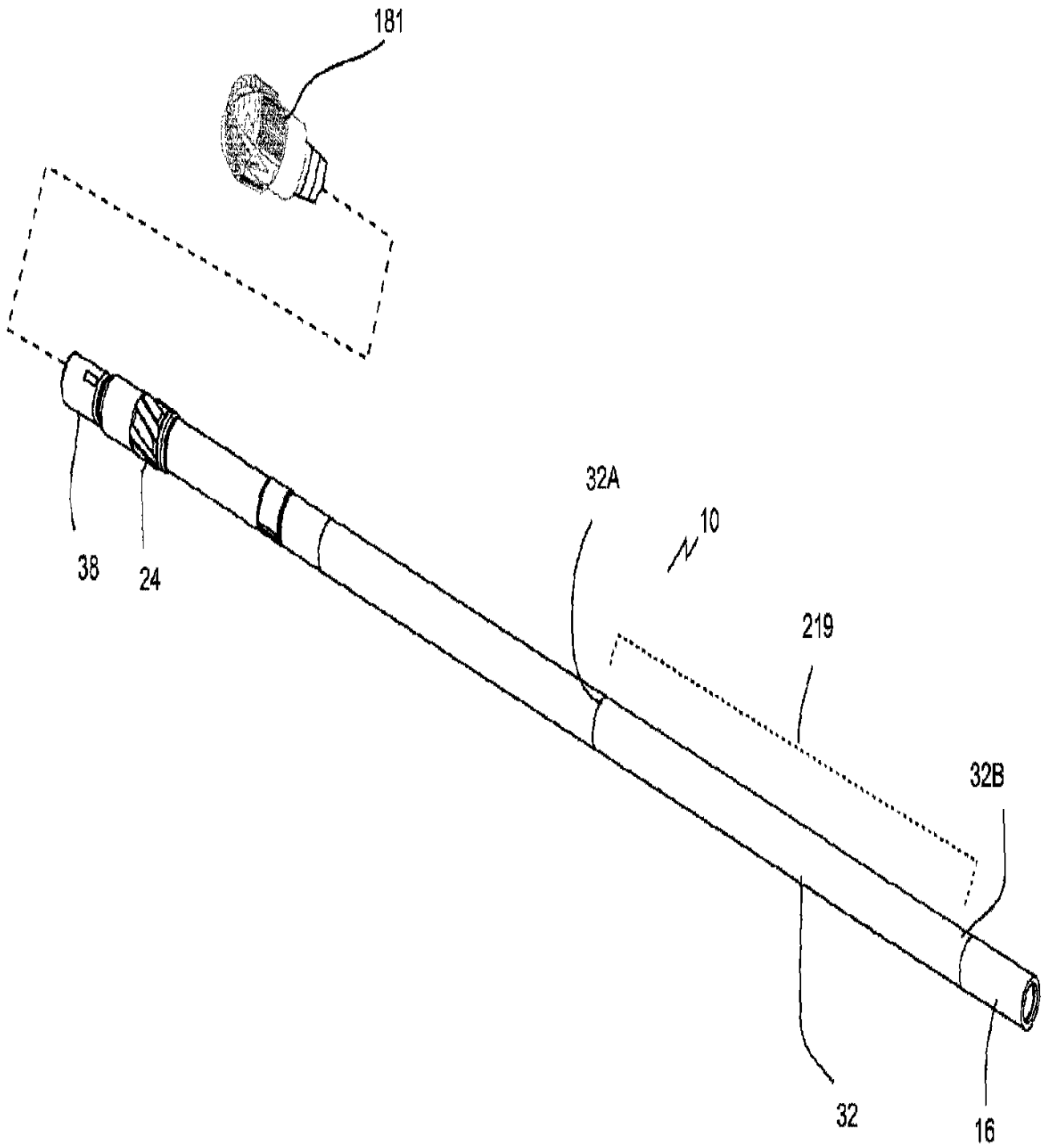
Various downhole tools, such as drilling motors, drilling tools, reamer tools, casing reamer shoes, and related methods of installation, assembly and use. Casing reamer shoes and drilling reamers or motors may have internal impellers, progressive cavity

(72) **Inventeurs(suite)/Inventors(continued)**: KJELLBOTN, PETER, CA

(74) **Agent**: NISSEN, ROBERT A.

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pumps, hollow rotors and other parts, universal joints, and other features. A progressive cavity section may have a rotor and a stator. Rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, may be rigid during use. The stator contacting surfaces and the rotor contacting surfaces may be made of metal. After the casing is run, the casing is cemented and the reamer shoe drilled out.



1. A downhole tool comprising:
a progressive cavity section with a stator and a rotor; and
in which the stator, rotor, or stator and rotor are formed by electrochemical machining (ECM).
2. The downhole tool of claim 1 in which rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid.
3. The downhole tool of claim 2 in which the stator contacting surfaces and the rotor contacting surfaces are made of metal.
4. The downhole tool of claim 1 in which rotor contacting surfaces of the stator are defined by an elastomeric coating within the stator.
5. The downhole tool of claim 1 - 4 in which the progressive cavity section is connected to rotate a reamer part of a casing reamer shoe.
6. The downhole tool of claim 1 - 4 in which the progressive cavity section is connected to rotate a drill bit.
7. The downhole tool of any one of claim 1 - 6 in which the stator has a length of at least eighty inches defined between axial ends of the stator.
8. The downhole tool of claim 7 in which the stator has a length of at least one hundred and fifty inches defined between axial ends of the stator.
9. The downhole tool of claim 8 in which the stator has a length of at least three hundred inches defined between axial ends of the stator.
10. The downhole tool of any one of claim 1 - 9 in which the stator is formed by ECM.

11. A method comprising:
positioning the downhole tool of any one of claim 1 - 10 in a well; and
pumping fluid to operate the progressive cavity section to rotate the rotor relative to the stator.
12. A method comprising:
forming a stator, rotor, or stator and rotor by electrochemical machining (ECM); and
forming a downhole tool by inserting the rotor into the stator.
13. The method of claim 12 in which within the downhole tool, rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid.
14. The method of claim 13 in which the stator contacting surfaces and the rotor contacting surfaces are made of metal.
15. The method of claim 12 in which rotor contacting surfaces of the stator are defined by an elastomeric coating within the stator.
16. The method of claim 12 - 15 in which the stator and the rotor within the downhole tool form a progressive cavity power section connected to rotate a reamer part of a casing reamer shoe.
17. The method of claim 12 - 15 in which the stator and the rotor within the downhole tool form a progressive cavity power section connected to rotate a drill bit.
18. The method of any one of claim 12 - 17 in which the stator has a length of at least eighty inches defined between axial ends of the stator.
19. The method of claim 18 in which the stator has a length of at least one hundred and fifty inches defined between axial ends of the stator.

20. The method of claim 19 in which the stator has a length of at least three hundred inches defined between axial ends of the stator.

21. The method of any one of claim 12 - 20 in which forming the stator or rotor by ECM further comprises advancing a cutting tool into or over a workpiece along an axis of the workpiece, with a sidewall of the cutting tool having a helically lobed profile, in which advancing is carried out while:

an electrical field is established across a gap defined by the sidewall of the cutting tool and a sidewall of the workpiece;

an electrolytic solution flows through the gap; and

the cutting tool rotates about the axis such that the sidewall of the workpiece takes on a shape that is the inverse of the helically lobed profile of the sidewall of the cutting tool.

22. The method of any one of claim 12 - 20 in which the stator is formed by ECM.

DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND RELATED METHODS OF USE AND ASSEMBLY

TECHNICAL FIELD

[0001] This document relates to downhole tools with progressive cavity sections, and related methods of use and assembly.

BACKGROUND

[0002] Progressive cavity sections, such as power sections and pumps are used in downhole tools, particularly in drilling and production applications. Casing reamer shoes have been used with a progressive cavity power section to achieve a reaming function. Multi-part stators are known, as are non-elastomeric stators. Counter-weighted, hollow stators are known. Drilling motors and other drilling tools use progressive cavity sections. United States patent nos. 6,241,494, 4,764,094, 5,221,197, United States patent publication nos. 2010/0032170 and 2010/0038142, and French patent no. 2,349,729 provide some examples of such tools.

SUMMARY

[0003] A downhole tool is disclosed comprising: a progressive cavity section with a stator and a rotor; and in which the stator, the rotor, or the stator and the rotor are formed by electrochemical machining (ECM).

[0004] A method is disclosed comprising: forming a stator, a rotor, or the stator and the rotor by electrochemical machining (ECM); and forming a downhole tool by inserting the rotor into the stator.

[0005] A downhole tool is disclosed comprising: a progressive cavity section with a stator and a rotor; and in which the stator is formed from a single integral block of material, and the stator has a length of at least fifty inches defined between axial ends of the stator.

[0006] A method is disclosed comprising: forming a stator from a single integral block of material, in which the stator has a length of at least fifty inches defined between axial ends of the stator; and assembling a downhole tool by inserting a rotor into the stator.

[0007] A downhole tool is disclosed comprising: a progressive cavity section with a stator and a rotor; and in which the stator is formed by plural axial stator sections connected end to end, and adjacent axial stator sections, of the plural axial stator sections, are connected by dowels.

[0008] A method is disclosed comprising: forming a stator by connecting plural axial stator sections together end to end using dowels between the plural axial stator sections; and assembling a downhole tool by inserting a rotor into the stator.

[0009] A downhole tool is disclosed comprising: a progressive cavity section with a stator and a rotor; and in which the stator is formed by three dimensional printing.

[0010] A method is disclosed comprising: forming a stator by three dimensional printing; and assembling a downhole tool by inserting a rotor into the stator.

[0011] A method is disclosed comprising: forming a hollow rotor sleeve; forming a stator by three dimensional printing; and inserting the hollow rotor sleeve into the stator to form a progressive cavity section.

[0012] A downhole reamer tool is disclosed, comprising: a tubular body defining an interior passageway between an uphole end and a downhole end of the tubular body; and a reamer part mounted to the tubular body between the uphole end and the downhole end, the reamer part being mounted to rotate, relative to the tubular body, around a circumferential path about an outer-facing surface of the tubular body upon application of fluid flow within the interior passageway.

[0013] A method is also disclosed comprising: positioning a tubing string downhole in a well, the tubing string including a reamer tool; and pumping fluid through the tubing string to rotate a reamer part, of the reamer tool, relative to an uphole end tubing connector and a downhole end tubing connector of the reamer tool.

[0014] A casing reamer shoe is also disclosed comprising: a progressive cavity section with a stator and a rotor; a reamer part mounted to be rotated by the stator or the rotor; and in which the rotor is formed by a hollow helically lobed sleeve.

[0015] A method is also disclosed comprising: positioning a casing string downhole in a well, with a downhole end of the casing string mounting a casing reamer shoe; and pumping fluid through the casing string to operate a progressive cavity section of the casing

reamer shoe to rotate a reamer part of the casing reamer shoe, in which a rotor of the progressive cavity section is formed by a hollow helically lobed sleeve.

[0016] A downhole reamer tool is also disclosed comprising: a progressive cavity section with a stator and a rotor, with the rotor having an uphole end tubing connector, and the stator mounted to rotate relative to the rotor upon application of fluid flow between the rotor and the stator; and a reamer part mounted to be rotated by the stator.

[0017] A casing or drill string with a downhole reamer tool is also disclosed.

[0018] A method is also disclosed comprising: positioning a tubing string downhole in a well, with the tubing string mounting a downhole reamer tool; and pumping fluid through the tubing string to operate a progressive cavity section, which has a stator and a rotor, with a reamer part connected to rotate relative to the stator, in which pumping fluid causes the stator and reamer part to rotate relative to the tubing string and the rotor.

[0019] A casing reamer shoe comprising: a tubular body with an uphole end tubing connector defining an interior passageway; a reamer part mounted to rotate relative to the tubular body at a first speed under fluid flow in the interior passageway; and a nose mounted to rotate relative to the tubular body at a second speed under fluid flow in the interior passageway, the first speed being different than the second speed.

[0020] A method is also disclosed comprising: positioning a casing string downhole in a well, with a downhole end of the casing string mounting a casing reamer shoe; and pumping fluid through the casing string to rotate a reamer part and a nose, both of the casing reamer shoe, at a first speed and a second speed, relative to an uphole end tubing connector of the casing reamer shoe, with the first speed being different than the second speed.

[0021] A casing reamer shoe is also disclosed comprising: a tubular body; the tubular body having a progressive cavity section with a stator and a rotor; a reamer part connected to be rotated by the stator or rotor; and a universal joint connected between the reamer part and the rotor, or between the rotor and a bearing on the tubular body, the universal joint being structured to convert eccentric motion of the rotor into concentric motion.

[0022] A method is also disclosed comprising: positioning a casing string downhole in a well, with a downhole end of the casing string mounting a casing reamer shoe; and pumping fluid through the casing string to operate a progressive cavity section of the casing

reamer shoe to rotate a reamer part, in which a universal joint connects between the reamer part and a rotor of the progressive cavity section, or between the rotor and a bearing on the casing reamer shoe, the universal joint being structured to convert eccentric motion of the rotor into concentric motion.

[0023] A downhole reamer tool is also disclosed comprising: a tubular body with an uphole end tubing connector defining an interior passageway; a reamer part mounted to rotate relative to the tubular body; an impeller mounted within the tubular body and connected to rotate the reamer part; and the interior passageway having a plurality of radial passageways that direct fluid through the interior passageway in a radial direction against the impeller to drive the impeller and rotate the reamer part.

[0024] A method is also disclosed comprising: positioning a tubing string downhole in a well, with the tubing string mounting a downhole reamer tool; and pumping fluid through the tubing string to direct fluid through a plurality of radial passageways in a radial direction against an impeller, of the downhole reamer tool, to drive the impeller and rotate the reamer part, relative to the downhole reamer tool.

[0025] A method is also disclosed comprising: forming a hollow rotor sleeve; forming a stator by three dimensional printing; and inserting the hollow rotor sleeve into the stator to form a progressive cavity section.

[0026] A casing reamer shoe is disclosed comprising: a progressive cavity section with a stator and a rotor; a reamer part mounted to be rotated by the stator or the rotor; and in which rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid during use.

[0027] A casing reamer shoe comprising: a progressive cavity section with a stator and a rotor; a reamer part mounted to be rotated by the stator or the rotor; and in which the stator is formed by plural axial stator sections connected end to end, and adjacent axial stator sections, of the plural axial stator sections, are connected by dowels.

[0028] After drilling is completed for a particular section of a well, casing may be put down the hole to create a smooth interior bore through which additional work may be completed. However, the hole may not be perfect and often includes defects that can stop the casing from going all the way down. Accordingly, a reamer tool, the operating tip of which

is usually called a shoe, may be put towards the bottom to ream out the hole as the casing slides down. In one non-limiting embodiment, there is a reamer system, device, and/or mandrel assembly that is, advantageously, a low-cost system that attaches to any of a great variety of shoes (e.g. float shoe, reamer shoe, guide shoe) from a variety of manufacturers. Such a system may include an internal/central axle that rotates inside a housing and/or includes a pin-down connection (e.g. pin to pin, box-pin) to couple to a shoe so it can connect to any tool/shoe. The internal axle may spin when fluid is pumped through the mandrel assembly and spins a sub that is connected to the shoe which therefore also spins. The internal axle and/or other centrally positioned parts may comprise of an aluminum and/or zinc alloy (or other material that may be drilled through rather easily, since the mandrel assembly is generally left at a bottom of the hole when the casing is finished being installed). There may be a power section, such as an internal corkscrew shaped set of blades/lobes that cause the internal axle to rotate and thus cause the tool to rotate when fluid is pumped through the housing that contains the corkscrew.

[0029] A reaming power assembly is disclosed, comprising: a) an inner mandrel having spiral lobes disposed on an outer surface thereof; b) an outer mandrel disposed around the inner mandrel and having spiral lobes disposed on an inner surface of the outer mandrel; and c) a spacing between the outer surface of the inner mandrel and the inner surface of the outer mandrel through which fluid may be pumped to generate torque therebetween; wherein at least one of the inner and outer mandrel is free to rotate.

[0030] A reaming tool is disclosed functionally coupled to an end of the assembly such that torque therefrom may be used to rotate the reaming tool.

[0031] A reaming device is disclosed comprising: a) a hollow inner mandrel having spiral lobes disposed on an outer surface thereof; b) an outer mandrel disposed around the inner mandrel and having spiral lobes disposed on an inner surface of the outer mandrel; and c) a spacing between the outer surface of the inner mandrel and the inner surface of the outer mandrel through which fluid may be pumped to generate torque therebetween; wherein at least one of the inner and outer mandrel is free to rotate; wherein the outer mandrel has a number of spiral lobes equal to the number of spiral lobes of the inner mandrel plus one.

[0032] A stabilized accentuated reamer is disclosed, comprising: a) a power section having a rotor and a stator; b) a stator outer housing having a bladed profile; and c) a drill string.

[0033] A reaming system is disclosed, comprising: a) an inner mandrel having spiral lobes disposed on an outer surface thereof; wherein the inner mandrel is hollow; wherein the hollow of the inner mandrel is sized large enough to freely pass a standard drill bit therethrough; b) an outer mandrel disposed around the inner mandrel and having spiral lobes disposed on an inner surface of the outer mandrel; c) a spacing between the outer surface of the inner mandrel and the inner surface of the outer mandrel through which fluid may be pumped to generate torque therebetween; wherein at least one of the inner and outer mandrel is free to rotate; wherein the outer mandrel has a number of spiral lobes equal to the number of spiral lobes of the inner mandrel plus one; wherein one of the inner and outer mandrel is nonrotatably coupled to an end of a casing and the other is non-rotatably coupled to a bit or shoe; d) an upper flow diverter that diverts fluid flow from a center region of the reaming assembly to the spacing between the inner and outer mandrels; e) a lower flow diverter that diverts fluid flow from the spacing between the inner and outer mandrels to a center region of the reaming assembly; f) an upper and lower bearing assemblies rotatably coupled between the inner and outer mandrels; g) an elongated tubular housing, including: g1) a first end having a fluid inlet aperture; g2) a second end, opposite the first end, having a fluid outlet aperture; and g3) a coupling structure at the first end of the housing that selectably mates with a bottom end of a casing tube; h) a first bearing pack disposed circumferentially about the first end of the housing; i) a reaming tool functionally coupled to the inner mandrel or outer mandrel such that torque therefrom rotates the reaming tool; and j) a casing tube coupled to the housing.

[0034] In various embodiments, there may be included any one or more of the following features: Rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid. The stator contacting surfaces and the rotor contacting surfaces are made of metal. Rotor contacting surfaces of the stator are defined by an elastomeric coating within the stator. The progressive cavity section is connected to rotate a reamer part of a casing reamer shoe. The progressive cavity section is connected to rotate a drill bit. The drill bit

may be a polycrystalline diamond compact (PDC) or rotary drill bit. The stator has a length of at least fifty inches defined between axial ends of the stator. The stator has a length of at least fifty inches defined between axial ends of the stator. The stator has a length of at least eighty inches defined between axial ends of the stator. The stator has a length of at least one hundred and fifty inches defined between axial ends of the stator. The stator has a length of at least three hundred inches defined between axial ends of the stator. The stator is formed by ECM. Forming the stator, rotor, or the stator and the rotor by ECM further comprises advancing a cutting tool into or over a workpiece along an axis of the workpiece, with a sidewall of the cutting tool having a helically lobed profile, in which advancing is carried out while: an electrical field is established across a gap defined by the sidewall of the cutting tool and a sidewall of the workpiece; an electrolytic solution flows through the gap; and the cutting tool rotates about the axis such that the sidewall of the workpiece takes on a shape that is the inverse of the helically lobed profile of the sidewall of the cutting tool. Securing the dowels between adjacent plural axial stator sections using adhesive. Sliding an outer sleeve around the stator to form an interference fit between the stator and the outer sleeve. A progressive cavity power section with a stator and a rotor, with the progressive cavity power section connected to rotate the reamer part. The reamer part is mounted or formed on an external part of the stator, and the stator is connected to rotate relative to the tubular body. The rotor is fixed in relation to the uphole end and the downhole end of the tubular body. The interior passageway is connected to a fluid inlet of the progressive cavity section; and the interior passageway includes a power section bypass between an uphole end and a downhole end of the progressive cavity power section. The power section bypass is coaxial with the tubular body. The fluid inlet comprises a plurality of radial passageways that direct fluid through the interior passageway in a radial direction. The plurality of radial passageways comprise a plurality of diverter ports, which are angularly spaced from one another about a reamer tool axis, in which the diverter ports are oriented to have decreasing distance from the downhole end of the tubular body when moving from an entry to an exit of each of the plurality of diverter ports. The interior passageway is connected to a fluid outlet of the progressive cavity section. The fluid outlet and the fluid inlet are defined through the rotor. The reamer part is mounted on respective bearings at an uphole end and a downhole

end of the reamer part. The respective bearings comprise bearing packs. The respective bearings are exposed to fluid within the interior passageway during use. Rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid during use. The stator contacting surfaces and the rotor contacting surfaces are made of metal. The stator is formed by plural axial stator sections connected end to end. Adjacent axial stator sections, of the plural axial stator sections, are connected by dowels. Adhesive securing the dowels between adjacent axial stator sections. The plural axial stator sections are held together within an outer sleeve, with an interference fit between the plural axial stator sections and the outer sleeve. The stator is formed as a single piece by three dimensional printing. Respective tubing connectors at the uphole end and the downhole end of the tubular body. The reamer part comprises one or more of reamer blades and polycrystalline diamond cutters. The reamer part comprises reamer blades configured to act as stabilizer blades to center the downhole reamer tool within a well. The reamer part comprises a sleeve mounted coaxial with the tubular body. A casing or drill string comprising the reamer tool. The tubing string is a drilling string or a casing string. The tubing string is a drilling string. The drilling string comprises a fluid-actuated drilling motor and a drill bit, both located in a downhole direction relative to the reamer tool, and in which pumping fluid through the tubing string causes the fluid-actuated drilling motor to rotate the drill bit relative to the reamer tool. The tubing string remains angularly stationary while pumping fluid to rotate the reamer part. A hollow interior, defined by the hollow helically lobed sleeve, is closed. A wall within the hollow interior. Opposed axial ends of the hollow helically lobed sleeve are blocked by respective end walls. An uphole facing surface of the wall is striated. Rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid during use. The stator contacting surfaces and the rotor contacting surfaces are made of metal. The stator is formed by plural axial stator sections connected end to end. Adjacent axial stator sections, of the plural axial stator sections, are connected by dowels. Adhesive securing the dowels between adjacent axial stator sections. The plural axial stator sections are held together within an outer sleeve, with an interference fit between the plural axial stator sections and the outer sleeve. An inner diameter of the hollow helically lobed sleeve is sized to be commensurate with an inner diameter of the casing. A hollow interior, defined by the hollow helically lobed sleeve, is

closed. Pumping cement through the casing reamer shoe and up an annulus defined between the well and the casing string. Drilling out the casing reamer shoe. An uphole facing surface of the tool is striated. A stator of the progressive cavity section is formed by plural axial stator sections connected end to end. Prior to positioning the casing string downhole, assembling the casing reamer shoe by connecting adjacent axial stator sections, of the plural axial stator sections, with dowels. Assembling further comprises using an adhesive to glue the dowels between adjacent axial stator sections. Assembling further comprises sliding an outer sleeve around the plural axial stator sections, to form an interference fit between the plural axial stator sections and the outer sleeve. Sliding is carried out while one or both of a) the plural axial stator sections are cooled below, and b) the outer sleeve is heated above, room temperature. An inner diameter of the hollow helically lobed sleeve is sized to be commensurate with an inner diameter of casing of the casing string. Forming a casing reamer shoe, and further comprising a nose forming a downhole end of the casing reamer shoe, in which the stator is connected to rotate the nose. The casing reamer shoe defines an interior passageway that supplies fluid to the progressive cavity section and to outlet ports within the nose. The outlet ports include outlet ports directed in one or both of axial and radial directions. A tubular body defining the uphole end tubing connector and mounting the rotor; and a stabilizer mounted to the tubular body. A universal joint connected between the rotor and a bearing on the tubular body, the universal joint being structured to convert eccentric motion of the rotor into concentric motion. A first motor connected to rotate the nose relative to the tubular body; and a second motor connected to rotate the reamer part relative to the tubular body. The first motor comprises a progressive cavity section with a stator and a rotor; and the second motor comprises an impeller. The stator is connected to the tubular body, and the rotor is connected to rotate the nose. The interior passageway has a plurality of radial passageways that direct fluid in a radial direction against the impeller to drive the impeller and rotate the reamer part. A progressive cavity section with a stator and a rotor, in which the stator or the rotor is connected to rotate the reamer part or the nose. An impeller connected to rotate the reamer part or the nose. The first speed is faster than the second speed. The nose is structured as one or both a drill bit or a reamer. The interior passageway is connected to supply fluid to outlet ports within the nose. The outlet ports include outlet ports directed in

one or both of axial and radial directions. Pumping fluid to operate a progressive cavity section of the casing reamer shoe to rotate one or both the reamer part and the nose. Pumping fluid further comprises pumping fluid to operate an impeller to rotate one or both the reamer part and the nose. Pumping fluid further comprises supplying fluid to outlet ports within the nose to spray jets of fluid into the well from the nose. The first speed is faster than the second speed. The cooperating circumferential arrays of splines mesh via a circumferential array of pins. Each pin, of the circumferential array of pins, is tapered with decreasing radius from a central portion to each axial end of the pin. The cooperating circumferential arrays of splines comprise a radially-outward facing array of splines and a radially-inward facing array of splines. The cooperating circumferential arrays of splines are located at or near a first axial end of the shaft; and the shaft connects to the reaming part, or to a bearing on the tubular body, via a second set of cooperating circumferential arrays of splines, which are located at or near a second axial end of the shaft. The shaft is a hollow shaft sleeve. A hollow interior, defined by the hollow shaft sleeve, is closed. The universal joint is connected between the reamer part and the rotor. The universal joint is connected between the rotor and a bearing on the tubular body. The rotor is formed by a hollow helically lobed sleeve. The impeller comprises a circumferential array of fins on a radially inward facing surface of a sleeve that mounts the impeller to the tubular body. The circumferential array of fins are oriented parallel with an axis of the downhole reamer tool. The plurality of radial passageways are defined by slots in respective axial faces of each of a plurality of ring plates stacked axially one on the other. Each slot is curved or angled to eject fluid at non-zero angles relative to a radius defined by the respective ring plate and passing through a fluid exit end of the slot. The plurality of ring plates are stacked around a cylindrical wall of and coaxial with a collar, in which the plurality of radial passageways are defined from a central bore of the collar through the cylindrical wall of the collar. A pair of flanges, secured to or formed by the collar, compress the plurality of ring plates on the collar. An uphole flange of the pair of flanges connects to the tubular body. The cylindrical wall has an out-of-round circumferential profile that meshes with a corresponding inner circumferential profile of the plurality of ring plates. The out-of-round circumferential profile is polygonal. The impeller is connected to rotate the nose. The nose comprises one or more of blades and

polycrystalline diamond cutters. The tubular body further comprises a progressive cavity section connected to rotate the nose independent of the rotation of the reamer part by the impeller. A wire brush scraper on an external surface of the downhole reamer tool. The progressive cavity section is connected to rotate a reamer part of a casing reamer shoe. The outer mandrel has a number of spiral lobes equal to the number of spiral lobes of the inner mandrel plus one. One of the inner and outer mandrel is non-rotatably coupled to an end of a casing and the other is non-rotatably coupled to a bit or shoe. An upper flow diverter that diverts fluid flow from a center region of the reaming assembly to the spacing between the inner and outer mandrels. A lower flow diverter that diverts fluid flow from the spacing between the inner and outer mandrels to a center region of the reaming assembly. The inner mandrel is hollow. The hollow of the inner mandrel is sized large enough to freely pass a standard drill bit therethrough. Upper and lower bearing assemblies rotatably coupled between the inner and outer mandrels. A) an elongated tubular housing, including: a1) a first end having a fluid inlet aperture; a2) a second end, opposite the first end, having a fluid outlet aperture; and a3) a coupling structure at the first end of the housing that selectably mates with a bottom end of a casing tube. A casing tube coupled to the housing. One of the inner and outer mandrel is non-rotatably coupled to an end of a casing and the other is non-rotatably coupled to a bit or shoe. An upper flow diverter that diverts fluid flow from a center region of the reaming assembly to the spacing between the inner and outer mandrels. A lower flow diverter that diverts fluid flow from the spacing between the inner and outer mandrels to a center 5 region of the reaming assembly. The hollow of the inner mandrel is sized large enough to freely pass a standard drill bit therethrough. Upper and lower bearing assemblies rotatably coupled between the inner and outer mandrels. A) an elongated tubular housing, including: a1) a first end having a fluid inlet aperture; a2) a second end, opposite the first end, having a fluid outlet aperture; and a3) a coupling structure at the first end of the housing that selectably mates with a bottom end of a casing tube; b) a first bearing pack disposed circumferentially about the first end of the housing; and c) a reaming tool functionally coupled to the motor. A casing tube coupled to the housing.

[0035] These and other aspects of the device and method are set out in the claims.

BRIEF DESCRIPTION OF THE FIGURES

[0036] Embodiments will now be described with reference to the figures, in which like reference characters denote like elements, by way of example, and in which:

[0037] Fig. 1 is a perspective view of a downhole reamer tool with a progressive cavity power section.

[0038] Figs. 2A and 2B collectively form a cross-section view of the downhole reamer tool of Fig. 1.

[0039] Fig. 3 is an exploded perspective view of the downhole reamer tool of Fig. 1.

[0040] Fig. 4 is a perspective view of a casing reamer shoe with an impeller-powered reamer.

[0041] Figs. 5A and 5B are front and rear perspective views, respectively, of a discharge ring plate of the casing reamer shoe of Fig. 4.

[0042] Fig. 6 is an exploded perspective view of the casing reamer shoe of Fig. 4.

[0043] Fig. 7 is a cross-section view of the casing reamer shoe of Fig. 4.

[0044] Fig. 8 is a section view taken along the 8-8 section lines of Fig. 7.

[0045] Fig. 9 is a section view taken along the 9-9 section lines of Fig. 7.

[0046] Fig. 10 is a perspective view of a further embodiment of a casing reamer shoe an impeller-powered reamer.

[0047] Fig. 11A is a section view taken along section lines 11A-11A of Fig. 10.

[0048] Fig. 11B is a section view taken along section lines 11B-11B of Fig. 10.

[0049] Fig. 12 is a perspective view of a discharge ring plate of the casing reamer shoe in Fig. 10.

[0050] Fig. 13 is a cross-section view of the casing reamer shoe of Fig. 10.

[0051] Fig. 14 is an exploded perspective view of the casing reamer shoe of Fig. 10.

[0052] Fig. 15 is a perspective view of a further embodiment of a casing reamer shoe with a progressive cavity power section and an impeller-powered reamer.

[0053] Figs. 16A, 16B and 16C collectively form a cross-section view of casing reamer shoe of Fig. 15.

[0054] Fig. 17 is an exploded perspective view of the casing reamer shoe of Fig. 15.

[0055] Fig. 18 is a perspective view of a further embodiment of a casing reamer shoe with a progressive cavity power section.

[0056] Figs. 19A and 19B collectively form a cross-section view of the casing reamer shoe of Fig. 18.

[0057] Fig. 19C is close up side elevation view of a drive pin from the universal joint of the embodiment of Fig. 19A.

[0058] Fig. 20 is an exploded perspective view of the casing reamer shoe of Fig. 18.

[0059] Fig. 21 is a perspective view of a further embodiment of a casing reamer shoe with a progressive cavity power section.

[0060] Figs. 22A and 22B collectively form a cross-section view of the casing reamer shoe of Fig. 21.

[0061] Fig. 23 is an exploded perspective view of the casing reamer shoe of Fig. 21 with a progressive cavity power section.

[0062] Fig. 24 is a perspective view of a further embodiment of a casing reamer shoe with a progressive cavity power section.

[0063] Figs. 24A and 24B are enlarged detail perspective views of portions, circled in dashed lines, of the illustration of casing reamer shoe of Fig. 24.

[0064] Fig. 25 is a cross-section view through the upper flow diverter of the casing reamer shoe of Fig. 24.

[0065] Fig. 26 is a section view taken along the 26-26 section lines of Fig. 24.

[0066] Fig. 27 is a perspective view of a further embodiment of a casing reamer shoe.

[0067] Fig. 28 is a side elevation view of a casing reamer shoe in use in horizontal well.

[0068] Fig. 29 is a perspective view of a further embodiment of a casing reamer shoe with an impeller-powered reamer and a casing scraper wire brush.

[0069] Figs. 30A and 30B collectively form a cross-section view of the casing reamer shoe of Fig. 29.

[0070] Fig. 31 is a perspective view of a further embodiment of a casing reamer shoe with a progressive cavity power section.

[0071] Figs. 32A and 32B collectively form a cross-section view of the casing reamer shoe of Fig. 31.

[0072] Fig. 33 is an exploded perspective view of the casing reamer shoe of Fig. 31 with a progressive cavity power section.

[0073] Figs. 34A and 34B collectively form a cross-section view of the casing reamer shoe of Fig. 35.

[0074] Fig. 35 is an exploded perspective view of a further embodiment of a casing reamer shoe with a progressive cavity power section.

[0075] Fig. 36 is a schematic view, partially in section, of an electrochemical machining method used to form a stator.

[0076] Fig. 37 is a schematic view, partially in section, of a three dimensional printing method used to form a stator.

[0077] Fig. 38 is a perspective exploded view of a drilling motor and a drill bit.

[0078] Figs. 39A-C collectively form a cross-section view of the drilling motor of Fig. 38.

DETAILED DESCRIPTION

[0079] Immaterial modifications may be made to the embodiments described here without departing from what is covered by the claims.

[0080] In a typical power section of a positive displacement fluid motor used in drilling a wellbore that traverses subterranean hydrocarbon bearing formations, power generation is based upon the Moineau pump principle. In this type of motor design, a stator and rotor assembly converts the hydraulic energy of a pressurized circulating fluid to the mechanical energy of a rotating shaft. The rotor and stator are typically of a helically lobed design, with the rotor and stator having a corresponding helically lobed profile with plural helical lobes. The rotor is generally formed from steel or another suitable metal having one less lobe than the stator, which is typically lined with an elastomer layer.

[0081] In general, the power section may be categorized based upon the number of lobes and effective stages. The rotor and stator lobes may have a helical configuration defining plural stages, with each stage equating to the linear distance of a full wrap of the

stator helix. The rotor and stator lobes and helix angles may be selected such that the rotor and stator seal at discrete intervals, which results in the creation of axial fluid chambers or cavities that are filled by the pressurized circulating fluid. The action of the pressurized circulating fluid causes the rotor to rotate and precess within the stator. Motor power characteristics are generally a function of the number of lobes, lobe geometry, helix angle and number of effective stages. Motor output torque is directly proportional to the differential pressure developed across the rotor and stator. In drilling operations, bit rotation speed is directly proportional to the circulating fluid flow rate between the rotor and stator.

[0082] Progressive cavity sections, such as pumps or motors, or used in downhole contexts other than drilling. For example, a progressive cavity pump may be used at the end of a sucker rod string in a production well. Similarly, cutting and servicing tools, as well as well perforating and stimulation tools may incorporate progressive cavity sections.

[0083] A reamer is a type of rotary cutting tool used to clean and in some cases enlarge the size of a previously formed hole, generally to leave the sides of the hole sufficiently smooth for later purposes. The process of cleaning or enlarging the hole may be called reaming. Reamers take many forms and may be designed for use as a hand tool or in a machine tool, such as a milling machine or drill press, in drilling system for drilling for oil, and/or in other earth drilling contexts, and others. In the context of drilling for oil, immediately after a hole is drilled, the hole may lack a clean, smooth profile suitable for casing.

[0084] Drilling may alter the characteristics of the surrounding formation and produce a void with respect to pressure, and water content. In some cases chemical interactions may occur by exposure of materials surrounding the hole to the air. Further, natural layering, fissures, and fracture lines may react differently to the hole than the surrounding material. Accordingly, such newly-drilled holes may end up with discontinuities that make it difficult to operate the hole as desired. Reamer systems may be used in such and other contexts to make the sides of the hole sufficiently smooth for continued operation. Also, in completion operations reaming is followed with installation of a casing string that prevents further distortion of the surrounding material from intruding on the working portion of the hole.

[0085] Casing may refer to steel pipe that is landed within the well and cemented in place during wellbore construction in order to stabilize the wellbore. The casing string may be made up of a plurality of casing sections, which are threaded together and collectively extend from the surface to a landing point within an open hole. The base of the casing string may contain a shoe, which may operate as one or more of a reamer, guide, or float shoe. Once in position the casing may be cemented in place. Once casing is installed, the wellbore may be further extended by drilling through the casing shoe using a drill bit of a relatively smaller inner diameter than the diameter of the casing that is drilled through. Once drilling is complete, a subsequent casing string is run from surface to extend from the bottom of the previous casing string to the bottom of the further drilled open hole. Once installed, the subsequent casing string is cemented in place. The process can be repeated to further extend the wellbore, leading to a situation where the wellbore thus comprises a series of concentric casing strings of gradually decreasing inner diameter extending to great depths and distances within the formation.

[0086] Casing is usually selected to have an outer diameter that is commensurate with an open hole diameter. A float shoe may be used to guide the casing toward the center of the hole to minimize the impact of rock ledges or washouts in obstructing the travel of the casing string as the casing is run into the wellbore. The float shoe functions to assist in cementing operations, and may be constructed of a drillable material to permit the float shoe to be drilled through if the well is to be deepened beyond the casing landing point. If a casing string gets snagged on an obstruction in the well, the entire string may become jammed, holding up the completion operation and requiring extensive and expensive intervention operations. A reamer thus works synergistically with the running of a casing string to obliterate and remove obstructions in the wellbore, improving ease of casing travel through the well, reducing the chance of a stuck casing string, and all the while cleaning and polishing the wellbore to prepare same for cementing and completion. The nature of a reamer shoe as a reamer usually means that the reamer is wider than or equal to the outer diameter (OD) of the casing string, and thus difficult or impossible to remove from the well if run into the well with a casing string. Thus, a casing reamer shoe may be left at the bottom of the hole and drilled out if required.

[0087] Reaming a deviated well, such as a horizontal well, may present additional challenges relative to a vertical well. For example, it may be a challenge to slide a string of mandrels, pipes and others, inside the dogleg or toe part of the hole, as the weight of such units may rest against the side of the hole, creating friction. Such friction may increase the difficulty to advance a drill or reamer during horizontal operation, and may increase the chance of a casing string getting stuck or otherwise hung up prior to landing.

[0088] Referring to Fig. 28, a method of using a downhole tool 10, such as a reamer tool as shown, to cut the final size and finish of a horizontal drill hole is illustrated. Generally, a reamer tool will not make the original hole, but instead, will enlarge and/or clean or otherwise smooth the interior wall of a previously drilled or bored hole. In some cases, the reamer tools disclosed here may be used as part of a drilling operation, however. The illustrated reamer tool 10 may be supported at a downhole end of a casing 172, which is supported by a suitable rig structure such as a derrick 170. The reamer tool 10 may be disposed within a well bore 176. The derrick 170 may include suitable structure and devices to operate the reamer tool 10 and to permit the incremental addition of casing sections to the casing string as the reamer tool 10 works its way in a downhole direction through the wellbore 176. The reamer tool 10 may advantageously allow for the wellbore 176 to be reamed and lined with a casing 172 for future production and stimulation operations.

[0089] Referring to Fig. 28, derrick 170 may comprise a lifting device such as a guyed mast, for example a gin pole, which may be articulated over a load by adjusting its guys. The term derrick may include the framework supporting a drilling apparatus in an oil well drilling or completion rig. The illustrated derrick comprises a crown block 178. The illustrated crown block 178 may be functionally coupled to a traveling block 180 that travels vertically within the derrick 170. A crown block may form a stationary section of a block and tackle system that contains a set of pulleys or sheaves through which the drill line 182 (wire rope) may be threaded and positioned opposite and above traveling block 180. Traveling block 180 is the freely moving section of a block and tackle system that contains a set of pulleys or sheaves through which the drill line (wire rope) may be threaded and positioned opposite (and under) the crown block (the stationary section). The combination of the traveling block 180, crown block 178 and wire rope drill line 182 may produce the ability

to lift string weights in the hundreds of thousands of pounds. On larger drilling rigs, when raising and lowering derrick 170, line tensions over a million pounds are not unusual.

[0090] Referring to Fig. 28, the rig may comprise sufficient surface pumping equipment to operate the fluid-actuated reamer tool 10. Derrick 170 may comprise a motor 184 or other power source that may be used to operate one or more pumps, winches, drills, and/or the like and combinations thereof. The motor 184 may be used to pump fluid through the casing 172 and through reamer tool 10 to cause the reamer tool 10 to rotate at high speeds and with sufficient torque to effectively ream the hole or wellbore 176.

[0091] Derrick 170 may also include a blowout preventer 186 functionally coupled around a top of the wellbore 176. The blowout preventer 186 may comprise a large, specialized valve or similar mechanical device, usually installed redundantly in stacks, used to seal, control and monitor an oil and gas well. Blowout preventers were developed to cope with extreme erratic pressures and uncontrolled flow (formation kick) emanating from a well reservoir during drilling. A kick may lead to a potentially catastrophic event known as a blowout. In addition to controlling the down hole (occurring in the drilled hole) pressure and the flow of oil and gas, a blowout preventer is intended to prevent tubing (e.g. drill pipe and well casing), tools and drilling fluid from being blown out of the wellbore (also known as the bore hole, the hole leading to the reservoir) when a blowout threatens. A blowout preventer improves the safety of crew, rig (the equipment system used to drill a wellbore) and environment, and are used in the monitoring and maintenance of well integrity. Blowout preventers are intended to provide fail-safety to the systems that include them.

[0092] Referring to Fig. 28, the reamer tool 10 may be coupled to the bottom or downhole end of the casing 172 in a variety of suitable manners, including but not limited to mating threads, snap-fits, friction fitting, adhesives, bolts, and the like and combinations thereof. The reamer tool 10 may function with or as a shoe, which is the operating component that interfaces with the interior of the hole to be reamed and abrades away material, thereby reaming the hole. The shoe may include protrusions that, when the shoe spins, impact with non-cylindrical regions of the interior of the hole and thereby abrade the same making such regions smoother and increasing the effective interior diameter of the same so that the casing can follow behind the shoe without getting stuck.

[0093] **The STAR - Stabilized Accentuated Reamer**

[0094] Referring to Figs. 1 and 2A-B, a downhole reamer tool 10 is depicted comprising a reamer part 14 and a tubular body 12. An interior passageway 160 may be defined between a downhole end 40 and an uphole end 42 of tubular body 12. Reamer part 14 may mount to tubular body 12 between the uphole end 42 and the downhole end 40, for example at a location where axial ends 14C, 14D, of the reamer part 14, and in the example shown axial ends 32A, 32B of the stator 32, are spaced from both ends 40 and 42 of body 12. Referring to Figs. 1, 2A-B, and 3, reamer part 14 may be mounted to rotate, relative to the tubular body 12, for example around an outer circumferential path, such as path 13 (Fig. 1), about an outer-facing surface 200 of the tubular body 12. Figs. 2A-B, reamer part 14 may rotate upon application of fluid flow within interior passageway 160 of the tubular body 12. Fluid flow may comprise the flow of drilling fluid or other suitable fluids, such as water or invert, through at least a portion of tool 10 from uphole end 42 to downhole end 40.

[0095] Referring to Fig. 1, reamer part 14 may be mounted in a suitable fashion to rotate relative to tubular body 12. Reamer part 14 may be mounted to rotate via a suitable mechanism such as bearings (for example ball bearings, slide bearings, thrust bearings, or bearing surfaces), parts comprising sacrificial material, and others. Tubular body 12 may comprise tubing connectors 37 and 39 at the downhole end 40 and the uphole end 42, respectively. Tubing connectors 37 and 39, such as threaded pin and box ends as shown, may connect to part of the tubing string, such as casing string 173 or drilling string, including tools that make up the string. During use, body 12 may remain angularly stationary, while reamer part 14 may rotate relative to body 12, under fluid flow. In cases where body 12 is rotating, for example if the tubing string is rotating, body 12 may rotate at a relatively faster rate relative to tubular body 12 than the tubing string. Reamer part 24 may mount to a motor housing sleeve 26 and in the example shown housing sleeve 26 rotates with reamer part 24.

[0096] Referring to Fig. 1, the exterior of tool 10 may comprise a suitable reamer part 14. For example, a bladed profile with helical reamer blades 28 extending radially outwardly from a maximum outer diameter (OD) of the casing, tool or drill string may be used. The relative rotation caused by the fluid pumped through the interior passageway 160 may cause the reamer blades 28 to rotate and thereby ream the hole about the location of the

tool within the drill hole. Reamer blades 28 may be configured to act as stabilizer blades when the reamer part 14 is not rotating, to center tool 10 within the drill hole or well.

[0097] Referring to Fig. 2A, a motor 15, such as a mud motor or progressive cavity power section (PC motor), may be connected to rotate the reamer part 14. PC motor 15 may use fluid flow to create rotational motion, in the power section 17, and such motion may be transferred to the reamer part 14. The power section 17 of PC motor 15 may comprise an outer mandrel such as a stator 32 and an inner mandrel such as rotor 36.

[0098] Referring to Fig. 2A and 3, in some cases, the outer mandrel comprises a stator 32, and the inner mandrel comprises a rotor 36. Rotor 36 may comprise helical lobes 41 that extend from an exterior surface of rotor 36. Stator 32 may comprise opposing helical lobes 33 that extend from an interior surface of stator 32 that faces helical lobes 41 of the rotor 36 after assembly. There may be a region between the rotor 36 and the stator 32 that is spaced and shaped to permit fluid to flow between from one axial end of the PC motor 15 to the other. The spiral lobes 33, 41 may be mismatched such that they rotate against each other when fluid is pumped through the space between them and generate vibration (notation) as one rotates past the other. When the number of nodes on the rotor is one less than the number of nodes on the stator, the rotation may induce a vibration to reamer tool 10 and may help tool 10 overcome frictional forces and assist the blades 28 on an exterior of the stator 32 to cut through earth or rock. Motor 15 may comprise any suitable fluid-moving motor or pump. In some cases, PC motor 15 operates by rotating the outer mandrel relative to the inner mandrel, while in other cases, PC motor 15 rotates the inner mandrel relative to the outer mandrel. Lobe differentials, such as two or more lobes on the stator than on the rotor, may be used.

[0099] Referring to Figs 2 and 3, stator 32 may have a suitable shape. Stator 32 may be formed by plural axial stator sections connected end to end. Stator 32 may comprise adjacent stator housing sections 32'-32'''. Stator housings 32'-32''' may comprise an aperture or plurality of apertures 155 each sized to fit a single dowel 34. Dowels 34 may connect and fix one stator housing sections 32'-32''' to one or more of adjacent stator housing sections 32'-32'''. The plural axial housing sections 32'-32'''. Dowels may be

secured to stator housing sections 32'-32''' by adhesive, such as LOCTITE™ or another suitable adhesive.

[00100] Referring to Fig. 3, the plural axial housing sections 32'-32''' may be connected end to end. The plural axial stator sections 32-32''' may be held together within an outer sleeve 46, which holds the sections by a suitable mechanism, such as an interference fit between the plural axial stator sections 32'-32''' and the outer motor sleeve 46. The interference fit may be sufficiently tight to transmit torque during use between stator 32 and reamer part 14. In some cases a zero or positive interference fit may be used. Assembly of stator sections 32'-32''' may comprise sliding the outer motor sleeve 46 around the plural axial stator sections 32'-32''' to form the interference fit. Sliding may be carried out while one or both of a) the plural axial stator sections are cooled below, and b) the outer motor sleeve is heated above, room temperature. For example, dry ice may be loaded within sections 32'-32''' after connection by dowels, and the sleeve 46 may be heated with a torch or other suitable mechanism. Next, the stator 32 may be hoisted in the air by a lifting mechanism such as a crane, and lowered into the sleeve 46. Upon returning to room temperature, the parts contract and expand and grip one another. At room temperature it may be impossible to physically separate the stator 32 and sleeve 46.

[00101] Referring to Fig. 3, rotor contacting surfaces 188 of the stator 32, and stator contacting surfaces 190 of the rotor 36, may comprise rigid material, such as metal. Rigid includes non-elastomeric materials, and materials that do not flex when in use at downhole temperatures. Sealing may be achieved by carefully machining the surfaces 188 and 190 to achieve a sufficiently narrow clearance / negative interference fit to form an efficient pumping seal without seizing the unit. In some cases one or more of surfaces 188 and 190 are treated or coated to protect and increase the longevity of the tool 10. The coating may be a bearing material with a coefficient of kinetic friction that is less than or equal to 0.2 in relation to steel. The bearing material may have a coefficient of kinetic friction that is less than 0.1, in relation to steel. Other bearing materials with higher coefficients of friction may be used. The bearing material may comprise a non-metal. The bearing material may comprise one or both nylon or ultra-high-molecular-weight polyethylene. The coating on one or more surfaces 188 and 190 may be applied to a thickness that will not change the rigid

characteristics of each surface, so that the surfaces 188 and 190 still act as a metal on metal seal. An appropriate thickness, for example a thin coating with a diameter of 1/100 thousandth of an inch may be used, although thicknesses greater or smaller may be used. The coating may be applied by spraying on one or more surfaces 188 and 190. The coating may be cured in an oven to set. The coating may reduce or prevent corrosion, for example if an anti-corrosion agent is used. In some cases, anti-corrosion paint, such as a polytetrafluoroethylene-based paint, may be applied either alone or in combination with the coating. The coating may act as lubrication during operation of stator 32 and rotor 36. In some cases, surface 188 and/or surface 190 comprise an elastomeric material, such as rubber.

[00102] Referring to Figs. 2A-B, during use, fluid, such as drilling fluid, may be pumped from an uphole end 42 through the motor 15 to and out the downhole end 40. Motor 15 may comprise a fluid inlet 150 connected to the interior passageway 160. Fluid may pass through interior passageway 160, which in some cases extends from uphole end 42 through the uphole facing end 36A of rotor 36 to the fluid inlet 150. Fluid inlet 150 may provide an access point for fluid to travel to the helical lobes 33 and 41 of the motor 15. Fluid inlet 150 may comprise a plurality of diverter ports 151. Diverter ports 151 may be angularly spaced from one another about a reamer tool axis 153. Diverter ports 151 may be oriented to have decreasing distance from downhole end 42 when moving from an entry 151' to an exit 151'' of each of the plurality of diverter ports 151. Interior passageway 160 may comprise a motor bypass 148 that diverts a portion of the fluid from traveling to fluid inlet 150 and onto the power section 177. Motor bypass 148 may be defined by rotor 36. In some cases motor bypass 148 is coaxial with the tubular body 12. Fluid may exit from the power section 17 via a fluid outlet 15 of the motor 15. Fluid outlet 157 may direct fluid flow from the space between the stator 32 and rotor 36 to the interior passageway 160. Fluid outlet 157 may comprise a plurality of diverter ports 159, that are angularly spaced from one another about axis 153, in which ports 159 are oriented to have increasing distance from downhole end 42 when moving from an entry 159' to an exit 159'' of each of the plurality of diverter ports 159.

[00103] Referring to Figs. 2A-B and 3, reamer part 14 may mount to the tubular body 12 via suitable bearings, such as bearing pack 149, roller or slide bearings. Rotor 36 may

comprise bearing packs 149 that rotatably couple the rotor 36 to the stator 32. Bearing packs 149 may be replaced with any coupling structure that allows for rotational coupling, including but not limited to: ball bearings, roller bearings, ball thrust bearings, roller thrust bearings, tapered roller bearings, magnetic bearings, linear bearings, anti-friction bearings, rotary bearings, telescopic bearings, rotary unions, and the like and combinations thereof. tool 10 may be completely sealed from wellbore fluids and pressure, such that fluid does not exit the exterior of the tool 10, but instead is restricted to flow-through. Bearing pack 149 may comprise sealing ring 22A that seals between the rotor and the stator. Sealing ring 22A may provide a dynamic seal, which is a seal that maintains a seal during rotation of stator 32 and reamer housing sleeve 26. During rotation, pack 149 may be exposed to circulated fluid within the interior passageway 160. Circulated fluid may be used to cool the bearings by the sealing mechanism. Sealing ring may define teeth or fins 21 that interlock with opposing, complimentary teeth 19 defined by an end cap 18A. End cap 18A and seal ring 22A may rotate with the stator 32. A corresponding bearing pack 149 may be located on either end of the motor 15. Pack 149 may comprise outer load collar 20A and inner load collar 24A that distribute the load from a tubing string, such as a casing string or drill string, to the rotor 36. Pack 149 may be a plurality of bearing assemblies that secure axial ends of rotor 36 to the uphole end 42 and downhole end 40 of the tubular body 12. The plurality of bearing assemblies may have matching parts, such as end caps 18A, 18B, seal rings 22A, 22B, outer load collars 20A, 20B, inner load collars 24A, 24B and others. Other mechanisms of securing rotor 36 to uphole end 42 and downhole end 40 may be used, such as an induced fit between complimentary features, adhesive, such as LOCTITE™, and others.

[00104] Referring to Fig 3, reamer part 14 may be mounted or formed on an external part of stator 32. Reamer part 14 may comprise a sleeve, such as a sleeve formed by reamer housing sleeve 26. Reamer housing sleeve 26 may be mounted coaxial with the tubular body 12. Reamer part 14 and reamer housing sleeve 26 may be secured to rotate with stator 32 during operation of PC motor 15.

[00105] Referring to Fig. 1, reamer tool 10 may be configured for use in an oilfield application, for example as a drilling enhancement or for drilling applications. Reamer tool 10 may be used in drilling through unstable ground conditions. In the process of drilling,

reamer tool 10 may be carried down casing pipe to the hole to protect the wall to achieve drilling work. Reamer part 14 may comprise one or more of reamer blades 28 and polycrystalline diamond cutters 30. Reamer tool 10 may include a rotor and a stator rotatably coupled to each other (e.g. by operation of the illustrated pair of bearing packs disposed between the rotor and stator near opposite ends of tool 10), wherein the stator envelopes the rotor. As used herein, neither "rotor" nor "stator" implies rotational movement or fixed positioning.

[00106] Tool 10 may be coupled to a drill string used to drill earth/rock, such as but not limited to for drilling oil wells. Tool 10 may couple between sections of a tubing string, such as a casing or drilling string, such that fluid that is pumped through the string goes through tool 10 as well. The rotor 36 may be fixedly coupled to coupling subs 38, 16 at each ends 40, 42, respectively to allow the tool 10 to couple to the tubing string between segments of such. The tubing string, including tool 10, may be positioned downhole in a well and fluid may be pumped through the tubing string to rotate the reamer part 14. The drilling string may comprise a fluid-actuated drilling motor 15 and a drill bit (not pictured), both located in a downhole direction relative to the tool 10. Pumping fluid through the tubing string may cause motor 15 to rotate the drill bit relative to tool 10. While pumping fluid, the tubing string may remain angularly stationary to rotate the reamer part. Tool 10 may be used in a casing application as well.

[00107] The fluid may be diverted from the core of the drill string to a region between the rotor 36 and stator 32 of tool 10. In such a region, the fluid causes the rotor 36 and stator 32 to rotate relative to each other (generally only one will rotate and the other stays in fixed angular relation to the rest of the string). The rotor 36 and stator 32 are attached to the string in such a way as to cause the rotational force created by the pumped drilling fluid to be applied only to the stator 32, thereby causing it to rotate. The stator housing sections 32'-32'' may comprise a bladed profile that may be beveled unto the base pipe OD to ensure that the leading edge is less aggressive and the ensuing cutting action and torque generated is gradual. This profile is both upward directional and downward directional since it is designed to be used to ream both downwards and upwards (forwards and backwards, for horizontal drilling/reaming).

[00108] Tool 10 may be used for horizontal drilling, as the friction between the drill string and the bottom arc of the drill hole (where the drill string rests because of gravity) may be a tremendous friction force to overcome. This may make the horizontal well more difficult to drill, especially when the hole shifts, swells, cracks, fills-in, etc. Rotating the reamer tool 10 without having to rotate the whole drill string may improve the efficiency and utility of tool 10 in horizontal wells.

[00109] The illustrated tools 10 may be suited for rigs with sufficient hydraulic power to drill but where torque limitations on either surface equipment or string components or both, limit string rotation to combat hole problems. Example hole problems include tight spots, swelling shales and/or wellbore collapse, where traditionally, the solution would have required backreaming. The illustrated tools 10 may allow the drilling team to ream regions having such problems without requiring. The reamer tools 10 disclosed here may be used to ream a hole as it is being drilled.

[00110] The STAR Stabilized accentuated reamer tool 10 may actuate with circulation. When fluid is circulated up to the threshold flow rate, the external sleeve starts to rotate clockwise looking downwards. Such rotation is irrespective of the rotation of the drill string. The stabilized accentuated reamer is self torque-generating due to the associated hydraulic power section that generates both torque and rotation. This family of tools may enable a drilling team to ream in and out of hole without string rotation making it a suitable reaming solution for tight spots, hole pack-offs, swelling shales, and all manner of wellbore instability related issues. Due to its unique internal power generation this tool may contribute lesser torque to the string in drilling mode than regular reamers or stabilizers.

[00111] String rotation may be used to increase the available torque at the stabilized accentuated reamer for rock destruction and deformation. Due to its offset dynamics and harmonics (i.e. vibration during operation) tool 10 is expected to reduce stick slip or drill string vibrations. The stabilized accentuated reamer may be bored in the centre (i.e. include a narrowed core between the two diversion channels that allows fluid to pass either through the core or the diversion channels) to ensure better signal transfer for telemetry systems that require to communicate using the internal fluid medium in the drill string.

[00112] Tool 10 may act as a conventional stabilizer as well as a reamer. According to one embodiment of the invention, there is a tool 10 stabilizer with reaming functions for drilling applications. The reaming stabilizer may be hydraulically powered without a need for the string to rotate. The stabilizer allows a user to ream out the hole as the user goes down. In addition, if the casing or drilling string gets stuck, the user may activate the stabilizer to back up and ream along the way up. The stabilizer may be cheaper, doesn't lose the drill string, faster, more convenient, is easier to use, and less likely to get stuck. According to one embodiment of the invention, there is a tool 10 stabilizing accentuated reamer including a sealed motor section (i.e. no fluid going in or out of the string), a reaming stabilizer having an outer surface with multiple bearing packs, a flow diversion channel, a lobe (allows for the rotation), a stator with one more lobe than the rotor (stator is the outside component and the rotor is the internal component, even though the rotor would typically be the one that moves and in this case the rotor does not move at all), and a narrowed central bore.

[00113] According to one embodiment of the invention, there is a tool 10 stabilizing accentuated reamer that fits between sections of the drilling string and attaches to them the same way the drilling string sections attached to each other. The rotor attaches to the string adapters. The stator may be coupled to the rotor via sealed bearing packs and is disposed around the rotor. The flow diversion channels do not block flow of the fluid through the center but instead allow for flow to also go between the stator and rotor and thereby interact to cause rotation of the stator. The exterior surface of the stator has stabilizing geometry and reaming geometry so that it simultaneously performs both functions. According to one embodiment of the invention, there is a tool 10 stabilizing accentuated reamer including a sealed motor section (i.e. no fluid going in or out of the string) (may have sealable ports), a reaming stabilizer including an outer surface (e.g. hard facing, tungsten carbide inserts, any cutting surface, laser cladding, diamond impregnated, etc.), a plurality of multiple bearing packs (e.g. 2, 3, 4, 5, 6+, sealed, upward and downward acting bearings, ball bearings, radial bearings, friction, etc.), a plurality of flow diversion channels (e.g. multiple, center bore is there to allow for telemetry signals, center bore is narrowed), a plurality of lobes that allow

for the rotation (e.g. wherein the external array of lobes has one more lobe than the internal), and a stator with one more lobes than the rotor.

[00114] In operation, the drill team assembles the drill string as drilling occurs, and in doing so includes the tool 10 between two segments of the drill string. The tool 10 reams the hole as it is drilled and the drill string may be pushed/pulled as desired to engage the drill bit and the tool 10 in positions as needed and as appropriate. Telemetry signals may be transmitted through the drilling fluid through the drill string and may pass through the tool 10 without interference from the tool 10.

[00115] **The Hydra**

[00116] Referring to Figs. 4 and 7, a downhole reamer tool 10 is illustrated having a tubular body 12, a reamer part 14, and an impeller 58. The reamer part 14 may be mounted to rotate relative to the body 12. The impeller 58 may be mounted within the tubular body 12 and connected to rotate the reamer part 14. Referring to Figs. 6 and 7, the interior passageway 160 may have a plurality of radial passageways, such as apertures 55, that direct fluid through the interior passageway 160 in a radial direction 167 (Fig. 7) against the impeller 58 to drive the impeller 58 and rotate the reamer part 14.

[00117] Referring to Figs. 6-8, the impeller 58 may take a suitable shape. Referring to Figs. 7-8, a radially-inward facing surface 58A of a sleeve 59 of the impeller 58 may comprise a circumferential array of fins 58B. The sleeve 59 may mount the impeller 58 to the tubular body 12. The circumferential array of fins 58B may be oriented parallel with an axis 61 of the downhole reamer tool 10. Other orientations may be used, including orientations where fins 58B form a helix that wraps at least partially around surface 58A. In the example shown, with fins 58B parallel to axis 61, fluid flow expelled in radial directions against fins 58B imparts a circumferential torque upon fins 58B, causing fins 58B to spin.

[00118] Referring to Figs. 7-8, the radial passageways to impeller 58 may be formed by slots 57 in plates 56. The plurality of radial passageways may be at least partially defined by slots 57 in respective axial faces 57A of each of a plurality of ring plates 56 that are stacked axially one on the other. In the example shown, slots 57 are formed on one axial face 57A per plate 56, although in other cases slots 57 may be formed on opposing faces 57A. Each slot may have a suitable shape, for example slots 57 may be curved or angled to eject

fluid along an ejection path 71B at a nonzero angle 71 relative to a radius 71A, which is defined by the respective ring plate 56 and passes through a fluid exit end 71C of the slot 57. In the example shown, the orientation, size, and number of slots 57 in each plate 56 is selected to balance fluid momentum and ejection direction, to minimize vibration inducement by operation of impeller 58. In the example shown, all slots 57 are identical to provide symmetry and to maximize torque imparted upon impeller 58. Each slot 57 may align to receive fluid flow from a respective aperture 55 from an inner mandrel collar 54. The use of a plurality of plates 56 with slots 57 stacked one on the other creates a structural that acts as a single unit but without the demands of machining same if such were machined from a single block of material. Each plate 56 may be individually machined or otherwise fabricated with complex slots that may be impossible to form within a solid block.

[00119] Referring to Figs. 7 and 8, the plates 56 may be mounted in a suitable fashion within the tool 10. In the example shown the plurality of ring plates 56 are stacked around a cylindrical wall 54A of and coaxial with a collar 54. The plurality of radial passageways, including apertures 55, may be defined from a central bore 166 of the collar 54 through the cylindrical wall 54A of the collar 54. Referring to Fig. 8, the cylindrical wall 54A may have an out-of-round circumferential profile, such as a polygonal profile 54C, that meshes with a corresponding inner circumferential profile, such as a polygonal profile 56B, of the plurality of ring plates 56. Matching torque transfer profiles permit the parts to rotate together, and facilitate drill out.

[00120] Referring to Figs. 6 and 7, the plates 56 may mount on the collar 54 via a suitable mechanism. For example, a pair of flanges, 53A and 53B, secured to or formed by the collar 54, may compress the plurality of ring plates 56 on the collar 54. In the example shown, flange 53A is formed as part of collar 54, while flange 54B is part of a static mandrel 60 that is threaded or press fit to an uphole end of collar 54. The flange 54B effectively forms an uphole flange of the pair of flanges 53A, 53B, and connects to the tubular body 12, in this case indirectly via mandrel 60.

[00121] Referring to Figs. 6, 7, and 9, the reamer tool 10 may form a casing shoe reamer, with a nose 48. The nose 48 may be structured as one or both a drill bit or a reamer. In the example shown, the nose 48 functions in a drill bit capacity. For example, the lipstick-

style nose 48 defines one or more blades or bladed edges 48B that are positioned to act upon debris directly axially in the path of the nose 48 to pulverize and clear same out of the path of the tool 10. In other cases a reaming blade or other device may be mounted to a peripheral part of nose 48.

[00122] Referring to Figs. 6 and 7, drilling and cleaning action may also be achieved using outlet ports 72 in the nose 48. Interior passageway 160 may connect from the impeller 58 to the outlet ports 72, to produce fluid jets during use that act to remove, pulverize, and wash out debris in the wellbore. Referring to Fig. 7, the outlet ports 72 may include outlet ports directed in one or both of axial direction, in the case of port 72A, and radial directions, in the case of port 72B.

[00123] Referring to Figs. 6 and 7, the impeller 58 may be connected to rotate the nose 48, for example if nose 48 is threaded or press fitted to radial bearing 52, which threads or is press fit to reamer housing 50, which is mounted to rotate with impeller 58 relative to tubular body 12, in this case top sub 70. Top sub 70 may define an uphole tubing connector 37, and may mount via bearings 66A and 66B to a dynamic sleeve 68, which threads or is press fit to reamer housing 50. The top sub 70 may thread or press fit to a static sleeve 64, which connects via radial set screws 62 to static mandrel 60. In some cases, instead of or in addition to set screws 62, one or more locking split rings may be used within grooves that align during make up between sleeves 64 and 60. In one case during assembly the sleeve 60 is press fit into sub 70, sleeves 68 and 64 are then connected to sub 70, and as sleeve 64 is connected to sub 70, sleeve 64 positions the split ring or rings within the aligned grooves to mate sleeves 60 and 64. An uphole facing surface of the tool 10, for example surface 60A of static mandrel 60, may be striated, with striations 60B, or may be otherwise contoured to improve drillability. Reaming part 14 may be mounted to reamer housing 50.

[00124] Referring to Fig. 7, in use, the tool 10, which may be a casing shoe reamer as shown, may connect to a downhole end of a casing string. Fluid may pass down the casing string bore, and into passageway 160, passing into central bore 166 of collar 54, where the fluid is then diverted radially outward through apertures 55. From apertures 55, the fluid passes into slots 57, and is channeled radially outward to strike against fins 58B of impeller 58, causing impeller 58 to rotate. The rotation of the impeller 58 causes housing 50, reamer

part 14, and nose 48 to rotate. Referring to Figs. 7 and 9, fluid that exits a downhole end 58D of impeller 58 passes radially outward via outlet ports 73 into the wellbore, and radially inward into nose 48 via axial ports 52A in radial bearing 52. Fluid entering the hollow nose 48 is then ejected outward into the wellbore via ports 72. Fluid ejected out into the wellbore acts to pulverize and entrain debris, creating a swirling vortex along with the rotation of the nose 48 and reamer part 14, to lift debris up off the well bottom and carry same to surface. The reaming action of the reamer part 14 acts to smooth and enlarge the wellbore, preparing same for installation of the casing string. An impeller may permit the tool 10 to achieve high rpm in a relatively axially short span of space.

[00125] Referring to Figs. 10-13 and 29, 30A, and 30B, two other embodiments of impeller-powered reamer tools 10 are illustrated. Referring to Fig. 10, the tool 10 illustrated has many of the same features as tool 10 from Fig. 4. However, the nose 48 is configured to act as a reamer, with reamer blades 47. In addition, the reamer part 14 comprises relatively long, straight blades 49. Referring to Fig. 12, each plate 56 has six slots 57 instead of the three slots 57 found on the plates 56 of the embodiment of Fig. 4. Referring to Figs. 29, 30A, and 30B, the embodiment of Fig. 10 is illustrated with the addition of a wire brush scraper sub 75 between the nose 48 and the reamer housing 50. The scraper sub 75 acts as a casing scraper to polish the wellbore, and may include a plurality of brushes 75A on an external surface of the sub 75.

[00126] **The Hydra Hybrid**

[00127] Referring to Fig. 15, a further embodiment of a downhole reamer tool 10 is illustrated. The tool 10 has the ability to rotate the reamer part 14 and the nose 48 at different speed relative to the tubular body 12. Referring to Figs. 16A-C and 17, the tool 10 also comprises a progressive cavity power section 15 connected to rotate the nose 48, the reamer part 14, or both. In the example shown the motor 15 is connected to rotate the nose 48 independent of the rotation of the reamer part 14 by the impeller 58.

[00128] Referring to Figs. 16A-C, reamer part 14 and nose 48 may be mounted to rotate at different speeds relative to the tubular body 12, in this case top sub 98 and stator 32. The reamer part 14 may be mounted to rotate relative to the tubular body 12 at a first speed under fluid flow in the interior passageway 160. The nose 48 may be mounted to rotate

relative to the tubular body 12 at a second speed under fluid flow in the interior passageway 160. The first speed may be different, for example faster, than the second speed. The example shown provides relatively higher torque and rpm than the embodiments of Fig. 4 and 10.

[00129] Referring to Figs. 16A-C and 17, the tool 10 may incorporate plural motors to plural parts. For example, a first motor, such as PC motor 15, may be connected to rotate the nose 48 relative to the tubular body 12. Also, a second motor, such as impeller 58, may be connected to rotate the reamer part 14 relative to the tubular body 12. The PC motor 15 may comprise a stator 32 and a rotor 36. The stator 32 may be connected to the tubular body 12, for example rotationally fixed to the tubular body 12 as shown. The rotor 36 may be connected to rotate the nose 48. In other cases the stator 32 may rotate the reamer part 14 and the rotor 36 may be rotationally fixed to body 12. In some cases the PC motor 15 is connected to rotate the reamer part 14, while the impeller 58 is connected to rotate the nose 48. The nose 48 may comprise one or more of blades 47 and polycrystalline diamond cutters (not shown).

[00130] Referring to Figs. 16A-C and 17, the tool 10 may have various parts. A top sub 98 may define an uphole tubing connector 37 at uphole end 42. The top sub 98 may be threaded or press fitted to the stator 32, which may be made of plural or a single stator sections (a single piece is illustrated). The stator 32 is threaded or press fitted to a drive housing 96, which houses a drive shaft 94, which transfers torque from rotor 36 to a mandrel such as a drive adapter 92. Drive housing 96 may thread or press fit to a drive adapter sub 90, which mounts the drive adapter 92 via bearings 66B and 66C, and threads or is press fit to static sleeve 86. Bearings 66D and 66B mount dynamic sleeve 88, which connects via threading or press fit to reamer housing 50.

[00131] Referring to Fig. 16A, 16B and 17, rotor contacting surfaces 188 of the stator 32, and stator contacting surfaces 190 of the rotor 36, may comprise rigid material, such as metal. In some cases one or more of surfaces 188 and 190 may be treated or coated. An example treating method includes laser treatment. The coating may be a bearing material with a coefficient of kinetic friction that is less than or equal to 0.2 in relation to steel. The bearing material may have a coefficient of kinetic friction that is less than 0.1, in relation to

steel. The bearing material may comprise a non-metal. The bearing material may comprise one or both nylon or ultra-high-molecular-weight polyethylene. In other cases, surface 188 and/or surface 190 comprise an elastomeric material, such as rubber.

[00132] In use, when the casing string is downhole in a well, fluid is pumped through the casing string into an uphole portion 160A of the interior passageway 160. Fluid enters a fluid inlet 161 at an uphole end of the motor 15, travelling in a downhole direction through the motor 15 while imparting torque upon the rotor 36. The rotation of rotor 36 causes the nose 48 to rotate. Fluid travels around drive shaft 94, and passes via radially inward ports 95 into central bore 160B in drive adapter 92. Fluid then travels through bore 166 in collar 54, passing through apertures 55 and slots 57 to strike and rotate the impeller 58, causing reamer part 14 to rotate for reaming action. Fluid then travels into the wellbore via exit ports 73 in reamer housing 50, and while some fluid passes radially inward into nose 48 via ports 160C, Once in the rotating nose 48, fluid may exit via a variety of fluid outlet ports 72, jetting out at various angles to assist in drilling, reaming, and debris clean out to surface.

[00133] **MRS - Motorized Reamer Shoe**

[00134] Referring to Figs. 18-27, several embodiments of a reamer tool 10 are illustrated, with reamer parts 14 powered by a PC motor 15. Referring to Figs. 19A and 24, embodiments are shown where the stator 32 rotates relative to a stationary rotor 36, thereby rotating the reamer part 14. Referring to Figs. 19A, 22A, and 24, all embodiments incorporate a universal joint to convert eccentric rotor 36 motion into concentric motion to reduce vibration and increase tool 10 effectiveness. Referring to Figs. 19A and 22A, embodiments are shown with a hollow helically lobed sleeve rotor 36. Tools 10 may be used in suitable applications, such as deep water or deep well applications, as well as conventional wells.

[00135] Referring to Figs 19A-19B, and 20 an embodiment is shown where the stator 32 rotates relative to the rotor 36. The stator 32 may be mounted to rotate relative to the rotor 36 upon application of fluid flow between the rotor 36 and the stator 32. The reamer part 14 may be mounted to be rotated by the stator 32. The rotor 36 may be connected, for example rotationally fixed to the tubular body 12, for example by press fit or an uphole end 36A of rotor 36 threading to a rotor adapter 110, which mates with a drive shaft 124, which

mates with a drive adapter 144, which threads or press fits to a bearing shaft 132, which threads or press fits to a casing adapter / top sub 140. A downhole end 36B of the rotor 36 may form a free cantilevered end. The stator 32 may be mounted to rotate relative to top sub 140, which defines an uphole tubing connector 37, by an uphole end 32A of stator 32 threading or press fitting to a stator adapter 108, which threads or press fits to an end cap 128, which mounts upon bearing shaft 132 via bearings 66 and 130. A downhole end 32B of stator 32 threads or press fits to reamer housing 50, which mounts reamer part 14 and reamer blades 47.

[00136] Referring to Figs. 19A-B, the tool 10 may form a casing reamer shoe. A nose 48 may form a downhole end 40 of the casing reamer shoe, and the stator 32 may be connected to rotate the nose 48. In use the tubing or casing string may be positioned downhole in a well. Fluid may be pumped through the casing string to operate the progressive cavity power section 15, in which pumping fluid causes the stator 32 and reamer parts 14A and 14B to rotate relative to the string and the rotor 36. In use, fluid enters a portion 160A of the interior passageway 160 via connector 37, is redirected through the PC motor 15, where the stator 32 is actuated to rotate, and the fluid exits the downhole end 32B of the PC motor 15 into a central bore 160B of the reamer housing 50, where the fluid then exits the reamer tool 10 via one or outlet ports 72 within the nose 48, for example ports 72A pointed in an axial direction, and ports 72B pointed in a radial direction. One or more outlet ports 72 may comprise a nozzle 77 fitted and rated to create a fluid jet of controlled characteristics upon exit. A stabilizer 141, which includes a centralizer, may be present on top sub 140.

[00137] Referring to Figs. 19A-B and 20, the rotor 36 may be mounted to a universal joint for correcting eccentricity of rotation of rotor 36. A universal joint includes a coupling that can transmit rotary motion by a shaft over a range of angles. The universal joint 79 may be connected between the rotor 36 and a bearing, such as bearing shaft 132 mounted on ball bearings 130 and 66, on the tubular body, in this case top sub 140. The universal joint 79 may be structured to convert eccentric motion of the rotor 36 into concentric motion. Referring to Figs. 22A-B, an example is shown where the universal joint 79 is connected between the reamer part 14 and the rotor 36.

[00138] Referring to Figs. 19A-B and 20, the universal joint 79 may comprise a drive shaft 124. The shaft 124 may be mounted for rotation within the tubular body 12. The shaft 124 and the rotor 36 may mate via cooperating circumferential arrays of splines 124A and 125A, for example which mesh via a circumferential array of pins 116A. The cooperating circumferential arrays of splines may comprise a radially-outward facing array of splines 124B, for example mounted on the drive shaft 124, and a radially-inward facing array of splines 125A, for example mounted on the rotor 36, or in this case on a rotor adapter 110 that threads or press fits to an uphole end 36A of the rotor 36.

[00139] A pin and splined connection can be tailored to provide the required degree of conversion from eccentricity to concentricity. Referring to Fig. 19C, each pin 116A, of the circumferential array of pins 116A, may be tapered with decreasing radius from a central portion 117C to each axial end 117A and 117B of the pin 116A. In the example shown the pin 116A is beveled at each end 117A, and 117B. The shape used permits the pin 116A to tip axially forward and backward, while still retaining a meshing connection with the splines. Such allows the shaft 124 and adapter 110 to translate radially and pivot relative to one another. Pins 116A may be made of rigid material that does not deform under the relatively high temperatures experienced downhole. Rubberless or other metal on metal embodiments of the progressive cavity sections disclosed here may be used in high temperature downhole applications.

[00140] Referring to Figs. 19A-B and 20, a second set of splines and pins may be present. The cooperating circumferential arrays of splines 124A, 125A may be located at or near a first axial end 129A of the shaft 124. The shaft 124 may connect to a bearing, in this case bearing shaft 132 mounted to ball bearings 130 and 66, on the tubular body 12, via a second set of cooperating circumferential arrays of splines 124B, 125B. The second set of splines may be located at or near a second axial end 129B of the shaft 124. A second array of pins 116B may cooperate with splines 124B, 125B. Splines 124B, 125B, and pins 116B may have the same characteristics as splines 124A, 125A, and pins 116A, respectively.

[00141] Referring to Fig. 22A-B, an example is shown where the drive shaft 124 and spline-pin universal joint 79 is located between the rotor 36, in this case a downhole end 36B of rotor 36, and the reaming part 14. Specifically, the downhole end 36B threads or press fits

to a rotor adapter 110, which mates with drive shaft 124 via a spline and pin connection as above, and drive shaft 124 mates with a drive adapter 144 via a second spline and pin connection. Adapter 144 threads or press fits to bearing shaft 132, which threads or press fits into reamer housing 50, which mounts reamer part 14 and nose 48.

[00142] Referring to Figs. 19A-B and 20, each set of splines may be protected by a respective drive boot, in this case boots 122A and 122B, which mount via split rings 120A and 120B, and thrust seat caps 112A, 112B, to the rotor adapter 110 and the drive adapter 144, respectively. The thrust seat caps 112A, 112B form caps that secure the split rings 120A and 120B and keep the boots 122A and 122B in position around shaft 124 to protection the spline and pin connections clean from fluids. Such structures also help to contain lubricating fluid, such as grease from washing out of the spline and pin connections. A port 219 and an NPT threaded plug 221 may be used for grease injection in each of adaptors 110 and 144. Each of adaptors 110 and 144 may have a pair of plugs 221 and ports 219, one to permit venting while the other is filled.

[00143] Referring to Figs. 31-33, a further embodiment of a reamer tool 10 is illustrated. In the example shown, a drive shaft 124 is used to act as a universal joint 79 between the rotor 36 and the bearings 138 and 66. The drive shaft 124 may also be used on the downhole end of the rotor 36 similar to the embodiment of Fig. 21. The axial ends 129A and 129B of the shaft 124 may be press fit with rotor adapter 110 and drive adapter 144. The drive shaft 124 may be made of a resilient metal, which bends elastically during use to convert eccentricity to concentricity, for example titanium and other suitable metals. The drive shaft 124 may thus form a flex-shaft.

[00144] Referring to Figs. 34A, 34B and 35, a further embodiment of a reamer tool 10 is illustrated. In the example shown, a drive shaft 124 is used in a form that combines ideas from the splines of the embodiment of Fig. 19A, with the pinless design of Fig. 31. In the example the spline sets 124A-125A and 124B-125B mate directly in a gear to gear fashion. Referring to Figs. 34A-B and 35, the spline-spline connection may be structured to permit radial translation and pivoting between parts, similar to the type of movement permitted by the beveled drive pins 116A. The splines 124A may be tapered with decreasing distance from a central portion 119C to each axial end 119A and 119B of each spline 124A, 124B.

The shape used permits the drive shaft 124 to tip axially forward and backward, while still retaining a meshing connection with the splines. Such allows the shaft 124 and adapter 110 to translate radially and pivot relative to one another. Boots 122A and 122B may also be used.

[00145] Referring to Figs. 19A-B, the drive shaft 124 may be a hollow shaft sleeve as shown. A hollow interior 131, defined by the hollow shaft sleeve, may be closed, for example by end caps 118A, B secured within respective drive caps 114A, 114B. A hollow drive shaft may reduce the weight of the tool 10, and also may assist in drilling out the tool 10 when sacrificed at the bottom of a casing string. The inner diameter 133 may be selected to be commensurate with an inner diameter 173A of the casing 172 being run with tool 10.

[00146] Referring to Figs. 19A-B, in use a casing string 173 may be positioned downhole in a well. Fluid may be pumped through the casing string 173 and into an uphole portion 160A of interior passageway 160. Fluid may pass drive shaft 124 around an annulus defined between the drive shaft 124 and the stator adapter 108, by moving through radial ports 135 in drive adapter 144, passing around the shaft 124, and entering the PC motor 15. The fluid flow through motor 15 causes the stator 32 or rotor 36 (in this case the stator 32) to rotate, and the universal joint 79 acts to convert eccentric motion of the rotor 36, relative to the stator 32, into concentric motion, thus reducing vibration, which may deleteriously affect reaming operation. Fluid passing through motor 15 in a downhole direction then moves into bore 160B and out the ports 72 in the nose 48 as previously discussed above. Referring to Figs. 19A and 22B, uphole and downhole facing surfaces 137 and 139, respectively, may be structured, for example striated as shown, to improve drillability. In the example shown an surface 137 defines a striated uphole entry to bearing shaft 132, to permit a drill bit to be able to grip and drill through the shaft 132 and the interior contents of the tool 10.

[00147] Referring to Figs. 19A-B and 20, the rotor 36 may form a hollow helically lobed sleeve as shown. The rotor 36 may define a hollow interior 36C, which may be closed against fluid passage, for example via one or more walls. In the example shown opposed axial ends 36A and 36B of the hollow helically lobed sleeve are blocked by respective end walls, namely provided by rotor adapter 110 and rotor plug 104. An uphole facing surface of the wall may be striated. A casing 172 may be connected, for example directly as shown, or

indirectly through intermediary parts or tools, to the downhole reamer tool 10. An inner diameter 36D of the hollow helically lobed sleeve of rotor 36 may be sized to be commensurate with, for example equal to, an inner diameter 173A of the casing 172. In some cases nominal deviations between diameters 36D and 173A may be present. For example the diameter 36D may be larger than the diameter 173A, or smaller, for example equal to the drift ID of the casing. A smaller diameter 36D may be acceptable at the bottom of the well, if no further sections will be drilled, or if only a limited number of sections are to be drilled and the diameter 36D still permits sufficient play for such sections and casing to pass through. If the diameter 36D is too small, milling tools may be required to mill out the excess diameter, and such milling tools may require an extra trip in and out of the well to position and retrieve such tools.

[00148] Referring to Fig. 28, once the casing string is landed in the desired position, the casing 172 may be cemented in place. To accomplish such cement may be pumped down the internal bore of the casing 172, to the casing reamer tool 10, out the outlet ports 72 in the tool 10, and up the annulus defined between the well and the casing string 173. The tool 10 may be structured as a guide or float shoe, and may have a one-way valve to prevent backflow of cement. Upon setting of the cement, casing reamer tool may be drilled out by running a drill bit 181 at the end of a drill string 185 to the tool 10, and operating the drill bit 181 to drill out an axial passage in the tool 10. Once drilled out, the drill bit 181 continues on downhole to create and extend the well bore by adding a new section of well bore.

[00149] Referring to Figs. 21-23, a modification of the embodiment of Fig. 18 is illustrated. Referring to Figs. 22A and 22B, in the example shown, fluid is pumped into a portion 160A of the interior passageway 160, passing into the motor 15, and causing the rotor 36 to rotate, turn the drive shaft 124, and turn the reamer part 14 and nose 48. Fluid then continues down the internal annulus of the tool 10 between the drive shaft 124 and a static sleeve 142, passing through radial ports 143 in drive adapter 144 and entering a bore 160B of bearing shaft 132, exiting the nose 48 via fluid ports 72. Once the casing is landed the casing may be cemented in place and the tool 10 may be drilled through and the wellbore continued in a downhole direction.

[00150] Referring to Figs. 24, 24A, 24B, 25, 26, and 27, a further embodiment of a downhole reamer tool 10, such as a casing reamer shoe as shown, is illustrated. In the example shown fluid enters through the uphole end 42 into the portion 160A of interior passageway 160. The fluid passes through radial ports 135 into the motor 15. Upper and lower bearing assemblies 223 and 225 may be used. The reaming tool 10 may agitate a drill string or casing string by generating a shock-wave due to the rotation of the tool. This extends the reach of the casing 50 by creating agitation. In some extended reach wells (e.g. horizontal wells that are longer than the vertical section of the well) the tool 10 may run the casing 50 further than normally would be possible without extra hydraulic or mechanical evacuation. The torque produced may allow the tool 10 to drill with a casing bit. The tool 10 may replace a jetting assembly in deep water operations.

[00151] Referring to Figs. 36 and 39A-C, an electrochemical machining (ECM) method and resulting downhole tool 10 are illustrated. Referring to Fig. 36, in a first stage the stator is formed by ECM. Electrochemical machining (ECM) is a method of removing metal by an electrochemical process. It may be used for working extremely hard materials or materials that are difficult to machine using conventional methods. ECM may be used to cut small or odd-shaped angles, intricate contours or cavities in hard and exotic metals, such as titanium aluminides, and high nickel, cobalt, and rhenium alloys. Both external and internal geometries can be machined.

[00152] ECM may be characterized as “reverse electroplating” in that it removes material instead of adding it. An ECM cutting tool is guided along the desired path close to the workpiece but without touching the workpiece. High metal removal rates are possible with ECM, with no thermal or mechanical stresses being transferred to the part, and mirror surface finishes can be achieved.

[00153] In the ECM process, a cathode (tool) is advanced into an anode (workpiece). A pressurized electrolyte is injected at a set temperature to the area being cut. The feed rate may be the same as the rate of liquefaction of the material. The gap between the tool and the workpiece may vary, for example within 80 - 800 micrometers or 0.003 - 0.030 inches, or other suitable distances smaller or greater. As electrons cross the gap, material from the workpiece is dissolved and the tool forms the desired shape in the workpiece according to

the shape of the cutting tool. The electrolytic fluid carries away the metal hydroxide formed in the process.

[00154] Referring to Fig. 36, the stator 32 may be made via ECM. A power supply 214 may be connected to a metal block or tube 202, which forms a workpiece, and a shaping tool such as cutting tool 204, for example to pass current between the metal tube 202 and the shaping tool 204. The power supply 214 may thus establish an electrical field across gap 221 defined by the outer sidewall 225 of the cutting tool 204 and an inner sidewall 227 of the workpiece or tube 202. The metal tube 202 may form an anode. The shaping tool 204 may form a cathode.

[00155] The shaping tool 204 may have a tool head 208 positioned adjacent a surface 220 of the shaping tool 204, for example defining a gap between the tool head 208 and the surface 220, with surface 220 being eroded and retreating as the tool head 208 advances. An electrolyte 210 or other suitable conductive fluid may be injected and continually flowed through the gap 221 between the tool head 208 and the surface 220. The electrolyte 210 may be supplied to the shaping tool 204 from a suitable reservoir 203 via one or more of a pump 240 and a fluid line 216, for example that extends through the interior of the shaping tool 204. The electrolyte 210 may exit the shaping tool 204 via a nozzle 218, for example defined within the tool head 208 of the shaping tool 204, and upon exit the electrolyte comes into contact with the tube 202. Once the electrolyte passes the gap 221 and absorbs metal from the tube 202, the now-metal-carrying electrolyte may flow into a further reservoir 211, where the fluid may be recycled back into the supply reservoir 203, for example via a recovery line 213. The fluid may be filtered or treated prior to re-entering reservoir 203. In some cases spent fluid is discarded. A cooling circuit may be provided to manage temperature changes in the electrolyte fluid during the process.

[00156] During the ECM process the shaping tool 204 may be rotated and advanced around and along, respectively, an axis 209 of the metal tube 202, for example in a direction 222, via a suitable actuator 212 such as a linear actuator or hydraulic arm. Extension of the shaping tool 204 towards the surface 220 may cause release or removal of material from the metal tube 202.

[00157] Outer sidewall 225 of the cutting tool 204 may have a suitable shape such as a helically lobed profile as shown. Extension and rotation of the shaping tool 204 into the tube 202 advances the surface 220 and erodes material in the interior of the metal tube 202 to form helical lobes that are contoured into an inner surface 206 of the metal tube 202. The cutting tool 204 may rotate about the axis 209 such that the inner sidewall 227 of the workpiece or tube 202 takes on a shape that is the inverse of the helically lobed profile of the outer sidewall 225 of the cutting tool 204. Movement, for example advancement, extension, retraction, and / or rotation, of the shaping tool 204 may follow a preset path or pattern determined by a controller 258. The rotation and advancement of the tool 204 may follow the profile lines of the helical lobes of the tool 204, to ensure that the tube 202 takes on the same helically lobed profile. The controller 258 and the actuator 212 may be connected to one or more of the power supply 214, actuator 212, and pump 240 via respective control lines 244, 242, and 245. In some cases variations of ECM may be used, such as electrical discharge machining (EDM), or other processes that involve selective erosion of the interior surfaces of the workpiece to achieve the desired interior shape.

[00158] Referring to Figs. 38 and 39A-C, a drilling motor tool 10 is illustrated. The tool 10 may be formed by ECM or another suitable method. ECM may permit a suitable stator 32 to be formed from a single integral block of material such as tube 202 (Fig. 36). A single integral block of material may be initially a suitable unbroken shape such as a cylinder, although the block could have a solid or hollow core, and could be other than cylindrically shaped, such as shaped like a rectangular box. Further machining after ECM may be carried out to finalize the shape of the stator 32. ECM may permit extended lengths of integral stator sections to be made, for example stator sections may be made with an axial length 219 (Fig. 38) of at least fifty and in some cases fifty, eighty, one hundred fifty, and three hundred inches or more, defined between axial ends 32A and 32B of the stator. The resulting stator may have no break lines or transition points such as weld lines or abutting ends of adjacent sections connected by connectors such as dowels. Instead, the stator may have a continuous unbroken profile from axial end to axial end. The axial ends 32A and 32B may refer in some cases to the start and end points of the helically lobed profile. By contrast conventional computer numerical control (CNC) methods using a lathe and mill may only be

able to create a stator section of thirty six inches or less. The length of a tool 10 produced by ECM may be limited by the axial length of the cutting tool 202, with such axial length capable of being tailored to achieve the desired stator length, and hence in theory any length of stator 32 may be created. In other cases the rotor, or both the rotor and the stator, may be formed using ECM. In cases where the rotor is formed by ECM, the inner sidewall of the cutting tool may be shaped with a helically lobed profile, so that the cutting tool rotates about the axis such that the sidewall of the workpiece takes on a shape that is the inverse of the helically lobed profile of the inner sidewall of the cutting tool.

[00159] In some cases the resulting stator formed may be connected with adjacent stators as sections to form a larger stator. In the example shown the entire motor 15 is formed by a single stator 32, in which a corresponding rotor 36 is inserted to assemble the motor 15. Rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, may be rigid, for example metal, for further example the same type of metal or different metals as one another. In other cases an elastomeric coating such as rubber may be placed, for example lined with corresponding helically lobed shape, on the inner sidewall 227 of the stator 32. Referring to Figs. 28 and 38, once formed and assembled, the tool 10 may be used in a downhole operation by positioning the tool 10 in a well bore 176, and pumping fluid to operate the progressive cavity section to rotate the rotor relative to the stator. In the example shown the tool 10 may be connected to or incorporate a drill bit 181, such that the rotor 36 is connected to rotate the drill bit 181 under fluid pressure to drill the well. Referring to Figs. 39A-C, the tool 10 assembled may incorporate various suitable features, such as uphole and downhole tubing connectors 39 and 37, respectively, bearings 128, reamers 24, a drive shaft 94, and top and bottom subs 16 and 38, respectively.

[00160] Methods may be used other than ECM to form a stator 32 out of a single integral block of material. Referring to Fig. 37, for example, three-dimensional printing may be used. Three-dimensional (3D) printing, also known as a form of additive manufacturing (AM), refers to processes used to create a three-dimensional object in which layers of material are formed under computer control to create an object. Objects may be of almost any shape or geometry and may be produced using digital model data from a 3D model or another electronic data source such as an Additive Manufacturing File (AMF) file.

Stereolithography (STL) is one of the most common file types that 3D printers can read. Thus, unlike material removed from a stock in a conventional machining process, 3D printing or AM builds a three-dimensional object from computer-aided design (CAD) model or AMF file by successively adding material layer by layer.

[00161] In some cases the stator 32 may be formed as a single piece. For example the stator 32 may be formed as a single piece by three dimensional printing. Layers of metal may be added until the desired shape is achieved. The resulting stator may be used in a rubberless, rigid contact surface application as described elsewhere in this document. A hollow rotor sleeve may be inserted into the stator to form a progressive cavity power section. In other cases a single piece stator may be made by other suitable methods, such as electrochemical machining, or one piece CNC machining.

[00162] Referring to Fig. 37, the stator 32 may be made via a 3D printer 224. The 3D printer 224 may comprise a structural frame 232 upon which actuators and workpieces are mounted. Frame 232 may comprise a set of guide rails 230 mounted to the structural frame 232, a printing head 234 mounted to the guide rails 230, for example to slide in opposed directions along arrows 250 and in directions into and out of the page to provide freedom of movement in a plane 251, which in the example shown is a horizontal plane. A nozzle 228 may be mounted to the printing head 234. Printing material 226 may be supplied from a reservoir 252 to the printing head 234 and ejected onto a substrate such as platform 236 via the nozzle 228, for example to form the stator 32. The platform 236 may be raised and lowered via an actuator 248 such as in opposed directions 260, for example to facilitate addition of the printing material 226 to the platform 236. Actuators that do not require rails may be used, for example robotic arms may be used as actuators. The printing head 234, the actuator 248, and the container 252 may be connected to a controller 238 via respective control lines 254, 262, and 246. Once completed and cured, a rotor may be inserted into the stator 32 to assemble the tool 10.

[00163] Referring to Figs. 2A, 2B, and 3, stators 32 may be made by other suitable methods such as using dowels 34. A progressive cavity section may be produced with a stator 32 and a rotor 36, in which the stator is formed by plural axial stator sections, such as sections 32'-32''' connected end to end. Adjacent axial stator sections, of the plural axial

stator sections, may be connected by dowels 36 as before. Dowels may refer to pegs as shown in Fig. 3 that are separate and independent to sections 32'-32'''', or dowels may refer to pegs that are integral with one of the stator sections and extend out into engagement with an adjacent section in use. Adhesive and other techniques may be used as described elsewhere in this document. Dowels may be used to construct any suitable downhole tool incorporating a progressive cavity section.

[00164] The techniques, methods, and processes described here may be used to make and use various downhole tools, from drilling motors, to reamers, to rotary steerables, stimulation tools, pulsation tools, and others.

[00165] The stator 32, rotor 36, or both, may be subjected to various surface treatments to improve performance, for example to increase physical properties. Such treatments may include varying the coefficient of friction, surface hardness, metal porosity, and residual surface stresses. Processes may include heat treatments such as laser hardening, nitriding, carborizing, or boronizing, to modify surface hardness. Teflon, or ceramic coating, or polishing, may be used or carried out to reduce friction. Surface coating processes such as a chrome overlay, carbide overlay, physical vapor deposition, chemical vapor deposition, or high velocity oxygen fuel (HVOF) processes may be used.

[00166] The tool 10 may be used in a drilling application. In such cases the tool 10 may be ran with a drilling rig outfitted to drill with casing. The nose 48 of the tool 10 may be of similar construction as a typical drill bit, for example with cutting structures impregnated into a metal matrix. After drilling the well, and after the casing has been cemented in place, the tool 10 may be drilled out. In some cases the nose 48 may need to be milled out by a milling tool due to the hardness of material of the nose 48. Milling may require an extra run to bring the milling tool down the well, to the nose 48 and back up the well again, to change out the milling bit into a drill bit. In some cases a casing while drilling application may be carried out while drilling a vertical well, although the embodiments here are not limited to vertical wells. To drill a directional or horizontal well the tool 10 may have an adjustable housing, and may use a directional measurement (MWD - measuring while drilling) system. In some cases a non-magnetic environment may be needed with certain MWD technology. In other cases a gyro may be used with a drilling application.

[00167] The reamer tool 10 may be considered to be a mandrel assembly, with an inner mandrel and an outer mandrel. The tool 10 may be coupled to the bottom end of the casing in a variety of manners, including but not limited to mating threads, press fits, snap-fits, friction fitting, adhesives, bolts, and the like and combinations thereof. The tool 10 may grip a shoe, which is the operating component that interfaces with the interior of the hole to be reamed and abrades away material, thereby reaming the hole. The shoe may include protrusions that, when the shoe spins, impact with non-smooth regions of the interior of the hole and thereby abrade the same making such regions more smooth and increasing the effective interior diameter of the same so that the casing can follow behind without getting stuck. After the drilling is completed for a particular section of a hole, the operator may put casing down the hole to create a smooth interior bore through which additional work may be completed.

[00168] However, the hole is generally not perfect and often includes defects that can stop the casing from going all the way down. Accordingly, it is desirable to put a reaming tool, the operating tip of which is usually called a shoe, towards the bottom to ream out the hole as the casing slides down. In one non-limiting embodiment, there is a reaming system, device, and/or mandrel assembly that is, advantageously, a low cost system that attaches to or includes one of a great variety of shoes (e.g. float shoe, reamer shoe, guide shoe) from a variety of manufacturers. The tool 10 may include an internal/central axle that rotates inside a housing and/or includes a pin-down connection (e.g. pin to pin, box-pin) to couple to a shoe so it can connect to any tool/shoe. The internal axle spins when fluid is pumped through the mandrel assembly and spins a sub that is connected to the shoe which therefore also spins. The internal axle and/or other centrally positioned parts may be of an aluminum, bronze, brass, and/or zinc alloy (or other material that may be drilled through rather easily, since the mandrel assembly is generally left at a bottom of the hole when the casing is finished being installed).

[00169] Additionally, although the figures illustrate an outer mandrel with a certain number of spiral lobes on an interior thereof, a different number of lobes and/or lobes of different slopes, curvatures, sizes, shapes and the like may be present. Finally, it is envisioned that the components of the device may be constructed of a variety of materials,

including but not limited to metals (both drillable and not), plastics, ceramics, composites and the like and combinations thereof. Parts may be made up of more than one part connected together, for example a housing may be made of plural sleeves of material threaded or press fitted together to form one unit. Blades include helical blades. A magnet tool may be used in an uphole direction of the casing brush or other embodiments of tool 10 to assist in collectively large metallic debris.

[00170] Parts or components of tool 10 may be connected to one another and other parts of a tubing string by any suitable method, including mating threads, press fits, snap-fits, friction fitting, adhesives, bolts, bearings, and the like and combinations thereof. Points of dynamic contact may be coated with one or more of an anti-corrosion agent and a slip agent. Tools 10 may be used in suitable applications, such as deep water or deep well applications, as well as conventional wells. In some cases stators or rotors may be made with forty inches of axial length or more.

[00171] In the claims, the word “comprising” is used in its inclusive sense and does not exclude other elements being present. The indefinite articles “a” and “an” before a claim feature do not exclude more than one of the feature being present. Each one of the individual features described here may be used in one or more embodiments and is not, by virtue only of being described here, to be construed as essential to all embodiments as defined by the claims.

1. A downhole tool comprising:
 - a progressive cavity section with a stator and a rotor;
 - in which the stator is formed from a single integral block of material, and the stator has a length of at least fifty inches defined between axial ends of the stator;
 - in which rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid and do not flex when in use at downhole temperatures;
 - in which the stator contacting surfaces and the rotor contacting surfaces are made of metal;
 - in which the stator is formed by electrochemical machining (ECM) to structure the rotor contacting surfaces of the stator to achieve a sufficiently narrow clearance or negative interference fit with the rotor to form an efficient pumping seal without seizing the progressive cavity section in use; and
 - in which the rotor contacting surfaces of the stator have been heat treated for increased surface hardness.
2. The downhole tool of claim 1 in which the progressive cavity section is connected to rotate a reamer part of a casing reamer shoe.
3. The downhole tool according to any one of claim 1 - 2 in which the progressive cavity section is connected to rotate a drill bit.
4. The downhole tool according to any one of claim 1 - 3 in which the length of the stator is at least eighty inches defined between the axial ends of the stator.
5. The downhole tool of claim 4 in which the length of the stator is at least one hundred and fifty inches defined between the axial ends of the stator.
6. The downhole tool of claim 5 in which the length of the stator is at least three hundred inches defined between the axial ends of the stator.

7. The downhole tool according to any one of claim 1- 6 in which the rotor is formed by electrochemical machining (ECM).
8. The downhole tool according to any one of claim 1 - 7 in which the stator contacting surfaces of the rotor have been heat treated for increased surface hardness.
9. The downhole tool according to any one of claim 1 - 8 in which the rotor contacting surfaces of the stator and the stator contacting surfaces of the rotor have been heat treated with nitriding for increased surface hardness.
10. A method comprising:
positioning the downhole tool according to any one of claim 1 - 10 in a well; and
pumping fluid to operate the progressive cavity section to rotate the rotor relative to the stator.
11. A method comprising:
forming a stator from a single integral block of material, in which the stator has a length of at least fifty inches defined between axial ends of the stator;
assembling a downhole tool by inserting a rotor into the stator;
in which rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid and do not flex when in use at downhole temperatures;
in which the stator contacting surfaces and the rotor contacting surfaces are made of metal;
in which the stator is formed by electrochemical machining (ECM) to structure the rotor contacting surfaces of the stator to achieve a sufficiently narrow clearance or negative interference fit with the rotor to form an efficient pumping seal without seizing the progressive cavity section in use; and
in which forming comprises heat treating the rotor contacting surfaces of the stator to increase surface hardness.

12. The method of claim 11 in which the stator and the rotor within the downhole tool form a progressive cavity power section connected to rotate a reamer part of a casing reamer shoe.
13. The method according to any one of claim 11 - 12 in which the stator and the rotor within the downhole tool form a progressive cavity power section connected to rotate a drill bit.
14. The method according to any one of claim 11 - 13 in which the length of the stator is at least eighty inches defined between the axial ends of the stator.
15. The method of claim 14 in which the length of the stator is at least one hundred and fifty inches defined between the axial ends of the stator.
16. The method of claim 15 in which the length of the stator is at least three hundred inches defined between the axial ends of the stator.
17. The method according to any one of claim 11 - 16 in which the rotor is formed by electrochemical machining (ECM).
18. The method according to any one of claim 11 - 17 in which the stator contacting surfaces of the rotor have been heat treated to increase surface hardness.
19. The method according to any one of claim 11 - 18 in which the rotor contacting surfaces of the stator and the stator contacting surfaces of the rotor have been heat treated with nitriding to increase surface hardness.



CONFIRMATION DE SOUMISSION ÉLECTRONIQUE / CONFIRMATION OF ELECTRONIC SUBMISSION

Type(s) de soumission(s) demandée(s) / Submission type(s) requested

Maintenance fees

Date de réception selon l'heure locale du Bureau des brevets - Date of receipt according to the local time of the Patent Office

Thu Nov 14 00:00:00 GMT 2024

Soumis par - Submitted by

Auteur de la requête

Requester

ROBERT NISSEN

Adresse

Address

Numéro de demande ou de brevet / Application or patent number	Numéro de référence / Reference number	Titre / Title
2985258	158-2CA2	DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND RELATED METHODS OF USE AND ASSEMBLY

Confirmation du demandeur / breveté - Applicant / Patentee confirmation

En vertu de l'article 9 des Règles sur les Brevets, pour chaque demande ou brevet identifié, le demandeur / breveté est confirmé comme un des demandeurs ou brevetés au dossier.

In compliance with section 9 of the Patent Rules, for each of the identified applications or patents, the applicant / patentee is confirmed as one of the applicants or patentees on file.

Numéro de demande ou de brevet / Application or patent number	Demandeur / Breveté / Applicant / Patentee
2985258	CROSSBERRY HOLDINGS LIMITED

Taxes payées – Fees paid

Numéro de demande ou brevet / Application or patent number	Numéro de référence / Reference number	Type de taxe / Fee type	Montant / Amount
2985258	158-2CA2	MF (patent, 7th anniv.) - small	100.00
		Total	100.00

General Correspondence (Patent)

012
Cs

Date: March 13, 2024 3:03:34 PM

#4678089

Application Number

2985258

Title of invention

DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND
RELATED METHODS OF USE AND ASSEMBLY

Applicant(s) or Inventor Name(s)

Applicant or Inventor Name

Sender

Family Name: Nissen
First Name: Robert
Initial:
Name of Corporation or Firm: Nissen Patent Law
Address Line 1: 401-11044 82 Ave NW
Address Line 2:
Address Line 3:
City/Town: Edmonton
Province/State: Alberta
Country: Canada
Postal/Zip Code: T6G 0T2
Telephone Number: 7808027904
Fax Number:
Email Address: robbie@nissenlaw.ca
Communicate by: Electronic Mail (Non secure)

Correspondence Instructions

Applicant: CROSSBERRY HOLDINGS LIMITED

Filing Date: November 14, 2017

Application Number: 2,985,258

Title: DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND
RELATED METHODS OF USE AND ASSEMBLY

Our Ref: 158-2CA2

In response to the notice of allowance dated March 1, 2024, the Applicant submits the final fee for this application. Please complete issuance of the patent application. The Applicant's intention is to keep the application in good standing, and thus please take all steps required to do so and, if any step has not been taken that must be taken, please accept this correspondence as a request for an extension of time to take the step. Please charge any additional fees required to the credit card or to the Agent of Record's deposit account no. 600002856.

/Robert A. Nissen/
Agent of Record

Description of Fee (small entity fee)

1. Final Fee - basic fee - small entity fee (1 x \$169.00): \$169.00

Total Fee Payment: \$169.00

Payment method

Common Payment Component

Attachments

No attachment file provided.

Transmission Identifier: pgc_nissenpatents_20240313150334083_16435756

Date: March 13, 2024 3:03:34 PM

Commissioner of Patents
50 Victoria Street
Place du Portage
Phase I
Gatineau, Quebec
Canada
K1A 0C9

Application Number: 2985258
Title of invention: DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY
SECTIONS, AND RELATED METHODS OF USE AND ASSEMBLY
Applicant(s) or Inventor(s) Name(s): CROSSBERRY HOLDINGS LIMITED
CROSSBERRY HOLDINGS LIMITED
Reference Number: 158-2CA2

Instructions: Applicant: CROSSBERRY HOLDINGS LIMITED
Filing Date: November 14, 2017
Application Number: 2,985,258
Title: DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND
RELATED METHODS OF USE AND ASSEMBLY
Our Ref: 158-2CA2

In response to the notice of allowance dated March 1, 2024, the Applicant submits the final fee for this application. Please complete issuance of the patent application. The Applicant's intention is to keep the application in good standing, and thus please take all steps required to do so and, if any step has not been taken that must be taken, please accept this correspondence as a request for an extension of time to take the step. Please charge any additional fees required to the credit card or to the Agent of Record's deposit account no. 600002856.

/Robert A. Nissen/
Agent of Record

Description of Fee (small entity fee)
1. Final Fee - basic fee - small entity fee (1 x \$169.00): \$169.00
Total Fee Payment: \$169.00

Nissen, Robert
Nissen Patent Law
401-11044 82 Ave NW
Edmonton
Alberta
Canada
T6G 0T2

Tel: 7808027904
Email:robbie@nissenlaw.ca

Transmission Identifier: pgc_nissenpatents_20240313150334083_16435756



Courtoisie – Frais déjà payés à 50\$
Courtesy – Fees already paid at \$ 50

NISSEN, ROBERT A.
robbie@nissenlaw.ca

Détails de la lettre

Letter Details

Date de la lettre Letter Date:	2024-03-28
N° de la demande/brevet Application/Patent N°	2,985,258
:	:
Votre N° de référence Your Reference N°	158-2CA2
:	:

**A TITRE D'INFORMATIONS SEULEMENT –
AUCUNE ACTION N'EST REQUISE.**

Selon les données du Bureau des brevets, vous avez payé une ou plusieurs des 2^e, 3^e ou 4^e taxes pour le de maintien en état, applicables aux petites entités, d'un montant de 50,00 \$, entre le 2021-01-01 et 2024-03-28.

Bien que le paiement de 50,00 \$ soit conforme au site Web du Bureau des brevets, la 2^e, 3^e ou 4^e taxe pour le maintien en état, applicable à une petite entité, s'élevait à 51,00 \$, 50,90 \$, 52,63 \$ et 56,21 \$ en 2021, 2022, 2023 et 2024, respectivement.

Conformément au paragraphe 3(4) des Règles sur les brevets, telles que modifiées le 2024-03-25, le Commissaire aux brevets a prorogé le délai de paiement de la ou des taxes, si le délai de paiement de la taxe a expiré, et a renoncé à l'exigence de fournir une déclaration en vertu de l'alinéa 3(4)c) des *Règles sur les brevets*.

Conformément aux paragraphes 139.1(1) et 139.1(2) des *Règles sur les brevets*, dans leur version modifiée le 2024-03-25, le commissaire aux brevets a également renoncé à la différence entre le montant qui a été payé et le montant des droits qui étaient payables le jour où le paiement insuffisant a

**FOR INFORMATION ONLY – NO ACTION
REQUIRED.**

According to Patent Office records, you have paid one or more of the 2nd, 3rd or 4th small entity maintenance fees in the amount of \$50.00 between 2021-01-01 and 2024-03-28.

While the \$50.00 payment was consistent with the Patent Office's website, the prescribed 2nd, 3rd or 4th small entity maintenance fee in 2021, 2022, 2023, and 2024 was \$51.00, \$50.90, \$52.63, and \$56.21, respectively.

Pursuant to subsection 3(4) of the Patent Rules, as amended on 2024-03-25, the Commissioner of Patents has extended the time to pay the fee(s), if the period to pay the fee has expired, and has waived the requirement to provide a statement under paragraph 3(4)(c) of the *Patent Rules*.

Pursuant to subsections 139.1(1) and 139.1(2) of the *Patent Rules* as amended on 2024-03-25, the Commissioner of Patents has also waived the difference between the amount that was paid and the amount of the fee that was payable on the day on which the insufficient payment was made.

été fait.

Par conséquent, toute taxe pour le maintien en état, applicable aux petites entités, que vous avez payée au montant de 50,00 \$ entre le 2021-01-01 et le 2024-03-28 est considérée comme entièrement payée et aucune autre mesure n'est requise.

Pour plus d'informations, veuillez consulter le [site web de l'OPI](#) .

Référence pertinente :

- paragraphe 3(4) des *Règles sur les brevets*;
- paragraphes 139.1(1) et (2) des *Règles sur les brevets*

As such, any maintenance fee that you have paid in the amount of \$50.00 between 2021-01-01 and 2024-03-28 is considered fully paid and no further action is required.

Please visit [CIPO's website](#) for more information.

Relevant references:

- subsection 3(4) of the *Patent Rules*;
- subsections 139.1(1) and (2) of the *Patent Rules*



Brevet canadien / Canadian Patent

2,985,258

*Numéro de brevet
Patent number*

Le commissaire aux brevets a accordé un brevet pour l'invention décrite dans le mémoire descriptif portant le numéro de brevet susmentionné. Le mémoire descriptif est accessible dans la Base de données sur les brevets canadiens sur le site Web de l'Office de la propriété intellectuelle du Canada.

The Commissioner of Patents has granted a patent for the invention described in the specification under the above-noted patent number. The specification is accessible in the Canadian Patents Database on the website of the Canadian Intellectual Property Office.

Commissaire aux brevets
Commissioner of Patents



(CIPO - 91) 2020-08-15

Titre de l'invention / Title of invention

**OUTILS DE FOND DE TROU A SECTIONS DE CAVITE PROGRESSIVES, ET
METHODES D'UTILISATION ET ASSEMBLAGE ASSOCIEES**

**DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND
RELATED METHODS OF USE AND ASSEMBLY**

Breveté(s) / Patentee(s)

CROSSBERRY HOLDINGS LIMITED

Inventeur(s) / Inventor(s)

**PEARSON, ALLAN; LUCHAK, MARK; SCHEMING, OXANA; OSATCHUK,
MATT; VENABLES, ERIN; NKWOCHA, CHIMERE; SAMUEL, GEOFF;
KJELLBOTN, PETER**

Date de l'octroi et de la délivrance du brevet /

Patent grant and issue date

2024-04-23

Date de dépôt de la demande /

Filing date of the application

2017-11-14

Date d'accessibilité au public /

Date application open to public inspection

2018-05-11

Canada



NISSEN, ROBERT A.
robbie@nissenlaw.ca

Date : 2017/11/29

CERTIFICAT DE DÉPÔT FILING CERTIFICATE

N° de demande/Application No. : 2,985,258

Date de dépôt/Filing Date : 2017/11/14

Votre référence/
Your Reference : 158-2CA2

Date prévue de mise à la disponibilité du public /
Expected Open to Public Inspection Date : 2018/05/11

Date de priorité/
Priority Date : Canada (2961629) 2017/03/22; United States of America (62/420,923)
2016/11/11

Titre de l'invention/
Title of Invention : DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND RELATED METHODS
OF USE AND ASSEMBLY

Demandeur(s)/Applicant(s) : INFOCUS ENERGY SERVICES INC.

Inventeur(s)/Inventor(s) : PEARSON, ALLAN; LUCHAK, MARK; SCHEMING, OXANA; OSATCHUK, MATT;
VENABLES, ERIN; NKWOCHA, CHIMERE; SAMUEL, GEOFF; KJELLBOTN, PETER

La requête d'examen et la taxe prescrite n'avaient pas été soumises au moment de la création du certificat de dépôt. Veuillez consulter le site Web de l'OPIC pour obtenir plus de renseignements.

The request for examination and the prescribed fee has not been submitted when the filing certificate was created. Please visit CIPO's website for more information.

Avis spécial

Veillez noter que la taxe annuelle qui permet de maintenir votre demande en état est applicable tous les ans à compter du 2e anniversaire jusqu'au 20e et vous devez la payer au plus tard à la date d'anniversaire. L'omission de payer cette taxe avant l'expiration du délai fixé résultera en l'abandon de votre demande.

Special Notice

You are reminded that annual fees to maintain your application are needed for each one-year period between the 2nd and 20th anniversaries, and must be paid on or before each anniversary. Failure to pay within the prescribed time limit will lead to abandonment of your application.

Commissaire aux brevets/Commissioner of Patents



NISSEN, ROBERT A.
robbie@nissenlaw.ca

Date : 2019/07/16

Date de dépôt/Filing Date : 2017/11/14
Votre référence/
Your Reference : 158-2CA2

Titre de l'invention/
Title of Invention : DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND RELATED METHODS
OF USE AND ASSEMBLY

Montant dû/Amount Due : \$50.00

Date limite de paiement/
Payment Due Date : 2019/11/14

N° de demande/Application No. : 2,985,258

OBJET: TAXE DE MAINTIEN

La présente a pour but de vous rappeler que pour maintenir votre demande en vigueur, vous devez payer la taxe annuelle au plus tard à la date d'anniversaire du dépôt, à compter du 2^e anniversaire.

Vous pouvez payer annuellement ou à l'avance les taxes de maintien pour un nombre d'années donné. Vous pouvez économiser du temps en payant en ligne; vos paiements seront enregistrés et confirmés le jour même. Pour plus de renseignements sur la méthode de paiement en ligne, rendez-vous au : www.opic.ic.gc.ca/taxesdemaintien.

L'omission de payer cette taxe dans les délais fixés résultera en l'abandon de la demande de brevet.

Veuillez prendre note que vous ne recevrez pas d'autre rappel concernant la demande de brevet susmentionnée.

Pour de plus amples renseignements, veuillez communiquer avec l'Office de la propriété intellectuelle du Canada.

SUBJECT: MAINTENANCE FEE

You are reminded that, in order to maintain the patent application in force, an annual fee must be paid on or before the anniversary of the filing date, starting with the second anniversary.

The maintenance fees can be paid yearly or for any number of years in advance. You can save time by paying online; your payment will be recorded and acknowledged the same day. For online payment information, visit www.cipo.ic.gc.ca/maintenancefees

Failure to pay within the prescribed time limit will lead to the abandonment of the patent application. Please note that this is the only reminder notice that will be issued for this particular application.

Should you require more information, please do not hesitate to contact the Canadian Intellectual Property Office.

Commissaire aux brevets/Commissioner of Patents



Courtoisie - Réception de la requête d'examen
Courtesy - Acknowledgment of Request for Examination

NISSEN, ROBERT A.
robbie@nissenlaw.ca

Détails de la lettre
Letter Details

Date de la lettre: Letter Date:	2021/09/08
N° de la demande: Application N°:	2,985,258
Votre n° de référence: Your Reference N°:	158-2CA2

Date de dépôt/Filing Date:	2017/11/14
Demandeur(s)/Applicant(s):	INFOCUS ENERGY SERVICES INC.
Inventeur(s)/Inventor(s):	PEARSON, ALLAN; LUCHAK, MARK; SCHEMING, OXANA; OSATCHUK, MATT; VENABLES...
Titre de l'invention:	OUTILS DE FOND DE TROU A SECTIONS DE CAVITE PROGRESSIVES, ET METHODES D'...
Title of Invention:	DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND RELATED METHODS OF ...

Les dossiers du Bureau des brevets indiquent que la requête d'examen et les taxes réglementaires ont été reçues dans le délai réglementaire.

Patent Office records indicate that the request for examination and the prescribed fee(s) have been received within the prescribed time period.

L'examen de la demande se déroulera selon les délais d'usage.

Examination of the application will take place in due course.

Si le demandeur a connaissance de documents non-brevet (p. ex. articles de revues scientifiques, livres, affiches, articles) ou de documents en langue étrangère (p. ex. documents de brevet ou non-brevet) pouvant s'avérer pertinents à la brevetabilité de l'invention revendiquée, il doit envisager de fournir des copies ou des traductions de ces documents pertinents, lorsque ces copies ou traductions pourraient être difficilement accessibles par le Bureau. La remise volontaire de ces renseignements réduira la probabilité qu'une demande officielle soit présentée en vertu de l'art. 85 des *Règles sur les brevets* et peut accélérer le traitement de la demande.

If the applicant is aware of non-patent documents (e.g. journal articles, books, posters, articles) or foreign-language documents (e.g. patent or non-patent documents) that may be relevant to the patentability of the claimed invention, they should consider submitting copies or translations of the relevant documents, where the copies or translations of the documents may not be readily available to the Office. Voluntarily providing this information will reduce the likelihood of a formal requisition being made under s.85 of the *Patent Rules*, and may serve to expedite prosecution.

Pour de plus amples renseignements concernant cette lettre, veuillez consulter le *Recueil des pratiques du Bureau des brevets* (RPBB) accessible au canada.ca/brevets ou téléphoner au 1 819 997-2839.

For more information regarding this letter, please refer to the *Manual of Patent Office Practice* (MPOP) at canada.ca/patents or phone 1-819-997-2839.



Courtoisie - Certificat d'inscription (transfert)
Courtesy - Certificate of Recordal (Transfer)

NISSEN, ROBERT A.
robbie@nissenlaw.ca

Détails du certificat
Certificate Details

Date du certificat:
Certificate Date: 2023/01/27

N° d'inscription:
Recordal N°: 05860255

Votre n° de référence:
Your Reference N°: 158-2CA2

De/From: INFOCUS ENERGY SERVICES INC.

À/To: MESSABEN CORP.

Transfert: TRANSFERT DROIT EXCLUSIF

Transfer: TRANSFER FULL INTEREST

Les dossiers du Bureau des brevets indiquent qu'un transfert a été
inscrit relativement à la (aux) demande(s) et/ou au(x) brevet(s)
suivants:

Patent Office records indicate that a transfer has been
recorded for the following application(s) and/or patent(s):

Demandes/Applications:

2,985,258



Courtoisie - Certificat d'inscription (transfert)
Courtesy - Certificate of Recordal (Transfer)

NISSEN, ROBERT A.
robbie@nissenlaw.ca

Détails du certificat
Certificate Details

Date du certificat:
Certificate Date: 2024/01/24

N° d'inscription:
Recordal N°: 05881441

Votre n° de référence:
Your Reference N°: 158-2CA2

De/From: MESSABEN CORP.

À/To: CROSSBERRY HOLDINGS LIMITED

Transfert: TRANSFERT DROIT EXCLUSIF

Transfer: TRANSFER FULL INTEREST

Les dossiers du Bureau des brevets indiquent qu'un transfert a été inscrit relativement à la (aux) demande(s) et/ou au(x) brevet(s) suivants:

Patent Office records indicate that a transfer has been recorded for the following application(s) and/or patent(s):

Demandes/Applications:

2,985,258



Avis du commissaire - Demande jugée acceptable
Commissioner's Notice - Application Found Allowable

NISSEN, ROBERT A.
robbie@nissenlaw.ca

Détails de l'avis
Notice Details

Date de l'avis: Notice Date:	2024-03-01
N° de la demande: Application N°:	2,985,258
Votre n° de référence: Your Reference N°:	158-2CA2
Date d'échéance de l'avis: Notice Due Date:	2024-07-02
Montant dû:	169,00\$
Amount Due:	\$169.00

Date de dépôt/Filing Date:	2017-11-14		
Demandeur(s)/Applicant(s):	CROSSBERRY HOLDINGS LIMITED		
Inventeur(s)/Inventor(s):	PEARSON, ALLAN; LUCHAK, MARK; SCHEMING, OXANA; OSATCHUK, MATT; VENABLES...		
Titre de l'invention:	OUTILS DE FOND DE TROU A SECTIONS DE CAVITE PROGRESSIVES, ET METHODES D'UTILISATION ET ASSEMBLAGE ASSOCIEES		
Title of invention:	DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND RELATED METHODS OF USE AND ASSEMBLY		
Revendications/Claims:	019		
Pages en sus : Excess Pages:	Taxe :	Fee :	
Revendications excès : Excess Claims:	Taxe :	Fee :	
Examinée tel que modifiée: Examined as amended:	2023-07-17		

Le présent avis du commissaire aux brevets vise à informer le demandeur que la demande de brevet a été jugée acceptable et que le paiement de la taxe finale réglementaire doit être fait au plus tard le 2024-07-02.

Si la taxe finale, dont le montant est indiqué ci-dessus, n'est pas payée au plus tard le 2024-07-02, la demande sera réputée abandonnée.

Lorsque la taxe finale sera payée, votre demande de brevet donnera lieu à la délivrance d'un brevet.

Veillez vous assurer de l'exactitude des renseignements au dossier avant de faire le paiement de la taxe finale, car peu de modifications sont autorisées après le paiement de la taxe finale et après la délivrance d'un brevet. Veuillez consulter le site web de l'OPIIC concernant les taxes générales pour les brevets:

<https://www.ic.gc.ca/eic/site/cipointernet-internetopic.nsf/fra/wr00142.html>

Références pertinentes:

- * par. 86(1) des *Règles sur les brevets*
- * par. 87(1) des *Règles sur les brevets*

Pour de plus amples renseignements concernant cet avis ou la façon de rétablir une demande de brevet abandonnée, veuillez consulter le *Recueil des pratiques du Bureau des brevets* (RPBB) accessible au canada.ca/brevets ou téléphoner au 1 819 997-2839.

OCT262 October 2022

This is a Notice from the Commissioner of Patents to inform the applicant that the application for a patent has been found allowable and payment of the prescribed final fee is required before the end of 2024-07-02.

If the final fee, in the amount indicated above, is not paid before the end of 2024-07-02, the application will be deemed to be abandoned.

Once the final fee is paid, your patent application will proceed to grant.

Please ensure the accuracy of the information on file before payment of the final fee as there are limited modifications that are allowed after payment of the final fee and post grant. For more information regarding fees, please refer to the CIPO Patent Fees website:

<https://www.ic.gc.ca/eic/site/cipointernet-internetopic.nsf/eng/wr00142.html>

Relevant references:

- * s.86(1) of the *Patent Rules*
- * s.87(1) of the *Patent Rules*

For more information regarding this notice or on how to reinstate an abandoned patent application, please refer to the *Manual of Patent Office Practice* (MOPOP) at canada.ca/patents or phone 1-819-997-2839.

General Correspondence (Patent) ⁰⁰⁸ JF

Date: July 17, 2023 3:10:37 PM

Application Number

2985258

Title of invention

DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND
RELATED METHODS OF USE AND ASSEMBLY

Applicant(s) or Inventor Name(s)

Applicant or Inventor Name

Sender

Family Name: Nissen
First Name: Robert
Initial:
Name of Corporation or Firm: Nissen Patent Law
Address Line 1: 401-11044 82 Ave NW
Address Line 2:
Address Line 3:
City/Town: Edmonton
Province/State: Alberta
Country: Canada
Postal/Zip Code: T6G 0T2
Telephone Number: 7808027904
Fax Number:
Email Address: robbie@nissenlaw.ca
Communicate by: Electronic Mail (Non secure)

Correspondence Instructions

Applicant: MESSABEN CORP.

Filing Date: November 14, 2017

Application Number: 2,985,258

Title: DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND
RELATED METHODS OF USE AND ASSEMBLY

Our Ref: 158-2CA2

In response to the official action dated March 16, 2023, the Applicant submits the attached cover letter (2 pages) and amended claims (3 pages). The Applicant's intention is to keep the application in good standing, and thus please take all steps required to do so and, if any step has not been taken that must be taken, please accept this correspondence as a request for an extension of time to take the step. Please charge any additional fees required to the credit card or to the Agent of Record's deposit account no. 600002856.

/Robert A. Nissen/
Agent of Record

Description of Fee

No fee has been entered.

Total Fee Payment: \$0.00

Payment method

No Charge

Attachments

1. 158-2CA2_response.pdf

Other

Cover Letter

2. 158-2CA2_amended_claims.pdf

Claim

Transmission Identifier: pgc_nissenpatents_20230717151037986

Date Reçue/Date Received 2023-07-17

Date: July 17, 2023 3:10:37 PM

Commissioner of Patents
50 Victoria Street
Place du Portage
Phase I
Gatineau, Quebec
Canada
K1A 0C9

Application Number: 2985258
Title of invention: DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY
SECTIONS, AND RELATED METHODS OF USE AND ASSEMBLY
Applicant(s) or Inventor(s) Name(s): MESSABEN CORP.
MESSABEN CORP.
Reference Number: 158-2CA2

Instructions: Applicant: MESSABEN CORP.
Filing Date: November 14, 2017
Application Number: 2,985,258
Title: DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND
RELATED METHODS OF USE AND ASSEMBLY
Our Ref: 158-2CA2

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/Robert A. Nissen/
Agent of Record

Attached are the following documents:

1. 158-2CA2_response.pdf
Cover Letter
Other
2. 158-2CA2_amended_claims.pdf

Claim

Nissen, Robert
Nissen Patent Law

Date Reçue/Date Received 2023-07-17

401-11044 82 Ave NW
Edmonton
Alberta
Canada
T6G 0T2
Tel: 7808027904
Email:robbie@nissenlaw.ca

Transmission Identifier: pgc_nissenpatents_20230717151037986

Application No.: 2,985,258

To:
Commissioner of Patents
Canadian Intellectual Property Office

AMENDMENT/REMARKS FOLLOWING EXAMINER'S REPORT

Our ref: 158-2CA2

Application No.: 2,985,258

**Title: DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND
RELATED METHODS OF USE AND ASSEMBLY**

Filed: November 14, 2017

Applicant: MESSABEN CORP.

Classification: E21B 4/02 (2006.01)

Examiner: Mallory MacLean

This is in response to the official action dated March 16, 2023.

AMENDMENT

IN THE CLAIMS

Please cancel the claim pages of record, and replace them with the claims on the attached replacement claim pages.

REMARKS

Claim amendment

Claims 10-13 are amended for clarity and antecedent issues.

The examiner indicated that:

Claim 11 is indefinite and does not comply with subsection 27(4) of the *Patent Act*. The term "the progressive cavity section" (claim 11, line 11) has no antecedent.

Claims 12 and 13 are indefinite and do not comply with subsection 27(4) of the *Patent Act*. It is unclear whether the element "a progressive cavity power section" refers to the element "the progressive cavity section" or an additional element thereto.

To facilitate prosecution, and without admitting that the claims were indefinite, the Applicant has amended Claims 11-13 to satisfy the examiner's concerns.

The examiner indicated that:

Application No.: 2,985,258

Claim 10 does not comply with subsection 63(2) of the *Patent Rules*. A dependent claim must refer to a preceding claim or claims. Specifically, it appears to the examiner that claim 10 mistakenly refers to itself rather than the intended claims 1-9.

The Applicant respectfully traverses this rejection. Claim 10 has been amended to depend from Claim 1 - 9. Claim 10 complies with subsection 63(2).

The Applicant has addressed the examiner's requisition. It is noted that no s. 85 requisition has been issued. Accordingly, the Applicant has not supplied any information concerning corresponding patents. If the examiner wishes disclosure of any s. 85 information, or a discussion of the relevance of any other references, the examiner is requested to make a s. 85 requisition. Nothing herein should be construed as an allegation that no relevant art exists other than what was cited by the examiner.

The Applicant submits that the examiner's requisitions have been satisfied. Allowance of the application is respectfully requested.

July 17, 2023

Respectfully submitted

/Robert A. Nissen/

Robert A. Nissen

Agent of Record

#401, 11044 - 82 Avenue
Edmonton, Alberta T6G 0T2
Ph. 780-802-7904
Fax 888-744-4480

1. A downhole tool comprising:
 - a progressive cavity section with a stator and a rotor;
 - in which the stator is formed from a single integral block of material, and the stator has a length of at least fifty inches defined between axial ends of the stator;
 - in which rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid and do not flex when in use at downhole temperatures;
 - in which the stator contacting surfaces and the rotor contacting surfaces are made of metal;
 - in which the stator is formed by electrochemical machining (ECM) to structure the rotor contacting surfaces of the stator to achieve a sufficiently narrow clearance or negative interference fit with the rotor to form an efficient pumping seal without seizing the progressive cavity section in use; and
 - in which the rotor contacting surfaces of the stator have been heat treated for increased surface hardness.
2. The downhole tool of claim 1 in which the progressive cavity section is connected to rotate a reamer part of a casing reamer shoe.
3. The downhole tool according to any one of claim 1 - 2 in which the progressive cavity section is connected to rotate a drill bit.
4. The downhole tool according to any one of claim 1 - 3 in which the length of the stator is at least eighty inches defined between the axial ends of the stator.
5. The downhole tool of claim 4 in which the length of the stator is at least one hundred and fifty inches defined between the axial ends of the stator.
6. The downhole tool of claim 5 in which the length of the stator is at least three hundred inches defined between the axial ends of the stator.

7. The downhole tool according to any one of claim 1 - 6 in which the rotor is formed by electrochemical machining (ECM).
8. The downhole tool according to any one of claim 1 - 7 in which the stator contacting surfaces of the rotor have been heat treated for increased surface hardness.
9. The downhole tool according to any one of claim 1 - 8 in which the rotor contacting surfaces of the stator and the stator contacting surfaces of the rotor have been heat treated with nitriding for increased surface hardness.
10. A method comprising:
positioning the downhole tool according to any one of claim 1 - 9 in a well; and
pumping fluid to operate the progressive cavity section to rotate the rotor relative to the stator.
11. A method comprising:
forming a stator from a single integral block of material, in which the stator has a length of at least fifty inches defined between axial ends of the stator;
assembling a downhole tool by inserting a rotor into the stator;
in which rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid and do not flex when in use at downhole temperatures;
in which the stator contacting surfaces and the rotor contacting surfaces are made of metal;
in which the stator is formed by electrochemical machining (ECM) to structure the rotor contacting surfaces of the stator to achieve a sufficiently narrow clearance or negative interference fit with the rotor to form an efficient pumping seal without seizing a progressive cavity section in use; and
in which forming comprises heat treating the rotor contacting surfaces of the stator to increase surface hardness.

12. The method of claim 11 in which the stator and the rotor within the downhole tool form the progressive cavity power section connected to rotate a reamer part of a casing reamer shoe.
13. The method according to any one of claim 11 - 12 in which the stator and the rotor within the downhole tool form the progressive cavity power section connected to rotate a drill bit.
14. The method according to any one of claim 11 - 13 in which the length of the stator is at least eighty inches defined between the axial ends of the stator.
15. The method of claim 14 in which the length of the stator is at least one hundred and fifty inches defined between the axial ends of the stator.
16. The method of claim 15 in which the length of the stator is at least three hundred inches defined between the axial ends of the stator.
17. The method according to any one of claim 11 - 16 in which the rotor is formed by electrochemical machining (ECM).
18. The method according to any one of claim 11 - 17 in which the stator contacting surfaces of the rotor have been heat treated to increase surface hardness.
19. The method according to any one of claim 11 - 18 in which the rotor contacting surfaces of the stator and the stator contacting surfaces of the rotor have been heat treated with nitriding to increase surface hardness.



Reçu du paiement électronique / Electronic Payment Receipt

Office de la propriété intellectuelle du Canada

Place du Portage I
50, rue Victoria
Gatineau (Québec) K1A 0C9
Canada

Canadian Intellectual Property Office

Place du Portage I
50 Victoria Street
Gatineau, Qc K1A 0C9
Canada

Émis à / Issued to

ROBERT A. NISSEN
c/o Nissen Patent Law
EDMONTON, Alberta
T6G 0T2
Canada

Numéro de confirmation Confirmation Number	Date et heure de réception Receipt Date and Time	Montant payé Amount Paid
16066036	2023-11-07 14:16:34	\$ 100.00

Brevet et/ou Patent and/or	Description	Taxes Fees
2985258	DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY Taxe de maintien en état - Demande - nouvelle loi / Maintenance Fee - Application - New Rules année(s)/year(s): 6 Numéro de référence / Reference Number: 158-2CA2	\$ 100.00

Total des taxes payées / Total Fees Paid: **\$ 100.00**

Information sur le paiement SVP appelez 1-819-994-2269 / For payment inquiries please call 1-819-994-2269



Courtoisie — Demande d'enregistrement d'un transfert (non conforme)
Courtesy— Request to Record a Transfer (Not Compliant)

NISSEN, ROBERT A.
robbie@nissenlaw.ca

Détails de la lettre

Letter Details

Date de la lettre 2024-01-02
Letter Date:
No de la demande/brevet 2,985,258
Application/Patent No:
Votre No de référence 158-2CA2
Your Reference No:

Votre lettre reçue le/Your Letter Received: 2023-12-21
Date de dépôt/Filing Date: 2017/11/14
Demandeur(s) ou Breveté(s)/Applicant(s) or Patentee(s): MESSABEN CORP.

Inventeur(s)/Inventor(s): PEARSON, ALLAN; LUCHAK, MARK; SCHEMING, OXANA; OSATCHUK, MATT; VENABLES, ERIN; NKWOCHA, CHIMERE; SAMUEL, GEOFF; KJELLBOTN, PETER
Titre de l'invention/Title of invention: DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND RELATED METHODS OF USE AND ASSEMBLY

La présente lettre vise à vous informer que la demande d'inscription d'un transfert, dans la demande de brevet ou au brevet susmentionné, n'est pas conforme aux *Règles sur les brevets*.

Les exigences ci-dessous marquées d'un « x » ne sont pas remplies et doivent être fournies au Bureau des brevets pour que la demande d'inscription d'un transfert soit reconnue :

La demande doit indiquer le nom du cessionnaire.

✓

La demande doit indiquer l'adresse postale du cessionnaire.

x

This letter is to advise that the request to record a transfer on the above-mentioned patent application or patent is not compliant with the *Patent Rules*.

The requirements marked with an "x" below are outstanding and must be submitted to the Patent Office in order to recognize the request to record the transfer:

The request must contain the name of the transferee.

The request must contain the postal address of the transferee.

La demande doit comporter le paiement de la taxe prévue à l'article 35 de l'annexe 2.

✓

The request must contain payment of the fee set out in item 35 of Schedule 2.

La demande a été présentée par le cessionnaire et une preuve satisfaisante du transfert, selon le commissaire, doit être fournie.

SO/NA

The request was submitted by the transferee and evidence satisfactory to the Commissioner of the transfer must be submitted.

Références pertinentes :

- art. 49 de la *Loi sur les brevets*
- art. 126 des *Règles sur les brevets*
- art. 35 de l'annexe 2 des *Règles sur les brevets*

Relevant references:

- s.49 of the *Patent Act*
- s.126 of the *Patent Rules*
- item 35 of Schedule 2 of the *Patent Rules*

Pour de plus amples renseignements concernant cette lettre, veuillez consulter le *Recueil des pratiques du Bureau des brevets* (RPBB) accessible au canada.ca/brevets ou téléphoner au 819-997-1950.

For more information regarding this letter, please refer to the *Manual of Patent Office Practice* (MOPOP) at Canada.ca/patents or phone 819-997-1950.



Reçu du paiement électronique / Electronic Payment Receipt

Office de la propriété intellectuelle du Canada

Place du Portage I
50, rue Victoria
Gatineau (Québec) K1A 0C9
Canada

Canadian Intellectual Property Office

Place du Portage I
50 Victoria Street
Gatineau, Qc K1A 0C9
Canada

Émis à / Issued to

ROBERT A. NISSEN
c/o Nissen Patent Law
EDMONTON, Alberta
T6E 1X2
Canada

Numéro de confirmation Confirmation Number	Date et heure de réception Receipt Date and Time	Montant payé Amount Paid
7967338	2019-11-14 17:14:58	\$ 50.00

Brevet et/ou Patent and/or	Description	Taxes Fees
2985258	DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY Taxe de maintien en état - Demande - nouvelle loi / Maintenance Fee - Application - New Act année(s)/year(s): 2 Numéro de référence / Reference Number: 158-2CA2	\$ 50.00

Total des taxes payées / Total Fees Paid: **\$ 50.00**

Information sur le paiement SVP appelez 1-819-994-2269 / For payment inquiries please call 1-819-994-2269



Reçu du paiement électronique / Electronic Payment Receipt

Office de la propriété intellectuelle du Canada

Place du Portage I
50, rue Victoria
Gatineau (Québec) K1A 0C9
Canada

Canadian Intellectual Property Office

Place du Portage I
50 Victoria Street
Gatineau, Qc K1A 0C9
Canada

Émis à / Issued to

ROBERT A. NISSEN
c/o Nissen Patent Law
EDMONTON, Alberta
T6E 1X2
Canada

Numéro de confirmation Confirmation Number	Date et heure de réception Receipt Date and Time	Montant payé Amount Paid
8746665	2020-11-13 21:02:06	\$ 50.00

Brevet et/ou Patent and/or	Description	Taxes Fees
2985258	DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY Taxe de maintien en état - Demande - nouvelle loi / Maintenance Fee - Application - New Rules année(s)/year(s): 3 Numéro de référence / Reference Number: 158-2CA2	\$ 50.00

Total des taxes payées / Total Fees Paid: **\$ 50.00**

Information sur le paiement SVP appelez 1-819-994-2269 / For payment inquiries please call 1-819-994-2269

General Correspondence (Patent)

Date: August 11, 2021 4:25:35 PM

007/008/CAP

067

RS

#6626003

Application Number

2985258

Title of invention

DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND RELATED METHODS OF USE AND ASSEMBLY

Applicant(s) or Inventor Name(s)

Applicant or Inventor Name

Sender

Family Name: Weir

First Name: Mark

Initial:

Name of Corporation or Firm: AVENTUM IP LAW LLP

Address Line 1: PO Box 13002

Address Line 2:

Address Line 3:

City/Town: Kanata

Province/State: Ontario

Country: Canada

Postal/Zip Code: K2K 0E2

Telephone Number: 6132325300

Fax Number: 6135639231

Email Address:

Communicate by: Regular Mail

Correspondence Instructions

CIPO Letter - 3rd Party Submission Of Prior Art and Exam Request and related attachments

-- Appendix 1 - CA 2985258 as filed Claims

-- Appendix 2 - US 9393648

-- Appendix 3  US 7192260

-- Appendix 4  US 9976227

Date Reque/Date Received 2021-08-11

file:///eprint-prod.ic.gc.ca/.../patent/inbasket/ToBeStamped/pgc_MarkWeir_20210811162535637_4553472061435590119_9490067.html[2021-08-12 12:40:45 PM]

Full-Metal v. InFocus, IPR2025-00391

InFocus - Exhibit No. 2005

Page 191

Description of Fee (small entity fee)

1. Examination of an application - small entity fee (1 x \$408.00): \$408.00

Total Fee Payment: \$408.00

Payment method

Common Payment Component

Attachments

1. 12084P0073CA01_CIPO_Letter_3rd_Party_Submission_Of_Prior_Art_and_Exam_Request.pdf

Other

CIPO Letter - 3rd Party Submission Of Prior Art and Exam Request and related attachments

2. 12084P0073CAG_Appendix_1_CA_2985258_as_filed_Claims.pdf

Other

Appendix 1 CA 2985258 as filed Claims

3. 12084P0073CAG_Appendix_2_US_9393648.pdf

Other

Appendix 2 - US 9393648

4. 12084P0073CAG_Appendix_3_US_7192260.pdf

Other

Appendix 3  US 7192260

5. 12084P0073CAG_Appendix_4_US_9976227.pdf

Other

Appendix 4  US 9976227

6. 12084P0073CAG_Appendix_5_US_6241494.pdf

Other

Appendix 5  US 6241494

Transmission Identifier: pgc_MarkWeir_20210811162535637_9490067

Date: August 11, 2021 4:25:35 PM

Commissioner of Patents
50 Victoria Street
Place du Portage
Phase I
Gatineau, Quebec
Canada

K1A 0C9

Application Number: 2985258

Title of invention: DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND RELATED METHODS OF USE AND ASSEMBLY

Applicant(s) or Inventor(s) Name(s): INFOCUS ENERGY SERVICES INC.

INFOCUS ENERGY SERVICES INC.

Reference Number: 12084P0073CAG

Instructions: CIPO Letter - 3rd Party Submission Of Prior Art and Exam Request and related attachments

-- Appendix 1 - CA 2985258 as filed Claims

-- Appendix 2 - US 9393648

-- Appendix 3  US 7192260

-- Appendix 4  US 9976227

-- Appendix 5  US 6241494

Attached are the following documents:

1. 12084P0073CA01_CIPO_Letter_3rd_Party_Submission_Of_Prior_Art_and_Exam_Request.pdf

CIPO Letter - 3rd Party Submission Of Prior Art and Exam Request and related attachments

Other

2. 12084P0073CAG_Appendix_1_CA_2985258_as_filed_Claims.pdf

Appendix 1 CA 2985258 as filed Claims

Other

3. 12084P0073CAG_Appendix_2_US_9393648.pdf

Appendix 2 - US 9393648

Other

4. 12084P0073CAG_Appendix_3_US_7192260.pdf

Appendix 3  US 7192260

Other

5. 12084P0073CAG_Appendix_4_US_9976227.pdf

Appendix 4  US 9976227

Other

6. 12084P0073CAG_Appendix_5_US_6241494.pdf

Appendix 5  US 6241494

Other

Description of Fee (small entity fee)

1. Examination of an application - small entity fee (1 x \$408.00): \$408.00

Total Fee Payment: \$408.00

Weir, Mark

AVENTUM IP LAW LLP

PO Box 13002

Kanata

Ontario

Canada

K2K 0E2

Tel: 6132325300

Fax: 6135639231

Transmission Identifier: pgc_MarkWeir_20210811162535637_9490067

Date Reque/Date Received 2021-08-11

file:///ecprint-prod.ic.gc.ca/.../patent/inbasket/ToBeStamped/pgc_MarkWeir_20210811162535637_4553472061435590119_9490067.html[2021-08-12 12:40:45 PM]

Full-Metal v. InFocus, IPR2025-00391

InFocus - Exhibit No. 2005

Page 193

IN THE CANADIAN PATENT OFFICE

Application No. : 2,985,258 **August 11, 2021**
Owner : INFOCUS ENERGY SERVICES INC.
Title : **DOWNHOLE TOOLS WITH PROGRESSIVE
CAVITY SECTIONS, AND RELATED METHODS OF
USE AND ASSEMBLY**
Filing Date : November 14, 2017
Aventum IP Ref. No.: : 12084P0073CAG
Examination Fee : \$408.00 (Small Entity) due November 14, 2022
TOTAL FEES : \$408.00

The Commissioner of Patents
Canadian Intellectual Property Office
Place du Portage I
50 Victoria Street, Room C-114
Gatineau, QC K1A 0C9

Dear Sir:

THIRD PARTY SUBMISSION OF PRIOR ART
UNDER SECTION 34.1 OF THE PATENT ACT
AND

REQUEST FOR EXAMINATION AND PAYMENT OF THE EXAMINATION FEE

It is requested that the necessary steps be taken to proceed with examination of the above-noted application. The Patent Office examination fee in the amount of **\$408.00 prescribed for small entity status** may be debited to our firm's account, the particulars of which are on the attached fee payment form. If this fee is incorrect, please debit the correct amount to our firm's deposit account 600001291.

This is a third-party submission of prior art and a protest filed against the issuance of a patent from the above-identified pending Canadian Application No. 2,985,258 (the '258 Application). We rely on Chapter 24 of the Manual of Patent Office Practice ("MOPOP") and on section 34.1 of the *Patent Act*, which provides that any person may file with the Commissioner prior art, consisting of patents, applications for patents open to public inspection and printed publications, that the person believes has a bearing on the patentability of any claim in an application for a

patent. A person who files prior art with the Commissioner under subsection 34.1(1) of the *Patent Act* shall explain the pertinence of the prior art. Section 12 of the Patent Rules provides that any written communication submitted to the Commissioner before the granting of a patent with the stated or apparent intention of protesting against the granting of that patent, will be acknowledged by the Commissioner.

For the reasons set out below, it is submitted that the prior art discussed herein is pertinent to the patentability of all claims currently pending in the above-captioned Canadian patent application. None of the pending claims are believed to be patentable and the patent application, as a whole, fails to describe a patentable invention. More particularly,

The '258 Application has a filing date of November 14, 2017, and purports to claim priority from United States provisional patent application 62/420,923 filed on November 11, 2016, and Canadian patent application 2,961,629 filed on March 22, 2017.

For purposes of this Protest only, it will be taken that the "claim date" as defined in section 28.1 of the *Patent Act* is November 11, 2016.

The claims of the '258 Application as they presently stand (*i.e.*, as originally filed on November 14, 2017) are reproduced in **Appendix 1** for ease of reference. The prior art submitted herewith is discussed below with reference to the subject matter of the Application as recited in the claims.

1. Background and Purported Invention of the '258 Application

The '258 Application is directed to *inter alia* a downhole tool including a stator that is formed using electrochemical machining (ECM). The '258 Application notes that electrochemical machining (ECM) is a method of removing metal by an electrochemical process. It may be used for working extremely hard materials or materials that are difficult to machine using conventional methods. (¶ [00151])

The '258 Application asserts that ECM may permit a suitable stator to be formed from a single integral block of material such as a tube. A single integral block of material may be initially a suitable unbroken shape such as a cylinder, although the block could have a solid or hollow core, and could be other than cylindrically shaped, such as shaped like a rectangular box. The '258 Application notes that ECM may permit extended lengths of integral stator sections to be made, for example stator sections may be made with an axial length of at least fifty and in some cases fifty, eighty, one hundred fifty, and three hundred inches or more, defined between axial ends of the stator. The resulting stator may have no break lines or transition points such as weld lines or abutting ends of adjacent sections connected by connectors such as dowels. Instead, the stator may have a continuous unbroken profile from axial end to axial end. By contrast conventional computer numerical control (CNC) methods using a lathe and mill may only be able to create a stator section of thirty six inches or less. The length of a tool produced by ECM may be limited by the axial length of the cutting tool, with such axial length capable of being tailored to achieve the desired stator length, and hence in theory any length of stator may be created.

2. The Pending Claims of the '258 Application

The '258 Application currently has 177 pending claims. Only a selected subset of the pending claims will be addressed in this submission.

Independent claim 1, currently on file, is directed to a downhole tool, and is reproduced below:

1. A downhole tool comprising:
a progressive cavity section with a stator and a rotor; and
in which the stator, rotor, or stator and rotor are formed by electrochemical machining (ECM).

Dependent claims 2, 3, and 7 currently on file, are reproduced below:

2. The downhole tool of claim 1 in which rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid.

3. The downhole tool of claim 2 in which the stator contacting surfaces and the rotor contacting surfaces are made of metal.

7. The downhole tool of any one of claim 1 - 6 in which the stator has a length of at least eighty inches defined between axial ends of the stator.

Independent claim 12, currently on file, is directed to a method of forming a downhole tool and recites limitations similar to the ones that are recited in independent claim 1. Claim 12 is reproduced below:

12. A method comprising:
forming a stator, rotor, or stator and rotor by electrochemical machining (ECM); and
forming a downhole tool by inserting the rotor into the stator.

Separate analysis of claim 12 is not presented herein since the analysis of claim 1 also applies to claim 12, *mutatis mutandis*.

Although separate analysis has not been provided for claims in addition to the ones that are explicitly mentioned above, it is believed that the prior art references mentioned in this submission are also relevant to the other claims in the '258 application.

3. Description of the Prior Art

It is submitted that the combination of features recited in at least the independent and dependent claims reproduced above has been known to a person skilled in the art pertinent to the general field of downhole tools.

It is submitted that the following enclosed prior art references are relevant to the patentability of the '258 Application:

D1:	US 9,393,648 B2 (published on October 6, 2011)	Appendix 2
D2:	US 7,192,260 B2 (published on April 14, 2005)	Appendix 3
D3:	US 9,976,227 B2 (published on November 19, 2014)	Appendix 4
D4:	US 6,241,494 B1 (published on June 5, 2001)	Appendix 5

In view of these prior art references, at least claims 1, 2, 3, 7, and 12 of the '258 Application define subject matter that is not patentable, as detailed below. All elements of the alleged invention were known prior to the claim date and were disclosed by one or more of the above listed references. Accordingly, at least the above-mentioned claims lack novelty or inventiveness in view of the cited prior art references.

4. Independent Claims 1 and 12 of the '258 Application Lack Novelty

Claim 1 lacks novelty over D1

D1 describes a Moineau style stator which appears to be pertinent to independent claim 1 of the '258 Application. As evidenced by the citations below, D1 disclosed several items pertinent to the '258 Application under examination, prior to the above-mentioned claim date, including all of the limitations recited in independent claim 1:

- A downhole tool comprising:
- A progressive cavity section with a stator and a rotor,
- The manufacturing of an integral stator with rigid lobes by ECM machining.

The following excerpts from D1 are presented as non-exhaustive examples of teaching that is believed to be relevant to the examination of the '258 Application, including disclosure of all of the above-mentioned limitations of independent claim 1.

"The present disclosure addresses one or more of the above-described drawbacks of conventional Moineau style motors and pumps. Aspects of the present disclosure include a Moineau style stator for use in such motors and/or pumps, such as in a downhole drilling motor. [...] The stator includes a stator tube (e.g., a steel tube) having a plurality of **rigid** helical lobes formed on an inner surface thereof". [Col. 2, lines 17-23]

"In one aspect, the present disclosure includes a Moineau style stator. The stator includes an **integral stator** tube having a longitudinal end with an internal pass-through diameter. The stator

tube defines an internal helical cavity and further includes a plurality of internal **rigid** helical lobes formed on an inner surface of the tube. The helical cavity has a major internal tube diameter that is greater than the pass through diameter of the longitudinal end”. [Col. 2, lines 40-47]

“In still another aspect, the present disclosure includes a method for fabricating a Moineau style stator. A stator tube is provided having at least one longitudinal end with a pass through diameter. ‘The stator tube further includes an internal relief groove in which an inner diameter of the relief groove is 3 greater than the pass-through diameter. An electrochemical machining electrode is assembled in the relief groove. The electrode includes a plurality of distinct work pieces, each of the work pieces having an outer diameter less than the pass-through diameter. The assembled electrode defines a major helical diameter greater than the pass-through diameter. An internal helical profile is electrochemically machined in the stator tube using the assembled electrodes, the internal helical profile including a plurality of helical lobes and a major internal tube diameter that is greater than the pass-through diameter of the longitudinal end. The electrodes are then disassembled and removed from the from the stator tube”. [Col. 2, line 60 to Col. 3, line 9]

With continued reference to FIG. 2, stator embodiments in accordance with the present disclosure include a stator tube having a plurality of helical lobes 115 formed on an inner surface thereof in which the major internal tube diameter 140 is greater than the pass through diameter 135 of end portion 130. As depicted at 139 on FIG. 2B, the helical cavity of the stator tube undercuts the pass through diameter of the tube. Stators in accordance with the present disclosure may also preferably include a major liner diameter 145 that is less than the pass through diameter 135 so as to provide a suitable interference fit between rotor and stator. In preferred embodiments of the present disclosure, the stator 100 includes an integral stator tube, i.e., a one piece stator tube 110. An integral stator tube advantageously improves the strength and durability of the stator. By integral it is meant that the stator tube is formed from a single **metallic** work piece and may therefore be said to be of a unitary construction. [Col. 6, lines 24-33]

Based on the foregoing, as D1 discloses all elements of claim 1 of the '258 Application, independent claim 1 of the '258 Application lacks novelty over D1. Independent claim 12 also lacks novelty over D1 for the same reasons, *mutatis mutandis*.

D1 also discloses the features of at least claims 2 and 3, at the bold and underlined locations indicated in the sections of D1 that have been reproduced above. As such, at least dependent claims 2 and 3 of the '258 Application lack novelty over D1.

Claim 1 lacks novelty over D2

D2 describes a Moineau style stator which appears to be pertinent to independent claim 1 of the '258 Application. As evidenced by the citations below, D2 disclosed several items pertinent to '258 Application under examination, prior to the above-mentioned claim date, including all of the limitations recited in independent claim 1:

- A downhole tool comprising:
- A progressive cavity section with a stator and a rotor
- The manufacturing of an integral stator with rigid lobes by ECM machining

The following excerpts from D2 are presented as non-exhaustive examples of teaching that is believed to be relevant to the examination of the '258 Application, including disclosure of all of the above-mentioned limitations of independent claim 1.

“U.S. Pat. Nos. 1,892,217 and 2,028,407, to R. J. L. Moineau, disclose a gear mechanism for use as a progressive cavity pump or motor. In a typical application of progressive cavity technology, the drilling of subterranean wells, a progressive cavity motor is used as a downhole motor to convert the energy of a flowing drilling fluid to mechanical power to rotate a drill bit.” [Col. 1, lines 24-30]

“In a progressive cavity pump or motor an **interference fit** between the external profile of the rotor and the internal profile of the stator provides a seal isolating the cavities of the pump or motor from adjoining cavities. The seal resists the fluid pressure which results from the mechanical pumping action, or from the conversion of fluid motion to mechanical energy in a motor. Because of the requirement for an interference fit between the rotor and stator, one or both of these components must be covered with a resilient, or dimensionally forgiving, material which also allows the pump or motor to pass or transfer abrasive particles and other objects carried along with the fluid. Historically, the resilient material has been provided on the interior of the stator”. [Col. 1, lines 31-44]

“In accordance with this invention, ECM is used to generate the lobe profiles of the stator of a progressive cavity device. The invention overcomes many of the problems identified in the prior art for progressive cavity pumps and motors, including excessive heat build-up and the ability to hold tolerances. A motor having a stator made in accordance with the invention is particularly well suited for use as a downhole motor in a well to drive a drill bit”. [Col. 2, line 66 to Col. 3, line 6]

“In order to still have a compliant seal between the stator and rotor, a thin layer of constant thickness elastomer is still required. The desired inside profile of the stator, offset by the desired thickness of the elastomer layer, is formed in a circular, cylindrical inner wall of a tubular, **metal workpiece serving as a stator blank**. The surface finish of the inner profile must allow for bonding of the elastomer forming the profile that contacts the rotor. The constant thickness of the thin elastomer layer significantly reduces the adverse effects experienced in the case of an elastomer lining having a varying thickness. Because the elastomer layer can be relatively thin throughout, its insulating effect is also reduced, allowing for better heat transfer to the **rigid** metallic housing.” [Col. 3, lines 7-21]

Based on the foregoing, as D2 discloses all elements of claim 1 of the ‘258 Application, independent claim 1 of the ‘258 Application lacks novelty over D2. Independent claim 12 also lacks novelty over D2 for the same reasons, *mutatis mutandis*.

D2 also discloses the features of at least claims 2 and 3. As such, at least dependent claims 2 and 3 of the '258 Application lack novelty over D2. It should also be noted that D2 discloses that "The stators of progressive cavity mechanisms are typically very long, some being up to seven meters in length." [Col. 1, lines 18-20] As such, claim 7 either lacks novelty over D2 or lacks inventiveness over D2.

Claims 1 and 12 lack novelty over D3

D3 describes a Moineau style stator which appears to be pertinent to independent claim 1 of the '258 Application. As evidenced by the citations below, D2 disclosed several items pertinent to '258 Application under examination, prior to the above-mentioned claim date, including all of the limitations recited in independent claim 1:

- A progressive cavity section with a stator and a rotor
- In which stator, rotor, or stator and rotor are formed by electrochemical machining.
- Elongated nature of the stator (minimum 80 inches)

The following excerpts from D3 are presented as non-exhaustive examples of teaching that is believed to be relevant to the examination of the '258 Application, including disclosure of all of the above-mentioned limitations of independent claim 1.

"In the examples and illustrations herein, apparatuses and methods are discussed for electrochemical machining of parts with reduced power consumption compared to the prior art of electrochemical machining. The teachings are in particular beneficial for the manufacturing of **elongated parts. Elongated parts are defined by having a first dimension significant longer than the other two dimensions perpendicular to the first dimension.** The examples and illustrations provided in this patent application are dealing with the manufacturing of a **rotor and a stator of a hydraulic motor or a progressing cavity pump** which are examples for elongated parts with a complex geometry. The outer or inner geometry of the rotor or stator may comprise symmetrically or asymmetrically twisted lobes that are shapes which are challenging to

manufacture with the required accuracy by conventional methods (milling for example). However, these examples are not meant as a limitation. Those skilled in the art will appreciate that the teachings disclosed herein can be used to manufacture other parts with a different use than rotors or stators that are described here to illustrate the invention” [Col. 2, line 57 to Col. 3, line 10].

Based on the foregoing, as D3 discloses all elements of claim 1 of the ‘258 Application, independent claim 1 of the ‘258 Application lacks novelty over D3. Independent claim 12 also lacks novelty over D3 for the same reasons, *mutatis mutandis*.

Additional References – D4

D4 relates to a non-elastomeric stator and downhole drilling motors incorporating same. D4 describes a Moineau style stator which is believed to be pertinent to the examination of the ‘258 Application. As evidenced by the citations below, D4 disclosed several features pertinent to the ‘258 Application, such as:

- A progressive cavity section with a stator and a rotor.
- In which the stator contacting surfaces and the rotor contacting surfaces are made of metal.
- in which rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor are rigid and do not flex when is use at downhole temperatures.

The following excerpt from D4 are presented as a non-exhaustive example of teaching of the above-captioned features and that is believed to be relevant to the examination of the ‘258 Application.

“It is therefore an object of the invention to provide a drilling motor power section which **has no elastomeric parts**. It is also an object of the invention to provide a drilling motor which is virtually immune to chunking. It is another object of the invention to provide a drilling motor

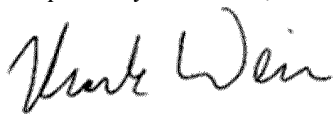
which is operable throughout a **wide range of temperatures without adversely affecting the integrity of the stator.**” [Col. 2, lines 38-45]

5. Conclusion

The published prior art references attached to this letter have significant bearing on the patentability of at least some of the pending claims in the ‘258 Application. The subject-matter of at least claims 1, 2, 3, 7, and 12 of the ‘258 Application is neither novel nor inventive in view of the discussed state of the art. It is submitted that none of the remaining pending claims appear to be patentable in view of the D1-D4 references, either for lack of Novelty or lack of Inventiveness. It is further submitted that the ‘258 Application as a whole fails to describe a patentable invention.

We look forward to receiving confirmation that this Protest has been applied against the ‘258 Application.

Respectfully submitted,



Mark Weir

Patent Agent at **AVENTUM IP LAW LLP**
SUITE 104, TOWER A,
555 LEGGET DRIVE
OTTAWA, ON K2K 2X3
CANADA
Direct: (343) 266-0398
Main: (613) 232-5300
MW/mh

Encls:

General Correspondence (Patent)

Date: August 11, 2021 4:25:35 PM

007/008/CAP

067

RS

#6626003

Application Number

2985258

Title of invention

DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND RELATED METHODS OF USE AND ASSEMBLY

Applicant(s) or Inventor Name(s)

Applicant or Inventor Name

Sender

Family Name: Weir

First Name: Mark

Initial:

Name of Corporation or Firm: AVENTUM IP LAW LLP

Address Line 1: PO Box 13002

Address Line 2:

Address Line 3:

City/Town: Kanata

Province/State: Ontario

Country: Canada

Postal/Zip Code: K2K 0E2

Telephone Number: 6132325300

Fax Number: 6135639231

Email Address:

Communicate by: Regular Mail

Correspondence Instructions

CIPO Letter - 3rd Party Submission Of Prior Art and Exam Request and related attachments

-- Appendix 1 - CA 2985258 as filed Claims

-- Appendix 2 - US 9393648

-- Appendix 3  US 7192260

-- Appendix 4  US 9976227

Date Reque/Date Received 2021-08-11

file:///e:\eprint-prod.ic.gc.ca/.../patent/inbasket/ToBeStamped/pgc_MarkWeir_20210811162535637_4553472061435590119_9490067.html[2021-08-12 12:40:45 PM]

Full-Metal v. InFocus, IPR2025-00391

InFocus - Exhibit No. 2005

Page 206

Description of Fee (small entity fee)

1. Examination of an application - small entity fee (1 x \$408.00): \$408.00

Total Fee Payment: \$408.00

Payment method

Common Payment Component

Attachments

1. 12084P0073CA01_CIPO_Letter_3rd_Party_Submission_Of_Prior_Art_and_Exam_Request.pdf

Other

CIPO Letter - 3rd Party Submission Of Prior Art and Exam Request and related attachments

2. 12084P0073CAG_Appendix_1_CA_2985258_as_filed_Claims.pdf

Other

Appendix 1 CA 2985258 as filed Claims

3. 12084P0073CAG_Appendix_2_US_9393648.pdf

Other

Appendix 2 - US 9393648

4. 12084P0073CAG_Appendix_3_US_7192260.pdf

Other

Appendix 3  US 7192260

5. 12084P0073CAG_Appendix_4_US_9976227.pdf

Other

Appendix 4  US 9976227

6. 12084P0073CAG_Appendix_5_US_6241494.pdf

Other

Appendix 5  US 6241494

Transmission Identifier: pgc_MarkWeir_20210811162535637_9490067

Date: August 11, 2021 4:25:35 PM

Commissioner of Patents
50 Victoria Street
Place du Portage
Phase I
Gatineau, Quebec
Canada

K1A 0C9

Application Number: 2985258

Title of invention: DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND RELATED METHODS OF USE AND ASSEMBLY

Applicant(s) or Inventor(s) Name(s): INFOCUS ENERGY SERVICES INC.

INFOCUS ENERGY SERVICES INC.

Reference Number: 12084P0073CAG

Instructions: CIPO Letter - 3rd Party Submission Of Prior Art and Exam Request and related attachments

-- Appendix 1 - CA 2985258 as filed Claims

-- Appendix 2 - US 9393648

-- Appendix 3  US 7192260

-- Appendix 4  US 9976227

-- Appendix 5  US 6241494

Attached are the following documents:

1. 12084P0073CA01_CIPO_Letter_3rd_Party_Submission_Of_Prior_Art_and_Exam_Request.pdf

CIPO Letter - 3rd Party Submission Of Prior Art and Exam Request and related attachments

Other

2. 12084P0073CAG_Appendix_1_CA_2985258_as_filed_Claims.pdf

Appendix 1 CA 2985258 as filed Claims

Other

3. 12084P0073CAG_Appendix_2_US_9393648.pdf

Appendix 2 - US 9393648

Other

4. 12084P0073CAG_Appendix_3_US_7192260.pdf

Appendix 3  US 7192260

Other

5. 12084P0073CAG_Appendix_4_US_9976227.pdf

Appendix 4  US 9976227

Other

6. 12084P0073CAG_Appendix_5_US_6241494.pdf

Appendix 5  US 6241494

Other

Description of Fee (small entity fee)

1. Examination of an application - small entity fee (1 x \$408.00): \$408.00

Total Fee Payment: \$408.00

Weir, Mark

AVENTUM IP LAW LLP

PO Box 13002

Kanata

Ontario

Canada

K2K 0E2

Tel: 6132325300

Fax: 6135639231

Transmission Identifier: pgc_MarkWeir_20210811162535637_9490067

Date Reque/Date Received 2021-08-11

file:///ecprint-prod.ic.gc.ca/.../patent/inbasket/ToBeStamped/pgc_MarkWeir_20210811162535637_4553472061435590119_9490067.html[2021-08-12 12:40:45 PM]

Full-Metal v. InFocus, IPR2025-00391

InFocus - Exhibit No. 2005

Page 208



Courtoisie — Avis à l'agent ou au demandeur d'une action de tiers
Courtesy – Advisory to Agent or Applicant of Third Party Action

NISSEN, ROBERT A.
robbie@nissenlaw.ca

Détails de la lettre
Letter Details

Date de la lettre 2021-09-08
Letter Date:
N° de la demande/brevet 2,985,258
Application/Patent N°:
Votre N° de référence 158-2CA2
Your Reference N°:

Votre lettre reçue le/Your Letter Received: 2021-08-11
Date de dépôt/Filing Date: 2017/11/14
Demandeur(s) ou Breveté(s)/Applicant(s) or Patentee(s): INFOCUS ENERGY SERVICES INC.
Inventeur(s)/Inventor(s): PEARSON, ALLAN; LUCHAK, MARK; SCHEMING, OXANA; OSATCHUK, MATT; VENABLES, ERIN; NKWOCHA, CHIMERE; SAMUEL, GEOFF; KJELLBOTN, PETER
Titre de l'invention/Title of invention: DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND RELATED METHODS OF USE AND ASSEMBLY
Requérant tiers/Third Party Requester: AVENTURE IP LAW LLP

Cette lettre vise à vous informer que le Bureau a reçu une communication à la date susmentionnée de la part d'un demandeur tiers pour entreprendre une action ou faire un paiement relativement à cette demande.

This letter is to advise that the Office has received a communication on the above-mentioned date from a third party requester to undertake an action or to make a payment on this application.

Toute demande sera prise en compte conformément, à la lumière de la *Loi sur les brevets* et des *Règles sur les brevets* dans la mesure où elles concernent la personne qui est apte à transiger dans cette affaire donnée.

Any request will be acted on accordingly, in view of the *Patent Act & Rules* as they pertain to who may conduct business before the Patent Office in this given matter.

La communication sera conservée dans un dossier mis à la disponibilité du public et peut être consultée dans le Base de données sur les brevets canadiens au : <http://www.ic.gc.ca/opic-cipo/cpd/fra/introduction.html>.

The communication will be retained as part of the file open to public inspection and can be viewed on the Canadian Patents Database at: <http://www.ic.gc.ca/opic-cipo/cpd/eng/introduction.html>.

Pour de plus amples renseignements concernant cette lettre, veuillez consulter le *Recueil des pratiques du Bureau des brevets*

For more information regarding this letter, please refer to the *Manual of Patent Office Practice* (MOPOP) at Canada.ca/patents or phone 819-

(RPBB) accessible au canada.ca/brevets ou
téléphoner au 819-997-2839.

997-2839.



Courtoisie – Accusé de réception d'antériorités
Courtesy – Acknowledgment of Prior Art

AVENTUM IP LAW LLP

555 Legget Drive, Suite 104
Tower A
OTTAWA Ontario
K2K 2X3

Détails de la lettre

Letter Details

Date de la lettre 2021-09-16
Letter Date:
N° de la demande/brevet 2,985,258
Application/Patent N°:
Votre N° de référence
Your Reference N°:

Votre lettre reçue le/Your Letter Received: 2021-08-11
Date de dépôt/Filing Date: 2017/11/14
Demandeur(s)/Applicant(s): INFOCUS ENERGY SERVICES INC.
PEARSON, ALLAN; LUCHAK, MARK; SCHEMING,
OXANA; OSATCHUK, MATT; VENABLES, ERIN;
Inventeur(s)/Inventor(s): NKWOCHA, CHIMERE; SAMUEL, GEOFF; KJELLBOTN,
PETER
Titre de l'invention/Title of invention: DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY
SECTIONS, AND RELATED METHODS OF USE AND
ASSEMBLY

La présente lettre a pour but de vous informer
que le Bureau accuse réception des antériorités
que vous avez présentées relativement à la
demande de brevet susmentionnée.

Votre lettre a été soumise à l'examineur.
Votre lettre a été versée au dossier de la
demande dans les registres du Bureau et sera
mise à la disponibilité du public.

L'état administratif d'un brevet ou d'une
demande de brevet mise à la disponibilité du
public peut être suivi dans la Base de données
sur les brevets canadiens au lien suivant :
[http://www.ic.gc.ca/opic-
cipo/cpd/fra/introduction.html](http://www.ic.gc.ca/opic-cipo/cpd/fra/introduction.html)

This letter is to advise that the Office
acknowledges receipt of your submission of prior
art on the above-mentioned patent application.

Your letter has been referred to the examiner.
Your letter has been added to Office records as
part of the application file and will be open to
public inspection.

The administrative status of any patent or
application for a patent open to public inspection
may be monitored on the Canadian Patent
Database at this link: [http://www.ic.gc.ca/opic-
cipo/cpd/eng/introduction.html](http://www.ic.gc.ca/opic-cipo/cpd/eng/introduction.html)

Références pertinentes:

- art. 10 de la *Loi sur les brevets*
- art. 34.1 de la *Loi sur les brevets*
- art. 12 des *Règles sur les brevets*

Relevant references:

- s.10 of the *Patent Act*
- s.34.1 of the *Patent Act*
- s.12 of the *Patent Rules*

Pour de plus amples renseignements concernant cette lettre, veuillez consulter le *Recueil des pratiques du Bureau des brevets* (RPBB) sur le site canada.ca/brevets ou téléphoner au 819-997-2839.

For more information regarding this letter, please refer to the *Manual of Patent Office Practice* (MOPOP) at Canada.ca/patents or phone 819-997-2839.



Courtoisie – Accusé de réception d'antériorités de l'agent, du représentant commun ou du demandeur
Courtesy – Acknowledgment of Prior Art to Agent, Common Representative, or Applicant

NISSEN, ROBERT A.
robbie@nissenlaw.ca

Détails de la lettre
Letter Details

Date de la lettre 2021-09-16
Letter Date:
N° de la demande/brevet 2,985,258
Application/Patent N°:
Votre N° de référence 158-2CA2
Your Reference N°:

Votre lettre reçue le/Your Letter Received: 2021-08-11
Date de dépôt/Filing Date: 2017/11/14
Demandeur(s)/Applicant(s): INFOCUS ENERGY SERVICES INC.
PEARSON, ALLAN; LUCHAK, MARK; SCHEMING,
OXANA; OSATCHUK, MATT; VENABLES, ERIN;
Inventeur(s)/Inventor(s): NKWOCHA, CHIMERE; SAMUEL, GEOFF; KJELLBOTN,
PETER
Titre de l'invention/Title of invention: DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY
SECTIONS, AND RELATED METHODS OF USE AND
ASSEMBLY

La présente lettre a pour but de vous informer que le Bureau a reçu des antériorités relativement à la demande de brevet susmentionnée. Ces dernières ont été versées au dossier de la demande de brevet dans les registres du Bureau et seront mises à la disponibilité du public.

This letter is to advise that the Office has received a submission of prior art on the above-mentioned patent application. It has been added to Office records as part of the application file and will be open to public inspection.

Une copie de l'accusé de réception envoyé à la personne qui a présenté les antériorités est jointe par souci de commodité.

A copy of the acknowledgement letter to the person who submitted the prior art is enclosed for your convenience.

Vous pouvez consulter la communication relative à l'antériorité dans la Base de données sur les brevets canadiens (BDBC) à <https://www.ic.gc.ca/opic-cipo/cpd/fra/introduction.html>. Le contenu de l'antériorité ne peut être visualisé dans la BDBC, mais peut être consulté dans la salle de recherche de l'OPIC ou en commandant une copie de la communication et de la protestation.

You can view the communication relating to the prior art on the Canadian Patents Database (CPD) at <http://www.ic.gc.ca/opic-cipo/cpd/eng/introduction.html>. The content of the prior art is not viewable on the CPD, but can be accessed in the search room at CIPO or by ordering a copy of the communication and protest.

Références pertinentes:

- art. 34.1 de la *Loi sur les brevets*
- art. 12 des *Règles sur les brevets*

Pour de plus amples renseignements concernant cette lettre, veuillez consulter le *Recueil des pratiques du Bureau des brevets* (RPBB) sur le site canada.ca/brevets ou téléphoner au 819-997-2839.

Relevant references:

- s.34.1 of the *Patent Act*
- s.12 of the *Patent Rules*

For more information regarding this letter, please refer to the *Manual of Patent Office Practice* (MOPOP) at Canada.ca/patents or phone 819-997-2839.



Reçu du paiement électronique / Electronic Payment Receipt

Office de la propriété intellectuelle du Canada

Place du Portage I
50, rue Victoria
Gatineau (Québec) K1A 0C9
Canada

Canadian Intellectual Property Office

Place du Portage I
50 Victoria Street
Gatineau, Qc K1A 0C9
Canada

Émis à / Issued to

ROBERT A. NISSEN
c/o Nissen Patent Law
EDMONTON, Alberta
T6E 1X2
Canada

Numéro de confirmation Confirmation Number	Date et heure de réception Receipt Date and Time	Montant payé Amount Paid
9658299	2021-10-15 17:32:14	\$ 50.00

Brevet et/ou Patent and/or	Description	Taxes Fees
2985258	DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY Taxe de maintien en état - Demande - nouvelle loi / Maintenance Fee - Application - New Rules année(s)/year(s): 4 Numéro de référence / Reference Number: 158-2CA2	\$ 50.00

Total des taxes payées / Total Fees Paid: **\$ 50.00**

Information sur le paiement SVP appelez 1-819-994-2269 / For payment inquiries please call 1-819-994-2269

General Correspondence (Patent)

Date: December 3, 2021 5:04:02 PM

**011
008
CAP
MB**

Application Number

2,985,258

#6231970

Title of invention

DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND RELATED METHODS OF USE AND ASSEMBLY

Applicant(s) or Inventor Name(s)

Applicant or Inventor Name

Sender

Family Name: Nissen
First Name: Robert
Initial:
Name of Corporation or Firm: Nissen Patent Law
Address Line 1: 10328 - 81 Avenue
Address Line 2: #200
Address Line 3:
City/Town: Edmonton
Province/State: Alberta
Country: Canada
Postal/Zip Code: T6E 1X2
Telephone Number: 7808027904
Fax Number:
Email Address: robbie@nissenlaw.ca
Communicate by: Electronic Mail (Non secure)

Correspondence Instructions

The Applicant requests advanced examination and submits the advanced examination fee. A competitor appears to be building a competing product that appears to fall within the claims as filed, and the Applicant's rights will likely be prejudiced by reason of the infringing activities of the competitor should prosecution of the above Canadian patent application not be advanced.

To facilitate prosecution the Applicant submits the attached list of references (7 pages) and copies of relevant non-patent

literature. The references listed include both references cited during the prosecution of the Applicant's corresponding U.S. patent (Patent no.: 10,676,992) as well as a list of additional references and non-patent literature. There have been allegations of invalidity of the U.S. patent made by one or more competitors. In the list of references submitted, we have included asterisks to identify which references the competitors believe are relevant to patentability. Please process the above request and fees, thanks. The Applicant wishes to keep this case in good standing, so please charge any additional fees required to do so to the credit card or to the Agent of Record's deposit account 600002856.

/Robert A. Nissen/
Agent of Record

Description of Fee (small entity fee)

1. Advance an application for a patent out of its routine order (1 x \$510.00): \$510.00

Total Fee Payment: \$510.00

Payment method

Common Payment Component

Attachments

1. references list.pdf
Other
List of references

2. NPL1i.pdf
Other
NPL1

3. NPL2i.pdf
Other
NPL2

4. NPL3i.pdf
Other
NPL3

5. NPL4i.pdf
Other
NPL4

6. NPL5.pdf
Other
NPL5

7. NPL6i.pdf
Other
NPL6

8. NPL7i.pdf
Other
NPL7

9. NPL8i.pdf
Other
NPL8

10. NPL9i.pdf
Other
NPL9

11. yang2016.pdf
Other
NPL10

Transmission Identifier: pgc_nissenpatents_20211203170402964_9791128

Date: December 3, 2021 5:04:02 PM

Commissioner of Patents
50 Victoria Street
Place du Portage
Phase I
Gatineau, Quebec
Canada
K1A 0C9

Application Number: 2,985,258

Title of invention: DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND RELATED METHODS OF USE AND ASSEMBLY

Applicant(s) or Inventor(s) Name(s): INFOCUS ENERGY SERVICES INC.
INFOCUS ENERGY SERVICES INC.

Reference Number: 158-2CA2

Instructions: The Applicant requests advanced examination and submits the advanced examination fee. A competitor appears to be building a competing product that appears to fall within the claims as filed, and the Applicant's rights will likely be prejudiced by reason of the infringing activities of the competitor should prosecution of the above Canadian patent application not be advanced.

To facilitate prosecution the Applicant submits the attached list of references (7 pages) and copies of relevant non-patent literature. The references listed include both references cited during the prosecution of the Applicant's corresponding U.S. patent (Patent no.: 10,676,992) as well as a list of additional references and non-patent literature. There have been allegations of invalidity of the U.S. patent made by one or more competitors. In the list of references submitted, we have included asterisks to identify which references the competitors believe are relevant to patentability.

Please process the above request and fees, thanks. The Applicant wishes to keep this case in good standing, so please charge any additional fees required to do so to the credit card or to the Agent of Record's deposit account 600002856.

/Robert A. Nissen/
Agent of Record

Attached are the following documents:

1. references list.pdf

List of references

Other

2. NPL1i.pdf

NPL1

Other

3. NPL2i.pdf

NPL2

Other

4. NPL3i.pdf

NPL3

Other

5. NPL4i.pdf

NPL4

Other

6. NPL5.pdf

NPL5

Other

7. NPL6i.pdf

NPL6

Other

8. NPL7i.pdf

NPL7

Other

9. NPL8i.pdf

NPL8

Other

10. NPL9i.pdf

NPL9

Other

11. yang2016.pdf

NPL10

Other

Description of Fee (small entity fee)

1. Advance an application for a patent out of its routine order (1 x \$510.00): \$510.00

Total Fee Payment: \$510.00

Nissen, Robert
Nissen Patent Law
10328 - 81 Avenue
#200
Edmonton
Alberta
Canada
T6E 1X2
Tel: 7808027904
Email:robbie@nissenlaw.ca

Transmission Identifier: pgc_nissenpatents_20211203170402964_9791128



Courtoisie – Requête pour avancer l'examen – Conforme
Courtesy – Advanced Examination Request – Compliant

NISSEN, ROBERT A.
robbie@nissenlaw.ca

Détails de la lettre
Letter Details

Date de la lettre 2021-12-22
Letter Date:
N° de la demande 2,985,258
Application N°:
Votre N° de référence 158-2CA2
Your Reference N°:

Votre lettre reçue le/Your Letter Received:	2021-12-03
Date de dépôt/Filing Date:	2017/11/14
Demandeur(s)/Applicant(s):	INFOCUS ENERGY SERVICES INC. PEARSON, ALLAN; LUCHAK, MARK; SCHEMING, OXANA; OSATCHUK, MATT; VENABLES, ERIN;
Inventeur(s)/Inventor(s):	NKWOCHA, CHIMERE; SAMUEL, GEOFF; KJELLBOTN, PETER
Titre de l'invention/Title of invention:	DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND RELATED METHODS OF USE AND ASSEMBLY

Cette lettre vise à vous informer que la requête pour avancer l'examen de la demande de brevet susmentionnée est conforme aux *Règles sur les brevets*.

Le commissaire avancera l'examen de la demande.

This letter is to advise that the request to advance examination of the above-mentioned application for a patent out of its routine order is compliant with the *Patent Rules*.

The Commissioner will advance out of its routine order the examination of the application.

Références pertinentes :

- art. 84 des *Règles sur les brevets*

Relevant references:

- s.84 of the *Patent Rules*

Pour obtenir de plus amples renseignements concernant cette lettre, veuillez consulter le *Recueil des pratiques du Bureau des brevets* (RPBB) accessible à canada.ca/brevets ou téléphoner au 819-997-2839.

For more information regarding this letter, please refer to the *Manual of Patent Office Practice* (MOPOP) at Canada.ca/patents or phone 819-997-2839.

17 February 2022 (17-02-2022)

NISSEN, ROBERT A.
robbie@nissenlaw.ca

Application No. : **2,985,258**
Owner : INFOCUS ENERGY SERVICES INC.
Title : **DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS,
AND RELATED METHODS OF USE AND ASSEMBLY**
Classification : E21B 4/02 (2006.01)
Your File No. : **158-2CA2**
Examiner : Mallory MacLean

YOU ARE HEREBY NOTIFIED OF A REQUISITION BY THE EXAMINER IN ACCORDANCE WITH SUBSECTION 86(2) OF THE *PATENT RULES*. IN ORDER TO AVOID ABANDONMENT UNDER PARAGRAPH 73(1)(a) OF THE *PATENT ACT*, A WRITTEN REPLY MUST BE RECEIVED WITHIN **FOUR (4)** MONTHS AFTER THE ABOVE DATE.

This application has been examined taking into account the applicant's correspondence received in this office on 3 December 2021 (03-12-2021).

The number of claims in this application is 177.

As the application is apparently directed to a plurality of inventions, as detailed below, the search and substantive examination of the claimed subject matter have been deferred pending the applicant's response to the present requisition.

The examiner has identified the following defects in the application:

The application does not comply with subsection 36(1) of the *Patent Act*. The claims are directed to a plurality of alleged inventions as follows:

Group A - Claims 1-22 are directed to a downhole tool comprising a progressive cavity section with a stator and a rotor, in which the stator, rotor, or stator and rotor are formed by electrochemical machining;

Group B - Claims 23-41 are directed to a downhole tool comprising a progressive cavity section with a stator and a rotor, in which the stator is formed from a single integral block of material, and the stator has a length of at least fifty inches;

Group C - Claims 42-52 are directed to a downhole tool comprising a progressive cavity section with a stator and a rotor, in which the stator is formed by plural axial stator sections connected end to end, and adjacent axial stator sections of the plural axial stator sections are connected by dowels;

Group D - Claims 53-55 are directed to a downhole tool comprising a progressive cavity

section with a stator and a rotor, in which the stator is formed by three dimensional printing;

Group E - Claims 56-86 are directed to a downhole reamer tool comprising a tubular body defining an interior passageway and a reaper part mounted to the tubular body, the reamer part being mounted to rotate relative to the tubular body upon application of fluid flow within the interior passageway;

Group F - Claims 87-109 are directed to a casing reamer shoe comprising a progressive cavity section with a stator and a rotor, a reamer part mounted to be rotated by the stator or the rotor, and in which the rotor is formed by a hollow helically lobed sleeve;

Group G - Claims 110-120 are directed to a downhole reamer tool comprising a progressive cavity section with a stator and a rotor, and a reamer part mounted to be rotated by the stator, the rotor having an uphole end tubing connector and the stator mounted to rotate relative to the rotor upon application of fluid flow;

Group H - Claims 121-138 are directed to a casing reamer shoe comprising a tubular body with an uphole end tubing connector defining an interior passageway, a reamer part mounted to rotate relative to the tubular body at a first speed, and a nose mounted to rotate relative to the tubular body at a second speed;

Group I - Claims 139-154 are directed to a casing reamer shoe comprising a tubular body, the tubular body having a progressive cavity section with a stator and a rotor, a reamer part, and a universal joint connected between the reaper part and the rotor, the universal joint being structured to convert eccentric motion of the rotor into concentric motion;

Group J - Claims 155-174 are directed to a downhole reamer tool comprising a tubular body with an uphole end tubing connector defining an interior passageway, a reamer part mounted to rotate relative to the tubular body, an impeller mounted within the tubular body, and the interior passageway having a plurality of radial passages that direct through in a radial direction against the impeller; and

Group K - Claims 175-177 are directed to a casing reamer shoe comprising a progressive cavity section with a stator and a rotor, a reamer part mounted to be rotated, and in which the rotor contacting surfaces of the stator and the stator contacting surfaces of the rotor are rigid in use.

The examiner considers that the subject matter of the independent claims of Groups A-K respectively are distinct alleged inventions and do not form a single inventive concept from an a posteriori analysis. United States Patent Application US 2011/0243774 A1 published 6 October 2011 to Underwood et al. for example discloses subject matter common to independent claims of respective Groups A-K in the description paragraphs [0002]-[0006] comprising a progressive cavity section with a stator and a rotor.

According to subsection 36(2) of the *Patent Act*, after limiting the claims of the present application to one invention only, the applicant may make any other invention disclosed the subject of a divisional application. The applicant is advised that once an election has been made, further prosecution of the present application will be limited to the invention so elected.

Claims 42-45 and 55-177 of the present application are conterminous with claims 1-120 and 124-130 of patent application CA2961629 and so both sets of cited claims cannot be granted in separate patents (see *GlaxoSmithKline Inc. v. Apotex Inc.* 2003 FCT 687 and *Whirlpool Co. v. Camco On.* 2000 SCC 67).

For both applications to proceed to grant, the overlapping subject-matter must be removed from one of the applications. Where one of the applications is otherwise in condition for allowance, it will not be held back solely because of a potential double-patenting issue. It is up to the applicant to ensure that all the claims to a given invention are included in a single application.

In accordance with subsection 84(2) of the *Patent Rules*, this application will no longer qualify for advanced examination requested by the applicant if the application is deemed to be abandoned or if an extension of time under subsection 3(1) of the *Patent Rules* is granted.

In view of the foregoing defects, the applicant is requisitioned, under subsection 86(2) of the *Patent Rules*, to amend the application in order to comply with the *Patent Act* and the *Patent Rules* or to provide arguments as to why the application does comply.

Under section 102 of the *Patent Rules*, any amendment made in response to this requisition must be accompanied by a statement explaining the purpose of the amendment and identifying the differences between the new page and the replaced page.

Mallory MacLean
Patent Examiner
819-639-7912

As per CIPO Client Service Standards, a response to a telephone enquiry or voice mail should be provided by the end of the next business day. In the event that attempts to reach the examiner are unsuccessful, the examiner's Section Head, Philip Vesely, can be reached at 819-639-7924.

For general inquiries: 1-866-997-1936 or for more options see
<http://www.ic.gc.ca/eic/site/cipointernet-internetopic.nsf/eng/wr00006.html>.

CIPO values your feedback and invites you to complete a short and anonymous ongoing survey on patent examination products and services. You can access the survey at the following link:
https://www.surveymonkey.com/r/PPE_EPBdB.

2985258A_MEM.docm

The Examination Search Report is provided for reference only and is not part of any requisition made by the examiner in accordance with the *Patent Act* or *Rules*. The applicant is not required to respond to the information contained in the Examination Search Report.

Examination Search Report

Box I: General Information			
Application No.	2,985,258	Search Report Date	2022-02-14
Title	DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND RELATED METHODS OF USE AND ASSEMBLY		
Examiner	Mallory MacLean	Search Conducted?	No
No search was conducted for the following reasons :			
- Search deferred - see report for reasoning (lack of unity, excluded subject matter etc.)			Yes
- Relied on previous search results (CIPO and/or by Foreign Office)			N/A

Box II: Family Prosecution		
Family Member	File Wrapper Reviewed	Status of Prosecution
US10676992B2	2022-02-14	Completed
CA2961629A1	2022-02-14	Not Started

Box IV: Search History
No Search Conducted

Version 9

General Correspondence (Patent)

Date: June 17, 2022 5:53:47 PM

008

MH

Application Number

2985258

Title of invention

DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND RELATED METHODS OF USE AND ASSEMBLY

Applicant(s) or Inventor Name(s)

Applicant or Inventor Name

Sender

Family Name: Nissen

First Name: Robert

Initial:

Name of Corporation or Firm: Nissen Patent Law

Address Line 1: 10328 - 81 Avenue

Address Line 2: #200

Address Line 3:

City/Town: Edmonton

Province/State: Alberta

Country: Canada

Postal/Zip Code: T6E 1X2

Telephone Number: 780-802-7904

Fax Number:

Email Address: robbie@nissenlaw.ca

Communicate by: Electronic Mail (Non secure)

Correspondence Instructions

Applicant: INFOCUS ENERGY SERVICES INC.

Filing Date: November 14, 2017

Application Number: 2,985,258

Title: DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND RELATED METHODS OF USE AND ASSEMBLY

Our Ref: 158-2CA2

In response to the official action of February 17, 2022, the Applicant submits a cover letter (3 pages) and amended claims (3 pages). The Applicant's intention is to keep the application in good standing, and thus please take all steps required to do so and, if any step has not been taken that must be taken, please accept this correspondence as a request for an extension of time to take the step. Please charge any additional fees required to the credit card or to the Agent of Record's deposit account no. 600002856.

/Robert A. Nissen/
Agent of Record

Description of Fee

No fee has been entered.
Total Fee Payment: \$0.00

Payment method

No Charge

Attachments

1. 158-2CA2_response.pdf
Other
Cover letter

2. 158-2CA2_amended_claims.pdf
Claim

Transmission Identifier: pgc_nissenpatents_20220617175347705

Date: June 17, 2022 5:53:47 PM

Commissioner of Patents
50 Victoria Street
Place du Portage
Phase I
Gatineau, Quebec
Canada
K1A 0C9

Application Number: 2985258
Title of invention: DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND RELATED METHODS OF USE AND ASSEMBLY
Applicant(s) or Inventor(s) Name(s): INFOCUS ENERGY SERVICES INC.
INFOCUS ENERGY SERVICES INC.
Reference Number: 158-2CA2

Instructions: Applicant: INFOCUS ENERGY SERVICES INC.

Filing Date: November 14, 2017

Application Number: 2,985,258

Title: DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND RELATED METHODS OF USE AND ASSEMBLY

Our Ref: 158-2CA2

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/Robert A. Nissen/

Agent of Record

Attached are the following documents:

1. 158-2CA2_response.pdf

Cover letter

Other

2. 158-2CA2_amended_claims.pdf

Claim

Nissen, Robert

Nissen Patent Law

10328 - 81 Avenue

#200

Edmonton

Alberta

Canada

T6E 1X2

Tel: 780-802-7904

Email:robbie@nissenlaw.ca

Transmission Identifier: pgc_nissenpatents_20220617175347705

Application No.: 2,985,258

To:
Commissioner of Patents
Canadian Intellectual Property Office

AMENDMENT/REMARKS FOLLOWING EXAMINER'S REPORT

Our ref: 158-2CA2

Application No.: 2,985,258

**Title: DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND
RELATED METHODS OF USE AND ASSEMBLY**

Filed: November 14, 2017

Applicant: INFOCUS ENERGY SERVICES INC.

Classification: E21B 4/02 (2006.01)

Examiner: Mallory MacLean

This is in response to the official action dated 17 February 2022.

AMENDMENT

IN THE CLAIMS

Please cancel claims pages of record, and replace them with claims 1-22 on the attached replacement claims pages 46-48.

REMARKS

Claim amendment

The Applicant has elected Group A and cancelled Claims 23-177 from Groups B-K.

The examiner indicated that:

The application does not comply with subsection 36(1) of the *Patent Act*. The claims are directed to a plurality of alleged inventions as follows:

and

The examiner considers that the subject matter of the independent claims of Groups A-K respectively are distinct alleged inventions and do not form a single inventive concept from an a posteriori analysis. United States Patent Application US 2011/0243774 A1 published 6 October 2011 to Underwood et al. for example discloses subject matter common to independent claims of respective Groups A-K in the description paragraphs [0002]-[0006] comprising a progressive cavity section with a stator and a rotor.

Application No.: 2,985,258

The Applicant respectfully traverses this rejection. The Applicant has elected Group A and has cancelled the claims from Groups B-K. The application complies with subsection 36(1) of the *Patent Act*.

The examiner indicated that:

Claims 42-45 and 55-177 of the present application are conterminous with claims 1-120 and 124-130 of patent application CA2961629 and so both sets of cited claims cannot be granted in separate patents (see *GlaxoSmithKline Inc. v. Apotex Inc.* 2003 FCT 687 and *Whirlpool Co. v. Camco On.* 2000 SCC 67).

For both applications to proceed to grant, the overlapping subject-matter must be removed from one of the applications. Where one of the applications is otherwise in condition for allowance, it will not be held back solely because of a potential double-patenting issue. It is up to the applicant to ensure that all the claims to a given invention are included in a single application.

The Applicant respectfully traverses this rejection. Claims 42-45 and 55-177 of the present application have been cancelled, and thus this rejection is moot.

The applicant has addressed the examiner's requisition. It is noted that no s. 85 requisition has been issued. Accordingly, the applicant has not supplied any information concerning corresponding patents. If the examiner wishes disclosure of any s. 85 information, or a discussion of the relevance of any other references, the examiner is requested to make a s. 85 requisition. Nothing herein should be construed as an allegation that no relevant art exists other than what was cited by the examiner.

The applicant submits that the examiner's requisitions have been satisfied. Allowance of the application is respectfully requested.

June 17, 2022

Respectfully submitted

/Robert A. Nissen/

Robert A. Nissen

Agent of Record

10328-81 Avenue, Suite 200
Edmonton, Alberta T6E 1X2

Application No.: 2,985,258

Ph. 780-802-7904
Fax 888-744-4480

1. A downhole tool comprising:
a progressive cavity section with a stator and a rotor; and
in which the stator, rotor, or stator and rotor are formed by electrochemical machining (ECM).
2. The downhole tool of claim 1 in which rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid.
3. The downhole tool of claim 2 in which the stator contacting surfaces and the rotor contacting surfaces are made of metal.
4. The downhole tool of claim 1 in which rotor contacting surfaces of the stator are defined by an elastomeric coating within the stator.
5. The downhole tool of claim 1 - 4 in which the progressive cavity section is connected to rotate a reamer part of a casing reamer shoe.
6. The downhole tool of claim 1 - 4 in which the progressive cavity section is connected to rotate a drill bit.
7. The downhole tool of any one of claim 1 - 6 in which the stator has a length of at least eighty inches defined between axial ends of the stator.
8. The downhole tool of claim 7 in which the stator has a length of at least one hundred and fifty inches defined between axial ends of the stator.
9. The downhole tool of claim 8 in which the stator has a length of at least three hundred inches defined between axial ends of the stator.
10. The downhole tool of any one of claim 1 - 9 in which the stator is formed by ECM.

11. A method comprising:
positioning the downhole tool of any one of claim 1 - 10 in a well; and
pumping fluid to operate the progressive cavity section to rotate the rotor relative to the stator.
12. A method comprising:
forming a stator, rotor, or stator and rotor by electrochemical machining (ECM); and
forming a downhole tool by inserting the rotor into the stator.
13. The method of claim 12 in which within the downhole tool, rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid.
14. The method of claim 13 in which the stator contacting surfaces and the rotor contacting surfaces are made of metal.
15. The method of claim 12 in which rotor contacting surfaces of the stator are defined by an elastomeric coating within the stator.
16. The method of claim 12 - 15 in which the stator and the rotor within the downhole tool form a progressive cavity power section connected to rotate a reamer part of a casing reamer shoe.
17. The method of claim 12 - 15 in which the stator and the rotor within the downhole tool form a progressive cavity power section connected to rotate a drill bit.
18. The method of any one of claim 12 - 17 in which the stator has a length of at least eighty inches defined between axial ends of the stator.
19. The method of claim 18 in which the stator has a length of at least one hundred and fifty inches defined between axial ends of the stator.

20. The method of claim 19 in which the stator has a length of at least three hundred inches defined between axial ends of the stator.

21. The method of any one of claim 12 - 20 in which forming the stator or rotor by ECM further comprises advancing a cutting tool into or over a workpiece along an axis of the workpiece, with a sidewall of the cutting tool having a helically lobed profile, in which advancing is carried out while:

an electrical field is established across a gap defined by the sidewall of the cutting tool and a sidewall of the workpiece;

an electrolytic solution flows through the gap; and

the cutting tool rotates about the axis such that the sidewall of the workpiece takes on a shape that is the inverse of the helically lobed profile of the sidewall of the cutting tool.

22. The method of any one of claim 12 - 20 in which the stator is formed by ECM.

30 August 2022 (30-08-2022)

NISSEN, ROBERT A.
robbie@nissenlaw.ca

Application No. : **2,985,258**
Owner : INFOCUS ENERGY SERVICES INC.
Title : **DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS,
AND RELATED METHODS OF USE AND ASSEMBLY**
Classification : E21B 4/02 (2006.01)
Your File No. : **158-2CA2**
Examiner : Mallory MacLean

YOU ARE HEREBY NOTIFIED OF A REQUISITION BY THE EXAMINER IN ACCORDANCE WITH SUBSECTION 86(2) OF THE *PATENT RULES*. IN ORDER TO AVOID ABANDONMENT UNDER PARAGRAPH 73(1)(a) OF THE *PATENT ACT*, A WRITTEN REPLY MUST BE RECEIVED WITHIN **FOUR (4)** MONTHS AFTER THE ABOVE DATE.

The applicant's letters of 3 December 2021 (03-12-2021) and 17 June 2022 (17-06-2022) have been received and the application has been examined having regard to the applicant's arguments. However, the examiner considers that the application still does not comply with the *Patent Act* or *Patent Rules*.

The number of claims in this application is 22.

Documents Cited:

D1:*	US 2011/0243774 A1	Underwood et al.	6 October 2011 (06-10-2011)
D2:*	US 2016/0168912 A1	Mitchell et al.	16 June 2016 (16-06-2016)
D3:*	US 2005/0079083 A1	Lievestro et al.	14 April 2005 (14-04-2005)

* document cited by a foreign patent office

The examiner has identified the following defects in the application:

Claims 1-4, 6, 10, 11-15, 17, and 22 encompass subject-matter that was disclosed in D1 before the claim date and do not comply with paragraph 28.2(1)(b) of the *Patent Act*.

With regard to claims 1, 10, 12, and 22, D1 teaches a downhole tool and method of forming said tool (abstract; fig. 1), the downhole tool comprising: a progressive cavity section (fig. 1, 80; [0023]-[0024]) with a stator (fig. 1, 100) and a rotor (fig. 1, 90); and in which the stator, rotor, or stator and rotor are formed by electrochemical machining (ECM) ([0029]).

With regard to claims 2 and 13, D1 teaches the tool and method in which rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid ([0033]).

With regard to claims 3 and 14, D1 teaches the tool and method in which the stator contacting surfaces and the rotor contacting surfaces are made of metal ([0027]).

With regard to claims 4 and 15, D1 teaches the tool and method in which rotor contacting surfaces of the stator are defined by an elastomeric coating within the stator (fig. 2a, 120; [0024]).

With regard to claims 6 and 17, D1 teaches the tool and method in which the progressive cavity section is connected to rotate a drill bit (fig. 1).

With regard to claim 11, D1 teaches a method comprising: positioning the downhole tool in a well; and pumping fluid to operate the progressive cavity section to rotate the rotor relative to the stator ([0002]-[0003]).

Claims 5 and 16 do not comply with section 28.3 of the *Patent Act*. These claims are directed to subject-matter that would have been obvious at the claim date to a person skilled in the art or science to which it pertains having regard to D1 in view of D2.

With regard to claims 5 and 16, D1 fails to teach the tool and method in which the progressive cavity section is connected to rotate a reamer part of a casing reamer shoe.

However, D2 teaches a downhole tool in which the progressive cavity section is connected to rotate a reamer part of a casing reamer shoe ([0006]).

It would be obvious to a person skilled in the art to modify the progressive cavity section of D1 to connect to a reamer part as taught by D2.

Therefore it would have been obvious to one skilled in the art to produce the claimed downhole tool and practise the method steps of forming a downhole tool by combining known features belonging in the same art.

Claims 7-9 and 18-20 do not comply with section 28.3 of the *Patent Act*. These claims are directed to subject-matter that would have been obvious at the claim date to a person skilled in the art or science to which it pertains having regard to D1 in view of the common general knowledge.

With regard to claims 7-9 and 18-20, D1 teaches the subject matter of independent claim 1 on which claims 7-9 and 18-20 ultimately depend on. The subject matter of claims 7-9 and 18-20 does not appear to contain any additional features which, in combination with features of any claim to which they refer, involve inventive structure, since they relate to minor constructional changes or design options which come within the scope of downhole tools by persons skilled in the art and producing results no other than expected from their combinations.

Therefore it would have been obvious to one skilled in the art to produce the claimed downhole tool and practise the method steps of forming a downhole tool by combining known features belonging in the same art.

Claim 21 does not comply with section 28.3 of the *Patent Act*. This claim is directed to subject-matter that would have been obvious at the claim date to a person skilled in the art or science to which it pertains having regard to D1 in view of D3.

With regard to claim 21, D1 fails to teach the method in which forming the stator or rotor by ECM further comprises advancing a cutting tool into or over a workpiece along an axis of the workpiece, with a sidewall of the cutting tool having a helically lobed profile, in which advancing is carried out while: an electrical field is established across a gap defined by the sidewall of the cutting tool and a sidewall of the workpiece; an electrolytic solution flows through the gap; and the cutting tool rotates about the axis such that the sidewall of the workpiece takes on a shape that is the inverse of the helically lobed profile of the sidewall of the cutting tool.

However, D3 teaches the method in which forming the stator or rotor by ECM further comprises advancing a cutting tool into or over a workpiece along an axis of the workpiece, with a sidewall of the cutting tool having a helically lobed profile, in which advancing is carried out while: an electrical field is established across a gap defined by the sidewall of the cutting tool and a sidewall of the workpiece; an electrolytic solution flows through the gap; and the cutting tool rotates about the axis such that the sidewall of the workpiece takes on a shape that is the inverse of the helically lobed profile of the sidewall of the cutting tool ([0031]-[0034], [0043]-[0047]).

It would be obvious to a person skilled in the art to modify the forming of the stator and rotor as taught by D1 to comprise the method as taught by D3.

Therefore it would have been obvious to one skilled in the art to practise the method steps of forming a downhole tool by combining known features belonging in the same art.

Claims 5, 6, 16, and 17 are dependent claims that refer to more than one claim not in the alternative and do not comply with subsection 63(3) of the *Patent Rules*. A preamble such as “according to any one of claims”, would make it clear that the above claims depend upon each claim in the alternative only.

Claims 8, 9, 19, and 20 are indefinite and do not comply with subsection 27(4) of the *Patent Act*. The elements “a length” (claims 8, 9, 19, 20, lines 1, 1, 1, 1) and “axial ends” (claims 8, 9, 19, 20, lines 2, 2, 2, 2), are defined with indefinite articles, causing a lack of clarity as to whether they are intended to refer to the same elements previously defined in the claims or an additional element thereto.

Claim 11 is indefinite and does not comply with subsection 27(4) of the *Patent Act*. The term “the downhole tool” (claim 11, line 2) has no antecedent.

Claim 21 is indefinite and does not comply with subsection 27(4) of the Patent Act. For clarity, method steps should begin with the active verb.

Claims 10 and 22 do not state any additional features over the claims to which they refer and do not comply with subsection 63(1) of the *Patent Rules*.

The description contains a statement that incorporates by reference another document and does not comply with subsection 57(1) of the *Patent Rules*. Such a statement is found at paragraph [0035] and should be removed.

In accordance with subsection 84(2) of the *Patent Rules*, this application will no longer qualify for advanced examination requested by the applicant if the application is deemed to be abandoned or if an extension of time under subsection 3(1) of the *Patent Rules* is granted.

In view of the foregoing defects, the applicant is requisitioned, under subsection 86(2) of the *Patent Rules*, to amend the application in order to comply with the *Patent Act* and the *Patent Rules* or to provide arguments as to why the application does comply.

Under section 102 of the *Patent Rules*, any amendment made in response to this requisition must be accompanied by a statement explaining the purpose of the amendment and identifying the differences between the new page and the replaced page.

Mallory MacLean
Patent Examiner
819-639-7912

As per CIPO Client Service Standards, a response to a telephone enquiry or voice mail should be provided by the end of the next business day. In the event that attempts to reach the examiner are unsuccessful, the examiner's Section Head, Philip Vesely, can be reached at 819-639-7924.

For general inquiries: 1-866-997-1936 or for more options see
<http://www.ic.gc.ca/eic/site/cipointernet-internetopic.nsf/eng/wr00006.html>.

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2985258B_MEM.docm

The Examination Search Report is provided for reference only and is not part of any requisition made by the examiner in accordance with the *Patent Act* or *Rules*. The applicant is not required to respond to the information contained in the Examination Search Report.

Examination Search Report

Box I: General Information			
Application No.	2,985,258	Search Report Date	2022-08-27
Title	DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND RELATED METHODS OF _USE AND ASSEMBLY		
Examiner	Mallory MacLean	Search Conducted?	No
No search was conducted for the following reasons :			
- Search deferred - see report for reasoning (lack of unity, excluded subject matter etc.)			N/A
- Relied on previous search results (CIPO and/or by Foreign Office)			Yes

Box II: Family Prosecution		
Family Member	File Wrapper Reviewed	Status of Prosecution
US10676992B2	2022-08-26	Completed
CA2961629A1	2022-08-26	Not Started

Box IV: Search History
No Search Conducted

Version 9



Reçu du paiement électronique / Electronic Payment Receipt

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ROBERT A. NISSEN
c/o Nissen Patent Law
EDMONTON, Alberta
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Canada

Numéro de confirmation Confirmation Number	Date et heure de réception Receipt Date and Time	Montant payé Amount Paid
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Brevet et/ou Patent and/or	Description	Taxes Fees
2985258	DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY Taxe de maintien en état - Demande - nouvelle loi / Maintenance Fee - Application - New Rules année(s)/year(s): 5 Numéro de référence / Reference Number: 158-2CA2	\$ 100.00

Total des taxes payées / Total Fees Paid: **\$ 100.00**

Information sur le paiement SVP appelez 1-819-994-2269 / For payment inquiries please call 1-819-994-2269

General Correspondence (Patent)

008
CAP
DM

Date: December 30, 2022 4:42:29 PM

Application Number

2,985,258

Title of invention

DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND
RELATED METHODS OF USE AND ASSEMBLY

Applicant(s) or Inventor Name(s)

Applicant or Inventor Name

Sender

Family Name: Nissen
First Name: Robert
Initial:
Name of Corporation or Firm: Nissen Patent Law
Address Line 1: 401-11044 82 Ave NW
Address Line 2:
Address Line 3:
City/Town: Edmonton
Province/State: Alberta
Country: Canada
Postal/Zip Code: T6G 0T2
Telephone Number: 7808027904
Fax Number:
Email Address: robbie@nissenlaw.ca
Communicate by: Electronic Mail (Non secure)

Correspondence Instructions

Our ref: 158-2CA2

Application No.: 2,985,258

Title: DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND
RELATED METHODS OF USE AND ASSEMBLY

Filed: November 14, 2017

Applicant: INFOCUS ENERGY SERVICES INC.

Classification: E21B 4/02 (2006.01)

Examiner: Mallory MacLean

In response to the office action dated August 30, 2022, the Applicant submits the attached response, including cover letter (9 pages), amended claims clean copy (3 pages), amended claims marked up copy (4 pages), replacement description page 11, and a copy of a non-patent literature reference (11 pages) referred to in the response. The Applicant's intention is to keep the application / patent in good standing, and thus please take all steps required to do so and, if any step has not been taken that must be taken, please accept this correspondence as a request for an extension of time to take the step. Please charge any additional fees required to the credit card or to the Agent of Record's deposit account no. 600002856.

/Robert A. Nissen/

Agent of Record

Description of Fee

No fee has been entered.

Total Fee Payment: \$0.00

Payment method

No Charge

Attachments

1. 158-2CA2_response.pdf

Other

Cover letter

Date Reçue/Date Received 2022-12-30

2. 158-2CA2_amended_claims_marked_up.pdf

Other

Claims marked up

3. 158-2CA2_amended_claims.pdf

Claim

4. 158-2CA2_repl_desc_page_11.pdf

Description

5. yang2016.pdf

Other

Yang reference

Transmission Identifier: pgc_nissenpatents_20221230164229737

Date: December 30, 2022 4:42:29 PM

Commissioner of Patents

50 Victoria Street

Place du Portage

Phase I

Gatineau, Quebec

Canada

K1A 0C9

Application Number: 2,985,258

Title of invention: DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY
SECTIONS, AND RELATED METHODS OF USE AND ASSEMBLY

Applicant(s) or Inventor(s) Name(s): INFOCUS ENERGY SERVICES INC.
INFOCUS ENERGY SERVICES INC.

Reference Number: 158-2CA2

Instructions: Our ref: 158-2CA2

Application No.: 2,985,258

Title: DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND
RELATED METHODS OF USE AND ASSEMBLY

Filed: November 14, 2017

Applicant: INFOCUS ENERGY SERVICES INC.

Classification: E21B 4/02 (2006.01)

Examiner: Mallory MacLean

In response to the office action dated August 30, 2022, the Applicant submits the attached response, including cover letter (9 pages), amended claims clean copy (3 pages), amended claims marked up copy (4 pages), replacement description page 11, and a copy of a non-patent literature reference (11 pages) referred to in the response. The Applicant's intention is to keep the application / patent in good standing, and thus please take all steps required to do so and, if any step has not been taken that must be taken, please accept this correspondence as a request for an extension of time to take the step. Please charge any additional fees required to the credit card or to the Agent of Record's deposit account no. 600002856.

/Robert A. Nissen/
Agent of Record

Attached are the following documents:

1. 158-2CA2_response.pdf

Cover letter

Other

2. 158-2CA2_amended_claims_marked_up.pdf

Claims marked up

Other

3. 158-2CA2_amended_claims.pdf

Claim

4. 158-2CA2_repl_desc_page_11.pdf

Description

5. yang2016.pdf

Yang reference

Other

Nissen, Robert
Nissen Patent Law
401-11044 82 Ave NW
Edmonton
Alberta
Canada
T6G 0T2
Tel: 7808027904
Email:robbie@nissenlaw.ca

Transmission Identifier: pgc_nissenpatents_20221230164229737

Claims 7-9 and 18-20 do not comply with section 28.3 of the *Patent Act*. These claims are directed to subject-matter that would have been obvious at the claim date to a person skilled in the art or science to which it pertains having regard to D1 in view of the common general knowledge.

The Applicant respectfully traverses this rejection. As above, Applicant's Claim 1 is novel and patentable over D1. The common general knowledge as articulated by the examiner (without admitting it to be common general knowledge) adds nothing to make up the deficiencies in D1. Thus, Applicant's Claim 1, and all claims dependent on Claim 1, is patentable having regard to D1 in view of the common general knowledge.

The examiner indicated that:

Claim 21 does not comply with section 28.3 of the *Patent Act*. This claim is directed to subject-matter that would have been obvious at the claim date to a person skilled in the art or science to which it pertains having regard to D1 in view of D3.

The Applicant respectfully traverses this rejection. As above, Applicant's Claim 1 is novel and patentable over D1. D3 adds nothing to make up the deficiencies in D1. D3 also fails to teach or suggest at least "rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid and do not flex when in use at downhole temperatures", "the stator contacting surfaces and the rotor contacting surfaces are made of metal", "the stator is formed by electrochemical machining (ECM) to structure the rotor contacting surfaces of the stator to achieve a sufficiently narrow clearance or negative interference fit with the rotor to form an efficient pumping seal without seizing the progressive cavity section in use", and "the rotor contacting surfaces of the stator have been heat treated for increased surface hardness". D3 echoes the requirement of a resilient liner, indicating that "[b]ecause of the requirement for an interference fit between the rotor and stator, one or both of these components must be covered with a resilient, or dimensionally forgiving, material..." (1:37-43). D3 further teaches away from a smooth metal to metal contact between rotor and stator by requiring a roughened

interior surface of his stator (claim 1 - the rough surface permits a resilient liner to be applied).

Thus, Applicant's Claim 1, and all claims dependent on Claim 1, is patentable having regard to D1 in view of D3.

The examiner indicated that:

Claims 5, 6, 16, and 17 are dependent claims that refer to more than one claim not in the alternative and do not comply with subsection 63(3) of the *Patent Rules*. A preamble such as "according to any one of claims", would make it clear that the above claims depend upon each claim in the alternative only.

The claims have been amended so that all multiple dependencies use the preamble suggested by the examiner. The amended claims comply with subsection 63(3).

The examiner indicated that:

Claims 8, 9, 19, and 20 are indefinite and do not comply with subsection 27(4) of the *Patent Act*. The elements "a length" (claims 8, 9, 19, 20, lines 1, 1, 1, 1) and "axial ends" (claims 8, 9, 19, 20, lines 2, 2, 2, 2), are defined with indefinite articles, causing a lack of clarity as to whether they are intended to refer to the same elements previously defined in the claims or an additional element thereto.

New Claims 4-6 and 14-16 are amended to articulate the length and axial end features with definite articles as suggested by the examiner. The claims are definite.

The examiner indicated that:

Claim 11 is indefinite and does not comply with subsection 27(4) of the *Patent Act*. The term "the downhole tool" (claim 11, line 2) has no antecedent.

New Claim 10 clearly refers to the downhole tool as defined with an antecedent in Claim 1, and is definite.

The examiner indicated that:

Claim 21 is indefinite and does not comply with subsection 27(4) of the *Patent Act*. For clarity, method steps should begin with the active verb.

Application No.: 2,985,258

The Applicant respectfully traverses this rejection. New Claim 17 (previous Claim 21) is written to clarify the previously defined step of forming, and is definite.

The examiner indicated that:

The description contains a statement that incorporates by reference another document and does not comply with subsection 57(1) of the *Patent Rules*. Such a statement is found at paragraph [0035] and should be removed.

The statement in the description has been removed as requested by the examiner. The description complies with subsection 57(1).

The applicant has addressed the examiner's requisition. It is noted that no s. 85 requisition has been issued. Accordingly, the applicant has not supplied any information concerning corresponding patents. If the examiner wishes disclosure of any s. 85 information, or a discussion of the relevance of any other references, the examiner is requested to make a s. 85 requisition. Nothing herein should be construed as an allegation that no relevant art exists other than what was cited by the examiner.

The examiner is requested to carefully review the prosecution of and prior art cited against the corresponding U.S. patent no. 10,676,992, and make a note to the Applicant's file of which cases were considered. In addition to the prior art listed against that patent, the Applicant requests the examiner to consider the following additional references alleged by a third party to be relevant to patentability: U.S. patent no. 9,976,227, Canadian patent no. 2,729,542, Chinese patent document no. 102528186A, Chinese patent document no. CN102501016A, and the attached Yang et al article from International Journal of Advanced Manufacturing Technologies. Copies of the listed patent documents can be obtained (and machine-translated if necessary) from Google patents or espacenet.com.

The applicant submits that the examiner's requisitions have been satisfied. Allowance of the application is respectfully requested.

Application No.: 2,985,258

December 30, 2022

Respectfully submitted

/Robert A. Nissen/

Robert A. Nissen

Agent of Record

10328-81 Avenue, Suite 200

Edmonton, Alberta T6E 1X2

Ph. 780-802-7904

Fax 888-744-4480

Application No.: 2,985,258

To:
Commissioner of Patents
Canadian Intellectual Property Office

AMENDMENT/REMARKS FOLLOWING EXAMINER'S REPORT

Our ref: 158-2CA2

Application No.: 2,985,258

**Title: DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND
RELATED METHODS OF USE AND ASSEMBLY**

Filed: November 14, 2017

Applicant: INFOCUS ENERGY SERVICES INC.

Classification: E21B 4/02 (2006.01)

Examiner: Mallory MacLean

This is in response to the official action dated 30 August 2022.

IN THE CLAIMS

Please cancel claims pages of record, and replace them with claims 1-19 on the attached replacement claims pages 46-48.

IN THE DESCRIPTION

Please replace description page 11 with the attached replacement description page 11.

REMARKS

Claim Amendment

The Applicant has amended the claims to match the claims of the corresponding U.S. patent no. 10,676,992, except that multiple dependencies are retained, and specific minor language amendments are made to some of the dependent claims as below to address specific objections. A marked up copy is included with this response for the convenience of the examiner.

More specifically, the following claim amendments are made.

Application No.: 2,985,258

Claim 1 is amended as follows:

- to incorporate features from previous Claims 2-3, which are cancelled, and Claim 10, which is renumbered to new Claim 7 and amended accordingly;
- to clarify what is meant by the term rigid and to describe the structure of the rotor contacting surfaces in terms of clearance and negative interference fit, as supported by the application as filed, for example para. 101; and
- to clarify that the rotor contacting surfaces of the stator are heat treated for increased surface hardness as supported by the application as filed, for example para. 165.

The amendments to Claim 1 necessitated the cancellation of claim 4 and renumbering of the remaining downhole tool claims.

Analogous amendments were made to Claim 12, renumbered as new Claim 11, necessitating the cancellation of previous Claims 13-15 and the amendment of claim 21 (new Claim 17).

New Claims 4-6 (previous Claims 7-9, respectively) and 14-16 (previous Claims 18-20, respectively) are amended to articulate the length and axial end features with definite articles as suggested by the examiner

New Claims 7 and 8 are inserted after New Claim 6 (previous Claim 9) to clarify that the stator contacting surfaces of the rotor are also heat treated to increase surface hardness as supported by the application as filed, for example para. 165.

New Claims 18 and 19 are added to clarify that the rotor contacting surfaces of the stator and the stator contacting surfaces of the rotor have been heat treated with nitriding to increase surface hardness, as supported by the application as filed, for example para. 165.

Description amendment

Application No.: 2,985,258

Paragraph 35 is amended to remove reference to incorporating the claims into the description.

The examiner indicated that:

Claims 1-4, 6, 10, 11-15, 17, and 22 encompass subject-matter that was disclosed in D1 before the claim date and do not comply with paragraph 28.2(1)(b) of the *Patent Act*.

The Applicant respectfully traverses this rejection.

Applicant's Claim 1 recites:

A downhole tool comprising:
a progressive cavity section with a stator and a rotor;
in which the stator is formed from a single integral block of material,
and the stator has a length of at least fifty inches defined between axial ends
of the stator;
in which rotor contacting surfaces of the stator, and stator contacting
surfaces of the rotor, are rigid and do not flex when in use at downhole
temperatures;
in which the stator contacting surfaces and the rotor contacting
surfaces are made of metal;
in which the stator is formed by electrochemical machining (ECM)
to structure the rotor contacting surfaces of the stator to achieve a sufficiently
narrow clearance or negative interference fit with the rotor to form an
efficient pumping seal without seizing the progressive cavity section in use;
and
in which the rotor contacting surfaces of the stator are heat treated
for increased surface hardness.

D1 fails to teach or suggest Applicant's Claimed structure.

D1 fails to teach or suggest at least "rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid and do not flex when in use at downhole temperatures", "the stator contacting surfaces and the rotor contacting surfaces are made of metal", "the stator is formed by electrochemical machining (ECM) to structure the rotor contacting surfaces of the stator to achieve a sufficiently narrow clearance or negative interference fit with the rotor to form an efficient pumping seal without seizing the progressive cavity section in use", and "the rotor contacting surfaces of the stator have been heat treated for increased surface hardness".

It is clear from D1 that in all instances he intends the user to create a finished positive displacement motor that incorporates an elastomeric liner between the rotor and stator. For example, he indicates:

- that “[c]onventional stators commonly include a helical cavity component bonded to an inner surface of a steel tube. The helical cavity component in such conventional stators typically includes an elastomer (e.g., rubber) and provides a resilient surface with which to facilitate the interference fit with the rotor.” (para. 4);
- that in some cases “...the helical cavity component is made substantially entirely of a single elastomer layer.” (para. 4);
- that prior art stators including a rigid internal helical profile have been developed to have “...a thin elastomer liner is deployed on the inner surface of a rigid, metallic stator former.” (para. 6);
- that his stator includes “... a resilient liner 120 deployed on an inner surface of the tube 110” (para. 24);
- that the “...resilient liner 120 defines major and minor internal liner diameters.” (para. 26); and
- that the resilient liner “resilient (e.g., elastomer) liner may be formed on the internal helical surface... using conventional injection molding techniques.” (para. 30).

Contrary to the Office Action’s suggestion otherwise, D1 describing the resilient liner using the word “may” does not suggest that in some cases the final motor would lack a resilient liner. D1’s entire background information section and the references above indicate that to the writer a resilient liner is explicitly and implicitly required in the finished product. As far as D1 describes a manufacturing process, or a stator on its own, his resilient liner could be said to be optional in the sense that D1 intends to capture a situation of partial stator manufacturing or assembly prior to application of the resilient liner. However, the user in all cases would understand that the finished motor with rotor and stator assembled would require a resilient liner.

Applicant's claimed downhole tool is advantageous over D1's tools. By providing a heat-treated, metal to metal seal between rotor and stator, using a stator formed by ECM and structured to achieve a sufficiently narrow clearance or negative interference fit with the rotor to form an efficient pumping seal without seizing the progressive cavity section in use, Applicant has produced an effective progressive cavity section in a downhole tool. Rubberless / metal on metal embodiments of the progressive cavity sections may be used in high temperature downhole applications, where a resilient liner would otherwise degrade (para. 139). ECM is also leveraged to create relatively long and structurally sound stators from single integral blocks of material, with smooth finishes suitable for forming the requisite seal required by the progressive cavity section. D1 fails to teach or suggest the claimed structure of the Applicant's downhole tool nor the associated advantages.

Thus, Applicant's Claim 1, and all claims dependent on Claim 1, are novel and patentable over D1.

For similar reasons, Applicant's Claims 10 and 11, and all claims dependent on such claims, are novel and patentable over D1.

The examiner indicated that:

Claims 5 and 16 do not comply with section 28.3 of the *Patent Act*. These claims are directed to subject-matter that would have been obvious at the claim date to a person skilled in the art or science to which it pertains having regard to D1 in view of D2.

The Applicant respectfully traverses this rejection. As above, Applicant's Claim 1 is novel and patentable over D1. D2 adds nothing to make up the deficiencies in D1. Thus, Applicant's Claim 1, and all claims dependent on Claim 1, is patentable having regard to D1 in view of D2.

The examiner indicated that:

1. A downhole tool comprising:
 - a progressive cavity section with a stator and a rotor; and
 - in which the stator, rotor, or stator and rotor are is formed by electrochemical machining (ECM).
2. ~~The downhole tool from a single integral block of claim 1 material, and the stator has a length of at least fifty inches defined between axial ends of the stator;~~
 - in which rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid; and do not flex when in use at downhole temperatures;
3. ~~The downhole tool of claim 2 in which the stator contacting surfaces and the rotor contacting surfaces are made of metal;~~
4. ~~The downhole tool of claim 1 in which the stator is formed by electrochemical machining (ECM) to structure the rotor contacting surfaces of the stator are defined by to achieve a sufficiently narrow clearance or negative interference fit with the rotor to form an elastomeric coating within the stator; efficient pumping seal without seizing the progressive cavity section in use; and~~
 - 5 in which the rotor contacting surfaces of the stator have been heat treated for increased surface hardness.
2. The downhole tool of claim 1—4 in which the progressive cavity section is connected to rotate a reamer part of a casing reamer shoe.
63. The downhole tool according to any one of claim 1 - 42 in which the progressive cavity section is connected to rotate a drill bit.

~~74.~~ The downhole tool ~~of~~according to any one of claim 1 - ~~63~~ in which the ~~stator~~ has a length of the stator is at least eighty inches defined between the axial ends of the stator.

~~85.~~ The downhole tool of claim ~~74~~ in which the ~~stator~~ has a length of the stator is at least one hundred and fifty inches defined between the axial ends of the stator.

~~96.~~ The downhole tool of claim ~~85~~ in which the ~~stator~~ has a length of the stator is at least three hundred inches defined between the axial ends of the stator.

~~107.~~ The downhole tool ~~of~~according to any one of claim 1—~~9 in~~ 6 in in which the ~~stator~~rotor is formed by electrochemical machining (ECM).

8. The downhole tool according to any one of claim 1 - 7 in which the stator contacting surfaces of the rotor have been heat treated for increased surface hardness.

9. The downhole tool according to any one of claim 1 - 8 in which the rotor contacting surfaces of the stator and the stator contacting surfaces of the rotor have been heat treated with nitriding for increased surface hardness.

10. A method comprising:
positioning the downhole tool according to any one of claim 1 - 10 in a well; and
pumping fluid to operate the progressive cavity section to rotate the rotor relative to the stator.

11. A method comprising:
positioning the downhole tool of any one of claim 1—10 in a well; and
pumping fluid to operate the progressive cavity section to rotate the rotor relative to the stator.

~~12.~~ A method comprising:

~~— forming a stator, rotor, or stator and rotor by electrochemical machining (ECM); and~~
~~— forming a stator from a single integral block of material, in which the~~
~~stator has a length of at least fifty inches defined between axial ends of the stator;~~
~~assembling a downhole tool by inserting the rotor into the stator;~~

~~13.~~ The method of claim ~~12~~ in which within the downhole tool, in which rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid: and do not flex when in use at downhole temperatures;

~~14.~~ The method of claim ~~13~~ in which the stator contacting surfaces and the rotor contacting surfaces are made of metal;

~~15.~~ The method of claim ~~12~~ in which the stator is formed by electrochemical machining (ECM) to structure the rotor contacting surfaces of the stator to achieve a sufficiently narrow clearance or negative interference fit with the rotor to form an efficient pumping seal without seizing the progressive cavity section in use; and
in which forming comprises heat treating the rotor contacting surfaces of the stator are defined by an elastomeric coating within the stator to increase surface hardness.

~~16~~12. The method of claim ~~12—15~~11 in which the stator and the rotor within the downhole tool form a progressive cavity power section connected to rotate a reamer part of a casing reamer shoe.

~~17~~13. The method according to any one of claim 11 - 12—15 in which the stator and the rotor within the downhole tool form a progressive cavity power section connected to rotate a drill bit.

14.

~~18.~~ The method ~~of~~according to any one of claim ~~12—17~~11 - 13 in which the stator has a length of the stator is at least eighty inches defined between the axial ends of the stator.

~~19~~15. The method of claim ~~18~~14 in which the ~~stator has a length of the stator is~~ at least one hundred and fifty inches defined between ~~the~~ axial ends of the stator.

~~20~~16. The method of claim ~~19~~15 in which the ~~stator has a length of the stator is~~ at least three hundred inches defined between ~~the~~ axial ends of the stator.

~~21~~17. The method ~~of~~according to any one of claim ~~12—20~~11 - 16 in which ~~forming the stator or rotor by ECM further comprises advancing a cutting tool into or over a workpiece along an axis of the workpiece, with a sidewall of the cutting tool having a helically lobed profile, in which advancing is carried out while~~ is formed by electrochemical machining (ECM).

18. an electrical field is established across a gap defined by the sidewall of the cutting tool and a sidewall of the workpiece;

an electrolytic solution flows through the gap; and

the cutting tool rotates about the axis such that the sidewall of the workpiece takes on a shape that is the inverse of the helically lobed profile of the sidewall of the cutting tool.

~~22.~~ The method of~~according to~~ any one of claim ~~12—20~~ in ~~which the~~ 11 - 17 in which the stator contacting surfaces of the rotor have been heat treated to increase surface hardness.

19. The method according to any one of claim 11 - 18 in which the rotor contacting surfaces of the stator is formed by ECM, and the stator contacting surfaces of the rotor have been heat treated with nitriding to increase surface hardness.

1. A downhole tool comprising:
 - a progressive cavity section with a stator and a rotor;
 - in which the stator is formed from a single integral block of material, and the stator has a length of at least fifty inches defined between axial ends of the stator;
 - in which rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid and do not flex when in use at downhole temperatures;
 - in which the stator contacting surfaces and the rotor contacting surfaces are made of metal;
 - in which the stator is formed by electrochemical machining (ECM) to structure the rotor contacting surfaces of the stator to achieve a sufficiently narrow clearance or negative interference fit with the rotor to form an efficient pumping seal without seizing the progressive cavity section in use; and
 - in which the rotor contacting surfaces of the stator have been heat treated for increased surface hardness.
2. The downhole tool of claim 1 in which the progressive cavity section is connected to rotate a reamer part of a casing reamer shoe.
3. The downhole tool according to any one of claim 1 - 2 in which the progressive cavity section is connected to rotate a drill bit.
4. The downhole tool according to any one of claim 1 - 3 in which the length of the stator is at least eighty inches defined between the axial ends of the stator.
5. The downhole tool of claim 4 in which the length of the stator is at least one hundred and fifty inches defined between the axial ends of the stator.
6. The downhole tool of claim 5 in which the length of the stator is at least three hundred inches defined between the axial ends of the stator.

7. The downhole tool according to any one of claim 1 - 6 in which the rotor is formed by electrochemical machining (ECM).
8. The downhole tool according to any one of claim 1 - 7 in which the stator contacting surfaces of the rotor have been heat treated for increased surface hardness.
9. The downhole tool according to any one of claim 1 - 8 in which the rotor contacting surfaces of the stator and the stator contacting surfaces of the rotor have been heat treated with nitriding for increased surface hardness.
10. A method comprising:
positioning the downhole tool according to any one of claim 1 - 10 in a well; and
pumping fluid to operate the progressive cavity section to rotate the rotor relative to the stator.
11. A method comprising:
forming a stator from a single integral block of material, in which the stator has a length of at least fifty inches defined between axial ends of the stator;
assembling a downhole tool by inserting a rotor into the stator;
in which rotor contacting surfaces of the stator, and stator contacting surfaces of the rotor, are rigid and do not flex when in use at downhole temperatures;
in which the stator contacting surfaces and the rotor contacting surfaces are made of metal;
in which the stator is formed by electrochemical machining (ECM) to structure the rotor contacting surfaces of the stator to achieve a sufficiently narrow clearance or negative interference fit with the rotor to form an efficient pumping seal without seizing the progressive cavity section in use; and
in which forming comprises heat treating the rotor contacting surfaces of the stator to increase surface hardness.

12. The method of claim 11 in which the stator and the rotor within the downhole tool form a progressive cavity power section connected to rotate a reamer part of a casing reamer shoe.
13. The method according to any one of claim 11 - 12 in which the stator and the rotor within the downhole tool form a progressive cavity power section connected to rotate a drill bit.
14. The method according to any one of claim 11 - 13 in which the length of the stator is at least eighty inches defined between the axial ends of the stator.
15. The method of claim 14 in which the length of the stator is at least one hundred and fifty inches defined between the axial ends of the stator.
16. The method of claim 15 in which the length of the stator is at least three hundred inches defined between the axial ends of the stator.
17. The method according to any one of claim 11 - 16 in which the rotor is formed by electrochemical machining (ECM).
18. The method according to any one of claim 11 - 17 in which the stator contacting surfaces of the rotor have been heat treated to increase surface hardness.
19. The method according to any one of claim 11 - 18 in which the rotor contacting surfaces of the stator and the stator contacting surfaces of the rotor have been heat treated with nitriding to increase surface hardness.

polycrystalline diamond cutters. The tubular body further comprises a progressive cavity section connected to rotate the nose independent of the rotation of the reamer part by the impeller. A wire brush scraper on an external surface of the downhole reamer tool. The progressive cavity section is connected to rotate a reamer part of a casing reamer shoe. The outer mandrel has a number of spiral lobes equal to the number of spiral lobes of the inner mandrel plus one. One of the inner and outer mandrel is non-rotatably coupled to an end of a casing and the other is non-rotatably coupled to a bit or shoe. An upper flow diverter that diverts fluid flow from a center region of the reaming assembly to the spacing between the inner and outer mandrels. A lower flow diverter that diverts fluid flow from the spacing between the inner and outer mandrels to a center region of the reaming assembly. The inner mandrel is hollow. The hollow of the inner mandrel is sized large enough to freely pass a standard drill bit therethrough. Upper and lower bearing assemblies rotatably coupled between the inner and outer mandrels. A) an elongated tubular housing, including: a1) a first end having a fluid inlet aperture; a2) a second end, opposite the first end, having a fluid outlet aperture; and a3) a coupling structure at the first end of the housing that selectably mates with a bottom end of a casing tube. A casing tube coupled to the housing. One of the inner and outer mandrel is non-rotatably coupled to an end of a casing and the other is non-rotatably coupled to a bit or shoe. An upper flow diverter that diverts fluid flow from a center region of the reaming assembly to the spacing between the inner and outer mandrels. A lower flow diverter that diverts fluid flow from the spacing between the inner and outer mandrels to a center 5 region of the reaming assembly. The hollow of the inner mandrel is sized large enough to freely pass a standard drill bit therethrough. Upper and lower bearing assemblies rotatably coupled between the inner and outer mandrels. A) an elongated tubular housing, including: a1) a first end having a fluid inlet aperture; a2) a second end, opposite the first end, having a fluid outlet aperture; and a3) a coupling structure at the first end of the housing that selectably mates with a bottom end of a casing tube; b) a first bearing pack disposed circumferentially about the first end of the housing; and c) a reaming tool functionally coupled to the motor. A casing tube coupled to the housing.

[0035] These and other aspects of the device and method are set out in the claims.

16 March 2023 (16-03-2023)

NISSEN, ROBERT A.
robbie@nissenlaw.ca

Application No. : **2,985,258**
Owner : MESSABEN CORP.
Title : **DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS,
AND RELATED METHODS OF USE AND ASSEMBLY**
Classification : E21B 4/02 (2006.01)
Your File No. : **158-2CA2**
Examiner : Mallory MacLean

YOU ARE HEREBY NOTIFIED OF A REQUISITION BY THE EXAMINER IN ACCORDANCE WITH SUBSECTION 86(2) OF THE *PATENT RULES*. IN ORDER TO AVOID ABANDONMENT UNDER PARAGRAPH 73(1)(a) OF THE *PATENT ACT*, A WRITTEN REPLY MUST BE RECEIVED WITHIN **FOUR (4)** MONTHS AFTER THE ABOVE DATE.

The applicant's letters of 3 December 2021 (03-12-2021), 17 June 2022 (17-06-2022) and 30 December 2022 (30-12-2022) have been received and the application has been examined having regard to the applicant's arguments. However, the examiner considers that the application still does not comply with the *Patent Act* or *Patent Rules*.

The number of claims in this application is 19.

A search of the prior art has thus far failed to reveal any pertinent references.

The examiner has identified the following defects in the application:

Claim 11 is indefinite and does not comply with subsection 27(4) of the *Patent Act*. The term "the progressive cavity section" (claim 11, line 11) has no antecedent.

Claims 12 and 13 are indefinite and do not comply with subsection 27(4) of the *Patent Act*. It is unclear whether the element "a progressive cavity power section" refers to the element "the progressive cavity section" or an additional element thereto.

Claim 10 does not comply with subsection 63(2) of the *Patent Rules*. A dependent claim must refer to a preceding claim or claims. Specifically, it appears to the examiner that claim 10 mistakenly refers to itself rather than the intended claims 1-9.

In accordance with subsection 84(2) of the *Patent Rules*, this application will no longer qualify for advanced examination requested by the applicant if the application is deemed to be abandoned or if an extension of time under subsection 3(1) of the *Patent Rules* is granted.

In view of the foregoing defects, the applicant is requisitioned, under subsection 86(2) of the

Patent Rules, to amend the application in order to comply with the *Patent Act* and the *Patent Rules* or to provide arguments as to why the application does comply.

Under section 102 of the *Patent Rules*, any amendment made in response to this requisition must be accompanied by a statement explaining the purpose of the amendment and identifying the differences between the new page and the replaced page.

Mallory MacLean
Patent Examiner
819-639-7912

As per CIPO Client Service Standards, a response to a telephone enquiry or voice mail should be provided by the end of the next business day. In the event that attempts to reach the examiner are unsuccessful, the examiner's Section Head, Philip Vesely, can be reached at 819-639-7924.

For general inquiries: 1-866-997-1936 or for more options see
<http://www.ic.gc.ca/eic/site/cipointernet-internetopic.nsf/eng/wr00006.html>.

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The Examination Search Report is provided for reference only and is not part of any requisition made by the examiner in accordance with the *Patent Act* or *Rules*. The applicant is not required to respond to the information contained in the Examination Search Report.

Examination Search Report

Box I: General Information			
Application No.	2,985,258	Search Report Date	2023-02-23
Title	DOWNHOLE TOOLS WITH PROGRESSIVE CAVITY SECTIONS, AND RELATED METHODS OF USE AND ASSEMBLY		
Examiner	Mallory MacLean	Search Conducted?	No
No search was conducted for the following reasons :			
- Search deferred - see report for reasoning (lack of unity, excluded subject matter etc.)			N/A
- Relied on previous search results (CIPO and/or by Foreign Office)			Yes

Box II: Family Prosecution		
Family Member	File Wrapper Reviewed	Status of Prosecution
US10676992B2	2023-02-23	Completed
CA2961629A1	2023-02-23	In Progress

Box III: Search History
No Search Conducted

CIPO Search Record - Version 10