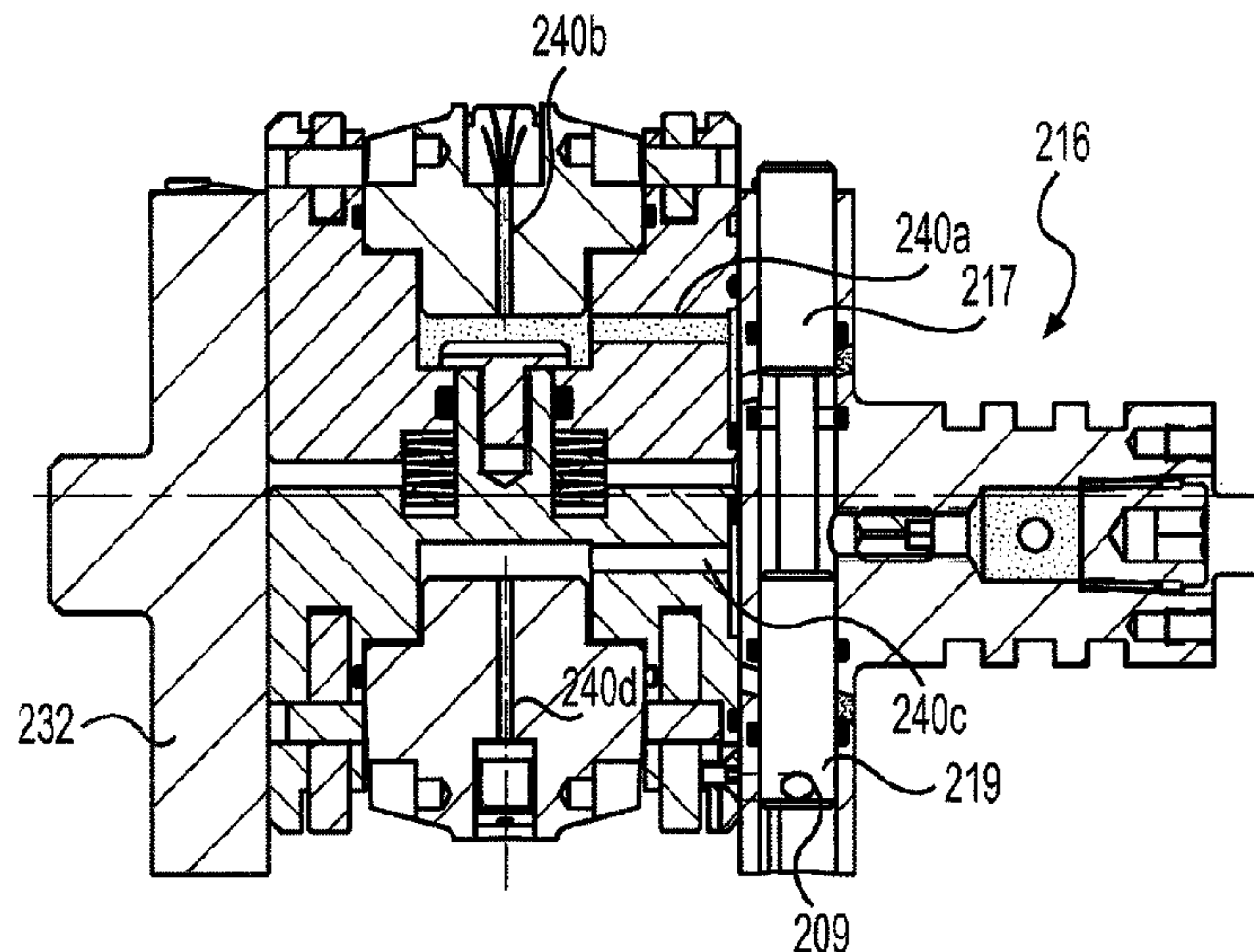




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(54) Titre : OUTIL D'ECHANTILLONNAGE COMPORTANT UN SYSTEME DE PURGE
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(57) **Abrégé/Abstract:**

A sampling tool for obtaining a sample from an interior wall of a tube comprises first and second cutter sub-assemblies operatively connected to a shaft. First and second actuators move the first and second cutter sub-assemblies between a retracted position and an extended position as the shaft moves. A valve selectively fluidly communicating an ejection port located in one of the first and second cutter sub-assemblies with a purge fluid supply. The valve discharges purge fluid through the ejection port onto the interior wall of the tube during cutting of a portion of the wall.

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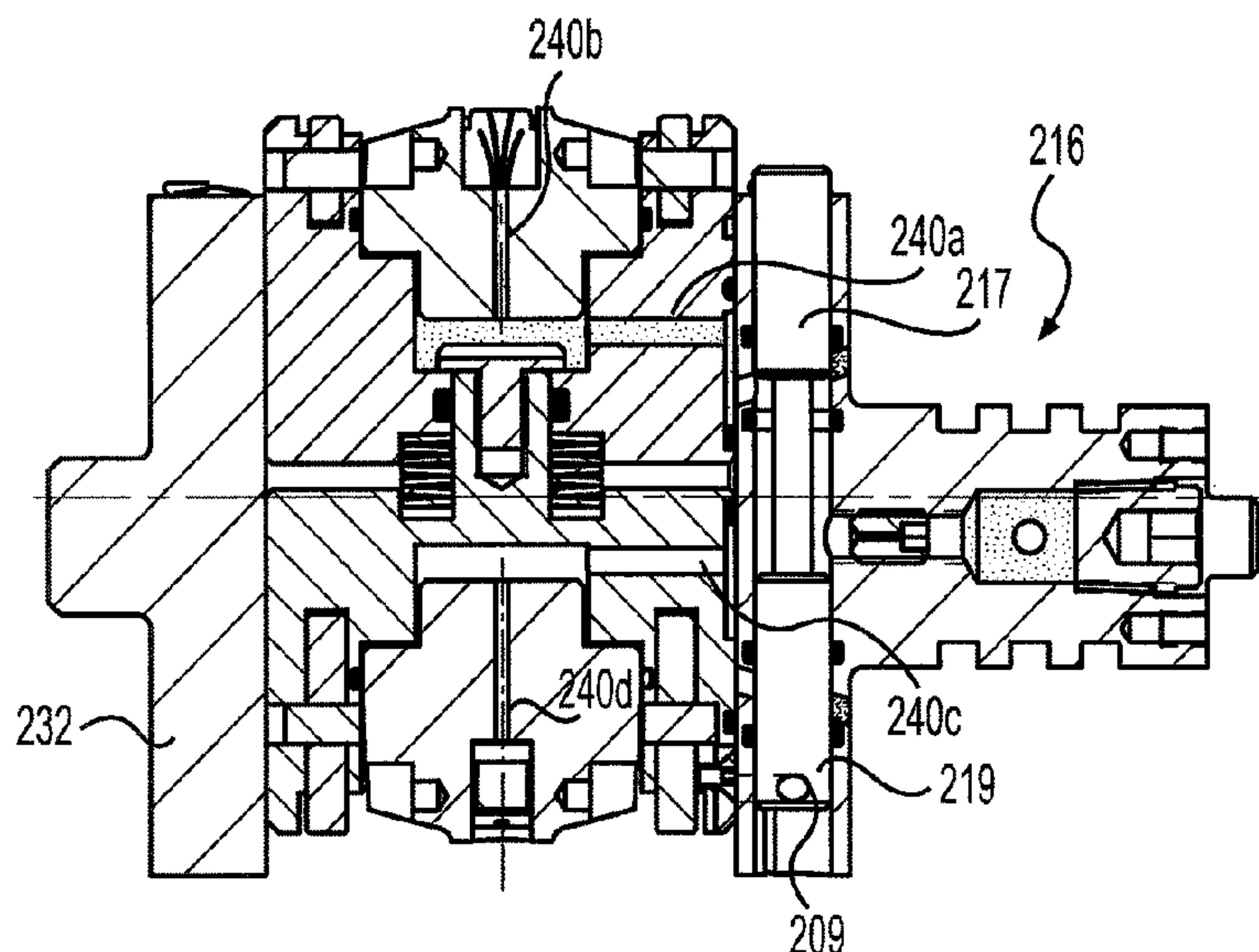
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(54) Title: SAMPLING TOOL HAVING A PURGE SYSTEM

**FIG. 9**

(57) Abstract: A sampling tool for obtaining a sample from an interior wall of a tube comprises first and second cutter sub-assemblies operatively connected to a shaft. First and second actuators move the first and second cutter sub-assemblies between a retracted position and an extended position as the shaft moves. A valve selectively fluidly communicating an ejection port located in one of the first and second cutter sub-assemblies with a purge fluid supply. The valve discharges purge fluid through the ejection port onto the interior wall of the tube during cutting of a portion of the wall.

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SAMPLING TOOL HAVING A PURGE SYSTEM

FIELD OF THE INVENTION

[0001] The present invention relates to a sampling tool having a purge system.

BACKGROUND OF THE INVENTION

5 [0002] One method of assessing the useful life of pressure tubes in nuclear reactors, such as a CANDU reactor, requires the periodic removal of a tube. Samples are cut from the removed tube and analyzed for deuterium content. The deuterium concentration is then used as a measure of the useful life of the remaining pressure tubes. This approach is very costly because of the long shutdown period required to remove and
10 replace a pressure tube.

[0003] Attempting to provide *in situ* sampling (without pressure tube removal) presents numerous difficulties. Obtaining a useful sample is made difficult by the hard oxidized surface, and the need to obtain sample material from beneath the surface layer. To preserve the structural integrity of the tube and avoid detrimental residual stress, the
15 sampling depth must be controlled and the sampled region must be left with smooth changes in geometry in all axes. Furthermore, the technique used for removing the surface material or sample must not involve excessive heating, as this affects the results of the subsequent analysis. Another difficulty is the recovery of the sample for analysis and preventing particles from being left in the pressure tube.

20 [0004] United States Patent No. 4,925,621, issued May 15, 1990, discloses an axial sampling tool useful for pressure tube sampling which addresses the above difficulties. The disclosed sampling tool permits *in situ* testing in that pressure tube removal is unnecessary. The sampling tool comprises two cutters and means for capturing the removed material. By moving both cutters axially in the pressure tube, one cutter removes
25 the surface oxide layer, and the second cutter removes a sample for analysis. The cutters and cutting operation are designed to avoid damaging the integrity of the pressure tube to allow it to remain in service.

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[0005] Although the axial sampling tool addresses the above difficulties, it requires the pressure tube to be isolated and drained before cutting the interior wall of the tube in order to avoid the sample being contaminated by heavy water.

[0006] The conference paper presented at the 5th International CANDU Maintenance Conference in November 2000 which is entitled "Advanced Pressure Tube Sampling Tools" and is authored by K. Wittich and J. King also discloses sampling tools. The conference paper presented at the 7th International CANDU Maintenance Conference in November 2005 which is entitled "Innovation in Pressure Tube Rolled Joint Sampling (Circumferential Sampling Tool Technology)" and is authored by B. Guler, J. King, and R. Wray also discloses sampling tools. Both papers are published by the Canadian Nuclear Society.

[0007] Therefore, there is a need for a sampling tool that address at least some of the above-identified difficulties and at least some of the inconveniences present in the prior art.

15 SUMMARY OF THE INVENTION

[0008] It is an object of the present invention to provide a sampling tool that allows *in situ* testing without requiring prior isolation and draining of the pressure tube. The sampling tool has at least two cutters that move along a portion of an interior wall of a tube. One cutter removes a portion of the interior wall of the tube, and the second cutter removes a sample from the interior wall of the tube from a location in the tube revealed by removing the portion of the interior wall of the tube. The sampling tool comprises purge fluid ejection ports for discharging purge fluid during cutting of at least one of the portion of the interior wall and the sample. Purge fluid discharge removes at least partially the heavy water at the cutting location.

25 [0009] In one aspect, the invention provides a sampling tool for obtaining a sample from an interior wall of a tube. The sampling tool comprises a cylindrical body having a central axis, and an aperture in the cylindrical body. A shaft is disposed in the cylindrical body along the central axis. The shaft is movable. A first cutter sub-assembly is operatively connected to the shaft. The first cutter sub-assembly has a first cutter. The first cutter sub-assembly is movable between a retracted position where the first cutter is disposed inside the cylindrical body at a first distance from the

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central axis and an extended position where the first cutter extends at least in part through the aperture at a second distance from the central axis. The second distance is greater than the first distance. The first cutter sub-assembly moves to the extended position when the shaft moves to a first position thereby causing the first cutter to cut a portion of the interior wall of the tube. A second cutter sub-assembly is operatively connected to the shaft. The second cutter sub-assembly has a second cutter. The second cutter sub-assembly is movable between a retracted position where the second cutter is disposed inside the cylindrical body at a third distance from the central axis and an extended position where the second cutter extends at least in part through the aperture at a fourth distance from the central axis. The fourth distance is greater than the third distance. The second cutter sub-assembly moves to the extended position when the shaft moves to a second position thereby causing the second cutter to cut the sample from the interior wall of the tube from a location revealed by cutting the portion of the interior wall of the tube with the first cutter. A first actuator is operatively connected to the first cutter sub-assembly for moving the first cutter sub-assembly between the retracted position and the extended position as the shaft moves to the first position. A second actuator is operatively connected to the second cutter sub-assembly for moving the second cutter sub-assembly between the retracted position and the extended position as the shaft moves to the second position. At least one of the first cutter sub-assembly and the second cutter sub-assembly has an ejection port. A valve is selectively fluidly communicating the ejection port with a purge fluid supply. The valve is fastened to one of the first cutter sub-assembly and the second cutter sub-assembly such that the valve moves with the at least one of the first cutter sub-assembly and the second cutter sub-assembly having the ejection port. The valve fluidly communicates the ejection port with the purge fluid supply when the at least one of the first cutter sub-assembly and the second cutter sub-assembly having the ejection port is in the extended position thereby discharging purge fluid through the ejection port onto the interior wall of the tube during cutting by a corresponding one of the first cutter and the second cutter. The purge fluid is discharged in an area of the corresponding one of the first cutter and the second cutter.

[0010] In a further aspect, the ejection port is a first ejection port and the first cutter sub-assembly has the first ejection port. The second cutter sub-assembly has a second ejection port.

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[0011] In an additional aspect, the valve selectively fluidly communicates the first ejection port and the second ejection port with the purge fluid supply. The valve fluidly communicates the first ejection port with the purge fluid supply when the shaft moves to the first position and the valve fluidly communicates the second ejection port with the purge fluid supply when the shaft moves to the second position.

[0012] In a further aspect, the valve is a first valve fastened to the first cutter sub-assembly. The first valve selectively fluidly communicates the first ejection port with the purge fluid supply. A second valve is fastened to the second cutter sub-assembly. The second valve selectively fluidly communicates the second ejection port with the purge fluid supply. The first valve fluidly communicates the first ejection port with the purge fluid supply when the shaft moves to the first position and the second valve fluidly communicates the second ejection port with the purge fluid supply when the shaft moves to the second position.

[0013] In an additional aspect, the valve is located axially between the first cutter sub-assembly and the second cutter sub-assembly.

[0014] In a further aspect, when the first valve fluidly communicates the first ejection port with the purge fluid supply, the second valve prevents fluid communication between the second ejection port and the purge fluid supply, and when the second valve fluidly communicates the second ejection port with the purge fluid supply the first valve prevents fluid communication between the first ejection port and the purge fluid supply.

[0015] In an additional aspect, the shaft is rotatable, and the first position and the second position of the shaft are angular positions.

[0016] In a further aspect, the valve is a spool valve.

[0017] In an additional aspect, the first cutter sub-assembly is located opposite to the second cutter sub-assembly.

[0018] In a further aspect, the shaft is axially movable, and the first position and the second position of the shaft are longitudinal positions of the shaft with respect to the cylindrical body.

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[0019] In an additional aspect, the valve is a poppet valve.

[0020] In a further aspect, the first cutter sub-assembly is located forwardly of the second cutter sub-assembly relative to a cutting direction of the first cutter and the second cutter.

5 [0021] In an additional aspect, the ejection port is a first ejection port and the at least one of the first cutter sub-assembly and the second cutter sub-assembly having the first ejection port also has a second ejection port.

[0022] In a further aspect, the first ejection port is located forwardly of the corresponding one of the first cutter and the second cutter relative to a cutting
10 direction of the first cutter and the second cutter. The second ejection port extends through the corresponding one of the first cutter and the second cutter.

[0023] In an additional aspect, the ejection port extends through the corresponding one of the first cutter and the second cutter.

[0024] In a further aspect, the ejection port is located forwardly of the
15 corresponding one of the first cutter and the second cutter relative to a cutting direction thereof.

[0025] In an additional aspect, the valve is fastened to the one of the first cutter sub-assembly and the second cutter sub-assembly by a pin.

[0026] In a further aspect, the purge fluid is light water.

20 [0027] In an additional aspect, the purge fluid supply is a reservoir disposed externally of the cylindrical body and fluidly communicating with the ejection port with a hose.

[0028] For the purposes of this application the term 'heavy water' is used for designating water in which the hydrogen is replaced by its heavier isotope,
25 deuterium, ^2H . By contrast, the term 'light water' is used for designating water containing the protium isotope, in contexts when such distinction is needed.

[0029] Embodiments of the present invention each have at least one of the above-mentioned objects and/or aspects, but do not necessarily have all of them. It

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should be understood that some aspects of the present invention that have resulted from attempting to attain the above-mentioned objects may not satisfy these objects and/or may satisfy other objects not specifically recited herein.

5 [0030] Additional and/or alternative features, aspects, and advantages of embodiments of the present invention will become apparent from the following description, the accompanying drawings, and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

10 [0031] For a better understanding of the present invention, as well as other aspects and further features thereof, reference is made to the following description which is to be used in conjunction with the accompanying drawings, where:

[0032] Figure 1 is a longitudinal cross-sectional view of an axial sampling tool;

[0033] Figure 2 is a close-up view of a cutter assembly of the axial sampling tool of Fig. 1;

15 [0034] Figure 3 is a partially cut away top plan view of a portion of the axial sampling tool of Fig. 1;

[0035] Figure 4 is a perspective view of a ramp disposed in the axial sampling tool of Fig. 1;

[0036] Figure 5 is a side elevation view of a circumferential sampling tool;

20 [0037] Figure 6 is a cross-sectional view of the circumferential sampling tool of Fig. 5 taken through line A-A of Fig. 5;

[0038] Figure 7 is a close-up view of a portion of the cross-sectional view of the circumferential sampling tool of Fig. 6;

25 [0039] Figure 8 is a cross-sectional view of the circumferential sampling tool of Fig. 5, a majority of which is taken through line D-D of Fig. 5, and portions of which are taken through line E-E and F-F of Fig. 5;

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[0040] Figure 9 is a cross-sectional view of a cutter assembly of the circumferential sampling tool of Fig. 7 showing purge fluid (in grey) flowing in the cutter assembly;

5 [0041] Figure 10 is a cross-sectional view of a cutter assembly of the circumferential sampling tool of Fig. 7 showing purge fluid (in grey) prevented from flowing to ejection ports in the cutter assembly;

[0042] Figure 11 is a cross-sectional view of an alternative embodiment of a cutter assembly for a circumferential sampling tool; and

10 [0043] Figure 12 is a cross-sectional view of a portion of a pressure tube where a sample has been obtained.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0044] The sampling tool of the present invention will be described as being used for obtaining samples from pressure tubes of nuclear reactors to be analyzed for deuterium content. However it should be understood that the sampling tool could be
15 used to collect other types of samples from other types of tubes or arcuate surfaces.

[0045] With reference to Figs. 1 to 4, an embodiment of a sampling tool, axial sampling tool 100, will be described.

[0046] The axial sampling tool 100 has a cylindrical body 122 having a central (longitudinal) axis 124. An aperture 128 is defined in the cylindrical body
20 122. A cutter assembly 130 disposed in the cylindrical body 122 is aligned radially with the aperture 128. The axial sampling tool 100 is connected to a positioning system (not shown) which permits accurate axial (i.e. longitudinal) positioning of the axial sampling tool 100 in the pressure tube.

[0047] The axial sampling tool 100 comprises a carriage 132 which supports
25 the cutter assembly 130. The carriage 132 is connected to a shaft 136 which is movable along the central axis 124. The carriage 132 is mounted on rollers, which are described in greater detail below. The rollers enable axial displacement of the carriage 132. The carriage 132 is displaced by using a fuelling machine for displacing the shaft 136.

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[0048] The cutter assembly 130 comprises an oxide cutter sub-assembly 102 and a sample cutter sub-assembly 103 disposed longitudinally next to each other. The oxide cutter sub-assembly 102 and the sample cutter sub-assembly 103 are spaced apart, but it is contemplated that they could be adjacent to each other. The oxide cutter sub-assembly 102 comprises an oxide cutter 104 to cut a portion of the interior wall of the tube, an oxide cartridge holder 164 and an oxide receptacle 160 for collecting an oxide portion of the interior wall of the tube that has been cut. The sample cutter sub-assembly 103 comprises a sample cutter 105 to cut a sample from the interior wall of the tube, a sample cartridge holder 176 and a sample receptacle 172 for collecting a sample. The oxide cutter 104 and the sampling cutter 105 are curved, and have a radius of curvature sufficiently similar to that of the pressure tube so as to avoid sharp edges and stress concentration in the pressure tube after cutting the sample. A chip clip 108 in proximity with the oxide cutter 104 defines the oxide receptacle 160, and a chip clip 108 in proximity with the sample cutter 105 defines the sample receptacle 172. The oxide cutter 104 is connected by a threaded fastener to an oxide cutter cartridge 156. The oxide cutter cartridge 156 is connected by a bayonet-type mount to the oxide cartridge holder 164. Similarly, the sample cutter 105 is connected by a threaded fastener to a sample cutter cartridge 168, and the sample cutter cartridge 168 is connected by a bayonet-type mount to the sample cartridge holder 176.

[0049] Two stacks of Belleville springs 178 are disposed under the oxide cartridge holder 164 and under the sample cartridge holder 176, respectively, thus biasing the oxide cutter 104 and the sample cutter 105 away from the axial axis 124. It is contemplated that other types of springs could be used instead of the Belleville springs 178.

[0050] The oxide cutter 104 and the sample cutter 105 are each movable between a retracted position close to the central axis 124 where they are disposed inside the cylindrical body 122 and an extended position away from the central axis 124 where they extend in part through the aperture 128 for cutting the oxide portion and the sample from the interior wall of the tube. Retraction or extension of the oxide cutter 104 and the sample cutter 105 are linked to a position of the shaft 136. Different positions of the shaft 136 along the central axis 124 trigger actuators for actuating the extension and the retraction of the oxide cutter 104 and the sample cutter

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105. The actuator for the oxide cutter 104 consists of two rollers 182 connected to the oxide cutter sub-assembly 102. The actuator for the sample cutter 105 consists of a roller 188 connected to the sample cutter sub-assembly 103. It is contemplated that a single roller 182 could be connected to the oxide cutter sub-assembly 102, or that two
5 rollers 188 could be connected to the sample cutter sub-assembly 103. It is also contemplated that the oxide cutter sub-assembly 102 and the sample cutter sub-assembly 103 could be actuated by types of actuators other than rollers.

[0051] A ramp 190, shown in Fig. 4, is disposed inside the cylindrical body 122 opposite the aperture 128. The ramp 190 is adapted to receive the rollers 182 and
10 188. The ramp 190 has ramp-up portions 190a and 190b, a flat portion 190c and ramp-down portions 190d and 190e. Each of the ramp-up portions 190a and 190b and of the ramp-down portions 190d and 190e are adapted to receive one of the two rollers 182 and the roller 188. As the shaft 136 is pushed by the fuelling machine toward the ramp 190 in a cutting direction 192 shown in Fig. 2, the shaft 136 reaches
15 a first position. The rollers 182 roll over the ramp-up portion 190a, thereby extending the oxide cutter 104 through the aperture 128. The oxide cutter 104 reaches the interior wall of the tube thereby cutting the oxide portion from the interior wall of the tube. The oxide cutter 104 remains extended to cut the oxide portion while the rollers 182 roll over the flat portion 190c. The rollers 182 then roll on the ramp-down portion
20 190d thereby moving the oxide cutter 104 back to its retracted position. As the shaft 136 continues to be moved in the cutting direction 192 toward a second position, the roller 188 rolls over the ramp-up portion 190b thereby extending the sample cutter 105 through the aperture 128 and cutting the sample for the location where the oxide layer has been removed. The sample cutter 105 remains extended to cut the sample
25 while the roller 188 is rolled on the flat portion 190c. As the roller 188 rolls on the ramp-down portion 190e, the sample cutter 105 is moved back to its retracted position. The overall height of the sample cutter sub-assembly 103 being higher than overall height of the oxide cutter sub-assembly 102, the sample is cut deeper than the oxide portion of the interior wall of the tube. This is achieved by providing shims (not
30 shown) between the sample cutter 105 and the sample cutter cartridge 168. The ramp portions 190b and 190e being shorter than the ramp portions 190a and 190d, the sample is also shorter than the oxide portion. As can be seen in Fig. 12, a depth D_s of the cut made by the sample cutter 105 is as a consequence greater than a depth D_o of

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the cut made by the oxide cutter 104. The sample cutter 105 is also narrower than the oxide cutter 104, and therefore a width W_s of the cut made by the sample cutter 105 is smaller than a width W_o of the cut made by the oxide cutter 104. It is contemplated that the ramp 190 could have an alternative shape for creating a different cutting
5 pattern.

[0052] Turning more specifically to Fig. 2, a purge fluid passage network 140 for discharging purge fluid at a cutting location during cutting of the oxide portion by the oxide cutter 104 and the sample by the sample cutter 105 will now be described. The purge fluid passage network 140 extends through the cutter assembly 130 and is
10 fed purge fluid by a purge fluid supply 107 (shown in Fig. 1). The purge fluid is preferably light water. The purge fluid supply 107 is in the form of a reservoir that is located inside the cylindrical body 122. It is contemplated that other types of purge fluid supply 107 could be used. For example, hydraulic pressure could be provided from an external reservoir that feeds a hydraulic hose into the axial sampling tool 100
15 (shown in dotted lines in Fig. 1). The purge fluid supply 107 is connected to the purge fluid passage network 140 by a hose 108. A displacement piston 123 is actuated by a shaft 125. By being displaced by the shaft 136, the shaft 125 moves the displacement piston 123 toward a center of the purge fluid supply 107 which in turns pressurizes the fluid in the purge fluid supply 107. Two spool valves 116a and 116b, described in
20 greater details below, control flow between the hose 108 and the purge fluid passage network 140.

[0053] The purge fluid passage network 140 comprises a passage in the oxide cutter sub-assembly 102 and a passage in the sample cutter sub-assembly 103. The passage in the oxide cutter sub-assembly 102 is connected to a poppet valve 116a and
25 ends at oxide ejection ports 110a and 110b. The passage in the sample cutter sub-assembly 103 is connected to a poppet valve 116b, and ends at sample ejection ports 112a and 112b.

[0054] The oxide ejection ports 110a and 110b are located forwardly and rearwardly, respectively, of a cutting edge of the oxide cutter 104 relative to the
30 cutting direction 192. The oxide ejection ports 110a and 110b are used for discharging the purge fluid at the cutting location of the oxide portion. The sample ejection ports 112a and 112b are located forwardly and rearwardly, respectively, of a

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cutting edge of the sample cutter 105 relative to the cutting direction 192. The sample
ejection ports 112a and 112b are used for discharging the purge fluid at the cutting
location of the sample. In an alternative embodiment, the oxide cutter sub-assembly
102 comprises only one oxide ejection port 110a or 110b, and the sample cutter sub-
5 assembly 103 comprises only one sample ejection port 112a or 112b. In another
alternative embodiment, only the oxide cutter sub-assembly 102 or the sample cutter
sub-assembly 103 have ejection ports.

[0055] Discharge of purge fluid at the cutting location allows an operator to
obtain a reliable analysis of the deuterium concentration of the sample without having
10 to drain the pressure tube. The discharge of purge fluid to the purge fluid passage
network 140 is controlled by the two poppet valves 116a and 116b located between
the cutter assembly 130 and the purge fluid supply 107. The poppet valves 116a and
116b are connected to the purge fluid supply 107 by the hose 108. The poppet valve
116a is fastened to the oxide cutter sub-assembly 102 by a pin 109. The poppet valve
15 116b is fastened to the sample cutter sub-assembly 103 by a pin (not shown). The pins
ensure that the poppet valve 116a moves in unison with the oxide cutter sub-assembly
102, and that the poppet valve 116b moves in unison with the sample cutter sub-
assembly 103. When the oxide cutter sub-assembly 102 moves upwardly, the poppet
valve 116a moves upwardly, and when the sample cutter sub-assembly 103 moves
20 upwardly the poppet valve 116b moves upwardly.

[0056] In operation, the axial sampling tool 100 is inserted into the pressure
tube and moved to the desired longitudinal position within the pressure tube by
adjusting a position using the positioning system. The shaft 136 is moved using the
fuelling machine to the first position, thereby moving the oxide cutter sub-assembly
25 102 toward the ramp 190 in the cutting direction 192. The rollers 182 ride up the ramp
portion 190a, which in turns moves the oxide cutter 104 into engagement with the
pressure tube. Simultaneously, the poppet valve 116a moves away from the central
axis 124 and purge fluid is delivered to the purge fluid passage network 140 inside the
oxide cutter sub-assembly 102, and is finally ejected through the oxide ejection ports
30 110a and 110b. The oxide cutter 104 removes the oxide portion as the rollers 182 ride
along the ramp-up portion 190a and the flat portion 190c until the rollers 182 descend
the ramp-down portion 190d, leaving a recess in the pressure tube. As the rollers 182

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descend the ramp-down portion 190d, the poppet valve 116a moves toward the central axis 124, thereby preventing fluid communication between the purge fluid supply 107 and the oxide cutter sub-assembly 102. During cutting, the oxide portion curls as it enters the opening between the oxide cutter 104 and the chip clip 108, and is captured
5 in the oxide receptacle 160.

[0057] The shaft 136 is consequently moved to the second position, thereby moving the sample cutter sub-assembly 103 toward the ramp 190. The sample is cut by the sample cutter 105 from the interior wall of the tube from the location in the tube where the oxide layer was cut by the oxide cutter 104 as the roller 188 rides up
10 ramp portion 190b and the flat portion 190c. Simultaneously, the displacement piston 123 moves to pressurize the purge fluid supply 107, and the poppet valve 116b moves away from the central axis 124 and purge fluid is delivered to the purge fluid passage network 140 inside the sample cutter sub-assembly 103, and is finally ejected through the sample ejection ports 112a and 112b. The sample cutter 105 removes the sample
15 as the roller 188 rides along the ramp-up portion 190b and the flat portion 190c until the roller 188 descends the ramp-down portion 190e, leaving a recess in the pressure tube. As the roller 188 descend the ramp-down portion 190e, the poppet valve 116b moves toward the central axis 124, thereby preventing fluid communication between the purge fluid supply 107 and the sample cutter sub-assembly 103. During cutting,
20 the sample curls as it enters the opening between the oxide cutter 105 and the chip clip 108, and is captured in the sample receptacle 172.

[0058] Turning now to Figs. 5 to 12, another embodiment of the sampling tool, circumferential sampling tool 200, will be described.

[0059] With reference to Fig. 5, the circumferential sampling tool 200 has a
25 cylindrical body 222 having a central (longitudinal) axis 224. The cylindrical body 222 has a plurality of bearing pads 226 externally located for supporting the circumferential sampling tool 200 when the circumferential sampling tool 200 is disposed inside the pressure tube. An aperture 228 is defined in the cylindrical body 222. A cutter assembly 230 is disposed in the cylindrical body 222 and is aligned
30 radially with the aperture 228.

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[0060] The circumferential sampling tool 200 is connected to a positioning system which permits accurate axial and angular positioning of the circumferential sampling tool 200 in the pressure tube. A shielding sleeve (not shown) is disposed over the circumferential sampling tool 200 for closing the aperture 228 when the circumferential sampling tool 200 is not in use. The circumferential sampling tool 200, the positioning system, and the shielding sleeve are disposed on a support cart (not shown), which is preferably wheeled to facilitate the positioning of the cart.

[0061] With reference to Fig. 6, the circumferential sampling tool 200 comprises a carriage 232 which supports the cutter assembly 230. The carriage 232 is connected via a coupler 234 to an output shaft 236. The coupler 234 is connected to the output shaft 236 via splines. An electric motor 238 is used to rotate the output shaft 236 and which in turn rotates the carriage 232 and the cutter assembly 230. The electric motor 238 is preferably a DC motor, however other types of motors are contemplated. It is contemplated that the motor 238 could be coupled to the cutter assembly 230 differently. For example, the output shaft 236 of the motor 238 could be connected to a driveshaft which in turn is connected to the carriage 232.

[0062] Turning now to Figs. 7 and 8, the cutter assembly 230 will be described in greater details. The cutter assembly 230 includes an oxide cutter sub-assembly 202 and a sample cutter sub-assembly 203. The oxide cutter sub-assembly 202 comprises an oxide cutter 204 to cut a portion of the interior wall of the tube, an oxide cartridge holder 264 and an oxide receptacle 260 for collecting the oxide portion of the interior wall of the tube. The oxide cutter 204 is connected by a threaded fastener 254 to an oxide cutter cartridge 256. A chip clip 258 is connected to the oxide cutter cartridge 256. The chip clip 258 retains the portion of the tube being cut by the oxide cutter 204 inside the oxide receptacle 260 formed between the oxide cutter 204, the oxide cutter cartridge 256, and the chip clip 258. The oxide cutter cartridge 256 is connected by a bayonet-type mount 262 to the oxide cartridge holder 264. The sample cutter sub-assembly 203 comprises a sample cutter 205 to cut a sample from the interior wall of the tube, a sample cartridge holder 276 and a sample receptacle 272 for collecting the sample. The sample cutter 205 is connected by a threaded fastener 266 to a sample cutter cartridge 268. A chip clip 270 is connected to the sample cutter cartridge 268. The chip clip 270 retains the sample being cut by

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the sample cutter 205 inside the sample receptacle 272 formed between the sample cutter 205, the sample cutter cartridge 268, and the chip clip 270. The sample cutter cartridge 268 is connected by a bayonet-type mount 274 to the sample cartridge holder 276.

5 [0063] The oxide cutter 204 and the sample cutter 205 are disposed radially opposite to each other. It is contemplated that the oxide cutter 204 and the sample cutter 205 could be disposed at other angles to each other. For example, it is contemplated that the oxide cutter 204 and the sample cutter 205 could be disposed perpendicularly to each other. The oxide cutter 204 and the sample cutter 205 are
10 preferably made of carbide. The oxide cutter 204 is wider than the sample cutter 205 for reasons explained further below.

[0064] Two stacks of Belleville springs 278 are disposed between the oxide cartridge holder 264 and the sample cartridge holder 276, thus biasing the oxide cutter 204 and the sample cutter 205 away from each other. A threaded fastener 280 is
15 inserted in the sample cartridge holder 276 and abuts the oxide cartridge holder 264, thus retaining the springs 278 between the two holders 264 and 276. It is contemplated that other types of springs could be used instead of the Belleville springs 278.

[0065] The oxide cutter 204 and the sample cutter 205 are each movable
20 between a retracted position close to the central axis 224 where they are disposed inside the cylindrical body 222 and an extended position away from the central axis 224 where they extend in part through the aperture 228 to cut the interior wall of the tube. Retraction or extension of the oxide cutter 204 and the sample cutter 205 are linked to a position of the output shaft 236. Different positions of the output shaft 236
25 trigger different actuators for actuating the extension and the retraction of the oxide cutter 204 and the sample cutter 205. The actuator for the oxide cutter 204 consists of two rollers 282 connected to either side of the sample cutter cartridge 268 and of four springs 284. Two of the springs 284 are connected to the oxide cartridge holder 264 via two spring caps 286 and two of the springs 284 are connected to the sample
30 cartridge holder 276 via two spring caps 286. The springs 284 bias the oxide cutter 204 toward its retracted position. The actuator for the sample cutter 205 consists of two rollers 288 connected to either side of the oxide cutter cartridge 256 and of the

four springs 284. The springs 284 bias the sample cutter 205 toward its retracted position. It is contemplated that only one roller 282 or only one roller 288 could be used. It is also contemplated that the oxide cutter 204 and the sample cutter 205 could be actuated by other types of actuators. For example, it is contemplated that the rollers 282, 288 could be replaced by fixed cams.

[0066] A ramp 290 is disposed inside the cylindrical body 222 opposite the aperture 228. The ramp 290 is adapted to receive the rollers 282 and 288. The ramp has a ramp-up portion, a flat portion and a ramp-down portion. As the output shaft 236 rotates toward a first position, the rollers 282 roll over up the ramp 290, thereby extending the oxide cutter 204 through the aperture 228, and the oxide cutter 104 remains in the extended position as the rollers 282 roll over the flat portion of the ramp 290. The rollers 282 then roll over the roll down portion the ramp 290 and the oxide cutter 204 is moved back to its retracted position. Similarly as the output shaft 236 rotates toward a second position, the rollers 288 roll over the ramp up portion the ramp 290, the sample cutter 205 is moved to its extended position, and remains in the extended position as the rollers 288 roll on the flat portion of the ramp 290. As the rollers 288 roll down the ramp 290, the sample cutter 205 is moved back to its retracted position. It is contemplated that the ramp 290 could have an alternative shape for creating a different cutting pattern.

[0067] Turning now back to in Fig. 9 and 10, a purge fluid passage network 240 for discharging purge fluid at a cutting location during cutting of a portion of the interior wall of the tube by the oxide cutter 204 and the sample by the sample cutter 205 will now be described. The purge fluid passage network 240 extends through the cutter assembly 230 and is fed purge fluid by a purge fluid supply 207. The purge fluid is preferably light water. The purge fluid supply 207 is in the form of a reservoir (shown in Fig. 6) that is located inside the cylindrical body 222. It is contemplated that other types of purge fluid supply 207 could be used. For example, hydraulic pressure could be provided from an external reservoir that feeds a hydraulic hose into the circumferential sampling tool 200 (such as shown in dotted lines in Fig. 6). The purge fluid supply 207 is connected to the purge fluid passage network 240 by a hose 208. A spool valve 216 having pistons 217 and 219, described in greater details below, controls flow between the hose 208 and the purge fluid passage network 240.

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[0068] The purge fluid passage network comprises passages 240a and 240b in the oxide cutter sub-assembly 202 and passages 240c and 240d in the sample cutter sub-assembly 203. The passage 240a is connected to the piston 217 and to the passage 240b, and the passage 240c is connected to the piston 219 and to the passage 240d. The passage 240b ends at two oxide ejection ports 210, and the passage 240d ends at two sample ejection ports 212. Note that only one of each of the ejection ports 210 and 212 is being shown. The oxide ejection ports 210 discharge the purge fluid at the cutting location of the portion of the interior walls of the tube, and the sample ejection ports 212 discharge the purge fluid at the cutting location of the sample. One oxide ejection port 210 is located in the oxide cutter cartridge 256, forwardly of an cutting edge of the oxide cutter 204 relative to a cutting direction 292 (i.e. direction of rotation of the output shaft 236, shown in Fig. 8). Another oxide ejection port 210 is located in the oxide cutter 204, rearwardly of a cutting edge of the oxide cutter 204 relative to the cutting direction 292. Similarly, the two sample ejection ports 212 are located forwardly and rearwardly, respectively, of a cutting edge of the sample cutter 205. It is contemplated that the fluid passage network 240 could be two independent networks, one comprising the passages 240a and 240b and the other one comprising the passages 240c and 240d. It is also contemplated that the circumferential tool 200 could comprise the purge fluid passage network 240 connected to only the oxide ejection ports 210, and to only the sample ejection ports 212. In an alternative embodiment, the oxide cutter sub-assembly 202 comprises a single oxide ejection port located rearwardly or forwardly of the oxide cutter 204. Similarly, a single sample ejection port 212 could be located forwardly or rearwardly of the sample cutter 205.

[0069] The two pistons 217 and 219 of the spool valve 216 are connected together by a shaft 221. The pistons 217 and 219 move upwardly alternatively for opening the passages 240a and 240b in the oxide cutter sub-assembly 202 and the passages 240c and 240d in the sample cutter sub-assembly 202. The motion of the pistons 217 and 219 depend on a position of the cutter assembly 230 and therefore on a position of the output shaft 236, as will be described in greater details below. More specifically, the piston 217 of the spool valve 216 controls flow of purge fluid incoming to the oxide cutter sub-assembly 202, and the piston 219 of the spool valve 216 controls flow of purge fluid incoming to the sample cutter sub-assembly 203. It is contemplated that the spool valve 216 could comprise only the piston 217 or only the

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piston 219 to supply purge fluid only to the oxide cutter 204 or only to the sample cutter 205, respectively. It is also contemplated that the circumferential sampling tool 200 could comprise two separate spool valves, each spool valve selectively communicating one of the oxide cutter sub-assembly 202 and the sample cutter sub-assembly 203 with the purge fluid supply 207.

[0070] A pin 209 is fastened between the sample cutter sub-assembly 203 and the piston 219. The pin 209 ensures that the piston 217 moves in unison with the oxide cutter sub-assembly 202, and that the piston 219 moves in unison with the sample cutter sub-assembly 203. It is contemplated that the pin 209 could alternatively be located between the oxide cutter sub-assembly 202 and the piston 217. It is also contemplated that the piston 217 could be fastened to the oxide cutter sub-assembly 202 by a first pin and to the sample cutter sub-assembly 203 by a second pin.

[0071] Discharge of purge fluid is ensured by having the purge fluid passage network 240 pressurized, and purge fluid is ejected, due to this hydraulic pressure, onto the cutting location through the ejection ports 210 and 212.

[0072] A mode of operation of the spool valve 216 will now be described. The spool valve 216 is in operative connection with the output shaft 236 for allowing the two pistons 217 and 219 to open and close in unison with movement of the oxide cutter sub-assembly 202 and the sample cutter sub-assembly 203, respectively. It is contemplated that the spool valve 216 could not be connected to the same shaft as the cutter assembly 230, but yet be arranged so as to coordinate its opening with a displacement of the cutter assembly 230.

[0073] When the output shaft 236 rotates toward the first position where the oxide cutter 104 extends through the aperture 228, the piston 217 is displaced away from the central axis 224, thereby enabling fluid communication between the oxide cutter sub-assembly 202 and the purge fluid supply 207. The piston 219 moves closer to the central axis 224 and prevents fluid communication between the sample cutter sub-assembly 203 and the purge fluid reservoir 207. When the output shaft 236 rotates toward the second position where the sample cutter 105 extends through the aperture 228, the piston 219 is displaced away from the central axis 224, thereby enabling fluid

communication between the sample cutter sub-assembly 203 and the purge fluid supply 207. The piston 217 moves closer to the central axis 224 and prevents fluid communication between the oxide cutter sub-assembly 202 and the purge fluid reservoir 207.

[0074] To obtain a sample from the interior wall of a pressure tube (including a rolled joint region), the circumferential sampling tool 200 is inserted in the tube. The positioning system is used to set the angular and axial position where the sample is to be collected inside the tube. The cutter assembly 230 uses gravity to collect the sample. As a consequence, the sample is normally collected from the upper half of the tube (i.e. between the 9 o'clock and 3 o'clock positions). The circumferential sampling tool 200 is locked in the position where the cutting assembly 230 is aligned with a location where the sample is desired to be cut, and the bearing pads 226 are actuated to maintain the circumferential sampling tool 200 in position by pushing against the interior wall of the tube. The motor 238 is then actuated for cutting into the interior wall of the pressure tube.

[0075] The motor 238 turns the carriage 232 in the direction indicated by the arrow 292 in Fig. 8, thus turning the cutter assembly 230 in the same direction. The output shaft 236 rotates toward the first position. When the rollers 282 encounter the ramp 290 and roll over it, the oxide cutter sub-assembly 202 and the piston 217 move upwardly. The motion of the oxide cutter sub-assembly 202 induces the oxide cutter 204 to move to its extended position through the aperture 228. The motion of the piston 217 induces fluid communication between the oxide cutter sub-assembly 202 and the fluid purge supply 207.

[0076] As the rollers 282 roll over the ramp 290, the oxide cutter 204 moves in an arc along a circumference of the interior wall of the tube and cuts an oxide layer from the interior wall of the tube. Simultaneously, the piston 217 opens the passages 240a and 240b, the purge fluid flows through the passages 240a and 240b and is ejected through the oxide ejection port 210 at the cutting location. The purge fluid displaces the heavy water from the portion of the interior wall of the tube that is being cut. In a preferred embodiment, the oxide cutter 204 cuts slightly deeper than the oxide layer to ensure complete removal of oxide. The chip clip 258 causes the chip of oxide layer to curl inside the oxide receptacle 260 as it is being cut.

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[0077] The Belleville springs 278 bias the oxide cutter 204 against the surface of the tube thus permitting the cutter to maintain contact with the surface should the surface be uneven and also allow the circumferential sampling tool 200 to be used in a variety of pressure tube diameters. When the rollers 282 pass the ramp 290, the
5 springs 284 bias the cutter assembly 230 back toward the inner wall of the cylindrical body 222, and therefore the oxide cutter 204 back to its retracted position. Simultaneously, the piston 217 moves downwardly and closes the passages 240a, 240b, thus preventing fluid communication between the oxide cutter sub-assembly 202 and the purge fluid supply 207. Once the oxide cutter 204 no longer contacts the
10 interior wall of the tube, the chip of oxide layer falls inside the oxide receptacle 260.

[0078] The output shaft 236 then continues to rotate toward the second position. When the rollers 288 encounter the ramp 290 and roll over it, the cutter assembly 230 moves upwardly, thus extending the sample cutter 204 through the aperture 228. Simultaneously, under the rotation of the output shaft 236, the piston
15 219 moves away from the central axis 224, opens passages 240c and 240d, and enables fluid communication between the sample cutter sub-assembly 204 and the purge fluid supply 207. As the rollers 288 roll over the ramp 290, the sample cutter 205 moves in an arc along a circumference of the interior wall of the tube and cuts a sample from the interior wall of the tube from the location in the tube where the oxide
20 layer was cut by the oxide cutter 204. Purge fluid flows through the passages 240c and 240d thereby displacing heavy water from the portion of the wall where the sample is being cut, and is ejected through the sample ejection port 212.

[0079] The chip clip 270 causes the sample chip to curl inside the sample receptacle 272 as it is being cut. The Belleville springs 278 bias the sample cutter 205
25 against the surface of the tube thus permitting the cutter to maintain contact with the surface should the surface be uneven. When the rollers 288 pass the ramp 290, the springs 284 bias the cutter assembly 230 back toward the inner wall of the cylindrical body 222, and therefore the sample cutter 205 moves back to its retracted position and the piston 219 closes the passages 240c, 240d. Once the sample cutter 205 no longer
30 contacts the interior wall of the tube, the sample chip falls inside the receptacle 272.

[0080] In an alternative embodiment shown in Fig. 11, the cutter assembly 230 is provided with rubber pieces used as dams 231a, 231b. It is contemplated that

the dams 231a, 231b could be metallic. The dams 231a and 231b extend from the oxide cutter sub-assembly 202 and the sample cutter sub-assembly 203, respectively. The dams 231a and 231b are used for preventing heavy water flow in the tube from removing the light water injected at the location where the interior wall is being cut. The dams 231a are
5 part of the oxide cutter cartridge 256, but could alternatively be part of the oxide cartridge holder 264. Similarly, the dams 231b are part of the sample cutter cartridge 268, but could alternatively be part of the sample cartridge holder 276. Also alternatively, only one dam 231a, 231b could be used per sub-assembly 202, 203, by positioning the dam upstream of the cutters 204, 205. The dams 231a and 231b do not have to perfectly seal the location of
10 the cut, as long as they cause heavy water to travel away from the cutting location.

[0081] Because the rollers 288 are bigger than the rollers 282, the sample cutter 205 cuts the interior wall of the pressure tube deeper than the oxide cutter 204. It is contemplated that the rollers 282 could be of a same height as the rollers 288 and that an overall height of the sample cutter sub-assembly 103 could be higher than an overall height
15 of the oxide cutter sub-assembly 102. This is achieved by providing shims (not shown) between the sample cutter 205 and the sample cutter cartridge 268. As can be seen in Fig. 12, the depth D_s of the cut made by the sample cutter 205 is as a consequence greater than the depth D_o of the cut made by the oxide cutter 204. The sample cutter 205 is narrower than the oxide cutter 204, and therefore the width W_s of the cut made by the sample cutter
20 205 is smaller than the width W_o of the cut made by the oxide cutter 204. Since the rollers 282 have a smaller diameter than the rollers 288, the arc defined by the sample cutter 205 as it moves against the surface of the interior wall of the tube is shorter than the arc defined by the oxide cutter 204 as it moves against the surface of the interior wall of the tube. Therefore the sample chip is shorter than the oxide layer chip. The deeper, narrower, and
25 shorter cut made by the sample cutter 205 ensures that the sample is free of oxide thus ensuring a reliable analysis of the deuterium concentration of the sample which can be used to determine the useful life of the pressure tube. Also, by displacing the heavy water from regions as they are being cut, as described above, a reliable analysis of the deuterium concentration of the sample can be obtained without having to isolate and drain the
30 pressure tube. Furthermore, since the oxide cutter 204 and the sample cutter 205 move about the circumference of the interior wall of the tube, they are not affected by

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surface variations in the axial direction of the tube. Therefore, the circumferential sampling tool 200 can be used to obtain samples in the rolled joint region of the pressure tube.

[0082] Once the sample collection is achieved, the circumferential sampling tool 200 is unlocked, the bearing pads 226 released, and the circumferential sampling tool 220 is retracted back inside the shielding sleeve. The sample contained in the sample receptacle 272 is then transferred to a flask contained in the cart. The above steps (starting with the setting of the angular and axial position where the sample is to be collected) can be repeated for obtaining other samples in other locations in the tube. Once all samples have been collected, the shielding sleeve is disconnected from the end fitting and the cart is rolled away from the pressure tube. Finally, the flask(s) containing the sample(s) is (are) retrieved. The above steps relate to one possible method of delivering the circumferential sampling tool 200 inside a pressure tube to obtain samples. It should be understood that other methods of delivering the circumferential sampling tool 200 are possible and contemplated.

[0083] Modifications and improvements to the above-described embodiments of the present invention may become apparent to those skilled in the art. The foregoing description is intended to be exemplary rather than limiting. The scope of the present invention is therefore intended to be limited solely by the scope of the appended claims.

What is claimed is:

1. A sampling tool for obtaining a sample from an interior wall of a tube comprising :

a cylindrical body having a central axis;

an aperture in the cylindrical body;

a shaft disposed in the cylindrical body along the central axis, the shaft being movable;

a first cutter sub-assembly operatively connected to the shaft, the first cutter sub-assembly having a first cutter, the first cutter sub-assembly being movable between a retracted position where the first cutter is disposed inside the cylindrical body at a first distance from the central axis and an extended position where the first cutter extends at least in part through the aperture at a second distance from the central axis, the second distance being greater than the first distance, the first cutter sub-assembly moving to the extended position when the shaft moves to a first position thereby causing the first cutter to cut a portion of the interior wall of the tube;

a second cutter sub-assembly operatively connected to the shaft, the second cutter sub-assembly having a second cutter, the second cutter sub-assembly being movable between a retracted position where the second cutter is disposed inside the cylindrical body at a third distance from the central axis and an extended position where the second cutter extends at least in part through the aperture at a fourth distance from the central axis, the fourth distance being greater than the third distance, the second cutter sub-assembly moving to the extended position when the shaft moves to a second position thereby causing the second cutter to cut the sample from the interior wall of the tube from a location revealed by cutting the portion of the interior wall of the tube with the first cutter;

a first actuator operatively connected to the first cutter sub-assembly for moving the first cutter sub-assembly between the retracted position and the extended position as the shaft moves to the first position;

a second actuator operatively connected to the second cutter sub-assembly for moving the second cutter sub-assembly between the retracted position and the extended position as the shaft moves to the second position;

at least one of the first cutter sub-assembly and the second cutter sub-assembly having an ejection port;

a valve selectively fluidly communicating the ejection port with a purge fluid supply, the valve being fastened to one of the first cutter sub-assembly and the second cutter sub-assembly such that the valve moves with the at least one of the first cutter sub-assembly and the second cutter sub-assembly having the ejection port, the valve fluidly communicating the ejection port with the purge fluid supply when the at least one of the first cutter sub-assembly and the second cutter sub-assembly having the ejection port is in the extended position thereby discharging purge fluid through the ejection port onto the interior wall of the tube during cutting by a corresponding one of the first cutter and the second cutter, the purge fluid being discharged in an area of the corresponding one of the first cutter and the second cutter.

2. The sampling tool of claim 1, wherein the ejection port is a first ejection port and the first cutter sub-assembly has the first ejection port; and

wherein the second cutter sub-assembly has a second ejection port.

3. The sampling tool of claim 2, wherein the valve selectively fluidly communicates the first ejection port and the second ejection port with the purge fluid supply; and

wherein the valve fluidly communicates the first ejection port with the purge fluid supply when the shaft moves to the first position and the valve fluidly communicates the second ejection port with the purge fluid supply when the shaft moves to the second position.

4. The sampling tool of claim 2, wherein the valve is a first valve fastened to the first cutter sub-assembly, the first valve selectively fluidly communicating the first ejection port with the purge fluid supply; and

further comprising a second valve fastened to the second cutter sub-assembly, the second valve selectively fluidly communicating the second ejection port with the purge fluid supply;

wherein the first valve fluidly communicates the first ejection port with the purge fluid supply when the shaft moves to the first position and the second valve fluidly communicates the second ejection port with the purge fluid supply when the shaft moves to the second position.

5. The sampling tool of claim 4, wherein the valve is located axially between the first cutter sub-assembly and the second cutter sub-assembly.

6. The sampling tool of claim 4, wherein when the first valve fluidly communicates the first ejection port with the purge fluid supply, the second valve prevents fluid communication between the second ejection port and the purge fluid supply, and when the second valve fluidly communicates the second ejection port with the purge fluid supply the first valve prevents fluid communication between the first ejection port and the purge fluid supply.

7. The sampling tool of claim 1, wherein the shaft is rotatable, and the first position and the second position of the shaft are angular positions.

8. The sampling tool of claim 7, wherein the valve is a spool valve.

9. The sampling tool of claim 7, wherein the first cutter sub-assembly is located opposite to the second cutter sub-assembly.

10. The sampling tool of claim 1, wherein the shaft is axially movable, and the first position and the second position of the shaft are longitudinal positions of the shaft with respect to the cylindrical body.

11. The sampling tool of claim 10, wherein the valve is a poppet valve.

12. The sampling tool of claim 10, wherein the first cutter sub-assembly is located forwardly of the second cutter sub-assembly relative to a cutting direction of the first cutter and the second cutter.

13. The sampling tool of claim 1, wherein the ejection port is a first ejection port and the at least one of the first cutter sub-assembly and the second cutter sub-assembly having the first ejection port also has a second ejection port.

14. The sampling tool of claim 13, wherein the first ejection port is located forwardly of the corresponding one of the first cutter and the second cutter relative to a cutting direction of the first cutter and the second cutter; and

wherein the second ejection port extends through the corresponding one of the first cutter and the second cutter.

15. The sampling tool of claim 1, wherein the ejection port extends through the corresponding one of the first cutter and the second cutter.

16. The sampling tool of claim 1, wherein the ejection port is located forwardly of the corresponding one of the first cutter and the second cutter relative to a cutting direction thereof.

17. The sampling tool of claim 1, wherein the valve is fastened to the one of the first cutter sub-assembly and the second cutter sub-assembly by a pin.

18. The sampling tool of claim 1, wherein the purge fluid is light water.

19. The sampling tool of claim 1, wherein the purge fluid supply is a reservoir disposed externally of the cylindrical body and fluidly communicating with the ejection port with a hose.

20. The sampling tool of claim 1, wherein the purge fluid supply is a reservoir located inside the cylindrical body.

21. A tool for sampling an interior wall of a tube, comprising:

a body for insertion in the tube;

a cutter assembly rotatably mounted to said body for rotation about a longitudinal axis of the tube and at least one pair of blades positioned at different angular orientations such that a second blade of said pair follows a first blade of said pair through said rotation, each of said pair of blades movable between a radially retracted position and a radially extended position for cutting a sample from said interior wall, wherein, in said extended positions, said second blade extends radially farther from said longitudinal axis than said first blade, for cutting a sample of greater depth;

said cutter assembly comprising a purge fluid passage with a purge outlet positioned to direct a purge fluid at a sample cutting location, to displace a contaminant;

an actuator configured to extend said blades at respective angular positions in said arc.

22. The tool of claim 21, wherein said purge outlet is part of a blade cartridge to which at least one of said first and second blades is mounted.

23. The tool of claim 22, wherein said purge outlet is located ahead of said one of said first and second blades, in a cutting direction.

24. The tool of any one of claims 21 to 23, comprising a valve for controlling discharge of said purge fluid from said purge outlet.

25. The tool of claim 24, wherein said purge fluid passage communicates with a pressurized purge fluid reservoir through said valve.

26. The tool of claim 25, wherein said valve is configured to open and close at respective angular positions of said cutter assembly.

27. The tool of claim 26, comprising a coupling pin for opening and closing said valve along with rotation of said cutter assembly.

28. The tool of claim 21, wherein said purge outlet is a first purge outlet, aligned with said first blade to direct a purge fluid at a sample cutting location of said first blade, and said tool further comprises a second purge outlet, aligned with said second blade to direct a purge fluid at a sample cutting location of said second blade.

29. The tool of claim 28, wherein said purge fluid passage is a first purge fluid passage, and wherein said cutter assembly further comprises a second purge fluid passage in communication with said second purge outlet.

30. The tool of claim 29, comprising valves controlling discharge of purge fluid through each of said first and second purge outlets, independently of one another.

31. The tool of claim 30, wherein said valves are configured to selectively discharge purge fluid onto one of said first sample cutting location and said second sample cutting location, while the respective one of said first and second blades is cutting.

32. The tool of claim 31, wherein said valves are configured to open and close along with rotation of said cutter assembly.

33. The tool of any one of claims 21 to 32, wherein said purge fluid passage and said purge outlet are for discharging water to displace heavy water from a sample.

34. A method of sampling an interior wall of a tube, comprising:

inserting a sampling tool in the tube, the sampling tool having at least one pair of rotatably-mounted blades;

rotating said pair of blades about a longitudinal axis of said tube, said pair of blades having different angular orientations so that a second one of said blades follows a first one of said blades through said rotation;

during said rotating, radially extending each of said blades to a cutting position for cutting a sample from said wall of said tube, such that rotation of each blade in said cutting position defines a cutting arc, the cutting arc of said second blade extending radially farther than the cutting arc of said first blade, for cutting a sample of greater depth;

during said rotating, directing a purge fluid towards said cutting arc of at least one of said blades, thereby displacing a contaminant from a sample.

35. The method of claim 34, wherein said directing a purge fluid comprises directing fluid ahead of one of said blades in said cutting arc.

36. The method of claim 34 or claim 35, comprising opening a valve along with said rotating to discharge pressurized purge fluid through an outlet.

37. The method of claim 36, wherein said rotating comprises rotating a cutter assembly, and wherein said opening a valve comprises opening said valve with pin coupled to said cutter assembly.

38. The method of any one of claims 34 to 38, wherein said sampling tool has first and second valves for discharging purge fluid towards said cutting arc of said first blade and said cutting arc of said second blade, respectively.

39. The method of claim 38, comprising opening one of said valves to direct purge fluid toward the cutting arc of the corresponding blade during cutting by that blade, and closing the other one of said valves.

40. The method of any one of claims 34-39, wherein said directing a purge fluid comprises directing water towards said cutting arc to displace heavy water from a sample.

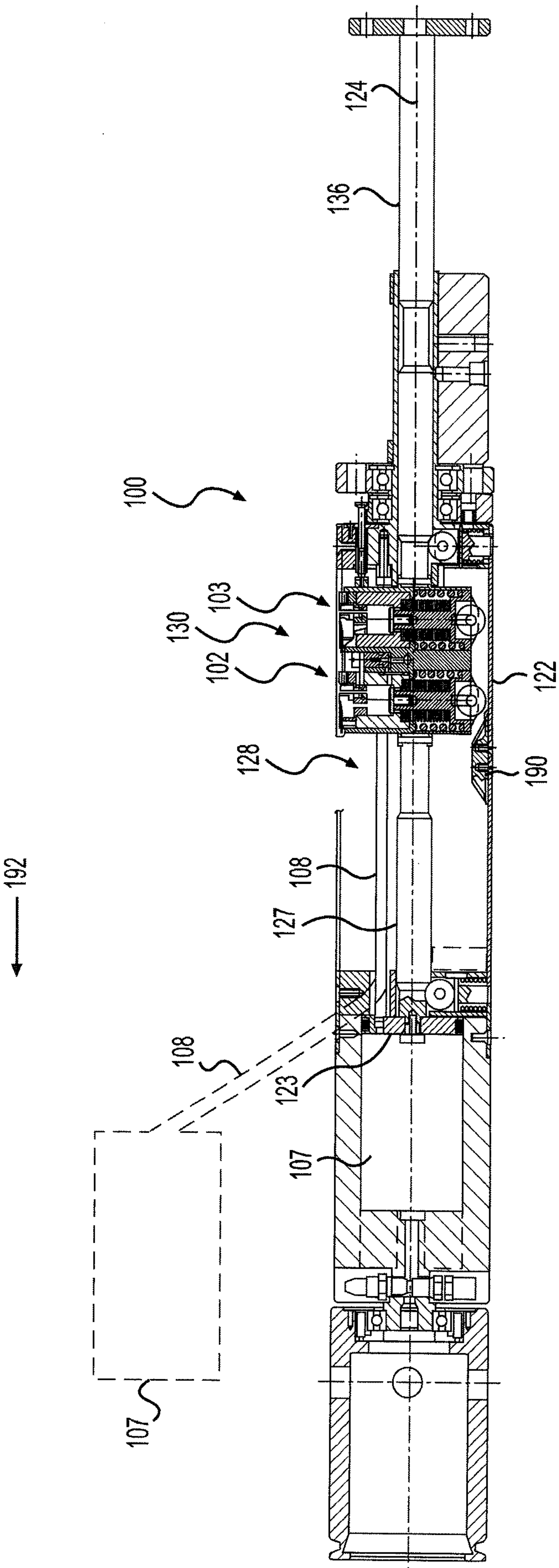
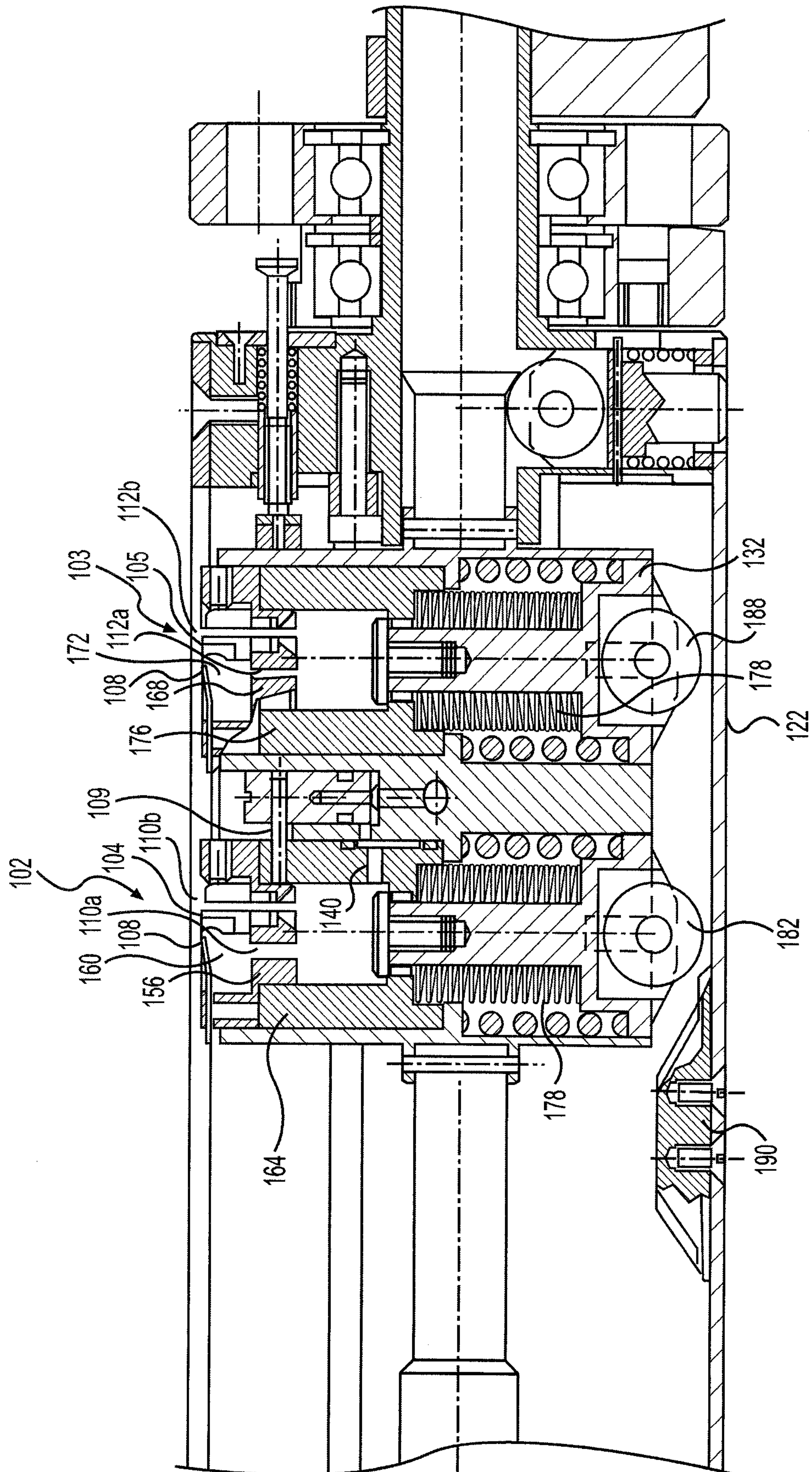
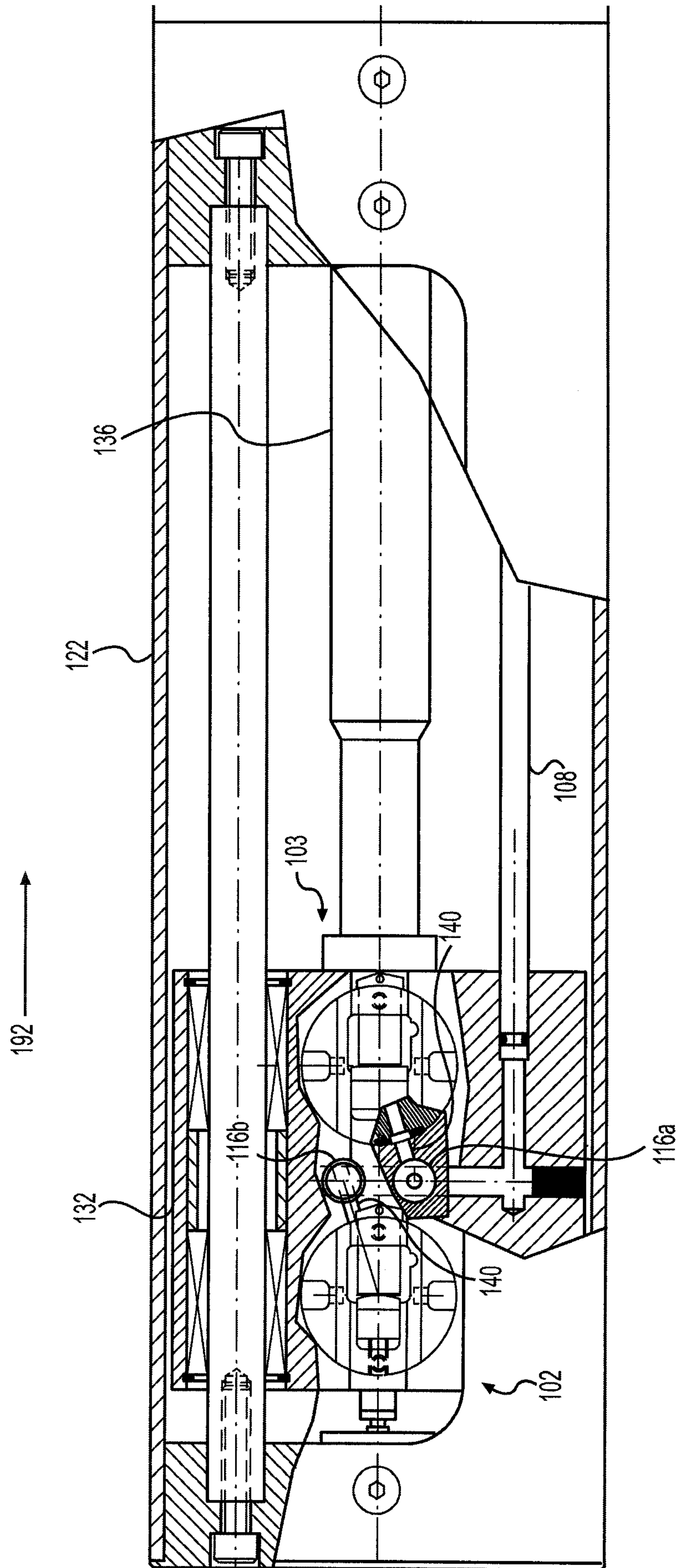
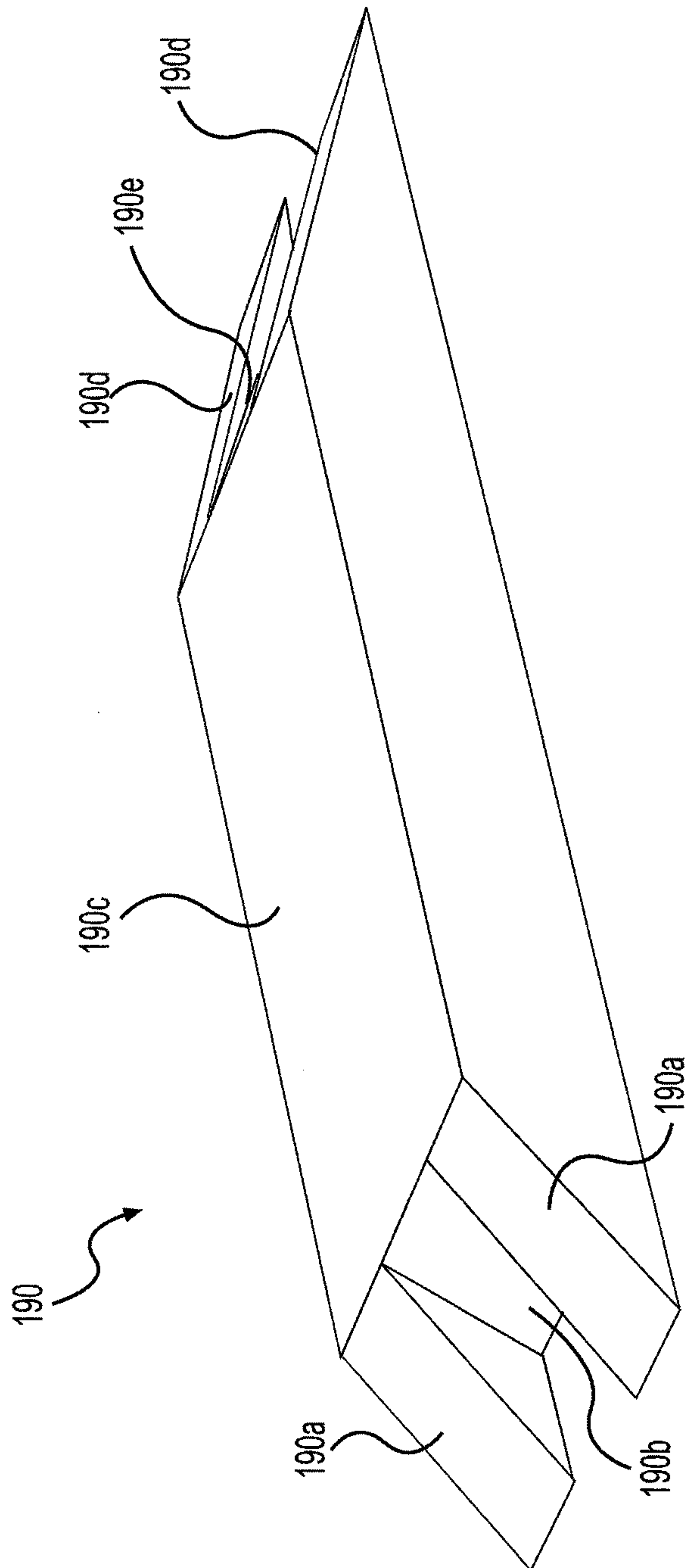


FIG. 1

**FIG. 2**

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**FIG. 3**

**FIG. 4**

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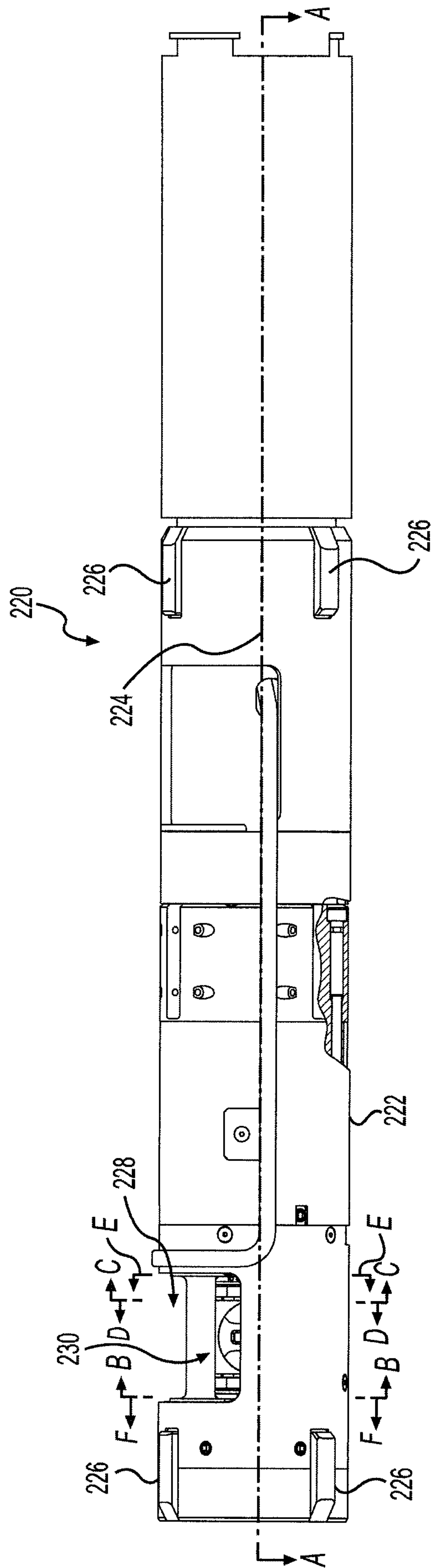
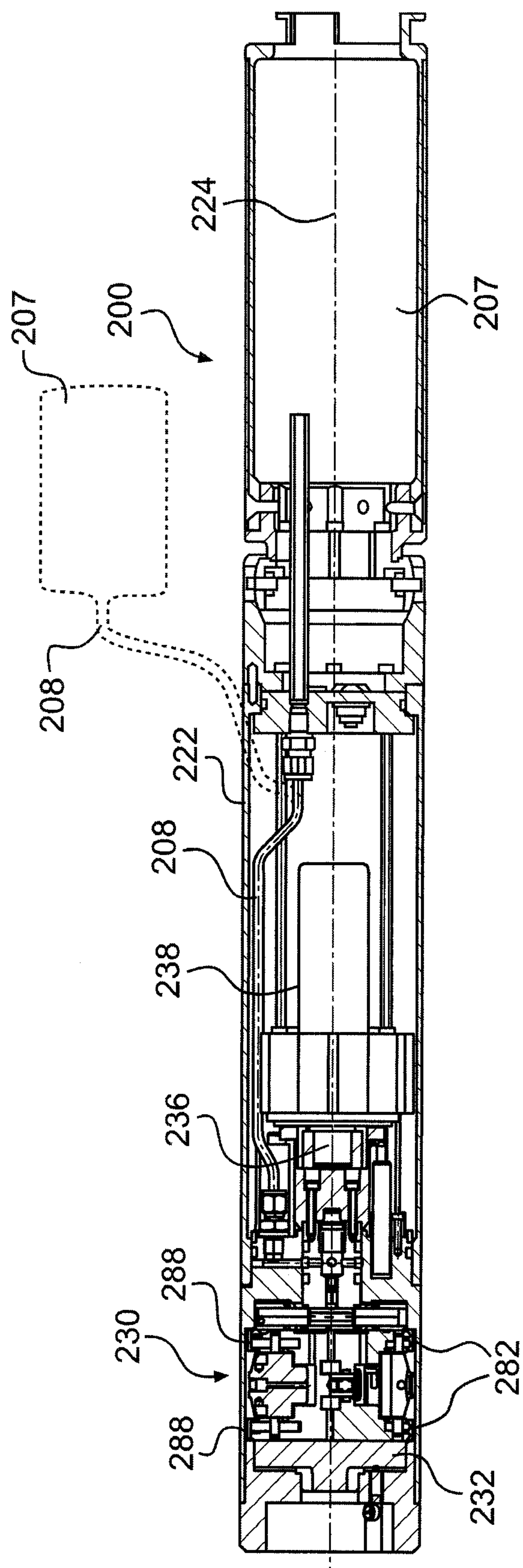
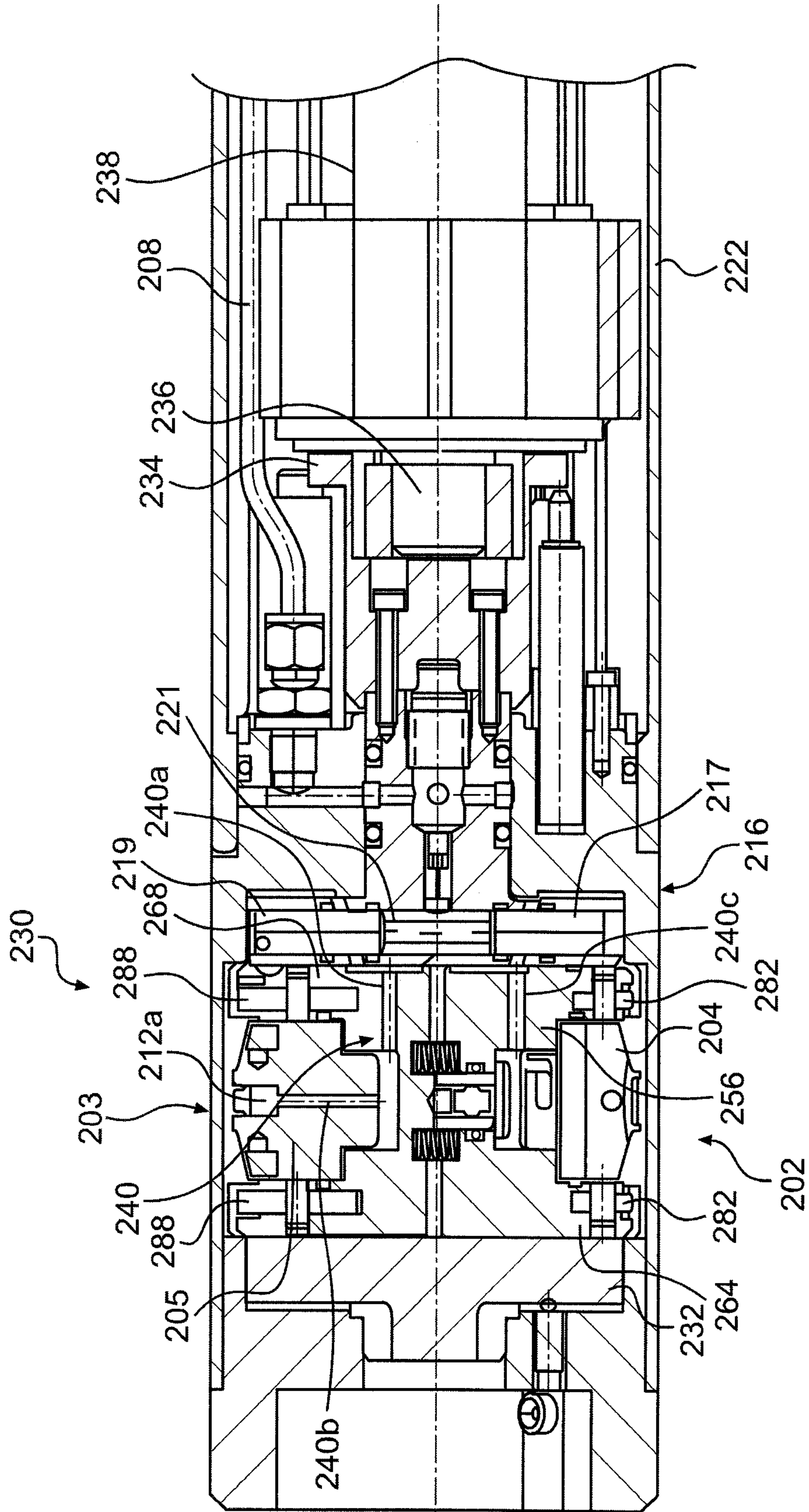
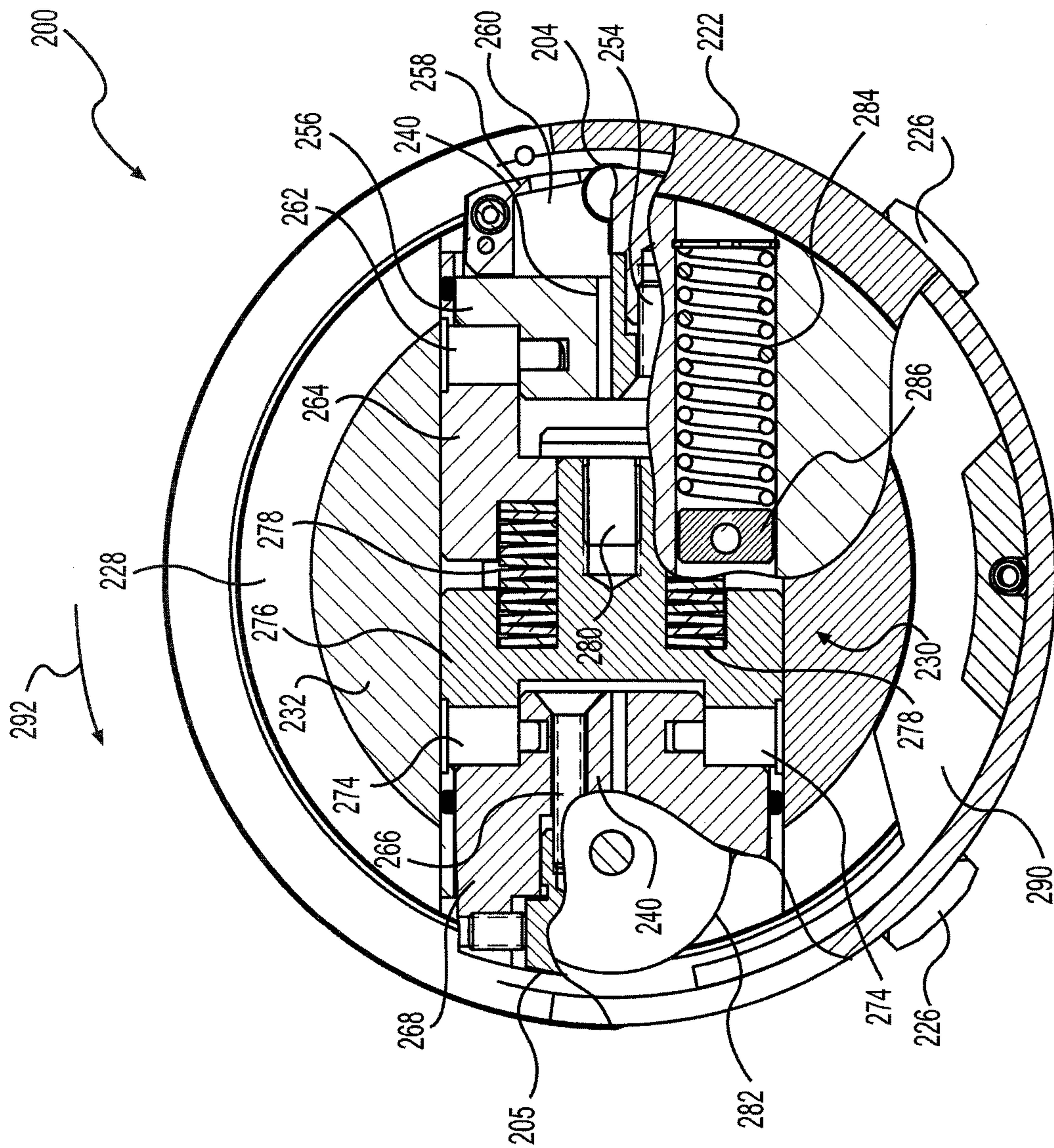


FIG. 5

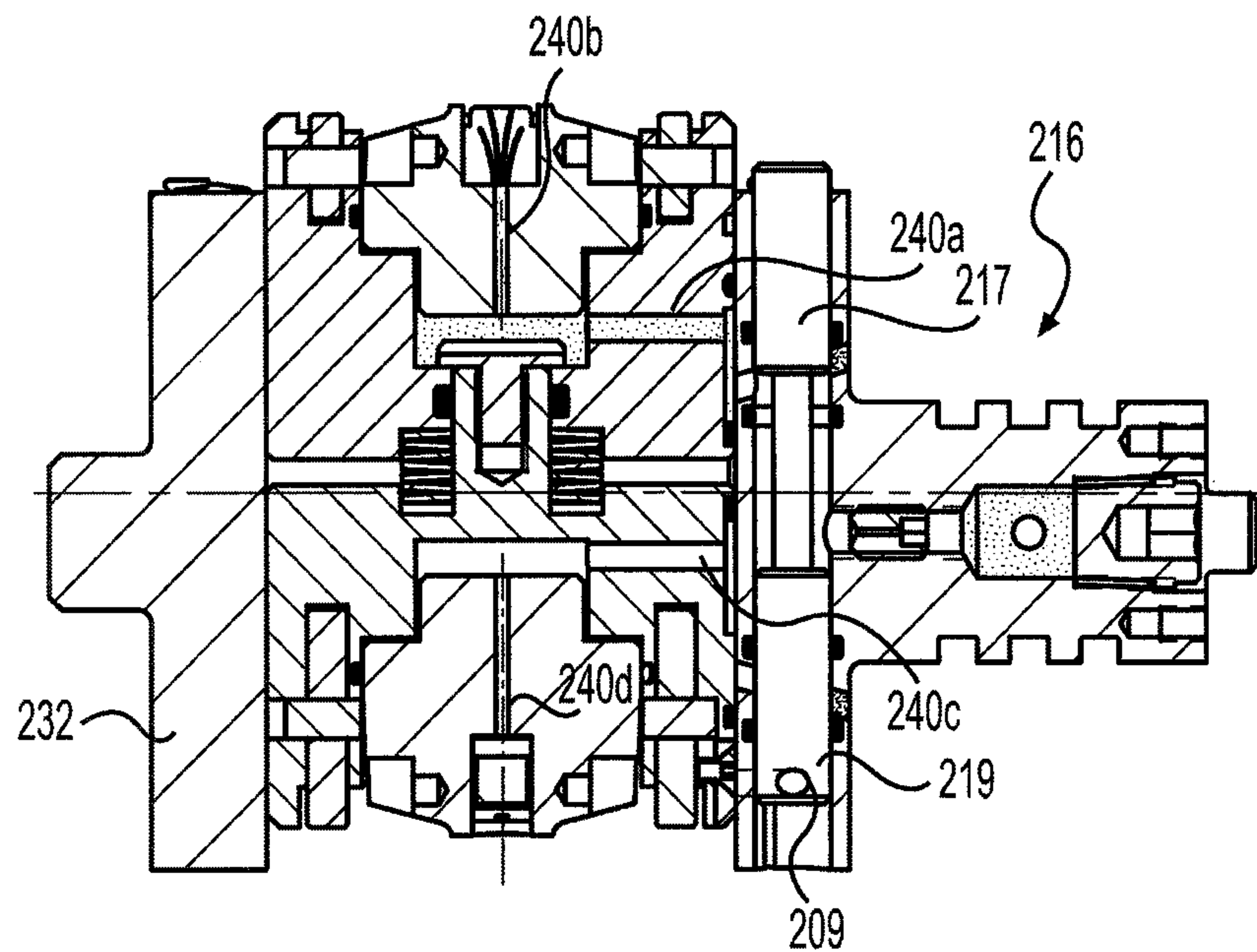
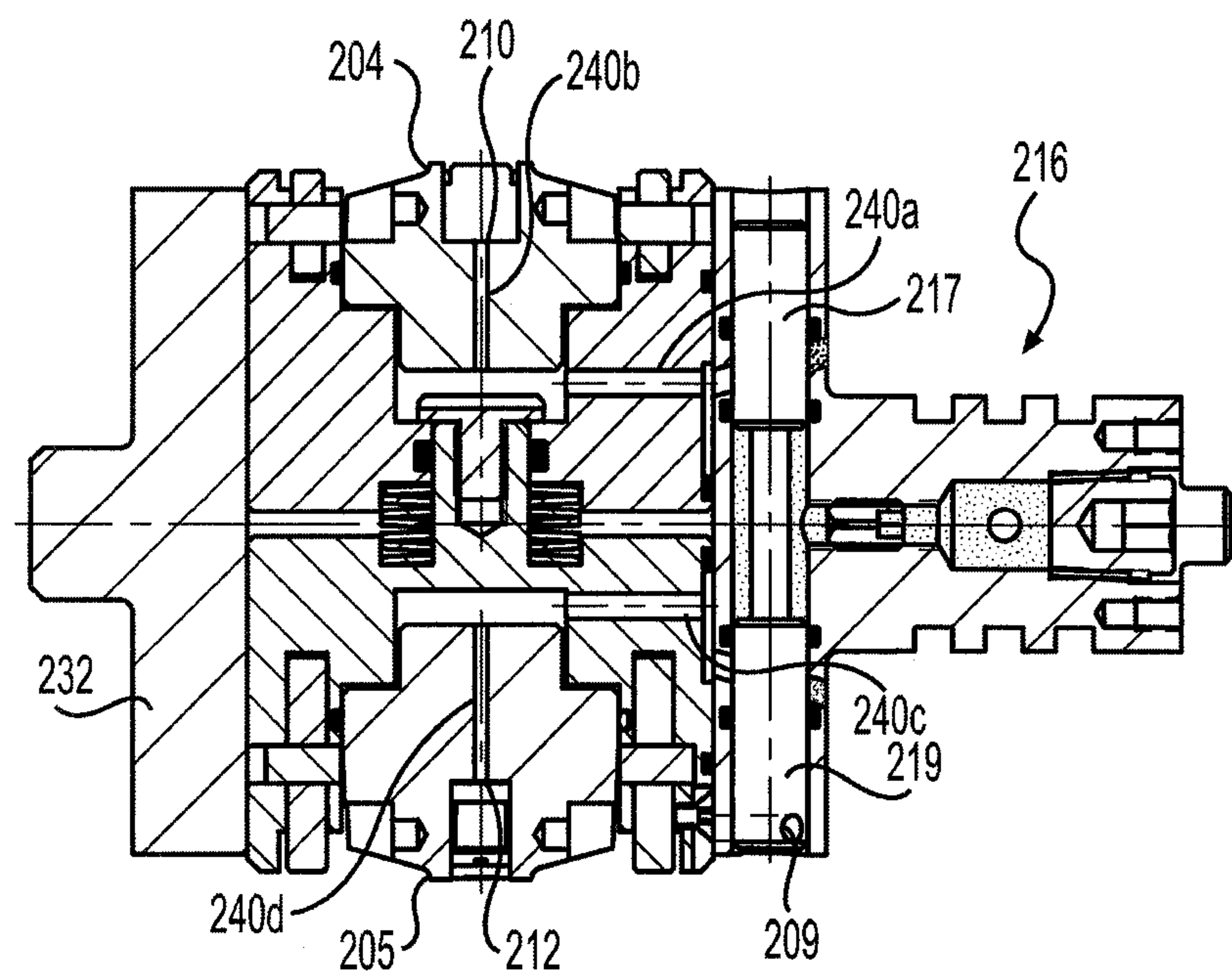
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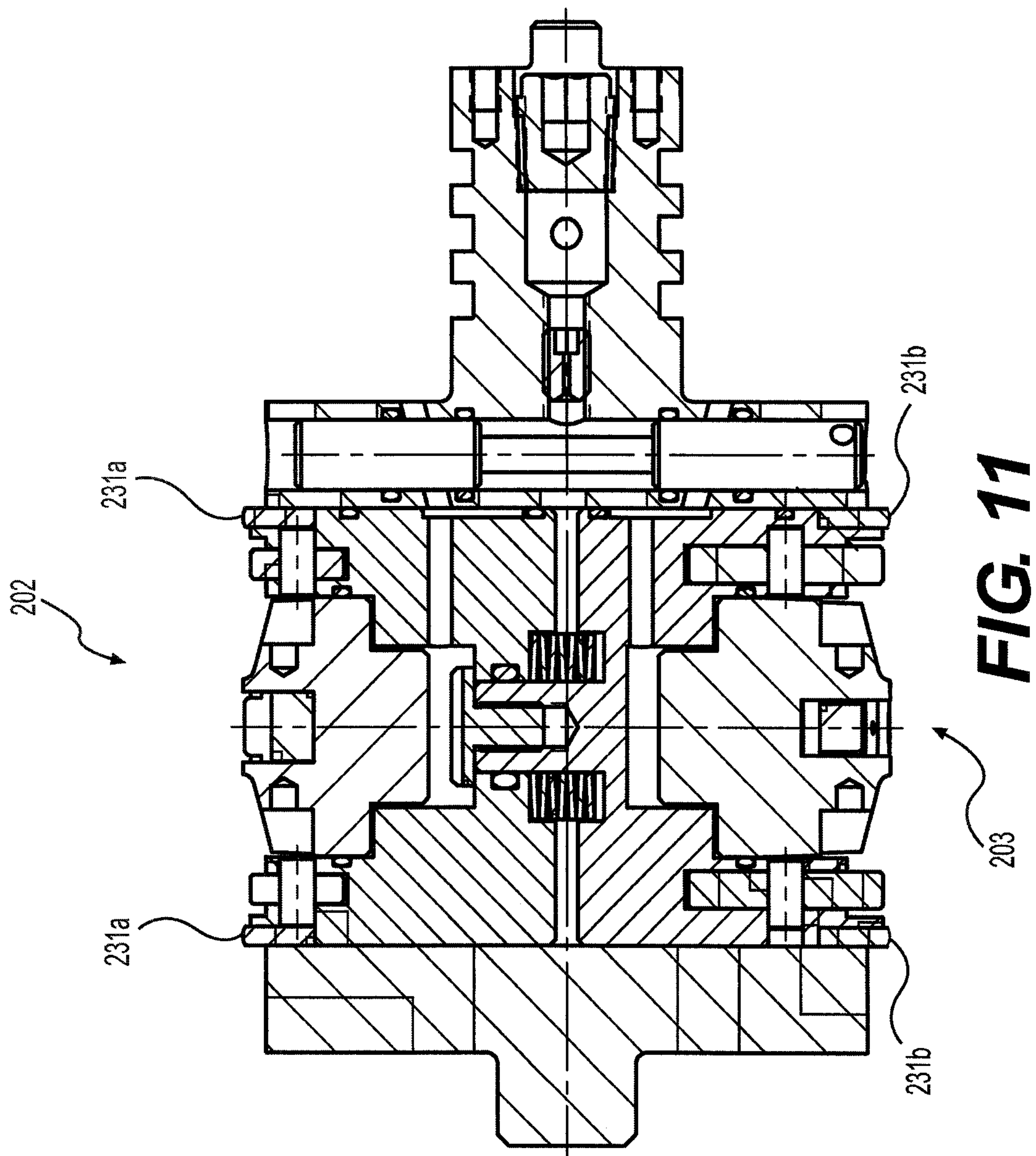
**FIG. 6**

**FIG. 7**

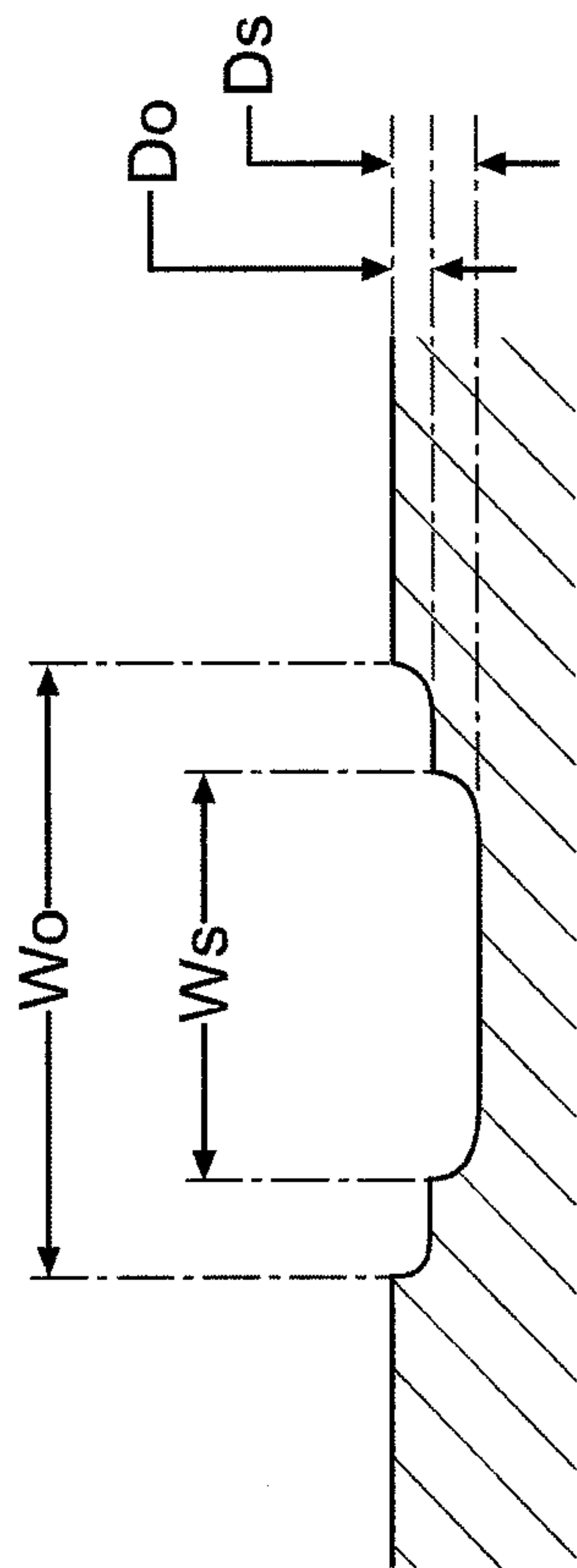
**FIG. 8**

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**FIG. 9****FIG. 10**



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**FIG. 12**

