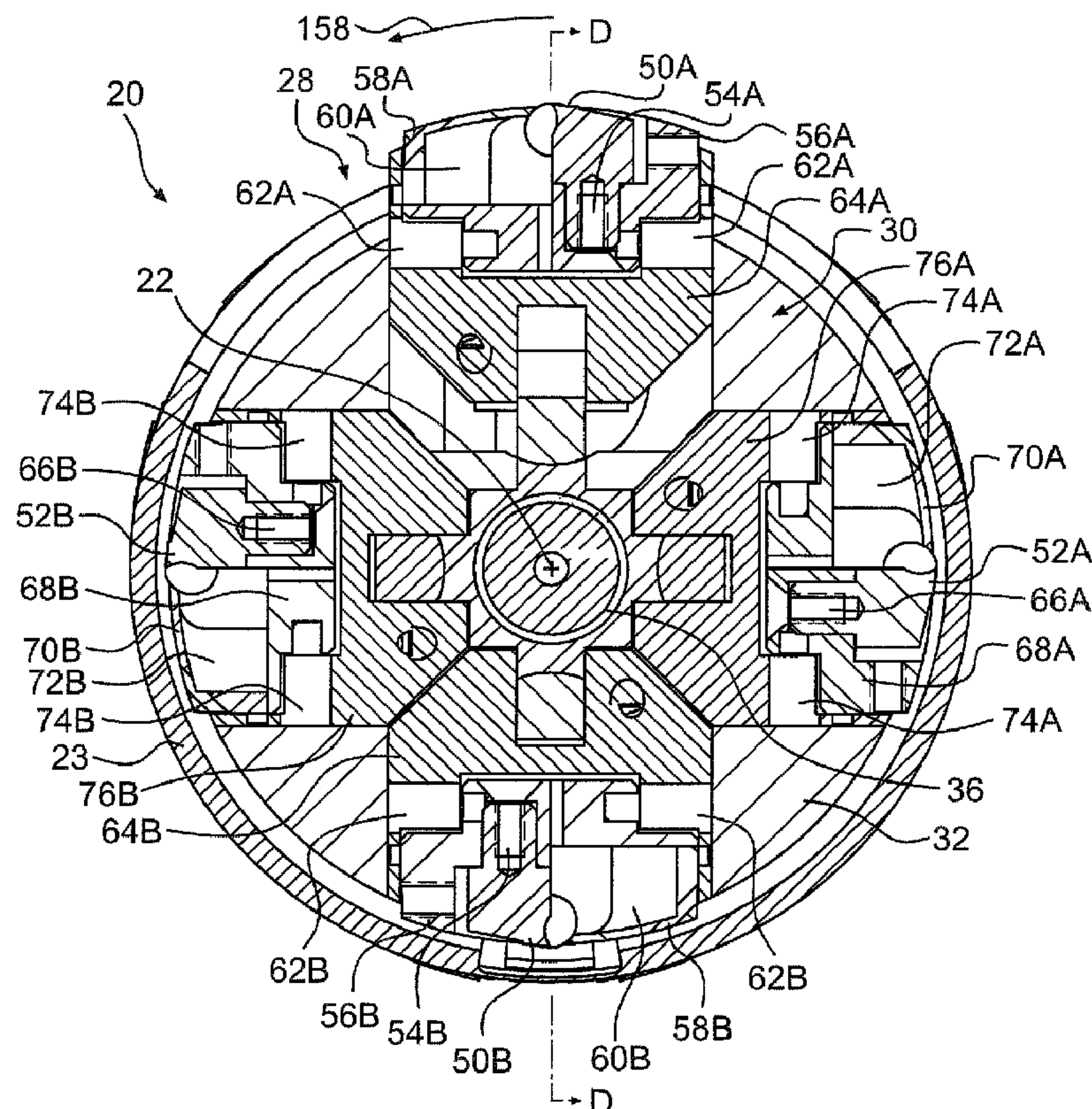




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(54) **Titre : OUTIL D'ECHANTILLONNAGE PERIPHERIQUE COMPORTANT DES COUTEAUX D'ECHANTILLONNAGE MULTIPLES**
(54) **Title: CIRCUMFERENTIAL SAMPLING TOOL HAVING MULTIPLE SAMPLE CUTTERS**



(57) **Abrégé/Abstract:**

A circumferential sampling tool for obtaining samples from an interior wall of a tube has a cylindrical body, a shaft disposed in the cylindrical body, a first cutter, a second cutter being disposed at an angle to first cutter, a third cutter, and a fourth cutter being

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

disposed at an angle to the third cutter. The first, second, third and fourth cutters are operatively connected to the shaft for rotation therewith. Each of the cutters is movable radially between a retracted and an extended position in response to rotation of the shaft in order to obtain samples from the tube. A method of obtaining samples from an interior wall of a tube is also disclosed.

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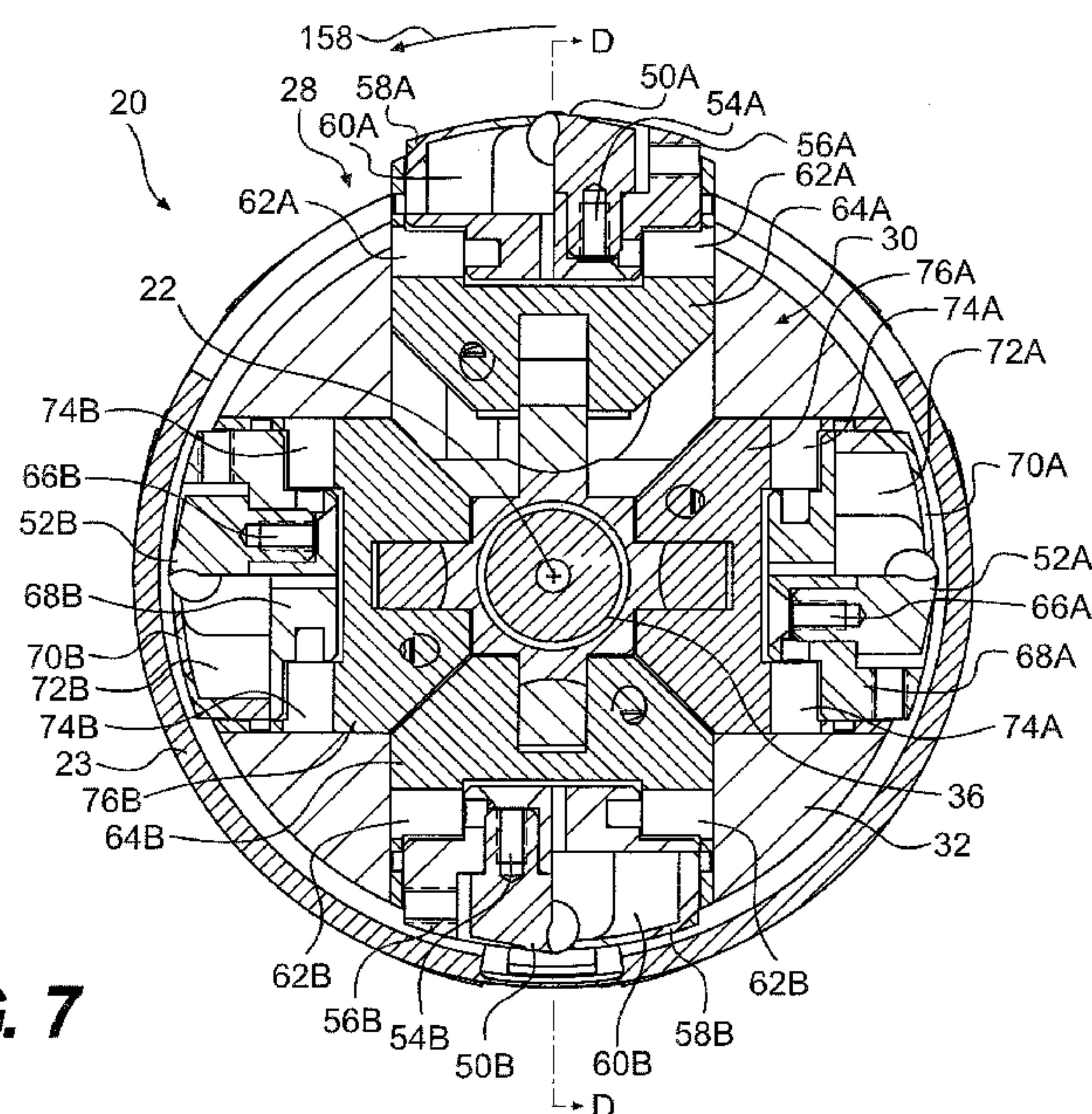
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(54) Title: CIRCUMFERENTIAL SAMPLING TOOL HAVING MULTIPLE SAMPLE CUTTERS

**FIG. 7**

(57) Abstract: A circumferential sampling tool for obtaining samples from an interior wall of a tube has a cylindrical body, a shaft disposed in the cylindrical body, a first cutter, a second cutter being disposed at an angle to first cutter, a third cutter, and a fourth cutter being disposed at an angle to the third cutter. The first, second, third and fourth cutters are operatively connected to the shaft for rotation therewith. Each of the cutters is movable radially between a retracted and an extended position in response to rotation of the shaft in order to obtain samples from the tube. A method of obtaining samples from an interior wall of a tube is also disclosed.

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CIRCUMFERENTIAL SAMPLING TOOL HAVING MULTIPLE SAMPLE CUTTERS

FIELD OF THE INVENTION

[0001] The present invention relates to a circumferential sampling tool having
5 multiple sample cutters and a method of using same.

BACKGROUND OF THE INVENTION

[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
10 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 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
15 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 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
20 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.

[0004] United States Patent No. 4,925,621, issued May 15, 1990 discloses a
sampling tool useful for pressure tube sampling which addresses the above
difficulties. The disclosed sampling tool permits *in situ* testing in that pressure tube
25 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 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.

[0005] Although the above-described sampling tool addresses the above difficulties, it proves impractical to obtain samples in some portions of the pressure tube. For example, as seen in Fig. 1, in a CANDU type fuel channel, the pressure tube 10 is joined to an end fitting (not shown) using a rolled joint 12. The above-described sampling tool makes obtaining useful samples in the rolled joint area difficult due to the high axial gradient of hydrogen/deuterium concentration and the circumferential ripples 14 in the rolled joint area.

[0006] Furthermore, the above-described sampling tool can only retrieve a single sample at a time, which means that the tool needs to be removed from the pressure tube to retrieve the sample (and the portion of oxide layer) before another sample can be obtained. This makes obtaining multiple samples from a tube time consuming.

[0007] 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.

[0008] Therefore, there is a need for a sampling tool and sample collection method that address at least some of the above-identified difficulties and at least some of the inconveniences present in the prior art.

SUMMARY OF THE INVENTION

[0009] It is an object of the present invention to provide a sampling tool that has at least two sets of two cutters that move circumferentially along a portion of an interior wall of a tube. For each set, 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.

[0010] It is another object of the present invention to provide a mechanism for selectively engaging each set of cutters.

[0011] It is yet another object of the present invention to provide a method of obtaining samples from a tube using the above tool.

5 [0012] In one aspect, the invention provides a circumferential sampling tool for obtaining samples from an interior wall of a tube. The tool has a cylindrical body having a central axis, a shaft disposed in the cylindrical body along the central axis, a motor operatively connected to the shaft for rotating the shaft, a first aperture in the cylindrical body, a first cutter assembly selectively engaged by the shaft, a second
10 aperture in the cylindrical body, a second cutter assembly selectively engaged by the shaft, and a shaft actuator operatively connected to the shaft for selectively engaging the shaft with the first cutter assembly and the second cutter assembly. The first cutter assembly includes a first cutter selectively operatively connected to the shaft for rotation therewith, a first actuator operatively connected to the first cutter, a second
15 cutter selectively operatively connected to the shaft for rotation therewith and being disposed at an angle to first cutter, and a second actuator operatively connected to the second cutter. The first cutter is movable radially between a retracted position where the first cutter is disposed inside the cylindrical body and an extended position where the first cutter extends at least in part through the first aperture. The first actuator
20 moves the first cutter between the retracted position and the extended position as the shaft rotates when the shaft is engaged with the first cutter assembly. The second cutter is movable radially between a retracted position where the second cutter is disposed inside the cylindrical body and an extended position where the second cutter extends at least in part through the first aperture. The second actuator moves the
25 second cutter between the retracted position and the extended position as the shaft rotates when the shaft is engaged with the first cutter assembly. The second cutter is in the retracted position when the first cutter is in the extended position, and the first cutter is in the retracted position when the second cutter is in the extended position. The second cutter assembly includes a third cutter selectively operatively connected to
30 the shaft for rotation therewith, a third actuator operatively connected to the third cutter, a fourth cutter selectively operatively connected to the shaft for rotation therewith and being disposed at an angle to third cutter, and a fourth actuator

operatively connected to the fourth cutter. The third cutter is movable radially between a retracted position where the third cutter is disposed inside the cylindrical body and an extended position where the third cutter extends at least in part through the second aperture. The third actuator moves the third cutter between the retracted position and the extended position as the shaft rotates when the shaft is engaged with the second cutter assembly. The fourth cutter is movable radially between a retracted position where the fourth cutter is disposed inside the cylindrical body and an extended position where the fourth cutter extends at least in part through the second aperture. The fourth actuator moves the fourth cutter between the retracted position and the extended position as the shaft rotates when the shaft is engaged with the second cutter assembly. The fourth cutter is in the retracted position when the third cutter is in the extended position. The third cutter is in the retracted position when the fourth cutter is in the extended position. When the shaft actuator engages the shaft with the first cutter assembly, rotating the shaft using the motor causes the first cutter to move to the extended position thereby cutting a portion of the interior wall of the tube and then causes the second cutter to move to the extended position thereby cutting a first sample from the interior wall of the tube from a location in the tube revealed by cutting the portion of the interior wall of the tube. When the shaft actuator engages the shaft with the second cutter assembly, rotating the shaft using the motor causes the third cutter to move to the extended position thereby cutting another portion of the interior wall of the tube and then causes the fourth cutter to move to the extended position thereby cutting a second sample from the interior wall of the tube from a location in the tube revealed by cutting the other portion of the interior wall of the tube.

[0013] In an additional aspect, the shaft actuator moves the shaft along the central axis.

[0014] In a further aspect, the shaft actuator moves the motor together with the shaft.

[0015] In an additional aspect, the motor is disposed inside a drive housing and the shaft actuator moves the drive housing.

[0016] In a further aspect, when the shaft actuator engages the shaft with the first cutter assembly, the motor rotates the shaft in a first direction, and when the shaft actuator engages the shaft with the second cutter assembly, the motor rotates the shaft in the first direction.

5 [0017] In an additional aspect, the shaft actuator includes an indexing motor an indexing lead screw. The indexing lead screw is received in an indexing lead screw nut connected to the cylindrical body. Rotating the indexing lead screw with the indexing motor moves the shaft along the central axis.

[0018] In a further aspect, the first cutter is wider than the second cutter and
10 the third cutter is wider than the fourth cutter.

[0019] In an additional aspect, an arc defined by the first cutter in the extended position as the shaft rotates is longer than an arc defined by the second cutter in the extended position as the shaft rotates, and an arc defined by the third cutter in the extended position as the shaft rotates is longer than an arc defined by the fourth
15 cutter in the extended position as the shaft rotates.

[0020] In a further aspect, a first receptacle is connected to the first cutter for receiving the portion of the interior wall of the tube cut by the first cutter, a second receptacle is connected to the second cutter for receiving the first sample cut by the second cutter, a third receptacle is connected to the third cutter for receiving the other
20 portion of the interior wall of the tube cut by the third cutter, and a fourth receptacle is connected to the fourth cutter for receiving the second sample cut by the second cutter.

[0021] In another aspect, the invention provides a method of obtaining samples from an interior wall of a tube. The method comprises: moving a first cutter
25 against the interior wall; moving the first cutter in an arc along a circumference of the interior wall thereby cutting a portion of the interior wall of the tube; moving the first cutter away from the interior wall of the tube; moving a second cutter against a first surface of the tube revealed by cutting the portion of the interior wall of the tube; moving the second cutter in an arc along the first surface thereby cutting a first
30 sample; moving the second cutter away from the first surface; moving a third cutter against the interior wall; moving the third cutter in an arc along the circumference of

the interior wall thereby cutting another portion of the interior wall of the tube; moving the third cutter away from the interior wall of the tube; moving a fourth cutter against a second surface of the tube revealed by cutting the other portion of the interior wall of the tube; moving the fourth cutter in an arc along the second surface
5 thereby cutting a second sample; moving the fourth cutter away from the second surface.

[0022] In an additional aspect, the method also comprises: engaging a first cutter assembly with a shaft, the first cutter assembly including the first and second cutters; and engaging a second cutter assembly with the shaft, the second cutter
10 assembly including the third and fourth cutters. Moving the first and second cutters includes rotating the shaft engaged with the first cutter assembly. Moving the third and fourth cutters includes rotating the shaft engaged with the second cutter assembly.

[0023] In a further aspect, the method also comprises: receiving the cut portion of the interior wall of the tube in a first receptacle; receiving the first sample
15 in a second receptacle; receiving the other cut portion of the interior wall of the tube in a third receptacle; and receiving the second sample in a fourth receptacle.

[0024] In an additional aspect, the cut portion of the interior wall of the tube includes at least a portion of an oxide layer, and the other cut portion of the interior wall of the tube includes at least a portion of an oxide layer.

20 [0025] In yet another aspect, the invention provides a circumferential sampling tool for obtaining samples from an interior wall of a tube. The tool has a cylindrical body having a central axis, an aperture in the cylindrical body, a shaft disposed in the cylindrical body along the central axis, a first cutter operatively connected to the shaft for rotation therewith, a first actuator operatively connected to
25 the first cutter, a second cutter operatively connected to the shaft for rotation therewith and being disposed at an angle to the first cutter, a second actuator operatively connected to the second cutter, a third cutter operatively connected to the shaft for rotation therewith and being disposed at an angle to the first and second cutters, a third actuator operatively connected to the third cutter, a fourth cutter
30 operatively connected to the shaft for rotation therewith and being disposed at an angle to the first cutter, the second cutter, and the third cutter, and a fourth actuator

operatively connected to the fourth cutter. The first cutter is movable radially between a retracted position where the first cutter is disposed inside the cylindrical body and an extended position where the first cutter extends at least in part through the aperture. The first actuator moves the first cutter between the retracted position and the extended position as the shaft rotates. The second cutter is movable radially between a retracted position where the second cutter is disposed inside the cylindrical body and an extended position where the second cutter extends at least in part through the aperture. The second actuator moves the second cutter between the retracted position and the extended position as the shaft rotates. The third cutter is movable radially between a retracted position where the third cutter is disposed inside the cylindrical body and an extended position where the third cutter extends at least in part through the aperture. The third actuator moves the third cutter between the retracted position and the extended position as the shaft rotates. The fourth cutter is movable radially between a retracted position where the fourth cutter is disposed inside the cylindrical body and an extended position where the fourth cutter extends at least in part through the aperture. The fourth actuator moves the fourth cutter between the retracted position and the extended position as the shaft rotates. The second cutter, the third cutter, and the fourth cutter are in their respective retracted positions when the first cutter is in the extended position. The first cutter, the third cutter, and the fourth cutter are in their respective retracted positions when the second cutter is in the extended position. The first cutter, the second cutter, and the fourth cutter are in their respective retracted positions when the third cutter is in the extended position. The first cutter, the second cutter, and the third cutter are in their respective retracted positions when the fourth cutter is in the extended position. Rotating the shaft causes the first cutter to move to the extended position thereby cutting a portion of the interior wall of the tube and then causes the second cutter to move to the extended position thereby cutting a first sample from the interior wall of the tube from a location in the tube revealed by cutting the portion of the interior wall of the tube. After relocating the tool in the tube, rotating the shaft causes the third cutter to move to the extended position thereby cutting another portion of the interior wall of the tube and then causes the fourth cutter to move to the extended position thereby cutting a second sample from the interior wall of the tube from a location in the tube revealed by cutting the other portion of the interior wall of the tube.

[0026] In a further aspect, the second cutter is disposed perpendicularly to the first cutter, the third cutter is disposed perpendicularly to the second cutter, the fourth cutter is disposed perpendicularly to the third cutter, and the first cutter is disposed perpendicularly to the fourth cutter. The first cutter is disposed opposite the third
5 cutter, and the second cutter is disposed opposite the fourth cutter.

[0027] In an additional aspect, a drive motor is disposed in the cylindrical body and is operatively connected to the shaft for rotating the shaft.

[0028] In a further aspect, the first actuator includes a first actuation bar disposed generally parallel to the central axis. The first actuation bar has a first roller
10 at a first end thereof, a second roller at a second end thereof, and at least one third roller between the first and second ends thereof. The second actuator includes a second actuation bar disposed generally parallel to the central axis. The second actuation bar has a fourth roller at a first end thereof, a fifth roller at a second end thereof, and at least one sixth roller between the first and second ends thereof. The
15 third actuator includes a third actuation bar disposed generally parallel to the central axis. The third actuation bar has a seventh roller at a first end thereof, an eighth roller at a second end thereof, and at least one ninth roller between the first and second ends thereof. The fourth actuator includes a fourth actuation bar disposed generally parallel to the central axis. The fourth actuation bar has a tenth roller at a first end
20 thereof, an eleventh roller at a second end thereof, and at least one twelfth roller between the first and second ends thereof. An extension ramp is connected to the cylindrical body. The extension ramp extends generally parallel to the central axis toward the first, second, third, and fourth cutters. The extension ramp defines an arc about the central axis. A retraction ramp is connected to the cylindrical body. The
25 retraction ramp extends generally parallel to the central axis toward the extension ramp and the first, second, third, and fourth cutters. The retraction ramp defines an arc about the central axis. A first holder is connected to the first cutter. The first holder has at least one slot defined therein at an angle to the central axis. The at least one slot of the first holder receives the at least one third roller therein. A second
30 holder is connected to the second cutter. The second holder has at least one slot defined therein at an angle to the central axis. The at least one slot of the second holder receives the at least one sixth roller therein. A third holder is connected to the

third cutter. The third holder has at least one slot defined therein at an angle to the central axis. The at least one slot of the third holder receives the at least one ninth roller therein. A fourth holder is connected to the fourth cutter. The fourth holder has at least one slot defined therein at an angle to the central axis. The at least one slot of the fourth holder receives the at least one twelfth roller therein. The first, second, third and fourth cutters are disposed between the extension ramp and the retraction ramp in a direction parallel to the central axis. When the first roller rolls over the extension ramp, the at least one third roller moves in the at least one slot of the first holder causing the first holder to move radially away from the central axis thereby causing the first cutter to move to the extended position. When the second roller rolls over the retraction ramp, the at least one third roller moves in the at least one slot of the first holder causing the first holder to move radially toward the central axis thereby causing the first cutter to move to the retracted position. When the fourth roller rolls over the extension ramp, the at least one sixth roller moves in the at least one slot of the second holder causing the second holder to move radially away from the central axis thereby causing the second cutter to move to the extended position. When the fifth roller rolls over the retraction ramp, the at least one sixth roller moves in the at least one slot of the second holder causing the second holder to move radially toward the central axis thereby causing the second cutter to move to the retracted position. When the seventh roller rolls over the extension ramp, the at least one ninth roller moves in the at least one slot of the third holder causing the third holder to move radially away from the central axis thereby causing the third cutter to move to the extended position. When the eighth roller rolls over the retraction ramp, the at least one ninth roller moves in the at least one slot of the third holder causing the third holder to move radially toward the central axis thereby causing the third cutter to move to the retracted position. When the tenth roller rolls over the extension ramp, the at least one twelfth roller moves in the at least one slot of the fourth holder causing the fourth holder to move radially away from the central axis thereby causing the fourth cutter to move to the extended position. When the tenth roller rolls over the retraction ramp, the at least one twelfth roller moves in the at least one slot of the fourth holder causing the fourth holder to move radially toward the central axis thereby causing the fourth cutter to move to the retracted position.

[0029] In an additional aspect, at least one spring is connected to the first cutter for biasing the first cutter against the interior wall of the tube when the first cutter is in the extended position, at least one spring is connected to the second cutter for biasing the second cutter against the interior wall of the tube when the second
5 cutter is in the extended position, at least one spring is connected to the third cutter for biasing the third cutter against the interior wall of the tube when the third cutter is in the extended position, and at least one spring connected to the fourth cutter for biasing the fourth cutter against the interior wall of the tube when the fourth cutter is in the extended position.

10 [0030] In a further aspect, the first cutter is wider than the second cutter and the third cutter is wider than the fourth cutter.

[0031] In an additional aspect, an arc defined by the first cutter in the extended position as the shaft rotates is longer than an arc defined by the second cutter in the extended position as the shaft rotates, and an arc defined by the third cutter in
15 the extended position as the shaft rotates is longer than an arc defined by the fourth cutter in the extended position as the shaft rotates.

[0032] 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 should be understood that some aspects of the present invention that have resulted
20 from attempting to attain the above-mentioned objects may not satisfy these objects and/or may satisfy other objects not specifically recited herein.

[0033] 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.

25 BRIEF DESCRIPTION OF THE DRAWINGS

[0034] 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:

[0035] Figure 1 is a cross-section of a portion of a pressure tube showing the rolled joint area;

[0036] Figure 2 is a perspective view of a circumferential sampling tool;

[0037] Figure 3 is a cross-sectional view of the circumferential sampling tool
5 of Fig. 2 taken through line A-A of Fig. 2 with both cutter assemblies disengaged from the drive module;

[0038] Figure 4 is a cross-sectional view of the circumferential sampling tool of Fig. 2 taken through line A-A of Fig. 2 with one of the cutter assemblies engaged with the drive module;

10 [0039] Figure 5 is a cross-sectional view of the circumferential sampling tool of Fig. 2 taken through line A-A of Fig. 2 with the other of the cutter assemblies engaged with the drive module;

[0040] Figure 6 is a cross-sectional view of the circumferential sampling tool of Fig. 2 taken through line B-B of Fig. 2 showing the drive module;

15 [0041] Figure 7 is a cross-sectional view of the circumferential sampling tool of Fig. 2 taken through line C-C of Fig. 2;

[0042] Figure 8 is a cross-sectional view of the circumferential sampling tool of Fig. 2 taken through line D-D of Fig. 7;

[0043] Figure 9 is an end view of an extension ramp of the circumferential
20 sampling tool of Fig. 2;

[0044] Figure 10 is a side view of the extension ramp of Fig. 9;

[0045] Figure 11 is an end view of a retraction ramp of the circumferential sampling tool of Fig. 2;

[0046] Figure 12 is a side view of the retraction ramp of Fig. 11; and

25 [0047] Figure 13 is a cross-sectional view of a portion of a pressure tube where a sample has been obtained using the circumferential sampling tool of Fig. 2.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0048] The circumferential 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 circumferential sampling tool could be used to collect other types of samples from other types of tubes or arcuate surfaces.

[0049] Turning to Fig. 2, an embodiment of a circumferential sampling tool 20 will be described. The tool 20 has a cylindrical body 21 having a central axis 22. The tool 20 has three main sections: the carriage module 23, the drive module 24, and the hydraulic regulator module 25. The carriage module 23, the drive module 24 and the hydraulic regulator module 25 are connected via flexible joints 26. The joints 26 allow the tool 20 to travel through the pressure tube sag without binding. It should be understood that the central axis 22 of the cylindrical body 21 illustrated in the figures corresponds to the axis resulting from the central axes of each of the modules 23, 24, 25 being coaxial. The cylindrical body 21 has a plurality of bearing pads 27 for supporting the tool 20 when the tool 20 is disposed inside the pressure tube. The bearing pads 27 are hydraulically actuated by an hydraulic system having a hydraulic regulator (not shown) housed in the hydraulic regulator module 25. Aperture 28 and 29 are defined in the carriage module 23. Cutter assemblies 30 and 31, described in greater detail below, are disposed inside the carriage module 23 in longitudinal alignment with the apertures 28 and 29 respectively. The cutter assembly 30 is held by a carriage 32. The carriage 32 is selectively connected via a splined coupler 34 to a driveshaft 36. Similarly, the cutter assembly 31 is held by a carriage 33. The carriage 33 is selectively connected via a splined coupler 35 to the driveshaft 36. As can be seen in Figs. 3 to 5, the carriages 32, 33 are disposed inside the carriage module 23 such that their splined couplers 34, 35 face each other. The driveshaft 36 is operatively connected to an electric drive motor 38 disposed in the drive module 24, as will be described in greater detail below. The electric drive motor 38 is used to selectively rotate the cutter assemblies 30 and 31 as will be described in greater detail below. The electric drive motor 38 is preferably a DC motor, however other types of motors are contemplated.

[0050] The circumferential sampling tool 20 is part of a circumferential sampling system, some of the features of which will be described briefly. The tool 20 is connected to a positioning system which permits accurate axial and angular positioning of the tool 20 in the pressure tube. A shielding sleeve is disposed over the tool 20 when the tool 20 is not pushed inside a pressure tube, thus closing the aperture 28. The tool 20, the positioning system, and the shielding sleeve are disposed on a support cart, which is preferably wheeled to facilitate the position of the cart.

[0051] Each of the cutter assemblies 30 and 31 can collect two samples. To obtain samples from the interior wall of a pressure tube (including a rolled joint region), the cart is first rolled in position adjacent an opened end of the tube. The opened end of the tube has an end fitting disposed thereon. The shielding sleeve is then connected to the end fitting. The positioning system is used to set the angular and axial position where the sample is to be collected inside the tube. As will be understood from the description of the cutter assemblies 30, 31 provided below, the cutter assemblies 30, 31 use gravity to collect the samples, and therefore the samples are normally collected from the upper half of the tube (i.e. between the 9 o'clock and 3 o'clock positions). The tool 20 is then pushed inside the tube such that the cutter assembly 30 is aligned with the location where a first sample is to be collected. The tool 20 is locked in this position and the bearing pads 27 are actuated to maintain the tool 20 in position by pushing against the interior wall of the tube. The driveshaft 36 is then moved axially, as described in greater detail below, such that a splined portion 40 of the driveshaft 36 moves from a disengaged position where it is disposed between the two couplers 34, 35, as shown in Fig. 3, to a position where it engages the coupler 34, as shown in Fig. 5. The drive motor 38 is then actuated, thus causing the cutter assembly 30 to rotate about the central axis 22. As it rotates, the cutter assembly cuts a portion of the interior wall of the tube in a circumferential direction thereof, thus obtaining the first sample. Additional details regarding this step will be provided below when describing the cutter assembly 30. The tool 20 is then unlocked and the bearing pads 27 released.

[0052] The tool 20 is then moved inside the tube (angularly and/or axially) such that the cutter assembly 30 is aligned with the location where a second sample is to be collected. The tool 20 is locked in this position and the bearing pads 27 are

actuated. The drive motor 38 is then actuated, thus causing the cutter assembly 30 to rotate about the central axis 22, thereby obtaining the second sample. The tool 20 is then unlocked and the bearing pads 27 released.

[0053] The tool 20 is then moved inside the tube (angularly and/or axially) such that the cutter assembly 31 is aligned with the location where a third sample is to be collected. The tool 20 is locked in this position and the bearing pads 27 are actuated. The driveshaft 36 is then moved axially such that the splined portion 40 of the driveshaft 36 moves from the position where it engages the coupler 34 to a position where it engages the coupler 35, as shown in Fig. 4. The drive motor 38 is then actuated, thus causing the cutter assembly 31 to rotate about the central axis 22 in the direction in which the cutter assembly 30 was rotated, thereby obtaining the third sample. The tool 20 is then unlocked and the bearing pads 27 released.

[0054] It is contemplated that the splined portion 40 of driveshaft 36 could be disengaged from the coupler 34 or 35, as the case may be, after each sample is obtained such that the driveshaft 36 does not engage the cutter assemblies 30, 31 while the tool 20 is being repositioned.

[0055] The tool 20 is then moved inside the tube (angularly and/or axially) such that the cutter assembly 31 is aligned with the location where a fourth sample is to be collected. The tool 20 is locked in this position and the bearing pads 27 are actuated. The drive motor 38 is then actuated, thus causing the cutter assembly 31 to rotate about the central axis 22, thereby obtaining the fourth sample. The tool 20 is then unlocked and the bearing pads 27 released.

[0056] It should be understood that the order in which the cutter assemblies 30, 31 are used to collect the samples could be different from those described above. For example, the cutter assembly 31 could be used to collect the first and fourth samples, and the cutter assembly 30 could be used to collect the second and third samples. It should also be understood that less than four samples could be collected.

[0057] Once all the samples have been collected, the tool 20 retracted back inside the shielding sleeve. The samples contained in the cutter assemblies 30, 31 are then transferred to flasks contained in the cart. The shielding sleeve is then disconnected from the end fitting and the cart is rolled away from the pressure tube.

Finally, the flasks containing the samples are retrieved. The above steps relate to one possible method of delivering the tool 20 inside a pressure tube to obtain samples. It should be understood that other methods of delivering the tool 20 are possible and contemplated.

- 5 [0058] Turning now to Figs. 7 and 8, the cutter assembly 30 will be described. The cutter assembly 31 is identical to the cutter assembly 30 and, for simplicity, will therefore not be described. It is contemplated, however, that at least some portions of the cutter assembly 31 could be different from the cutter assembly 30. For example, the cutter assembly 31 could be modified to provide wider and/or deeper cuts.
- 10 [0059] As can be seen in Fig. 7, the cutter assembly 30 has two oxide cutters 50A, 50B and two sample cutters 52A, 52B. The two oxide cutters 50A, 50B are disposed opposite to each other. Similarly the two sample cutters 52A, 52B are disposed opposite to each other. The sample cutters 52A, 52B are disposed perpendicularly to the oxide cutters 50A, 50B. It is contemplated that the oxide cutters 50A, 50B and the sample cutters 52A, 52B could be disposed at other angles to each other. It is contemplated that the cutter assembly 30 (and the cutter assembly 31) could only have one oxide cutter and one sample cutter. The oxide cutters 50A, 50B and the sample cutters 52A, 52B are preferably made of carbide. The oxide cutters 50A, 50B are wider than their corresponding sample cutters 52A, 52B for reasons explained further below.
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- 20

[0060] The oxide cutter 50A is connected by a threaded fastener 54A to an oxide cutter cartridge 56A. A chip clip 58A is connected to the oxide cutter cartridge 56A. The chip clip 58A retains the portion of the tube being cut by the oxide cutter 50A inside a receptacle 60A formed between the oxide cutter 50A, the oxide cutter cartridge 56A, and the chip clip 58A, as will be explained below. The oxide cutter cartridge 56A is connected by a bayonet-type mount 62A to an oxide cartridge holder 64A.

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[0061] Similarly, the sample cutter 52A is connected by a threaded fastener 66A to a sample cutter cartridge 68A. A chip clip 70A is connected to the sample cutter cartridge 68A. The chip clip 70A retains the sample being cut by the sample cutter 52A inside a receptacle 72A formed between the sample cutter 52A, the sample

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cutter cartridge 68A, and the chip clip 70A, as will be explained below. The sample cutter cartridge 68A is connected by a bayonet-type mount 74A to a sample cartridge holder 76A.

5 [0062] The cutters 50B and 52B are connected to corresponding cutter cartridges and cartridge holders and have corresponding chip clips, receptacles, and fasteners like the cutters 50A and 52A. Therefore, for simplicity, these elements have been labelled with the same reference numerals as for those of the cutters 50A and 52A but with the suffix B, and will not be described again in detail.

10 [0063] Each of the cutters 50A, 50B, 52A, and 52B is movable radially between a retracted position where it is disposed inside the cylindrical body 21 and an extended position where it extends in part through the aperture 28 to cut the interior wall of the tube. In a preferred embodiment, the distance between the oxide cutter 50A and the central axis 22 in its retracted and extended positions corresponds to the distance between the oxide cutter 50B and the central axis 22 in its retracted and
15 extended positions, and the distance between the sample cutter 52A and the central axis 22 in its retracted and extended positions corresponds to the distance between the sample cutter 52B and the central axis 22 in its retracted and extended positions. In Fig. 7, the cutters 50B, 52A, and 52B are in their respective retracted positions and the cutter 50A is in its extended position.

20 [0064] Each of the cutters 50A, 50B, 52A, and 52B is provided with an actuator to move it between the two positions as the cutter assembly rotates. Except as otherwise indicated, the actuators for each of the cutters 50A, 50B, 52A, and 52B are the same and actuate the cutters 50A, 50B, 52A, and 52B in the same way. Therefore only the actuator of the oxide cutter 50A will be described in detail.

25 [0065] As seen in Fig. 8, the actuator of the oxide cutter 50A includes an actuation bar 132A disposed generally parallel to the central axis 22. The actuation bar 132A has a roller 134A at a first end thereof, a roller 136A at a second end thereof, and two rollers 138A between the two ends thereof. As can be seen, the roller 134A is wider than the roller 136A, for reasons explained below. In the actuator for
30 the sample cutters 52A and 52B, the relative roller width of the end rollers is the opposite (i.e. the roller corresponding to the roller 134A is narrower than the roller

corresponding to the roller 136A), for reasons explained below. The two rollers 138A are received in two slots 140A formed in the lower portion of the oxide cartridge holder 64A. As can be seen, the two slots are disposed at an angle to the central axis 22. The actuation bar 132A is made in two parts 142A and 144A. The part 142A is received inside the part 144A and can move axially relative to the part 144A. Stacks of Belleville springs 146A bias the two parts 142A, 144A away from each other.

[0066] An extension ramp 150 is disposed inside of and is connected to the upper portion of the cylindrical body 21. As can be seen in Fig. 9, the extension ramp 150 defines an arc about the central axis 22. The extension ramp 150 extends generally parallel to the central axis toward the cutter assembly 30. As discussed below, the roller 134A rolls over the extension ramp 150 to move the oxide cutter 50A to its extended position.

[0067] A retraction ramp 152 is disposed inside of and is connected to the lower portion of the cylindrical body 21. As can be seen in Fig. 11, the retraction ramp 152 defines an arc about the central axis 22. The retraction ramp 152 extends generally parallel to the central axis toward the cutter assembly 30 and the extension ramp 150. As discussed below, the roller 136A rolls over the retraction ramp 152 to move the oxide cutter 50A to its retracted position.

[0068] As can be seen in Figs. 9 and 10, the extension ramp 150 has long ramp portions 154 and a short ramp portion 156. The wide rollers 134A, 134B of the actuators of the oxide cutters 50A, 50B roll over the long ramp portions 154. The corresponding rollers of the actuators of the sample cutters 52A, 52B, which are narrow, roll over the short ramp portion 156.

[0069] As can be seen in Figs. 11 and 12, the retraction ramp 152 is longer than the extension ramp 150, and similarly has long ramp portions 155 and a short ramp portion 157. The narrow rollers 136A, 136B of the actuators of the oxide cutters 50A, 50B roll over the short ramp portion 157 of the retraction ramp 152. The corresponding rollers of the actuators of the sample cutters 52A, 52B, which are wide, roll over the long ramp portions 155 of the retraction ramp 152.

[0070] When the splined portion 40 of the driveshaft 36 engages the splined coupler 34, as the drive motor 38 turns the cutter assembly 30 in the direction

indicated by arrow 158 in Fig. 7, the roller 134A rolls over the long portions 154 of the extension ramp 150. This causes the actuation bar 132A to move axially towards the left in Fig. 8. As the actuation bar 132A moves left (as seen in Fig. 8), the rollers 138A push against the slot 140A, which, due to their angle relative to the central axis 22, cause the oxide cartridge holder 64A to move upwardly. Therefore, the oxide cutter 50A moves to its extended position through the aperture 28. As the roller 134A rolls over the ramp 150, the oxide cutter 50A 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. In a preferred embodiment, the oxide cutter 50A cuts slightly deeper than the oxide layer to ensure complete removal of oxide. The chip clip 58A causes the chip of oxide layer to curl inside the receptacle 60A as it is being cut. The Belleville springs 146A bias the oxide cutter 50A against the surface of the tube thus providing a cutting force and permitting the cutter 50A to maintain contact with the surface should the surface be uneven. As the drive motor 38 continues to rotate, the roller 136A rolls over the short portion of the retraction ramp as the roller 134A rolls off the extension ramp 150A. This causes the actuation bar 132A to move axially towards the right in Fig. 8. As the actuation bar 132A moves right (as seen in Fig. 8), the rollers 138A push against the slot 140A, which, due to their angle relative to the central axis 22, cause the oxide cartridge holder 64A to move downwardly. Therefore, the oxide cutter 50A moves to its retracted position. Once the oxide cutter 50A no longer contacts the interior wall of the tube, the chip of oxide layer falls inside the receptacle 60.

[0071] As the drive motor 38 continues to rotate, the actuator of the sample cutter 52A moves the sample cutter 52A between its extended and retracted position in a similar manner. However, since the roller of this actuator rolls over the short portion 156 of the extension ramp 150, the arc defined by the sample cutter 52A as it moves against the surface of the interior wall of the tube is shorter than the arc defined by the oxide cutter 50A as it moves against the surface of the interior wall of the tube. Therefore the sample chip is shorter than the oxide layer chip.

[0072] The sample cutter 52A, when in the extended position, is disposed further from the central axis 22 than the oxide cutter 50A, thus resulting in the sample cutter 52A cutting deeper than the oxide cutter 50A. This is achieved by providing

shims (not shown) between the sample cutter 52A and the sample cutter cartridge 68A. Therefore, as can be seen in Fig. 13, the depth D_s of the cut made by the sample cutter 52A is greater than the depth D_o of the cut made by the oxide cutter 50A. Also, as previously mentioned, the sample cutter 52A is narrower than the oxide cutter 50A.

5 Therefore, as can also be seen in Fig. 13, the width W_s of the cut made by the sample cutter 52A is smaller than the width W_o of the cut made by the oxide cutter 50A. The deeper, narrower, and shorter cut made by the sample cutter 52A 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

10 pressure tube.

[0073] Once the sample has been cut by the sample cutter 52A and the sample cutter 52A has been returned to its retracted position, the drive motor 38 is stopped. The tool 20 is then repositioned in the pressure tube in order to obtain a second sample from a different location. Once the tool 20 is repositioned, the drive motor 38

15 is turned on so as to continue to rotate the cutter assembly 30 which causes the oxide cutter 50B to cut another oxide chip and the sample cutter 52B to cut another sample in the same manner as the one described above with respect to cutters 50A and 52A.

[0074] Once the sample has been cut by the sample cutter 52B and the sample cutter 52B has been returned to its retracted position, the drive motor 38 is stopped.

20 The splined portion 40 of the driveshaft 36 is disengaged from the splined coupler 34. The tool 20 is then repositioned in the pressure tube. Once the tool 20 is repositioned, the splined portion 40 of the driveshaft 36 engages the splined coupler 35. A third sample and a fourth sample can then be obtained by the cutter assembly 31 in the same manner as described above with respect to the cutter assembly 30.

25 [0075] As previously mentioned, it should be understood that the order in which the cutter assemblies 30, 31 are used to collect the samples could be different from those described above.

[0076] Therefore, the tool 20 advantageously allows four samples to be cut before the tool 20 has to be retracted back inside the shielding sleeve to transfer the

30 samples to flasks contained in the cart. It should also be understood that less than four samples could be collected.

[0077] Since the cutters of the cutter assemblies 30, 31 move about the circumference of the interior wall of the tube, they are not affected by surface variations in the axial direction of the tube. Therefore, the tool 20 can be used to obtain samples in the rolled joint region of the pressure tube.

- 5 [0078] Turning now to Fig. 6, the drive assembly 200 which rotates the driveshaft 36 and moves the driveshaft 36 axially such that the splined portion 40 of the driveshaft engages and disengages the splined couplers 34, 35 will be described.

[0079] The main components of the drive assembly 200 are the drive motor 38, an indexing motor 202 and a drive housing 204. The drive motor 38 and the
10 indexing motor 202 are disposed inside the drive housing 204 as shown. The drive housing 204 is disposed inside the drive module 24. The drive housing 204 is preferably waterproof in order to allow the tool 20 to operate in a wet environment.

[0080] An output shaft 206 of the drive motor 38 is connected to a drive output shaft 208. The drive output shaft 208 extends through the drive housing 204
15 and is rotatably supported in the drive housing 204 by bearings 210. The drive output shaft 208 is connected to a universal joint 212 (or another type of flexible drive coupling) which is connected to the driveshaft 36. This arrangement allows torque to be transmitted from the drive motor 38 to the driveshaft 36 even when the carriage module 23 is not coaxial with the drive module 24 (due to the pressure tube sag for
20 example).

[0081] The drive housing 204 is disposed between two supports 214, 216 connected inside the drive module 24. A shaft 218 extends from the support 214 to the support 216. The drive housing 24 is mounted on the shaft 218. Linear bearings 220 disposed between the drive housing 24 and the shaft 218 allow the drive housing
25 24 to slide along the shaft 218. The indexing motor 202 is connected to an indexing lead screw 222 which extends through the drive housing 24. The indexing lead screw 222 passes through the support 216 and is received in an indexing lead screw nut 224 connected to the support 216. By turning the indexing lead screw 222 using the indexing motor 202, the drive housing 204 slides along the shaft 218. As should be
30 understood, the direction in which the drive housing 204 slides depends on the direction in which the indexing lead screw 222 is turned. Since the driveshaft 36 is

connected to the drive motor 38 as described above, the movement of the drive housing 204 also causes the driveshaft 36 to move along the central axis 22. Therefore, by turning the indexing lead screw 222, the driveshaft 36 can be moved between the position where it engages the drive assembly 30 (Fig. 5), the position where it engages the drive assembly 31 (Fig. 4), and the position where it is disengaged from both drive assemblies 30, 31 (Fig. 3). It is contemplated that other types of actuators could be used to move the driveshaft 36 along the central axis 22. For example, a linear actuator, such as a linear hydraulic piston, disposed between the drive housing 204 and the support 216 could be used.

10 [0082] 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 tool for sampling an interior wall of a tube, comprising:

a body for insertion in the tube;

first and second blade carriages, each carrying a pair of blades;

a shaft extending along a longitudinal axis of said body, each of said first and second blade carriages selectively coupled to said shaft for rotation about said longitudinal axis, wherein a second blade of each pair follows a first blade of each pair through said rotation;

each blade radially movable to an extended position for cutting a sample from said interior wall;

at least one actuator for sequentially extending said first blade of a pair, and then said second blade of said pair, to cut samples from overlapping regions of said interior wall, wherein while one blade of said pair is extended, the other blade of said pair is retracted.
2. The tool of claim 1, comprising splined connections joining said blade carriages to said shaft, wherein said blade carriages can be de-coupled from said shaft by movement of said splined connections.
3. The tool of claim 1 or claim 2, wherein said first and second blade carriages are located at the same position along said longitudinal axis.
4. The tool of claim 1 or claim 2, wherein said first and second blade carriages are offset from one another along said longitudinal axis.
5. The tool of any one of claims 1 to 4, wherein each of said blades has a width measured along said longitudinal axis, wherein said width of said first blade is greater than said width of said second blade.
6. The tool of any one of claims 1 to 5, wherein said at least one actuator is configured to extend each blade at a respective angular position of the shaft.

7. The tool of any one of claims 1 to 6, wherein said second blade of each pair extends further than said first blade of each pair, for cutting a sample of greater depth.

8. The tool of any one of claims 1 to 7, comprising a receptacle mounted to receive a sample cut from said tube by said first blade or said second blade.

9. The tool of any one of claims 1 to 8, comprising a plurality of pairs of blades mounted to each of said blade carriages.

10. The tool of any one of claims 1 to 9, comprising a motor for driving said shaft, said motor in a housing sized for reception in said tube.

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

inserting a sampling tool in the tube, the sampling tool having a plurality of blade carriages, each having a pair of blades mounted thereto at different angular orientations;

coupling one of said blade carriages to a shaft extending along a longitudinal axis of said sampling tool;

rotating said one of said blade carriages about said longitudinal axis by turning said shaft, so that a second one of said blades follows a first one of said blades through said rotation;

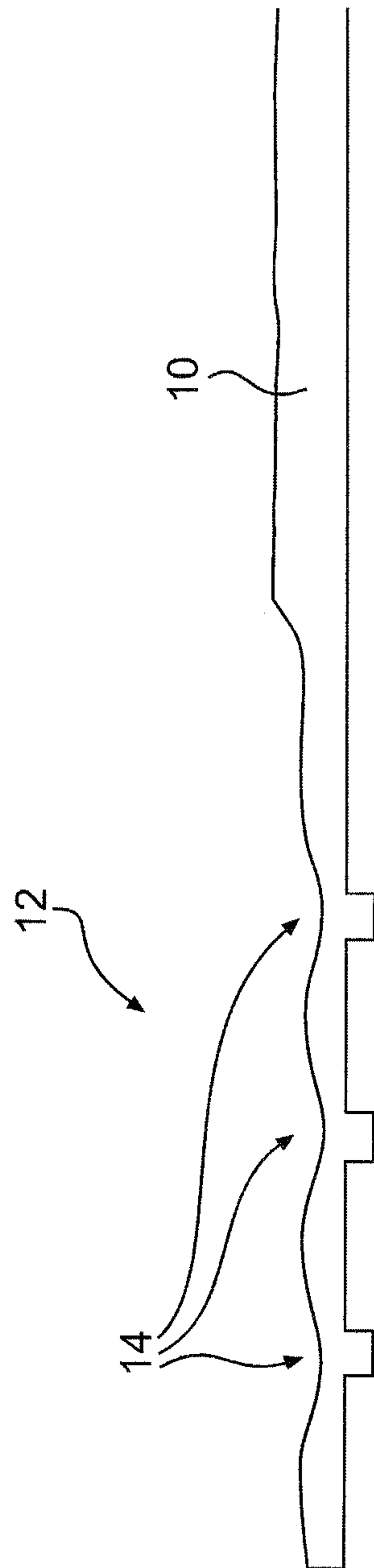
during said rotating, sequentially extending each of said blades in a radial direction to a cutting position for cutting a sample from said wall of said tube.

12. The method of claim 11, wherein said coupling comprises engaging a splined connection.

13. The method of claim 11 or claim 12, comprising cutting a sample from said interior wall with a blade mounted to a first blade carriage, and cutting a sample from said interior wall with a blade mounted to a second blade carriage, wherein said samples are cut at the same position along said longitudinal axis.

14. The method of claim 11 or claim 12, comprising cutting a sample from said interior wall with a blade mounted to a first blade carriage, and cutting a sample from said interior wall with a blade mounted to a second blade carriage, wherein said samples are cut at positions offset from one another along said longitudinal axis.
15. The method of any one of claims 11 to 14, comprising cutting a sample of a first longitudinal width with a first blade of a pair, and cutting a sample of a second longitudinal width less than said first longitudinal width, with a second blade of said pair.
16. The method of any one of claims 11 to 15, comprising rotating said blades by turning a shaft, and extending each blade at a respective angular position of said shaft.
17. The method of any one of claims 11 to 16, wherein said cutting position of a second blade of each pair is radially farther from said longitudinal axis than a first blade of each pair.
18. The method of any one of claims 11 to 17, comprising directing a sample cut from said said tube into a receptacle mounted to said body.
19. The method of any one of claims 11 to 18, wherein a plurality of pairs of blades are mounted to each blade carriage, further comprising cutting a first sample with a first pair of blades mounted to a blade carriage, and cutting a second sample with a second pair of blades mounted to said blade carriage.
20. The method of any one of claims 11 to 19, wherein said rotating comprises turning said shaft with a motor received in said tube.

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**FIG. 1**

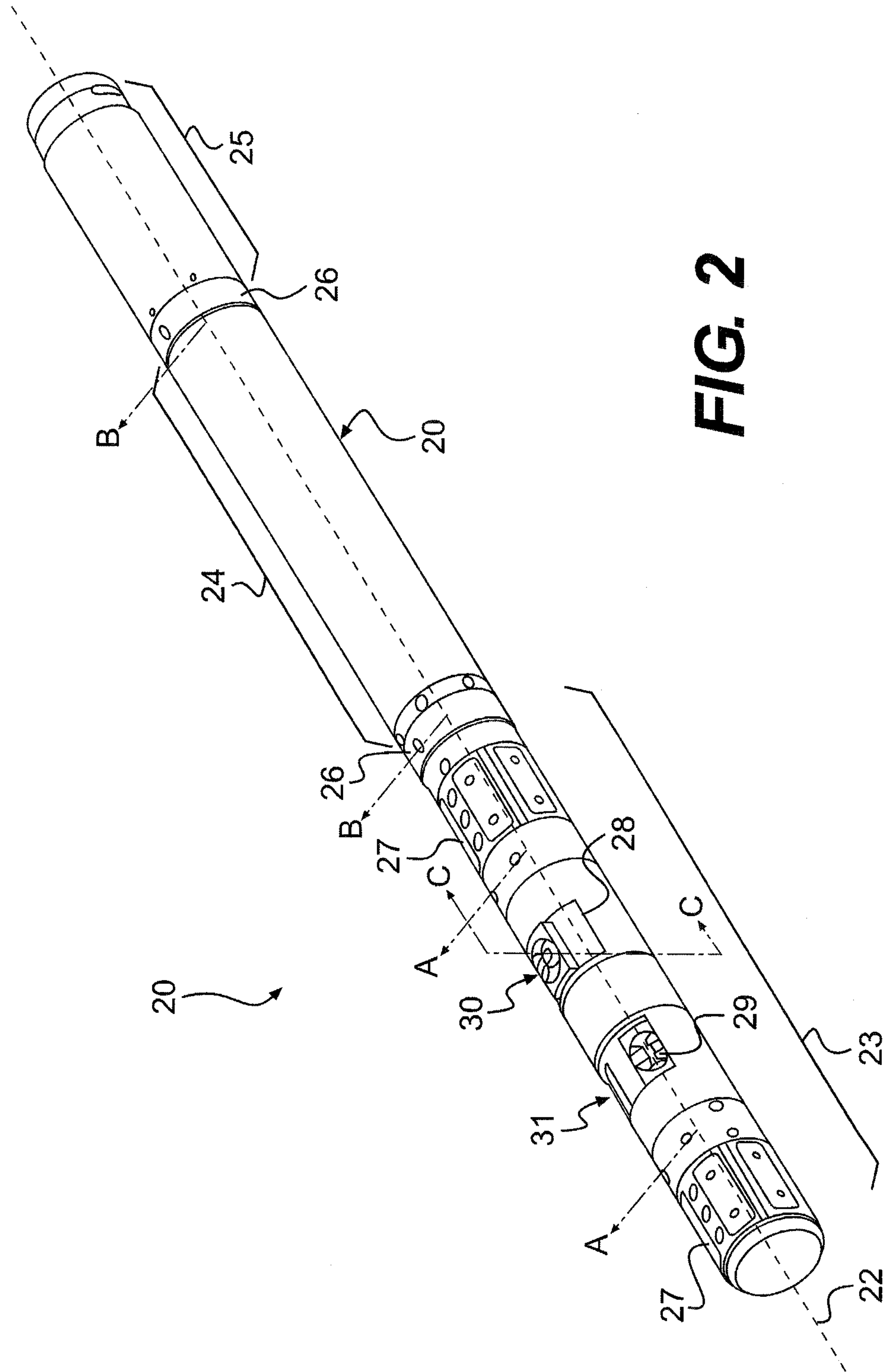
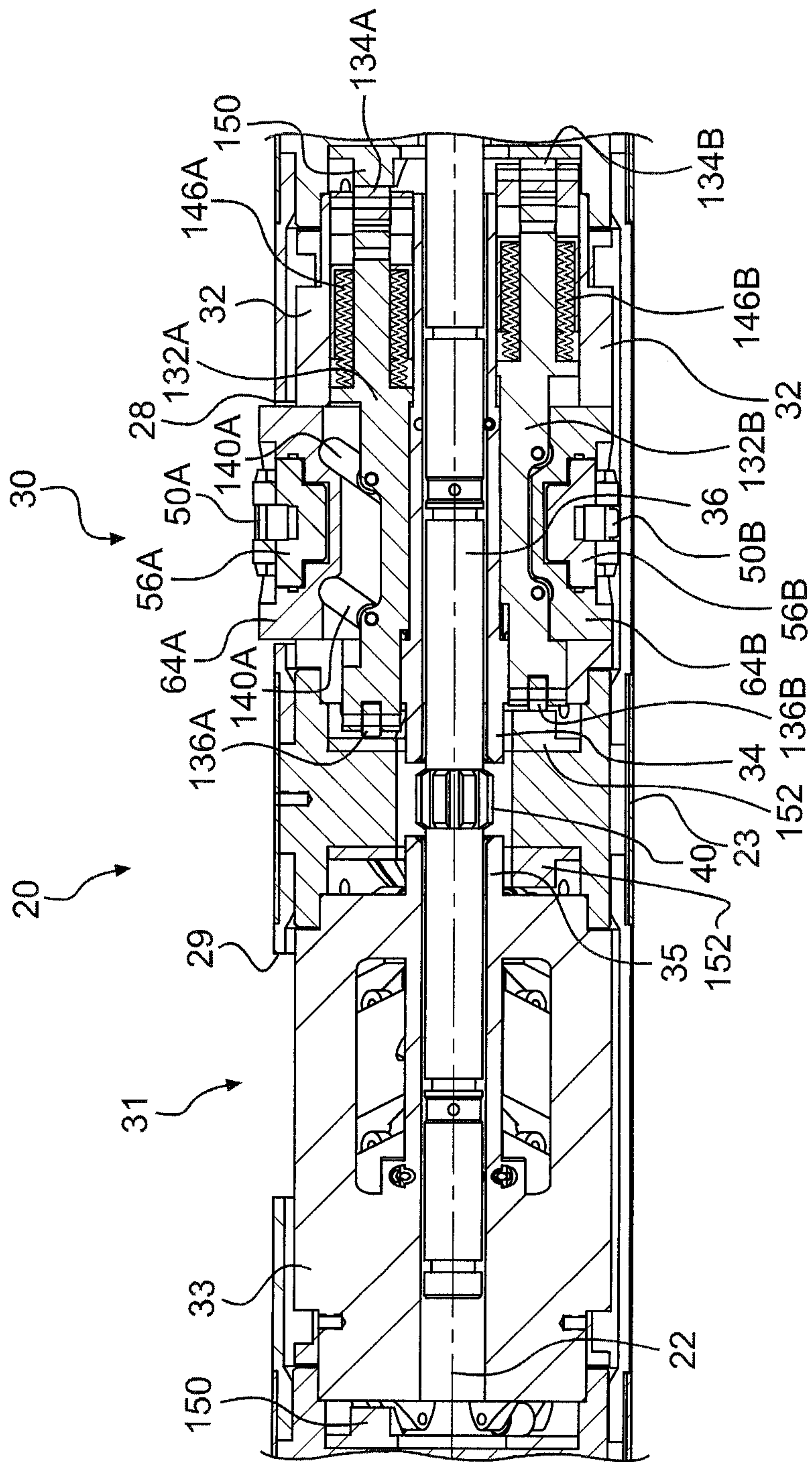


FIG. 2

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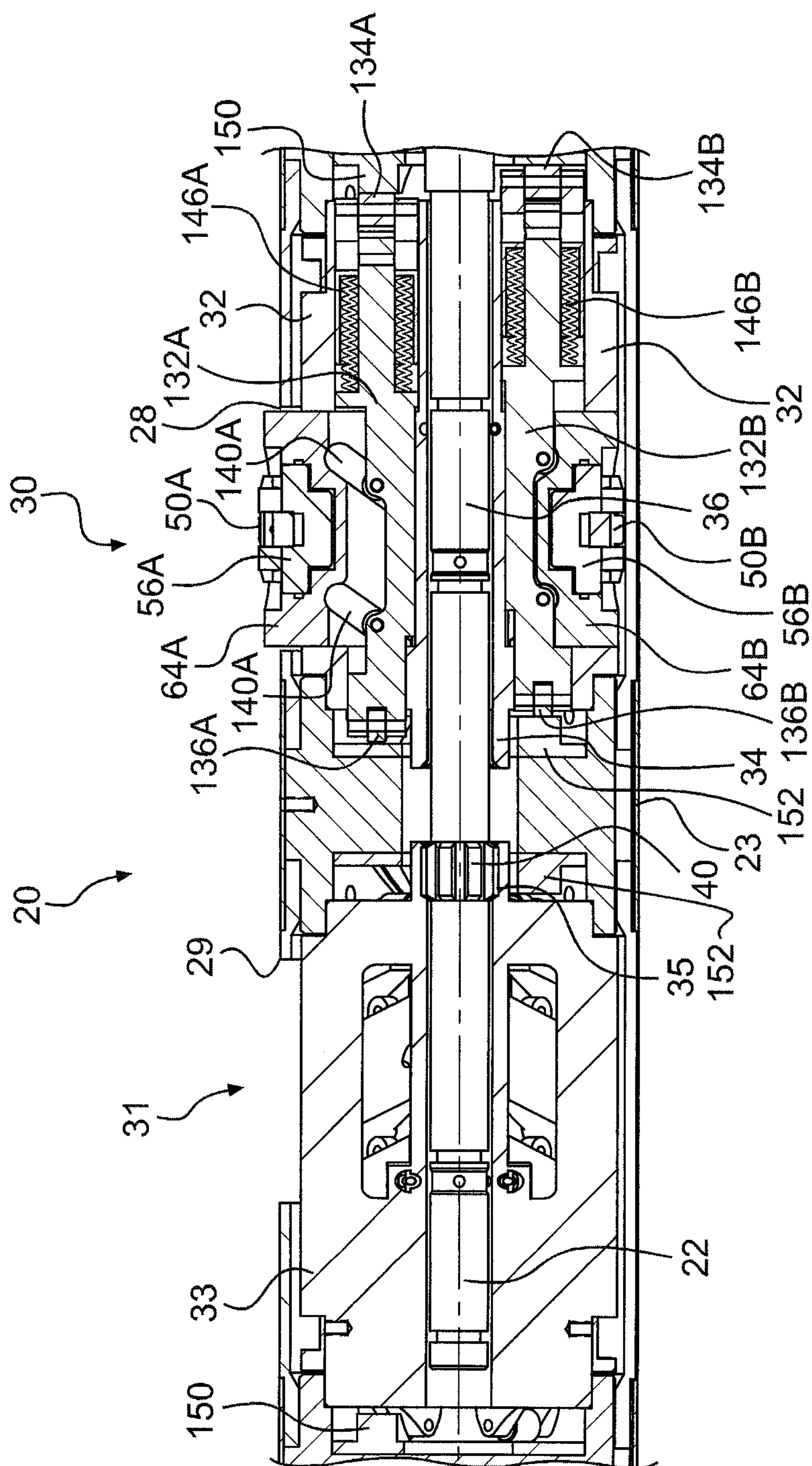
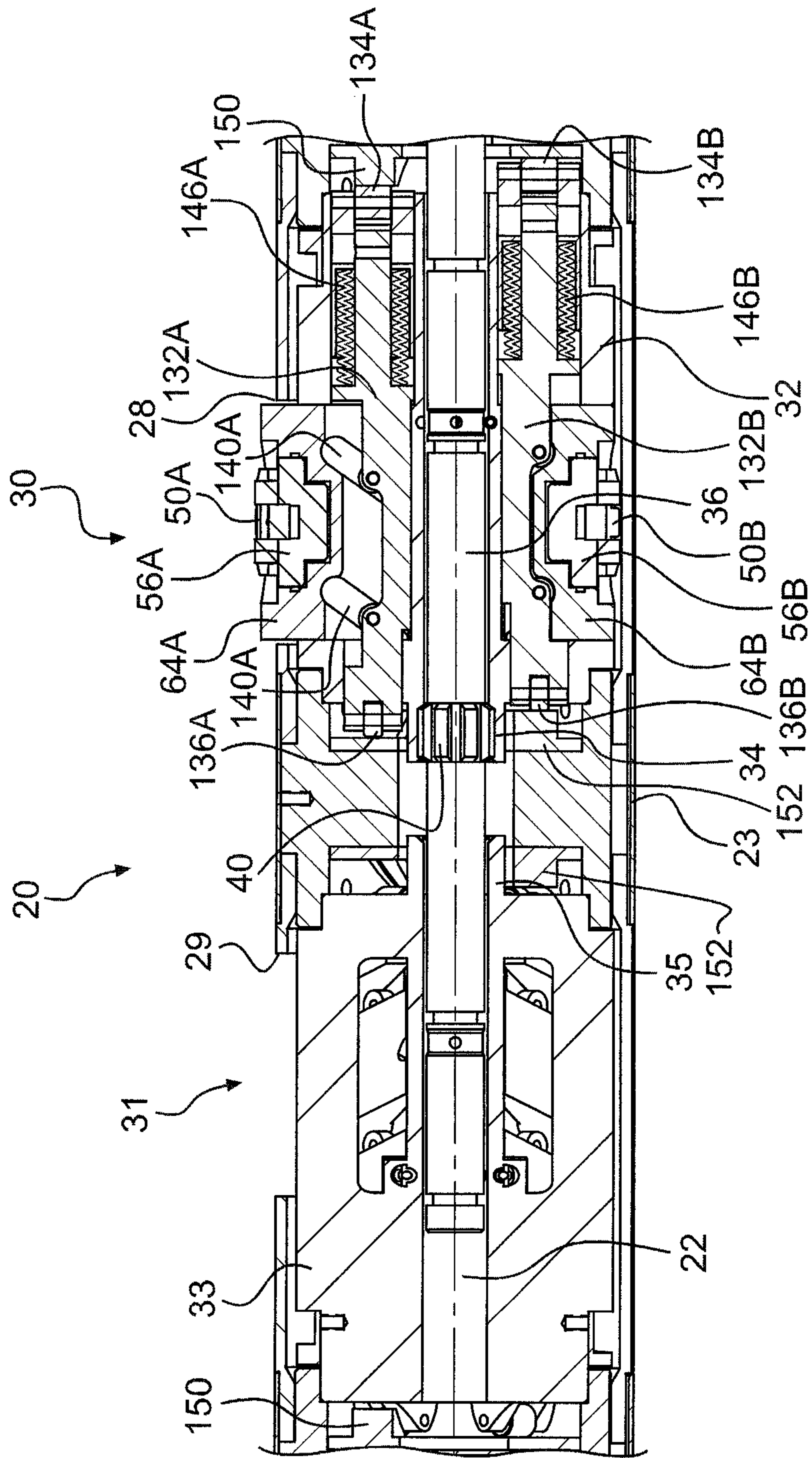


FIG. 4

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**FIG. 5**

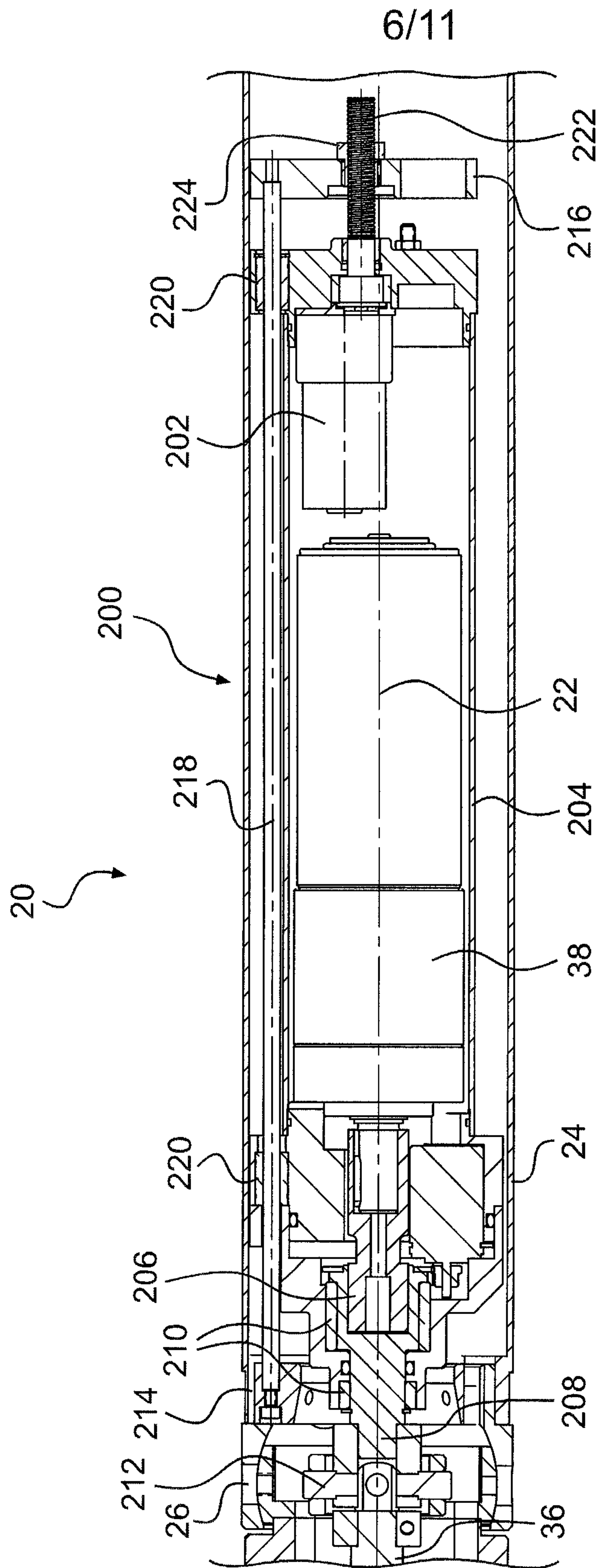
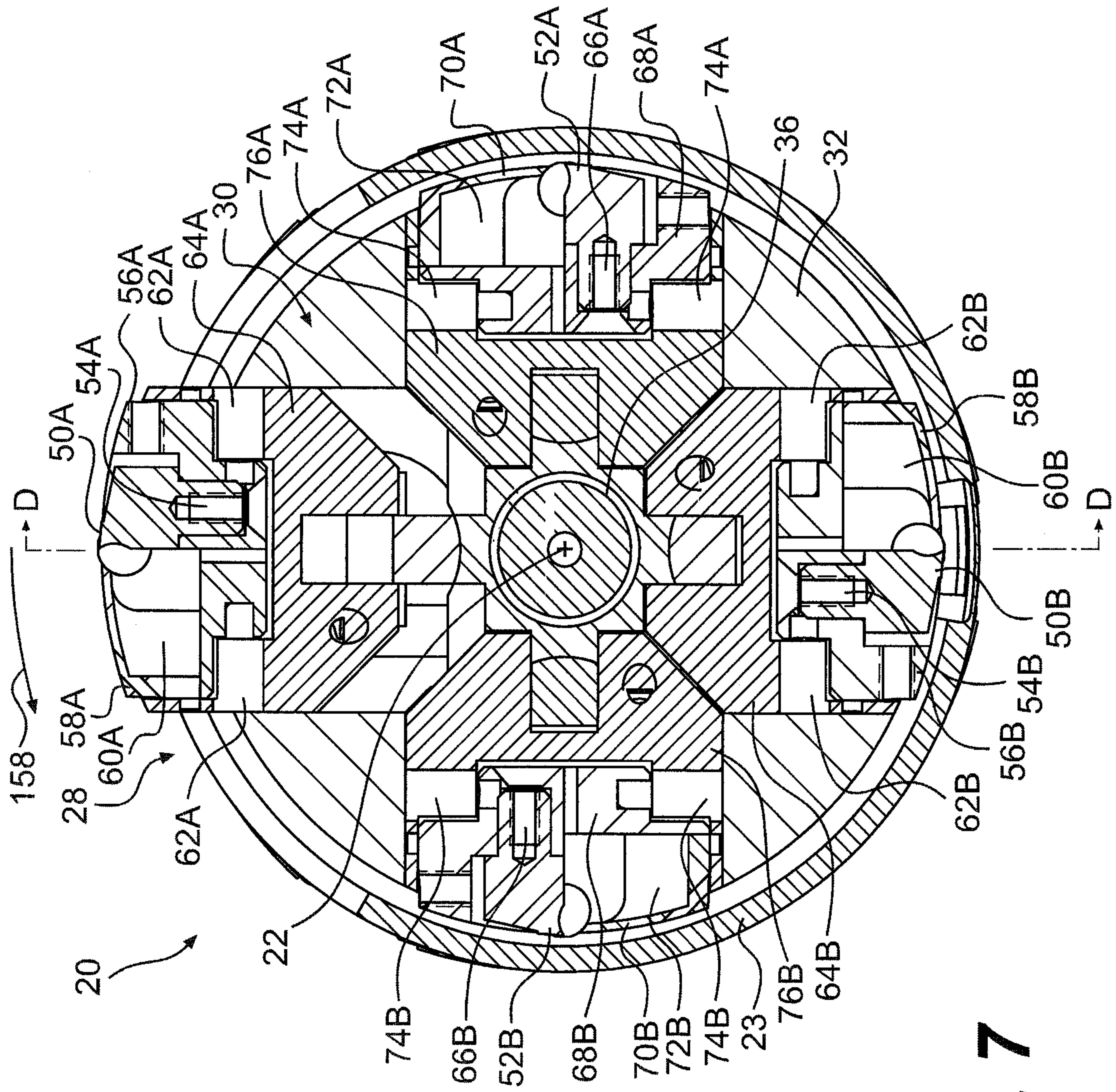
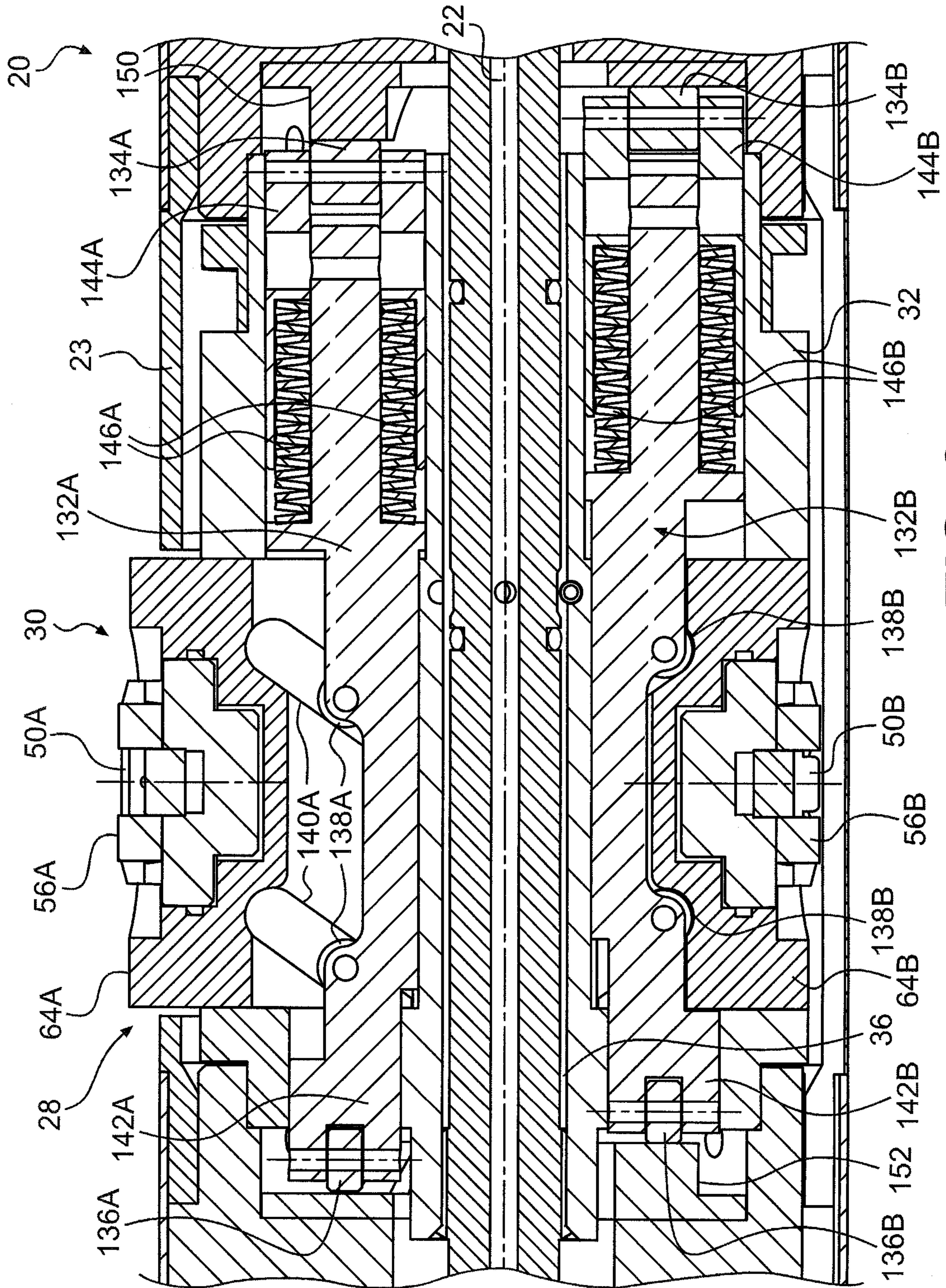


FIG. 6

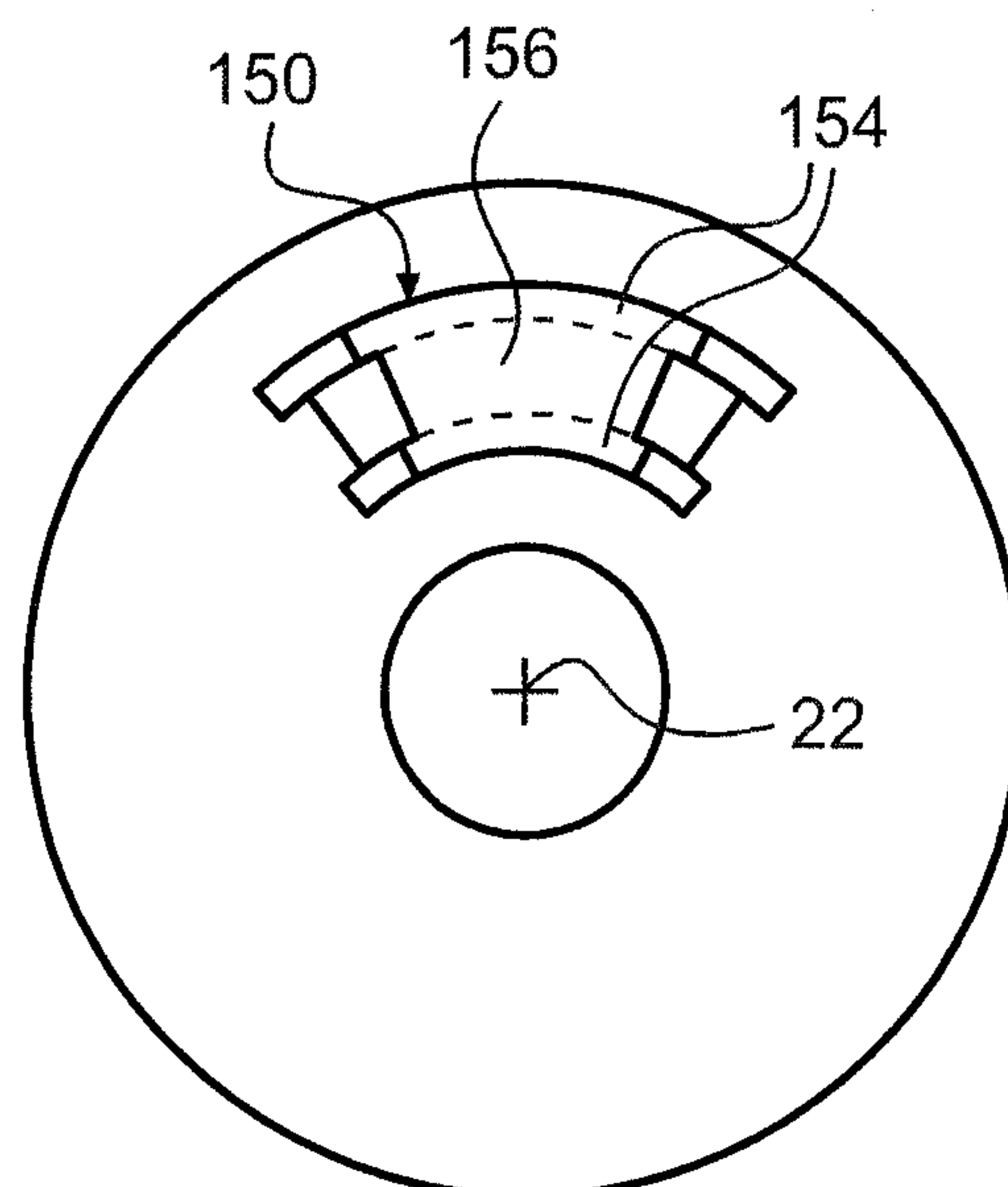
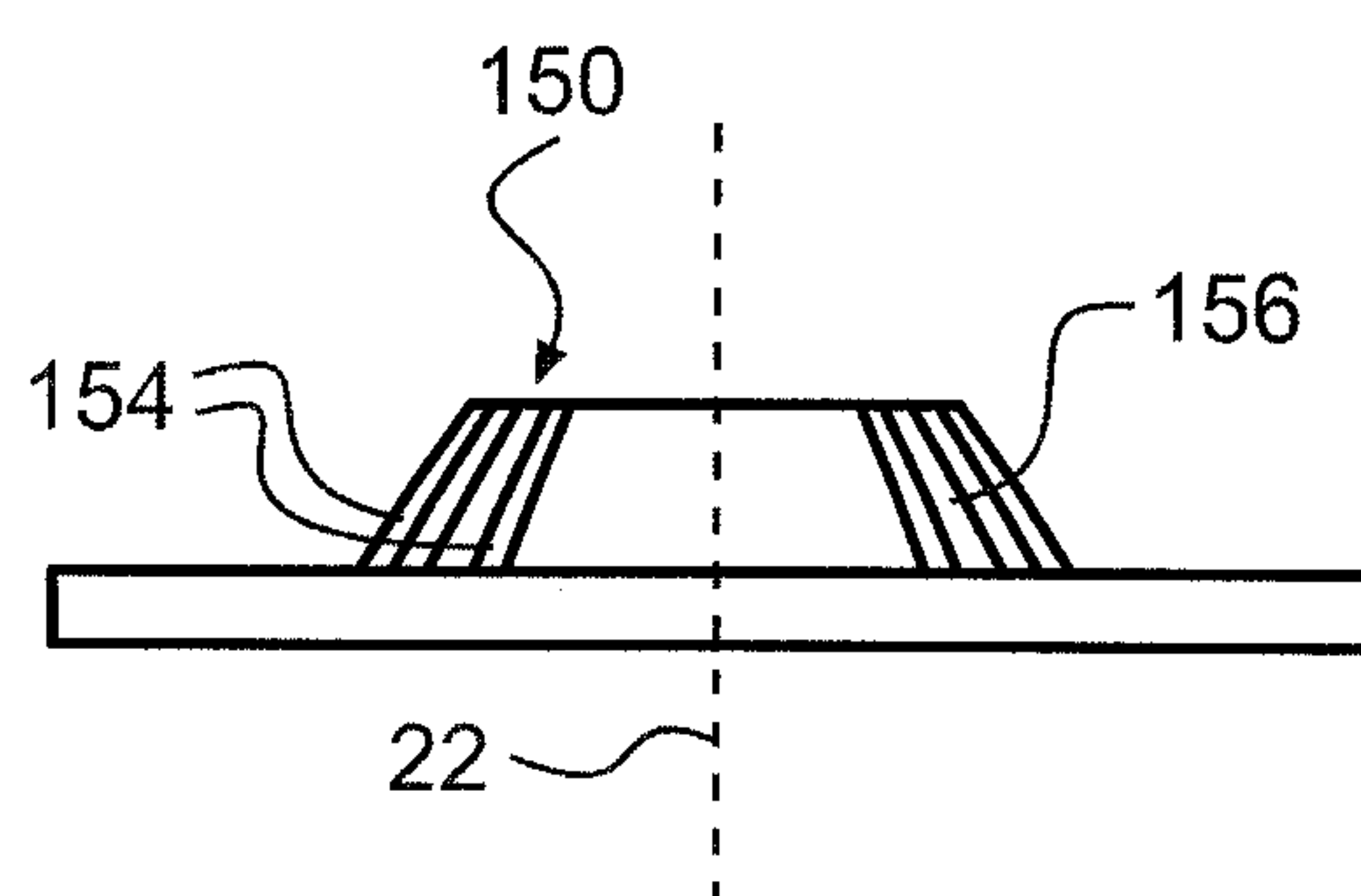
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**FIG. 7**

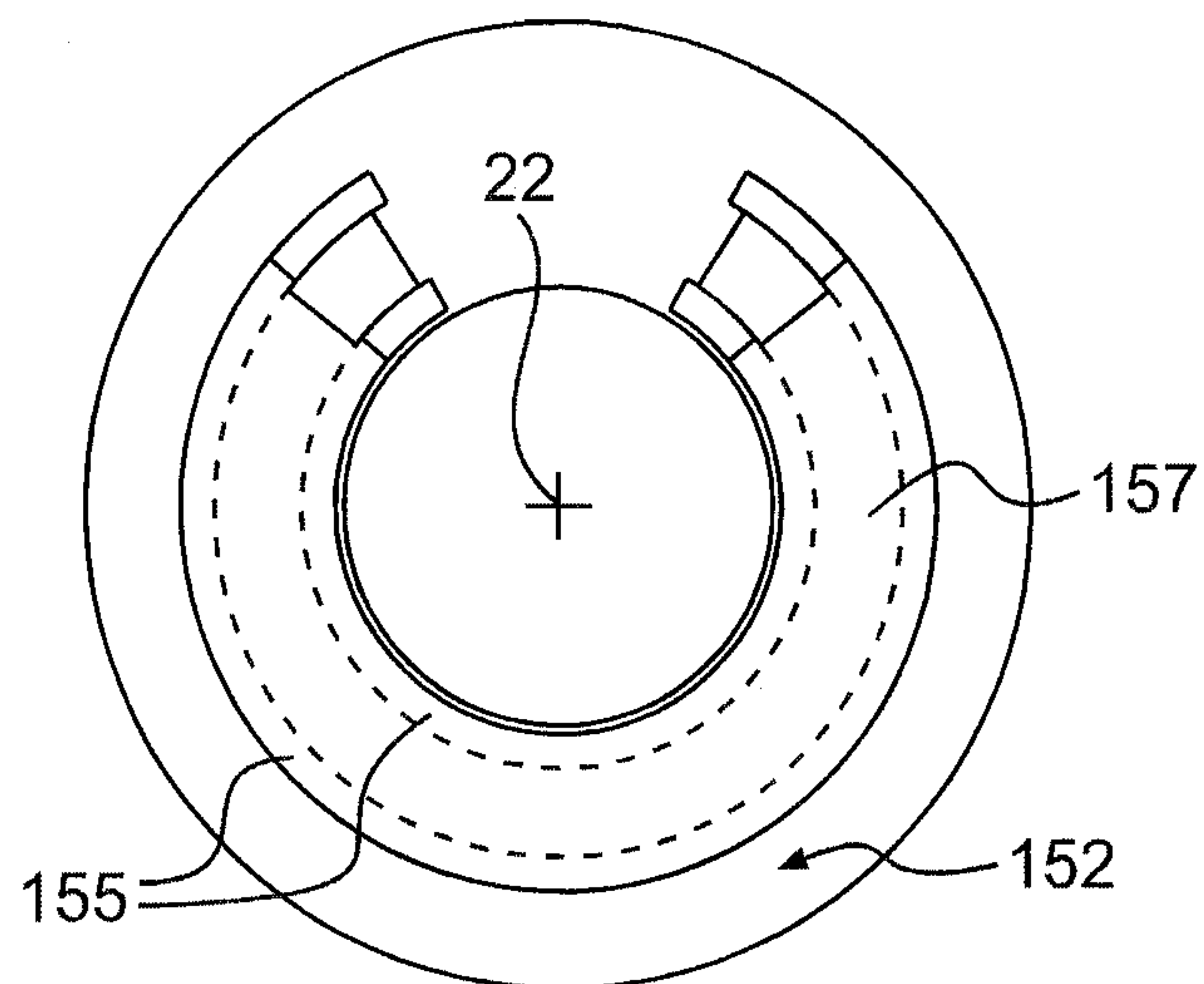
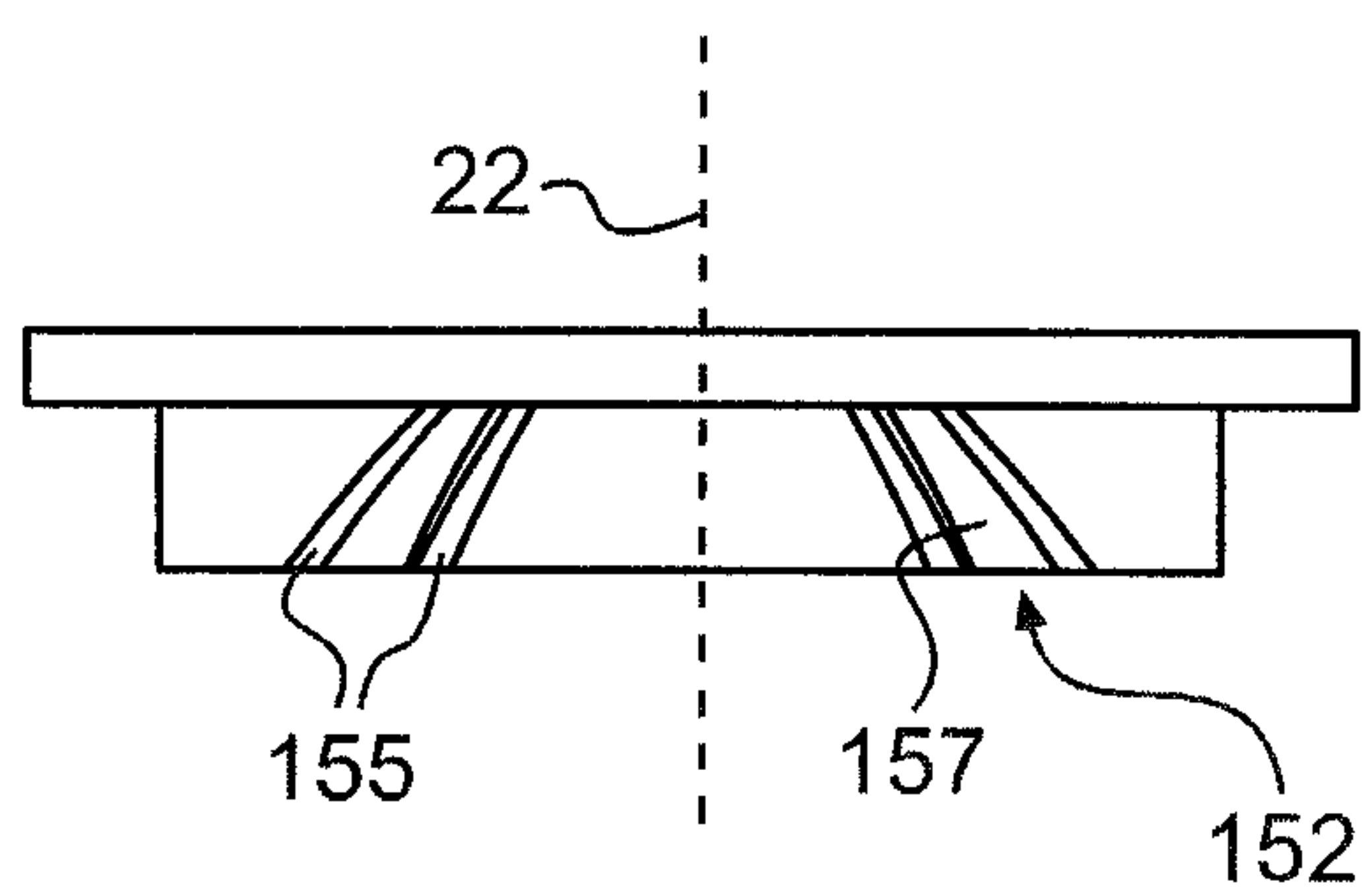
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**FIG. 8**

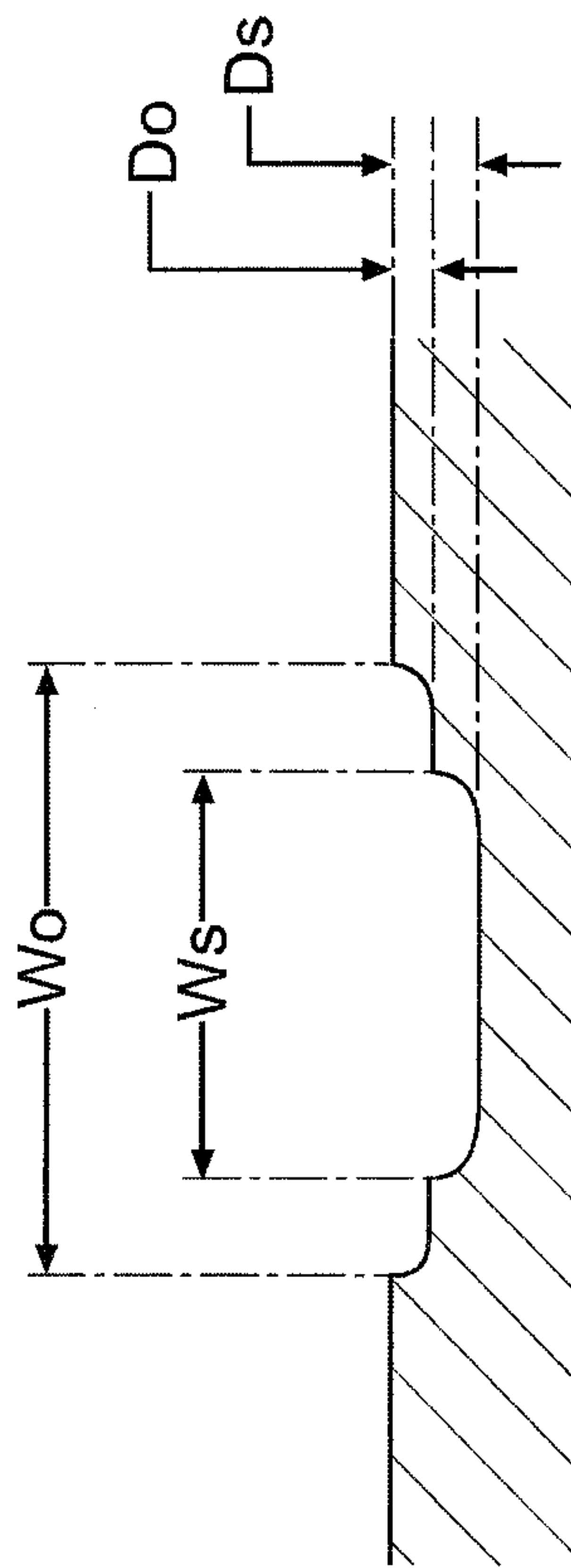
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**FIG. 9****FIG. 10**

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**FIG. 11****FIG. 12**

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**FIG. 13**

