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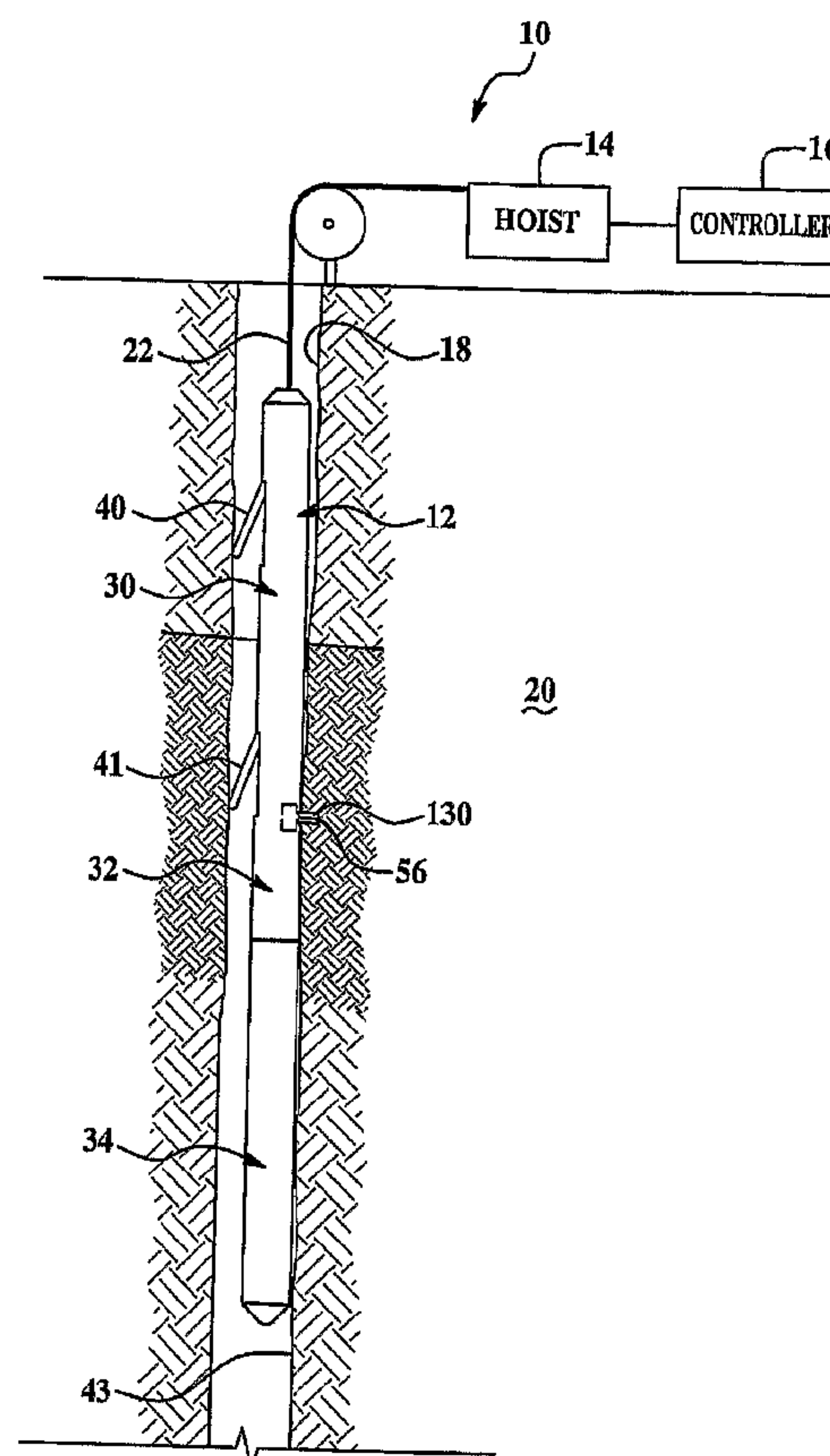
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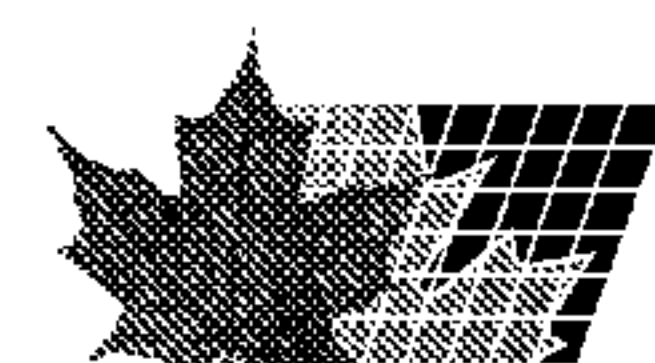
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(54) Title: ROTARY CORING DEVICE AND METHOD FOR ACQUIRING A SIDEWALL CORE FROM AN EARTH FORMATION



(57) Abrégé/Abstract:

A rotary coring device and method for acquiring a sidewall core from an earth formation adjacent a wellbore are provided. The rotary coring device includes a coring tool having a housing with a core receptacle therein and being adapted for positioning at



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

selected depths within the wellbore. The coring tool further includes a first gear assembly operably coupled to a rotary coring bit. The first gear assembly is configured to rotate the rotary coring bit. The rotary coring device further includes an electrical motor configured to drive the first gear assembly for rotating the rotary coring bit at one of a plurality of rotational speeds. The rotary coring device further includes a hydraulic actuator configured to move the rotary coring bit in a first direction toward the earth formation for obtaining the sidewall core and to move the rotary coring bit in a second direction away from the earth formation.

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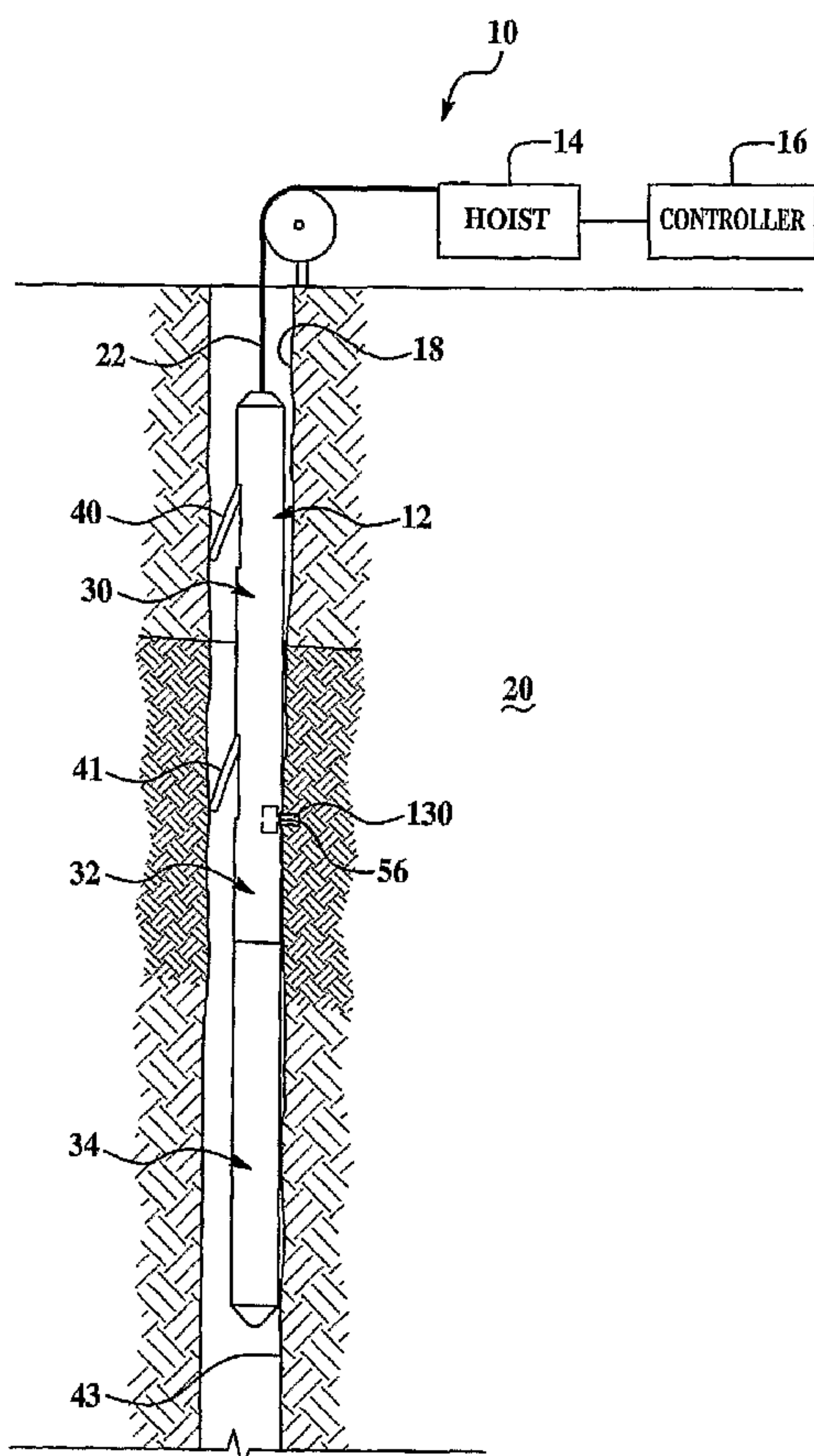
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coring bit in a first direction toward the earth formation for obtain-
ing the sidewall core and to move the rotary coring bit in a second
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ROTARY CORING DEVICE AND METHOD FOR ACQUIRING A SIDEWALL CORE FROM AN EARTH FORMATION

BACKGROUND

5 [0001] Rotary coring devices have been developed to obtain core samples from subsurface earth formations adjacent wellbores. One rotary coring device utilizes a hydraulic motor to rotate a rotary coring bit to obtain a core sample. A drawback with this rotary coring device is that when the device operates at relatively high temperatures (e.g., greater than 350° F), the viscosity of the oil driving the
10 hydraulic motor decreases. When the viscosity of the oil decreases, an output torque of the hydraulic motor is reduced below a desired torque level. Further, a rotational speed of a rotor of the hydraulic motor is reduced below a desired rotational speed.

 [0002] U.S. Patent No. 6,371,221 describes a rotary coring device that
15 utilizes a first electric motor for rotating a rotary coring bit and a second motor for linearly moving the rotary coring bit. A drawback with this rotary coring device is that when the rotary coring device is disposed several thousand feet underground, supplying power to two electric motors is extremely difficult due to large power losses in conductors extending from an above-ground power source to the rotary
20 coring device.

 [0003] Accordingly, the inventors herein have recognized a need for a rotary coring device that reduces and/or eliminates the above-mentioned deficiencies.

SUMMARY

25 [0004] Accordingly, in one aspect of the present invention there is provided a rotary cutting device for cutting an earth formation adjacent a wellbore, comprising:

- (a) a tool having a first gear assembly operably coupled to a bit, the first gear assembly configured to rotate the bit;
- 30 (b) an electrical motor configured to drive the first gear assembly for rotating the bit;
- (c) a controller electrically coupled to the electrical motor, the controller configured to generate communication signals to induce the electrical motor to rotate the bit at at least two speeds, a first rotational speed based on a first parameter
35 associated with a portion of the earth formation and a second rotational speed based

on a second parameter associated with a portion of the earth formation;

(d) a variable reluctance position sensor operably coupled to a rotor of the electrical motor, the position sensor generating position signals indicative of a rotational position of the rotor; and

5 (e) a hydraulic actuator configured to move the bit in a first direction away from the tool toward the earth formation.

[0005] According to another aspect of the present invention there is provided a method for cutting at least one hole in an earth formation, comprising:

(a) rotating a bit utilizing a first gear assembly being driven by an
10 electrical motor;

(b) generating commutating signals for controlling operation of the electrical motor at at least two rotational speeds utilizing a controller;

(c) generating position signals indicative of a rotational position of a rotor of the electrical motor utilizing a variable reluctance position sensor operably
15 coupled to the rotor;

(d) basing a first rotational speed of the electrical motor on a first parameter of the earth formation;

(e) basing a second rotational speed of the electrical motor on a second parameter of an earth formation; and

20 (f) moving the rotating bit in a first direction toward the earth formation utilizing a hydraulic actuator, to cut a hole in the earth formation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Figure 1 is a block diagram of a core extraction system having a
25 coring apparatus for obtaining a sidewall core from an earth formation, in accordance with an exemplary embodiment;

[0007] Figure 2 is a cross-sectional view of a portion of the rotary coring device utilized in the coring apparatus of Figure 1;

[0008] Figure 3 is a side view of a portion of the rotary coring device
30 utilized in the coring apparatus of Figure 1;

[0009] Figure 4 is an isometric view of a portion of a rotary coring device utilized in the coring apparatus of Figure 1;

[0010] Figure 5 is a schematic of the rotary coring device disposed in a
35 wellbore;

[0011] Figure 6 is a schematic of a hydraulic control system and hydraulic actuators for moving a coring tool of the rotary coring device to a desired position
70 within a wellbore;

[0012] Figure 7 is an isometric view of the coring tool utilized in the rotary coring device;

75 [0013] Figure 8 is a side view of a portion of the rotary coring device in a first operational position within the wellbore;

[0014] Figure 9 is a side view of the portion of the rotary coring device in a second operational position within the wellbore;
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[0015] Figure 10 is a side view of the portion of the rotary coring device in a third operational position within the wellbore;

[0016] Figure 11 is a side view of the variable reluctance position sensor
85 utilized in the rotary coring device, in accordance with an exemplary embodiment;

[0017] Figure 12 is an isometric view of a rotor utilized in the variable reluctance position sensor of Figure 11;

90 [0018] Figure 13 is a cross-sectional view of the variable reluctance position sensor of Figure 11;

[0019] Figure 14 is a cross-sectional view of the variable reluctance position sensor of Figure 13 taken along lines 14-14;
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[0020] Figure 15 is a cross-sectional view of the variable reluctance position sensor of Figure 13 taken along lines 15-15; and

[0021] Figure 16 is an electrical schematic of a position sensing system
100 utilized in the core extraction system of Figure 1.

[0022] Figures 17-19 are schematics of position signals generated by the variable reluctance position sensor of Figure 11.

105 **DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS**

[0023] Referring to Figure 1, a core extraction system 10 for obtaining a sidewall core from an earth formation 20 adjacent a wellbore is provided. The core extraction 10 includes a coring apparatus 12, a hoist 14, and a controller 16.

110 [0024] The coring apparatus 12 is disposed at selected depths within the wellbore 18 of the earth formation 20 via a wireline 22 coupled to the hoist 14. The coring apparatus 12 is configured to acquire at least one sidewall core of a portion of the earth formation proximate the wellbore 18 at a predetermined depth. The coring apparatus 12 includes an electro-hydraulic section 30, a rotary coring device 32, and a
115 core receptacle section 34.

[0025] The electro-hydraulic section 30 is provided to house electrical components and circuits for controlling the extension and retraction of locking arms 40, 41 in response to control signals from the controller 16. In particular, the electro-
120 hydraulic section 30 extends the locking arms 40, 41 in an outwardly direction to move the coring apparatus 12 adjacent a wall of the wellbore 18 for obtaining a sidewall core. Alternately, the electro-hydraulic section 30 retracts the locking arms 40, 41 to move the coring apparatus 12 away from the wall. The electro-hydraulic section 30 further includes a hydraulic control system 40, which will be described in
125 further detail below.

[0026] Referring to Figures 1-5, the rotary coring device 32 is provided to acquire sidewall cores from the earth formation 20. The rotary coring device 32 includes an electrical motor 50, a transmission assembly 52, a position sensing system
130 54, a coring tool 56, hydraulic actuators 58, 60, shafts 62, 64, guide plates 66, 68, pivot arms 70, 72, hydraulic actuators 74, 76, connecting arms 78, 80, and a core ejecting shaft 82.

[0027] Referring to Figure 2, the electrical motor 50 is provided to drive a gear assembly in the coring tool 56 for rotating a rotary coring bit 130 at one of a plurality of rotational speeds. In an exemplary embodiment, the electrical motor 50 comprises a DC electrical motor. It should be noted, however, that in other exemplary embodiments, the electrical motor 50 can comprise any other motor known to those skilled in the art, such as a variable reluctance motor or a switched reluctance motor for example. The electrical motor 50 includes a stator (not shown) and a rotor 90 that rotates at one of a plurality of rotational speeds, in response to commutation signals from the controller 16. For example, the controller 16 can generate commutation signals for inducing the electrical motor 50 to rotate at a first predetermined rotational speed in response to a predetermined parameter of the earth formation 20 at a first predetermined depth. Further for example, the controller 16 can generate commutation signals for inducing electrical motor 50 to rotate at a second predetermined rotational speed greater than the first predetermined speed, in response to a predetermined parameter of the earth formation 20 at a second predetermined depth. As shown, the electrical motor 50 is operably coupled to the transmission assembly 52. In particular, the rotor 90 of the motor 50 is operably coupled to a connecting member 100 of the transmission assembly 52.

[0028] Referring to Figures 2 and 4, the transmission assembly 50 is provided to transfer torque from the motor 52 to a gear assembly in the coring tool 56. The transmission assembly 52 includes housing portions 96, 98, a coupling member 100, a drive shaft 102, a bevel gear 104, and a pinion gear 106. The housing portions 96, 98 are operably coupled together and define an interior region for enclosing the remaining components of the transmission assembly 52. The coupling member 100 is operably coupled at first end to the rotor 90 of the motor 50. Further, the coupling member 100 is operably coupled at a second end to a first end of the drive shaft 102. A second end of the drive shaft 102 is fixedly attached to the bevel gear 104. Thus, rotation of both the rotor 90 induces rotation of the drive shaft 102 and the bevel gear 104. The bevel gear 104 is operably coupled to the pinion gear 106. Thus, rotation of the bevel gear 100 induces rotation of the pinion gear 106.

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[0029] Referring to Figures 4 and 7, the coring tool 56 is provided for extracting a sidewall core from the earth formation 20. The coring tool 56 includes a

housing 120, a gear assembly comprising a gear 122 and a gear 124, a movable plate 126, a pair of guide pins 128 (one being shown), a pair of guide pins 129 (one being shown), and a rotary coring bit 130. The housing 120 defines an interior region for holding the gear 122, the gear 124, and the movable plate 126. When the coring tool 56 is moved to an operational position where the pinion gear 106 of the transmission assembly 52 engages the gear 122, rotation of the pinion gear 106 induces rotation of the gear 122. Further, rotation of the gear 122 induces rotation of the gear 124 and the rotary coring bit 130. The movable plate 128 is movable along an axial direction of the rotary coring bit 130. The guide pins 128 are disposed on opposite sides of the movable plate 128 and are provided for the guiding movement of the rotary coring bit 130 in a linear direction (either outwardly or inwardly with respect to the housing 120) as will be explained in further detail below. The guide pins 129 are disposed on opposite sides of the housing 120 and are also provided for guiding movement of the rotary coring bit 130 in a linear direction (either outwardly or inwardly with respect to the housing 120) as will be explained in further detail below.

[0030] Referring to Figure 5, as discussed above, the rotary coring device 32 includes hydraulic actuators 58, 60. The hydraulic actuators 58, 60 are provided to move the coring tool 56 to desired operational positions within the wellbore 18. The hydraulic actuators 58, 60 are configured to extend and retract piston shafts 62, 64, respectively. The shafts 62, 64 are further coupled to the guide plates 66, 68, respectively.

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[0031] Referring to Figures 5 and 7, the guide plates 66, 68 are provided to guide movement of the coring tool 56. The guide plate 66 includes cam slots 140, 142 extending therethrough. The cam slots 140, 142 are provided receive therein guide pins 128, 129 on a first side of the coring tool 56. The guide plate 68 includes cam slots 144, 146 extending therethrough. The cam slots 144, 146 are provided to receive therein guide pins 128, 129 on a second side of the coring tool 56.

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[0032] Referring to Figures 5 and 8, the remaining components of the rotary coring device 32 will now be explained. The pivot arms 70, 72 are operably coupled to the housing 120 of the coring tool 56. The pivot arm 70 has an elongated portion 160 and a U-shaped portion 162. The elongated portion 160 is connected at a first

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end to the housing 120. The elongated portion 160 is connected at a second end to the connecting arm 78. The U-shaped portion 162 extends outwardly from the elongated portion 160 and is configured to allow movement of the pivot arm 70 relative to a stationary pin. The pivot arm 72 has an elongated portion 164 and a U-shaped portion 166. The elongated portion 164 is connected at a first end to the housing 120. The elongated portion 164 is connected at a second end to the connecting arm 80. The U-shaped portion 166 extends outwardly from the elongated portion 164 and is configured to allow movement of the pivot arm 72 relative to a stationary pin. The hydraulic actuators 74, 76 are operably coupled to the connecting arms 78, 84 respectively, controlling movement of the coring tool 56. In particular, hydraulic actuators 74, 76 retract or extend the connecting arms 78, 80, respectively, to move the coring tool 56. The core injecting shaft 82 is utilized to contact a sidewall core contained within the coring tool 56 for ejecting the core from the coring tool 56 into the core receptacle section 34 when the coring tool 56 is disposed in an upright position in the wellbore 18 as shown in Figure 8.

[0033] Referring to Figure 8, positioning of the coring tool 56 for acquiring a sidewall core will now be explained. Initially, as shown, the coring tool 56 is disposed beneath the transmission assembly 52 in the wellbore 18. Referring to Figures 6 and 9, thereafter, the controller 16 outputs command signals to the hydraulic control system 40. The command signals induce the hydraulic control system 42 to induce the hydraulic actuators 58, 60 to urge the guide plates 66, 68, respectively, upwardly which causes the rotary coring tool 56 to rotate such that the rotary coring bit 130 is moved outwardly from the housing 120 of the coring tool 56. In particular, the guide pins 128, 129 on a first side of the rotary coring tool 56 move within the cam slots 140, 142. Concurrently, the guide pins 128, 129 on a second side of the rotary coring tool 56 move within the cam slots 144, 146 on the guide plate 68. Referring to Figure 10, when the hydraulic actuators 58, 60 urge the guide plates 66, 66 to a predetermined extended position, the gear 106 of the transmission assembly 52 is operably coupled to the gear 122 of the coring tool 56, for transmitting torque to the gear 122. Further, the guide pins 128 attached to the movable plate 126 urge the movable plate 126 outwardly (rightwardly in Figure 10) such that the rotary coring bit 130 contacts a portion of the earth formation 20. Thereafter, the controller 16

235 generates commutation signals to induce the motor 50 to rotate the rotary coring bit
130 for acquiring a sidewall core.

[0034] Referring to Figures 13-16, the position sensing system 54 is provided
to generate position signals indicative of a rotational position of the rotor 90 of the
240 motor 50. The signals generated by the position sensing system 54 are received by
the controller 16 and the controller 16 generates commutation signals for controlling
operation of the motor 50, in response to the position signals. The position sensing
system 54 includes the variable reluctance position sensor 180 and the amplifier
circuit 182.

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[0035] Referring to Figures 11-15, the variable reluctance position sensor 180
is configured to be mechanically coupled to the rotor 90 of the motor 50 for
generating voltage signals indicative of a position of the rotor 90. An advantage of
the variable reluctance position sensor 180 is that the sensor is not electrically coupled
250 to the motor 50, thus eliminating electrical noise generated by the motor 50, from
position signals generated by the sensor 180. A further advantage of the variable
reluctance position sensor 180 is that the sensor 180 can generate accurate position
signals when operating at relatively high temperatures. The variable reluctance
position sensor 180 includes a housing 190, a rotor 192, magnets 194, 196, 198, 200,
255 202, 204, 206, 208, and a stator assembly 210.

[0036] The housing 190 is provided to enclose the remaining components of
the variable reluctance position sensor 180. The housing 190 is constructed from a
non-magnetic material, such as aluminum for example.

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[0037] The rotor 192 is positioned within an aperture defined by the stator
assembly 210. The rotor 192 is generally cylindrical-shaped and is constructed from a
non-magnetic material, such as plastic for example. The rotor 192 includes a first
plurality of apertures extending from an outer surface of the rotor 192 inwardly into
265 the rotor 192, for receiving magnets 194, 196, 198, and 200 therein. The magnets
194, 196, 198, and 200 are disposed at positions 90° apart from one another about an
axis 201, at a first predetermined axial position along the rotor 192. The rotor 192
includes a second plurality of apertures extending from the outer surface of the rotor

192 inwardly into the rotor 192, for receiving magnets 202, 204, 206, 208 therein.

270 The magnets 202, 204, 206, 208 are disposed at positions 90° apart from one another about the axis 201, at a second predetermined axial position along the rotor 192. The magnets 202, 204, 206, 208 are offset 45 degrees from magnets 194, 196, 198, and 200 about the axis 201. The rotor 192 further includes an aperture 193 extending from a first end of the rotor 192 inwardly into the rotor 192 a predetermined distance.

275 The aperture 193 is configured to receive an end of the rotor 90 of the motor 50 for fixedly coupling the rotor 192 to the rotor 90. Thus, the rotor 192 rotates at a substantially similar speed as the rotor 90 of the motor 50.

[0038] The stator assembly 210 includes a non-magnetic body portion 212,

280 coil brackets 214, 216, 218 and coils 230, 232, 234. The non-magnetic body portion 212 is generally ring-shaped and has an aperture extending therethrough with a diameter larger than an outer diameter of the rotor 192. In other words, a small air gap is defined between an outer surface of the rotor 192 and inner surface defined by the non-magnetic body portion 212. The coil brackets 214, 216, 218 are provided to

285 fixedly hold the coils 230, 232, 234, respectively thereon. The coil brackets 214, 216, 218 are configured to be disposed in apertures extending into an exterior surface of the non-magnetic body portion 212. The coil brackets 214, 216, 218 are disposed at positions 120° apart from one another about the axis 201. Further, the coil brackets 214, 216, 218 are constructed from carbon steel for concentrating magnetic flux from

290 the rotor magnets around the coils 230, 232, 234, respectively.

[0039] The operation of the variable reluctance position sensor 180 will now be explained. The sensor 180 utilizes an interaction between electromagnetic fields generated by the magnets on the rotor 192 and electrical currents generated in the

295 coils 230, 232, 234 in response to the electromagnetic fields moving past the coils 230, 232, 234 when the rotor 192 is rotating. Faraday's Law of electromagnetic induction, states that a voltage (i.e., an electro-magnetic force EMF) is induced in a conductor such as a coil, when magnetic flux lines are at a right angle with respect to the conductor. Thus, in particular, when a magnet moves past a coil having a length

300 (L), a number of turns (N) and a cross-sectional area (A)--at a velocity (w) radians per second, and the magnetic field (B) generated by the magnet moves at a right angle

uniformly past the conductor, a voltage (E) is induced in the coil that is described by the following equation:

$$E = BNLA\omega \sin(\omega t)$$

305 Further, because the coils 230, 232, 234 are displaced from each other by 120°, the voltages (Ea), (Eb), (Ec) generated in the coils 230, 232, 234, respectively by rotation of the magnets on the rotor 192 are described by the following equations:

$$E_a = BNLA\omega \sin(\omega t)$$

310 $E_b = BNLA\omega \sin(\omega t - 120^\circ)$

$$E_c = BNLA\omega \sin(\omega t - 240^\circ).$$

Referring to Figure 17, an exemplary voltage waveform 236 representing the voltage (Ea) generated by the coil 230 over time is illustrated. Further, referring to Figure 18, an exemplary voltage waveform 238 representing the
315 voltage (Eb) generated by the coil 232 over time is illustrated. Further, referring to Figure 19, an exemplary voltage waveform 240 representing the voltage (Ec) generated by the coil 234 over time is illustrated.

[0040] The relationship between the electrical position and the mechanical
320 position of the rotor 192 of the variable reluctance position sensor 180 is determined utilizing the following equation:

$$\theta_e = (Pr/2) * \theta_m$$

where:

325 θ_e corresponds to an electrical degree position of the rotor 192 for magnetic orientation;

θ_m corresponds to a mechanical degree position of the rotor 192; and

Pr corresponds to a number of magnets on the rotor 192.

[0041] The relationship between the mechanical and electrical speeds of the
330 rotor 192 is determined utilizing the following equation:

$$\omega_e = Pr/2 * \omega_m$$

where:

ω_e corresponds to an electrical speed in radians per seconds (or RPM) of the rotor 192;

335 ω_m corresponds to a mechanical speed in radians per second (or RPM)
of the rotor 192.

[0042] Referring to Figure 16, the amplifier circuit 182 for amplifying and
filtering out noise in the voltages (Ea), (Eb), and (Ec) is illustrated. The amplifier
340 circuit 182 includes differential amplifiers 250, 252, 254, noise cancellation
amplifiers 256, 258, 260, and conductors 262, 264, 266, 268, 270, 272, 274, 276, 278,
280, 282, and 284.

[0043] The coil 230 is electrically coupled to an input terminal of the
345 amplifier 250 via the conductor 262. The amplifier 250 has first and second output
terminals electrically coupled to first and second terminals of the amplifier 256 via the
conductors 264, 266, respectively. An output terminal of the amplifier 256 is
electrically coupled to the controller 16 via the conductor 268. During operation, the
amplifier 250 receives the voltage (Ea) from the coil 230 and outputs an amplified
350 voltage ($G \cdot E_a$) on the conductor 264 and an amplified voltage ($-G \cdot E_a$) on the
conductor 266, where G corresponds to a predetermined voltage gain. The noise
cancellation amplifier 256 outputs the voltage (Ea'), having less electrical noise than
voltage (Ea), in response to receiving the voltages ($G \cdot E_a$) and ($-G \cdot E_a$). The voltage
(Ea') which is indicative of the position of the rotor 90 is received by the controller
355 16.

[0044] The coil 232 is electrically coupled to an input terminal of the
amplifier 252 via the conductor 270. The amplifier 252 has first and second output
terminals electrically coupled to first and second terminals of the amplifier 258 via the
360 conductors 272, 274, respectively. An output terminal of the amplifier 258 is
electrically coupled to the controller 16 via the conductor 276. During operation, the
amplifier 252 receives the voltage (Eb) from the coil 232 and outputs an amplified
voltage ($G \cdot E_b$) on the conductor 272 and an amplified voltage ($-G \cdot E_b$) on the
conductor 274, where G corresponds to the predetermined voltage gain. The noise
365 cancellation amplifier 258 outputs the voltage (Eb'), having less electrical noise than
voltage (Eb), in response to receiving the voltages ($G \cdot E_b$) and ($-G \cdot E_b$). The voltage

(Eb') which is also indicative of the position of the rotor 90 is received by the controller 16.

370 [0045] The coil 234 is electrically coupled to an input terminal of the amplifier 254 via the conductor 278. The amplifier 254 has first and second output terminals electrically coupled to first and second terminals of the amplifier 260 via the conductors 280, 282, respectively. An output terminal of the amplifier 260 is electrically coupled to the controller 16 via the conductor 284. During operation, the
375 amplifier 254 receives the voltage (Ec) from the coil 234 and outputs an amplified voltage ($G \cdot E_c$) on the conductor 280 and an amplified voltage ($-G \cdot E_c$) on the conductor 282, where G corresponds to the predetermined voltage gain. The noise cancellation amplifier 260 outputs the voltage (Ec'), having less electrical noise than voltage (Ec), in response to receiving the voltages ($G \cdot E_c$) and ($-G \cdot E_c$). The voltage
380 (Ec') which is indicative of the position of the rotor 90 is received by the controller 16.

[0046] Referring again to Figure 1, the controller 16 is provided to control operation of the coring apparatus 12 and the hoist 14. In particular, the controller 16
385 generates control signals for controlling operation of the hoist 14 for positioning the rotary coring device 32 at predetermined depths within the wellbore 18. Further, the controller 16 generates control signals for controlling operation of the hydraulic control system 44 for orientating the coring tool 56 of the rotary coring device 32 within the wellbore 20 for acquiring a sidewall core. Further, the controller 16
390 generates control signals for controlling operation of the motor 50 utilized in the rotary coring device 32 for driving the rotary coring bit 130. Further, the controller 16 receives the position voltages (Ea') (Eb'), (Ec') from the position sensing system 54 and utilizes the position voltages for controlling operation of the motor 50.

395 [0047] The rotary coring device and the method for acquiring a sidewall core provide a substantial advantage over other devices and methods. In particular, the rotary coring device provides a technical effect of utilizing an electric motor to drive a rotary coring bit which operates effectively at relatively high temperatures, (e.g. greater than 350°F) while utilizing a hydraulic actuator to orientate the coring tool

400 within a wellbore which reduces the amount of electrical power needed to obtain the
sidewall core.

[0048] The above-described methods can be embodied in the form of
computer-implemented processes and apparatuses for practicing those processes. In
405 an exemplary embodiment, the method is embodied in computer program code
executed by the computer or controller. The method may be embodied in the form of
computer program code containing instructions embodied in tangible media, such as
floppy diskettes, CD-ROMs, hard drives, or any other computer-readable storage
medium, wherein, when the computer program code is loaded into and executed by a
410 controller, the controller becomes an apparatus for practicing the invention.

[0049] The terms “first,” “second,” and the like, herein do not denote any
order, quantity, or importance, but rather are used to distinguish one element from
another, and the terms “a” and “an” herein do not denote a limitation of quantity, but
415 rather denote the presence of at least one of the referenced item. Unless defined
otherwise, technical and scientific terms used herein have the same meaning as is
commonly understood by one of skill in the art to which this invention belongs.

[0050] While the invention has been described with reference to an exemplary
420 embodiment, it will be understood by those skilled in the art that various changes may
be made and equivalents may be substituted for elements thereof without departing
from the scope of the invention. In addition, many modifications may be made to
adapt a particular situation or material to the teachings of the invention without
departing from the essential scope thereof. Therefore, it is intended that the invention
425 not be limited to the particular embodiment disclosed as the best mode contemplated
for carrying out this invention, but that the invention will include all embodiments
falling within the scope of the appended claims.

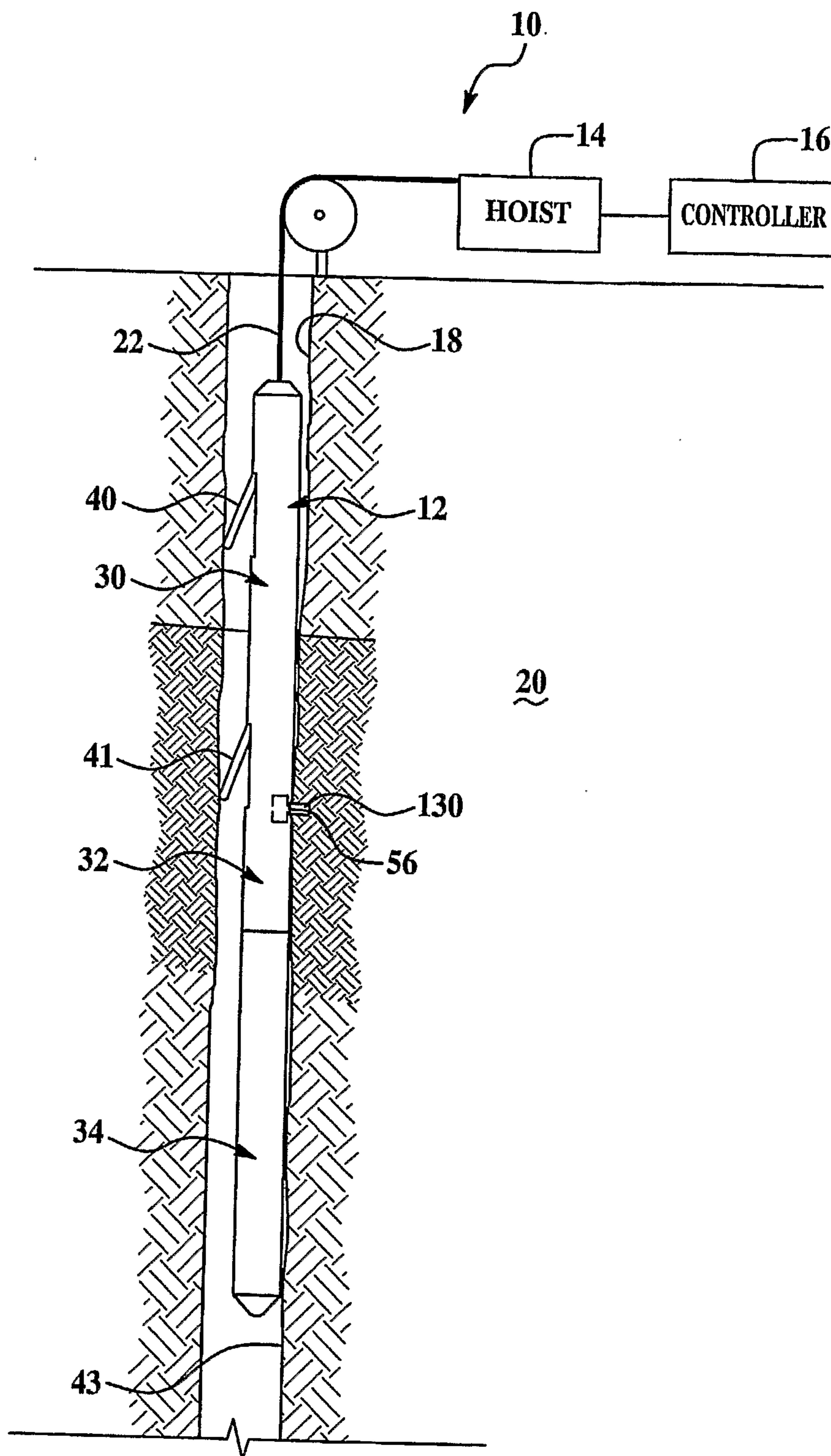
What is claimed is:

1. A rotary cutting device for cutting an earth formation adjacent a wellbore, comprising:
 - (a) a tool having a first gear assembly operably coupled to a bit, the first gear assembly configured to rotate the bit;
 - (b) an electrical motor configured to drive the first gear assembly for rotating the bit;
 - (c) a controller electrically coupled to the electrical motor, the controller configured to generate communication signals to induce the electrical motor to rotate the bit at at least two speeds, a first rotational speed based on a first parameter associated with a portion of the earth formation and a second rotational speed based on a second parameter associated with a portion of the earth formation;
 - (d) a variable reluctance position sensor operably coupled to a rotor of the electrical motor, the position sensor generating position signals indicative of a rotational position of the rotor; and
 - (e) a hydraulic actuator configured to move the bit in a first direction away from the tool toward the earth formation.
2. The rotary cutting device of claim 1, wherein the electrical motor comprises a DC electrical motor.
3. The rotary cutting device of claim 1, further comprising a drive shaft assembly operably coupled between the electrical motor and the first gear assembly, the drive shaft assembly comprising a drive shaft and a second gear assembly, the drive shaft being coupled at a first end to the rotor of the electrical motor, the drive shaft being coupled at a second end to the second gear assembly, the second gear assembly being operably coupled to the first gear assembly.
4. The rotary cutting device of any one of claims 1 to 3, wherein the hydraulic actuator is further configured to move the bit in a second direction opposite the first direction.
5. The rotary cutting device of claim 1, wherein the bit is further configured to obtain a sidewall core from the earth formation.

6. The rotary cutting device of claim 1, wherein the hydraulic actuator is further configured to rotate the tool in an angular range of 0-90 degrees.
7. The rotary cutting device of claim 6, wherein at the 0 degree position the bit extends in a direction substantially parallel to the earth formation and at the 90 degree position the bit extends in another direction substantially perpendicular to the earth formation.
8. A method for cutting at least one hole in an earth formation, comprising:
 - (a) rotating a bit utilizing a first gear assembly being driven by an electrical motor;
 - (b) generating commutating signals for controlling operation of the electrical motor at at least two rotational speeds utilizing a controller;
 - (c) generating position signals indicative of a rotational position of a rotor of the electrical motor utilizing a variable reluctance position sensor operably coupled to the rotor;
 - (d) basing a first rotational speed of the electrical motor on a first parameter of the earth formation;
 - (e) basing a second rotational speed of the electrical motor on a second parameter of the earth formation; and
 - (f) moving the rotating bit in a first direction toward the earth formation utilizing a hydraulic actuator, to cut a hole in the earth formation.
9. The method of claim 8, further comprising moving the bit in a second direction away from the earth formation utilizing the hydraulic actuator.
10. The method of claim 8, further comprising moving the bit in a second direction opposite the first direction.
11. The method of claim 8, further comprising obtaining a sidewall core from the earth formation utilizing the bit.
12. The method of claim 8, further comprising rotating the tool in an angular range of 0-90 degrees.

13. The method of claim 12, wherein at the 0 degree position the bit extends in a direction substantially parallel to the earth formation and at the 90 degree position the bit extends in another direction substantially perpendicular to the earth formation.

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**Figure 1**

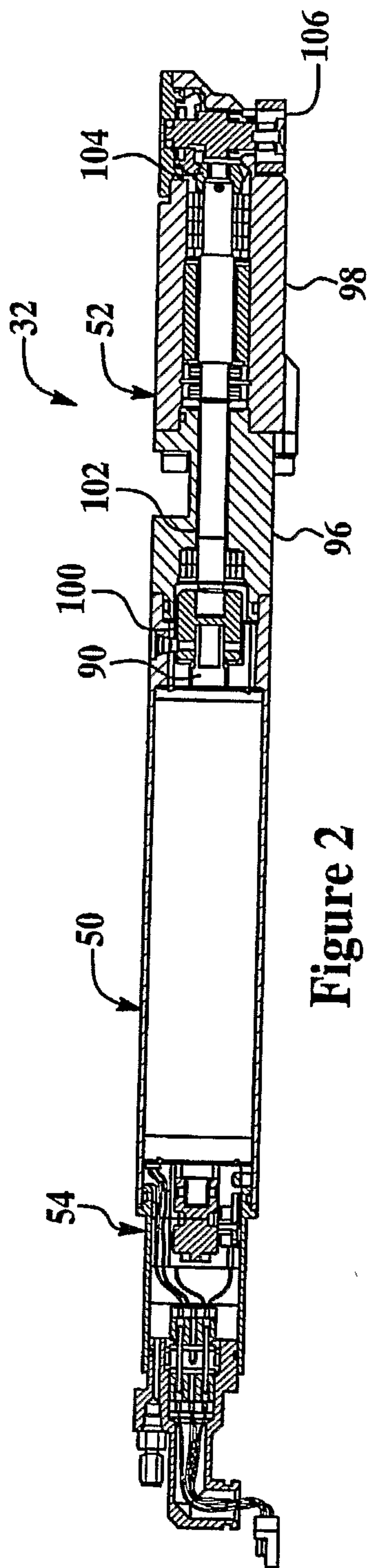


Figure 2

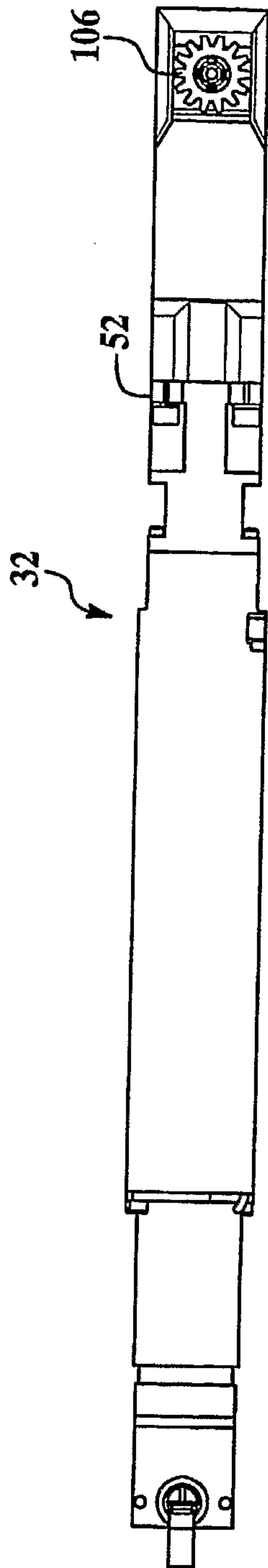


Figure 3

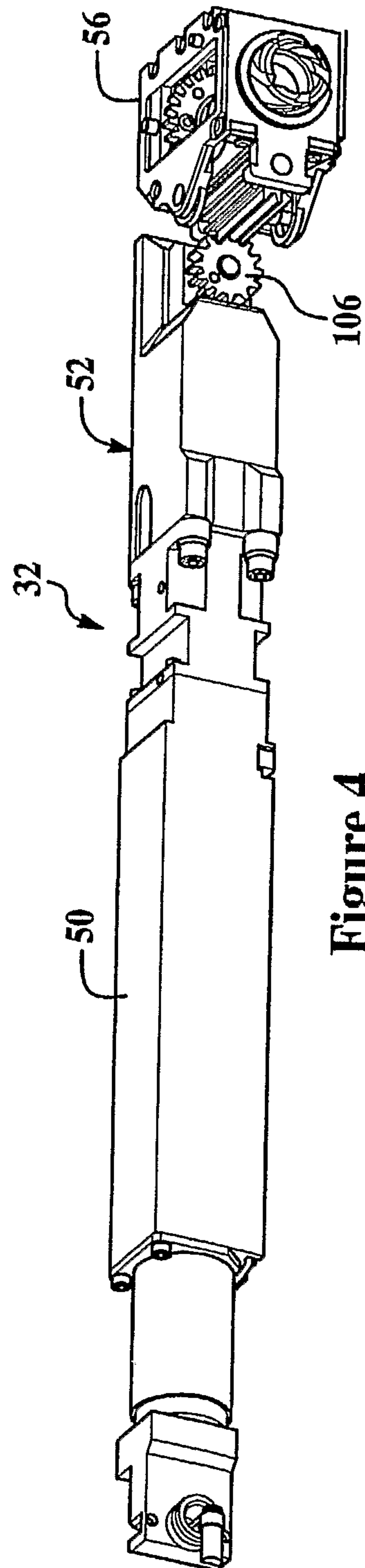


Figure 4

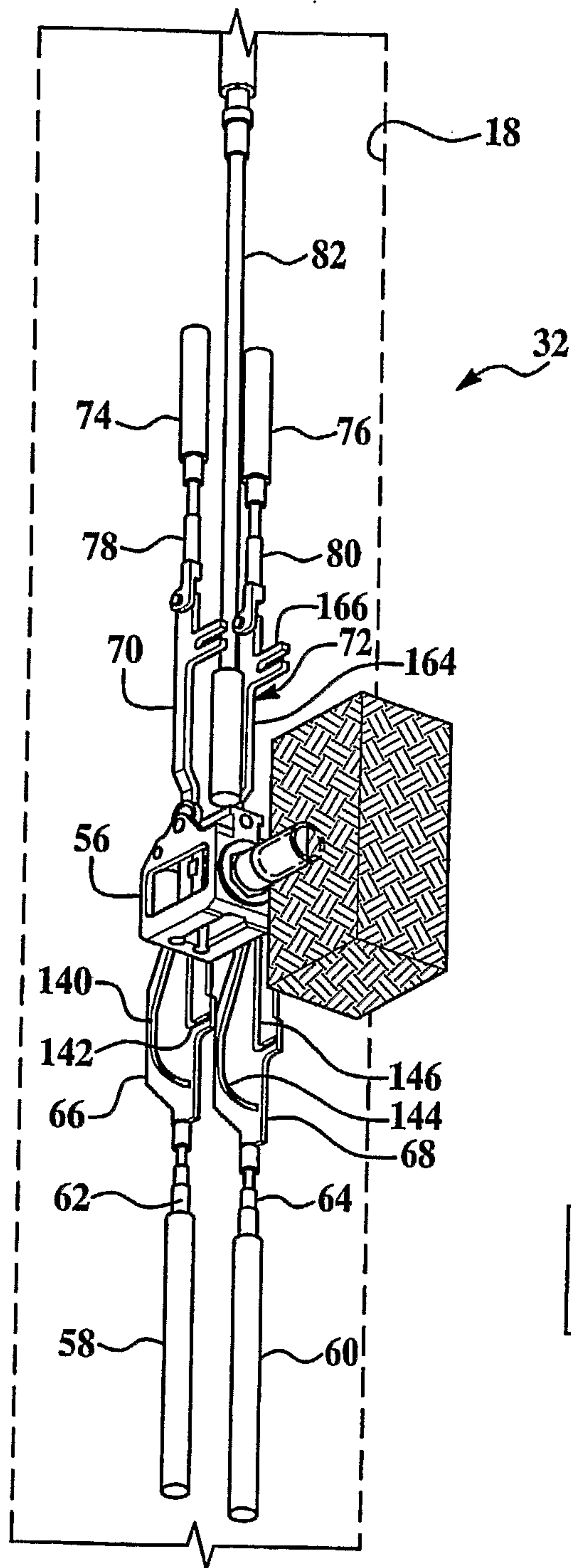


Figure 5

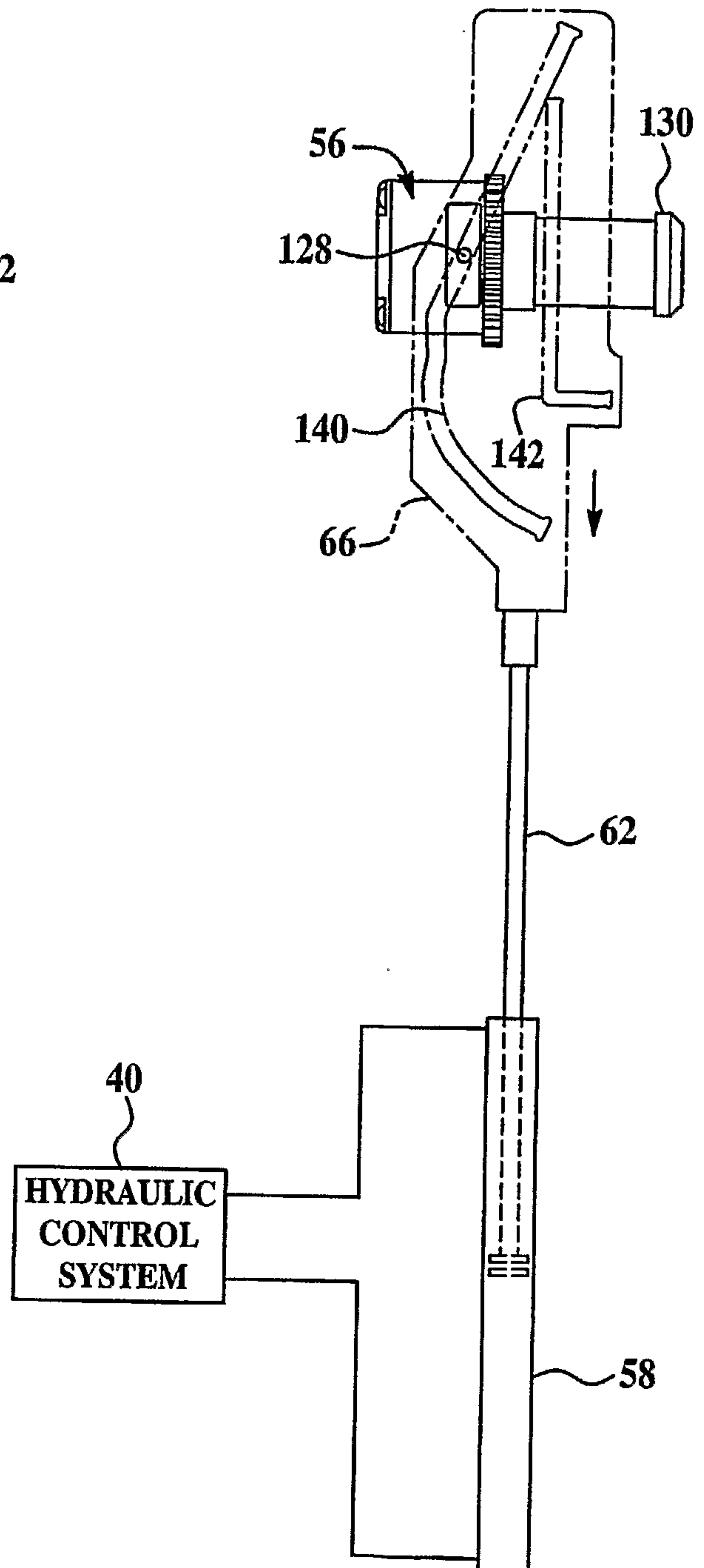


Figure 6

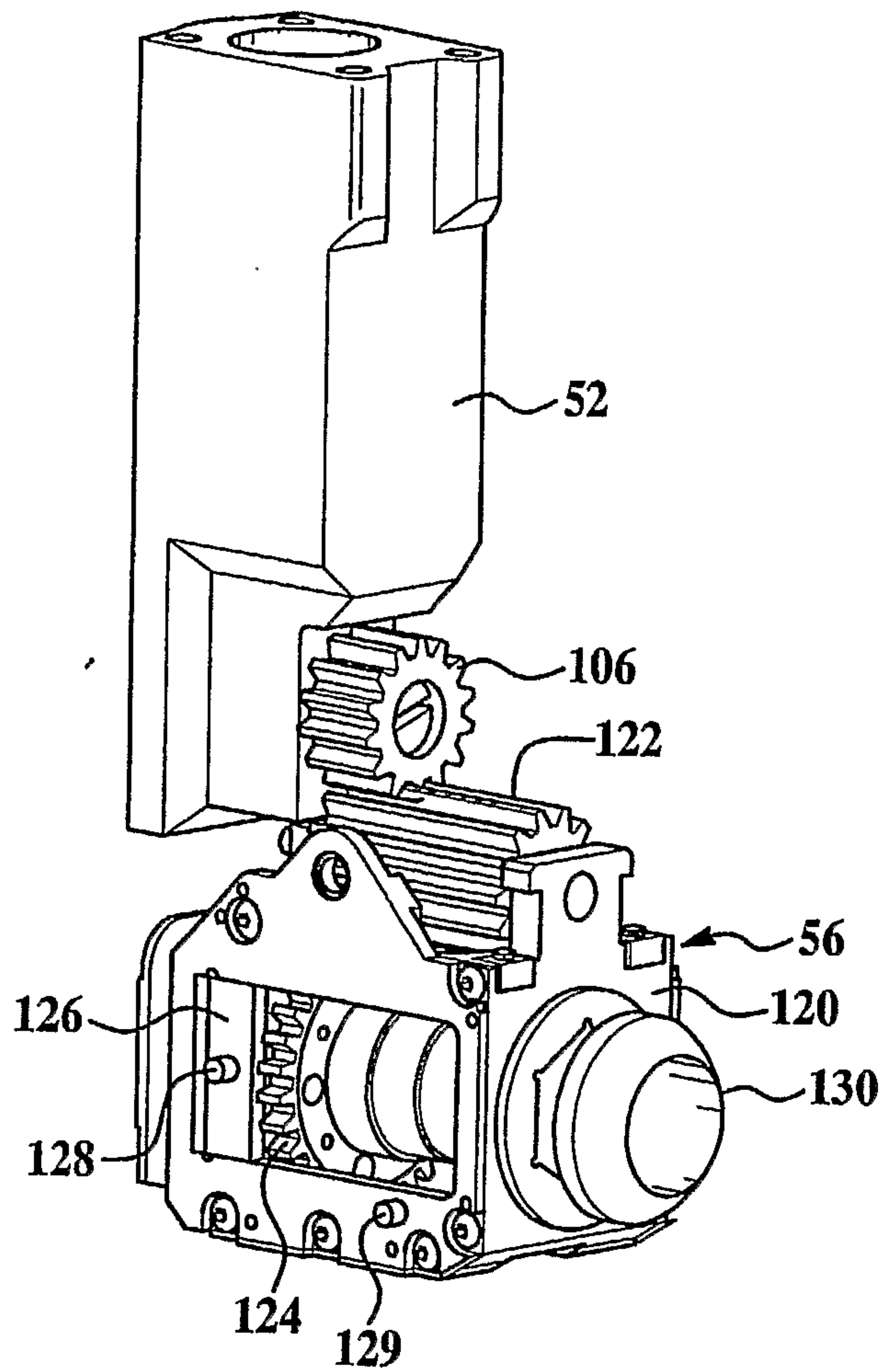


Figure 7

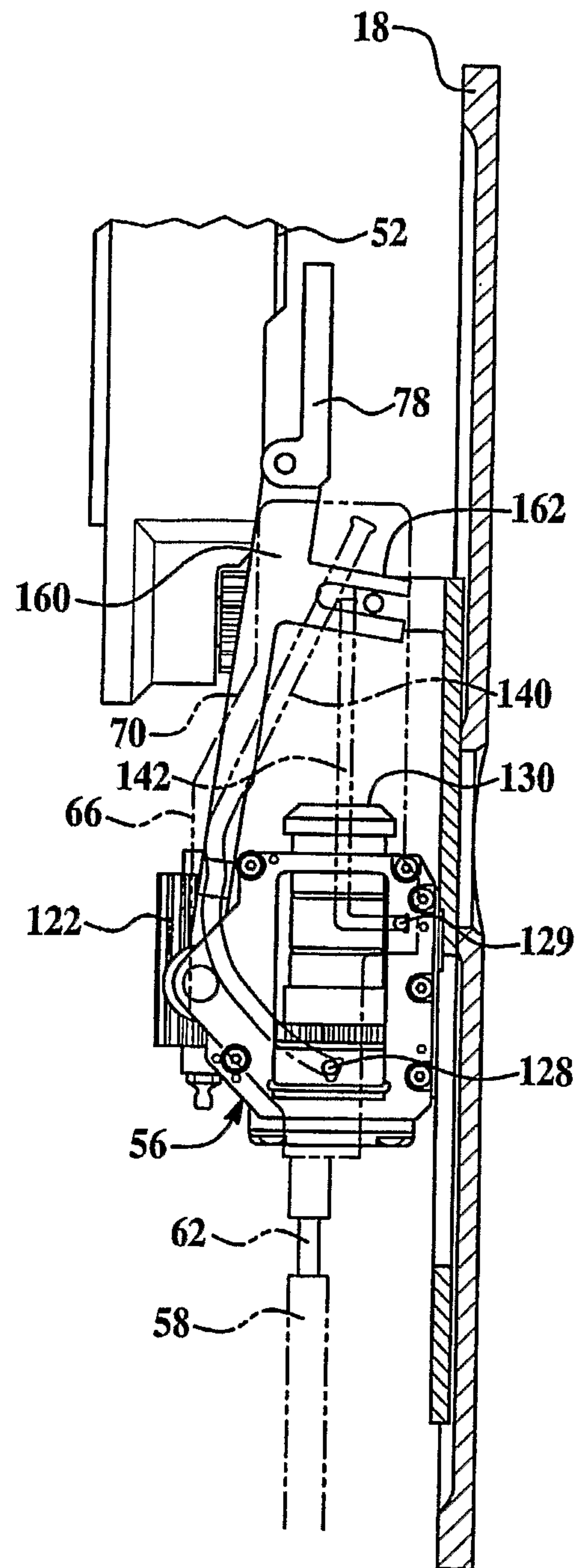
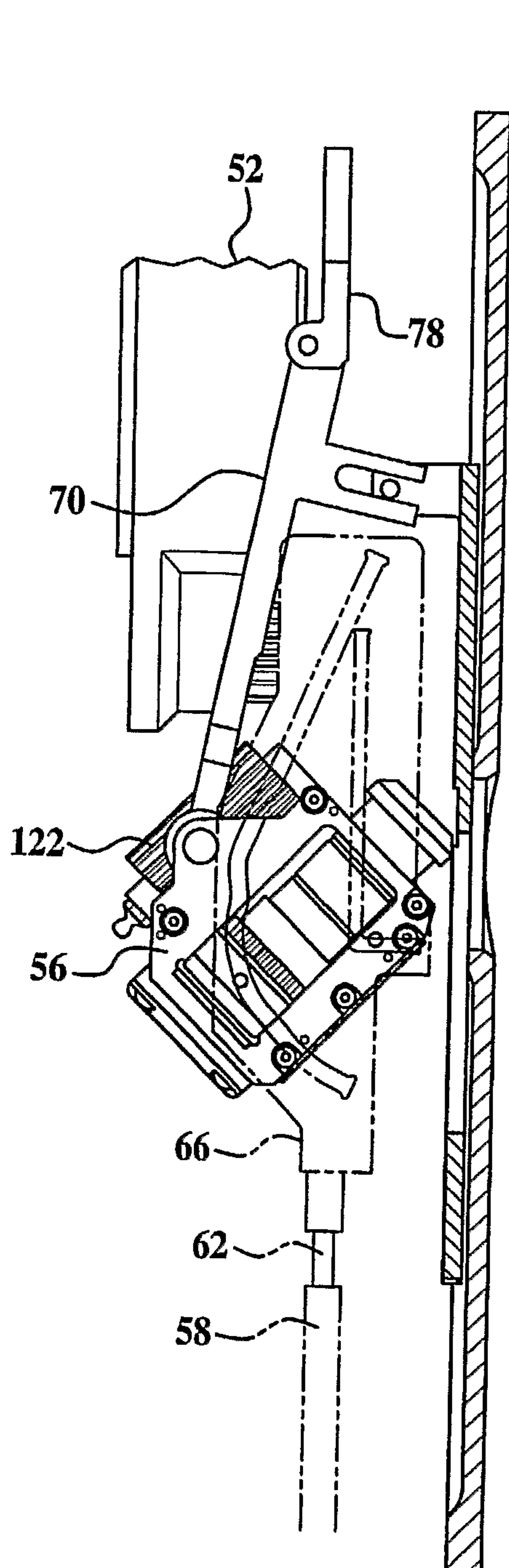
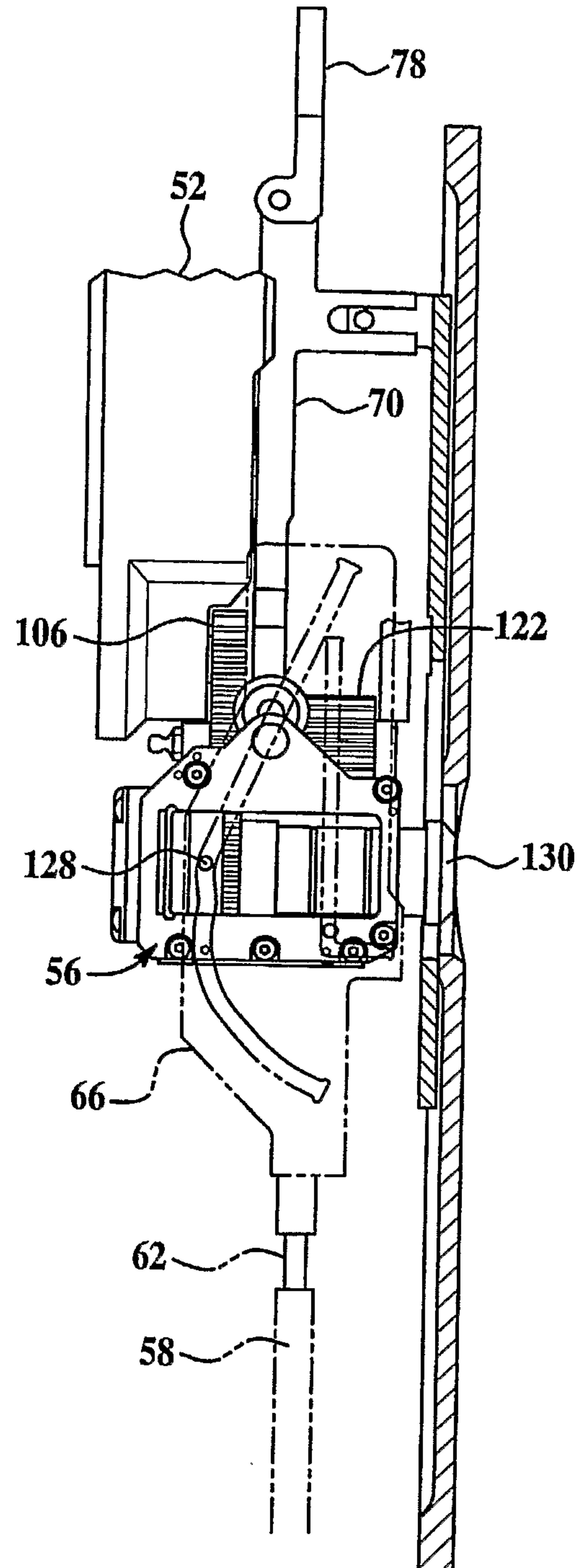


Figure 8

**Figure 9****Figure 10**

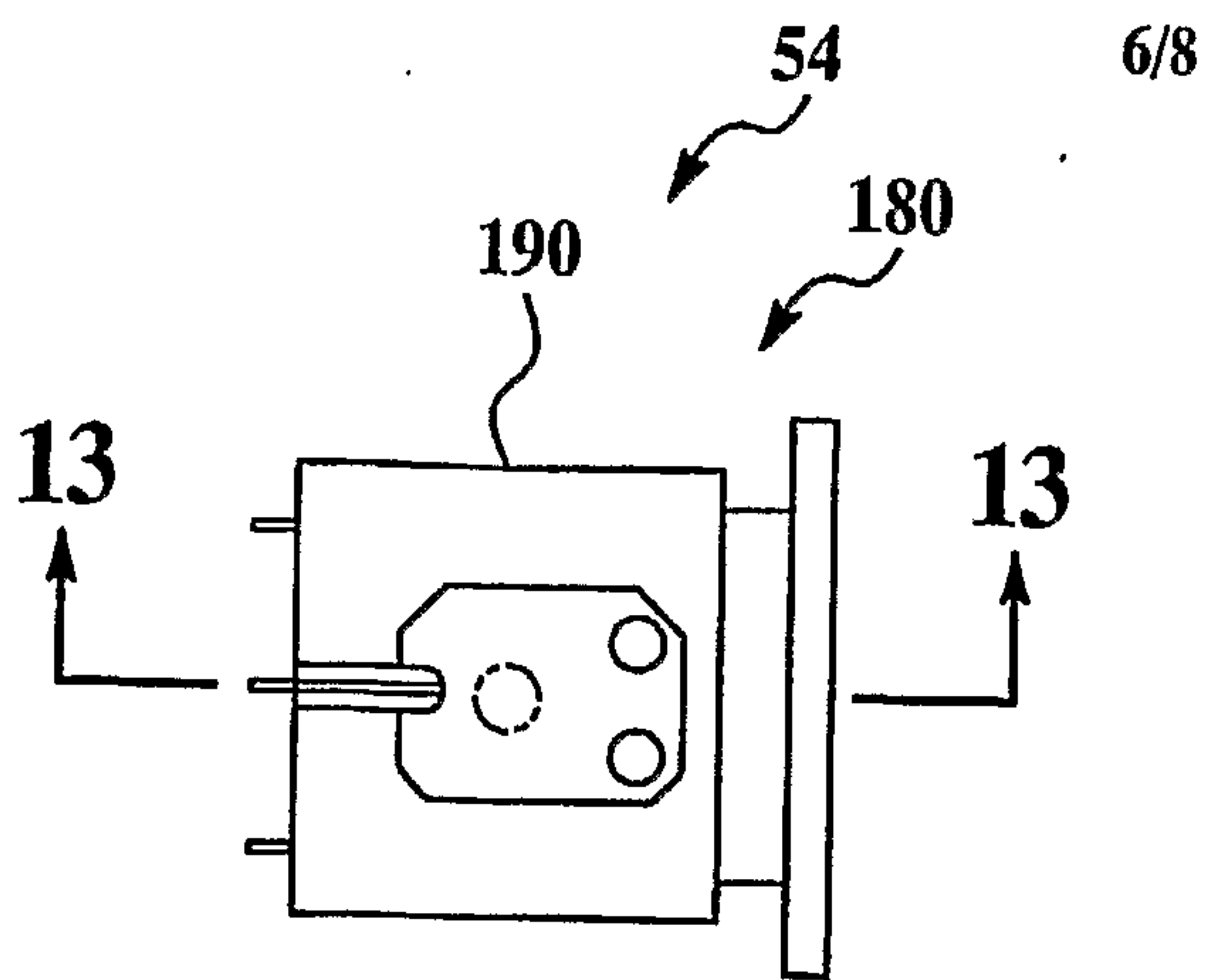


Figure 11

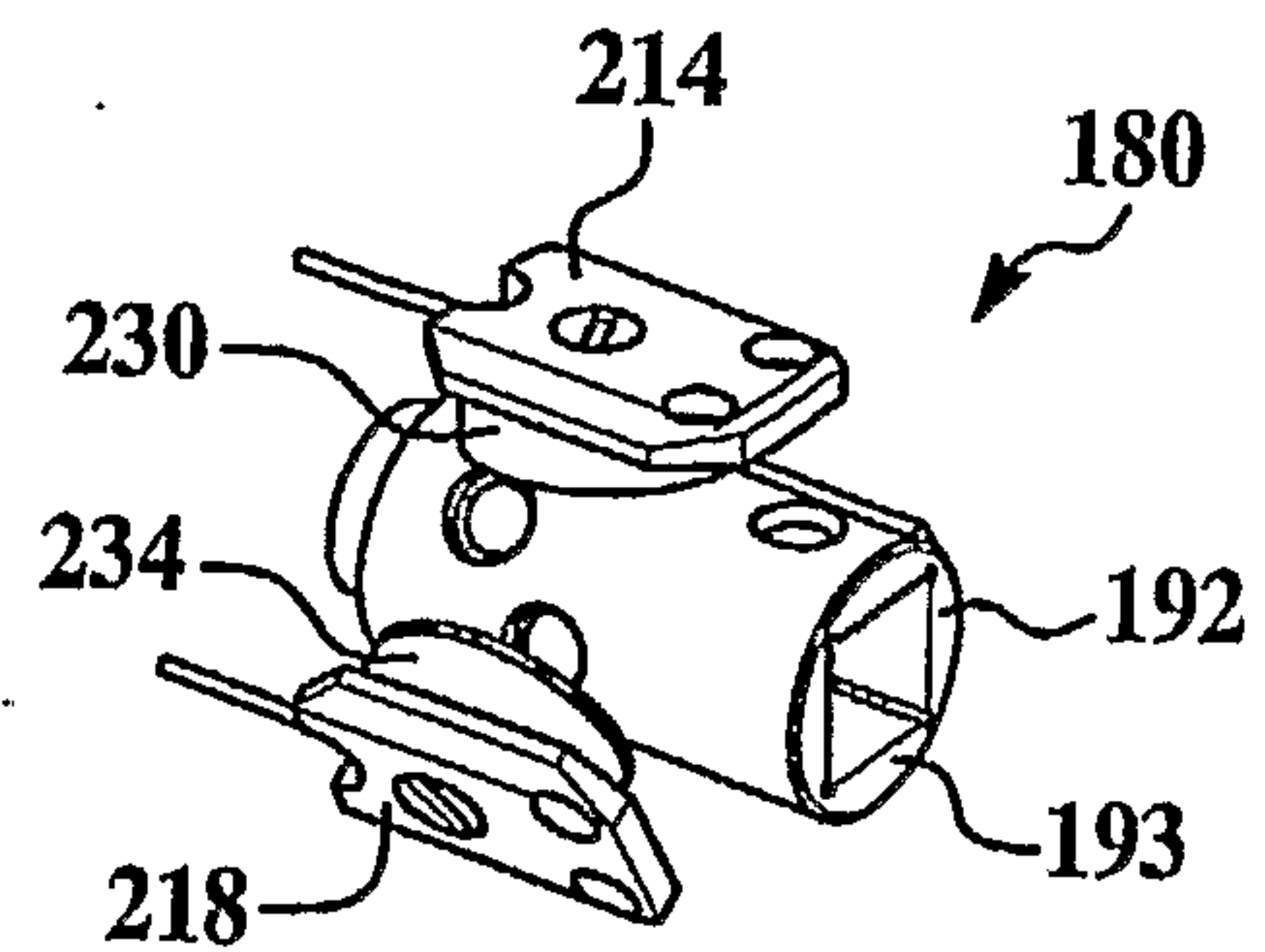


Figure 12

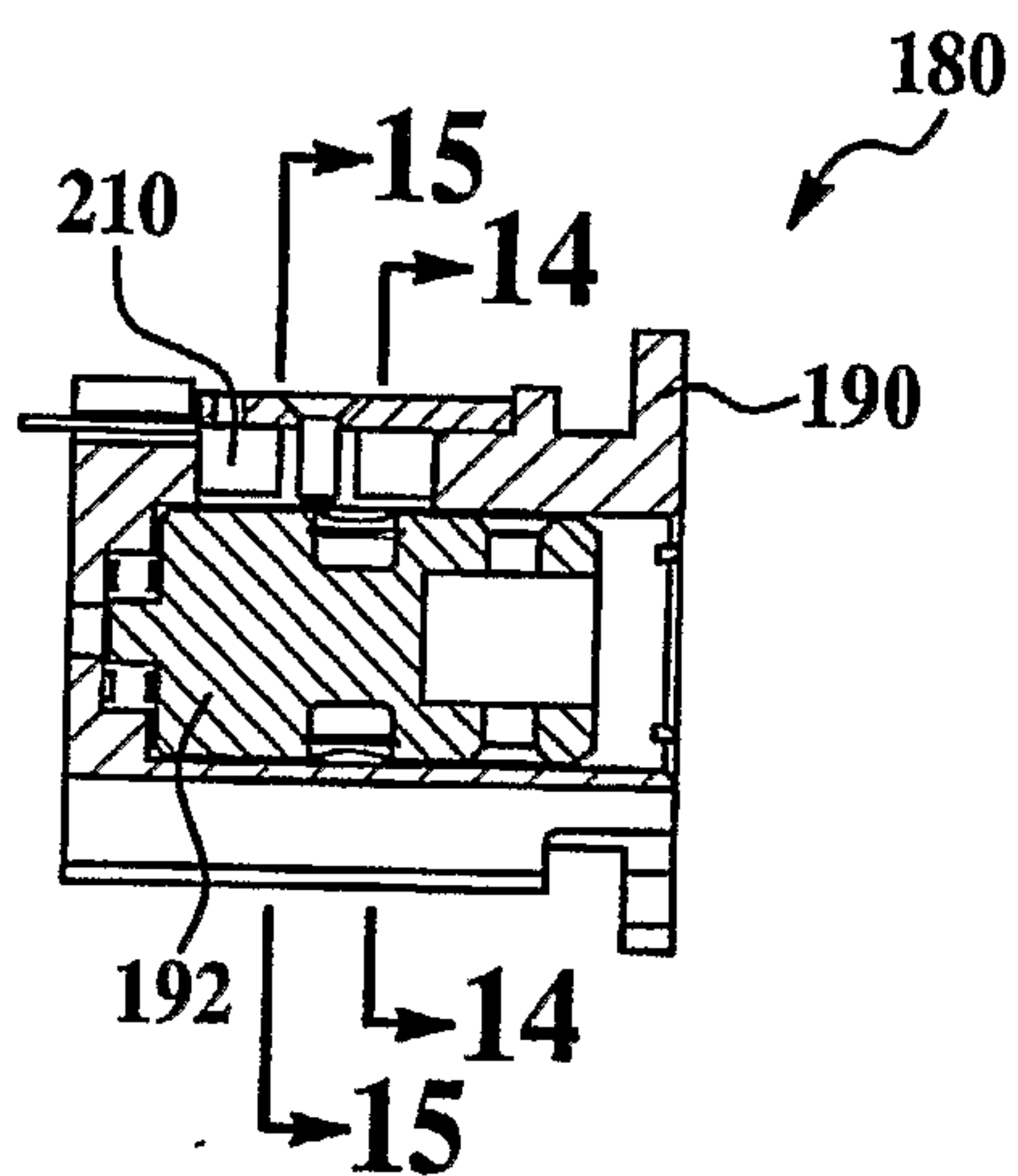


Figure 13

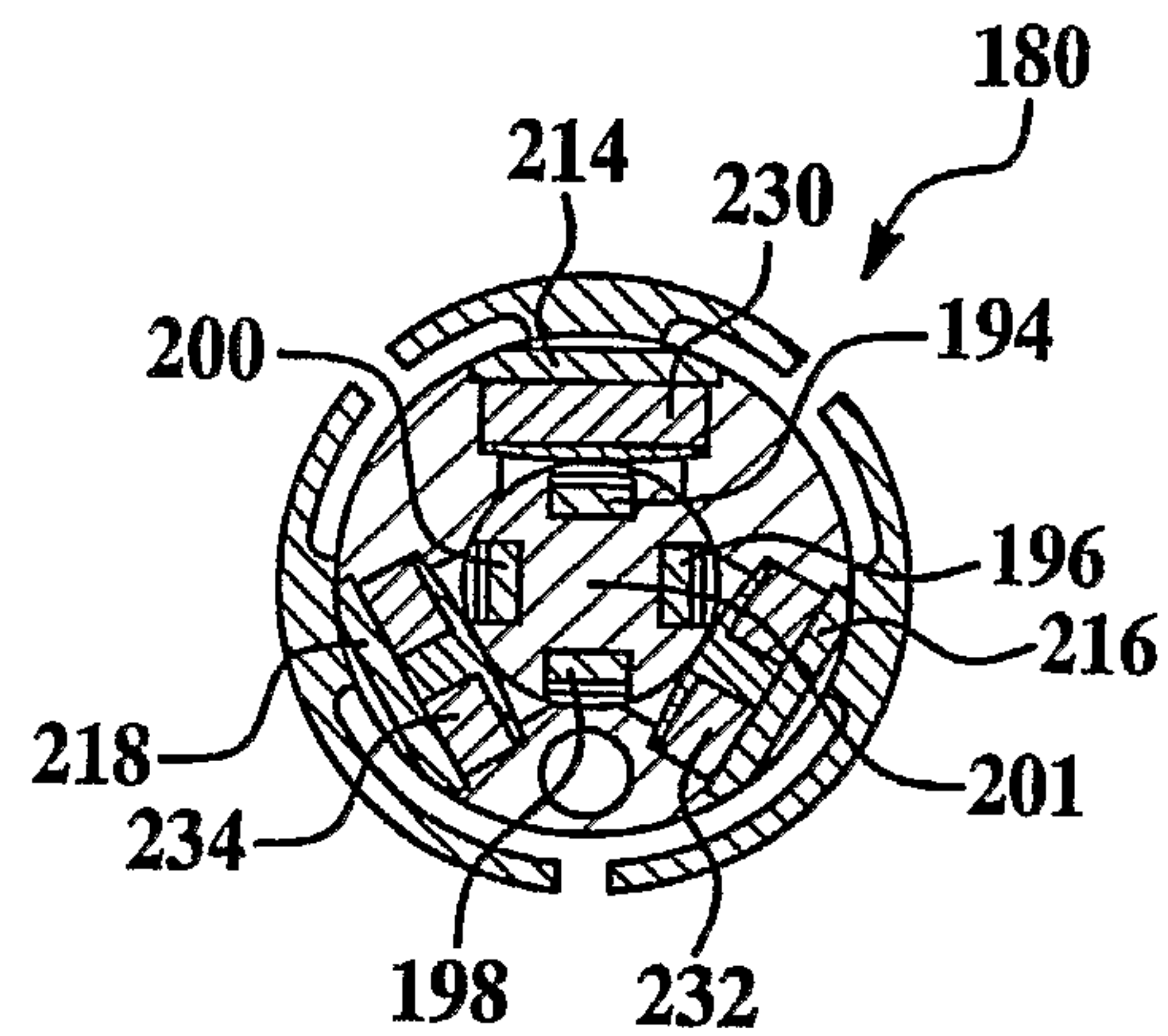


Figure 14

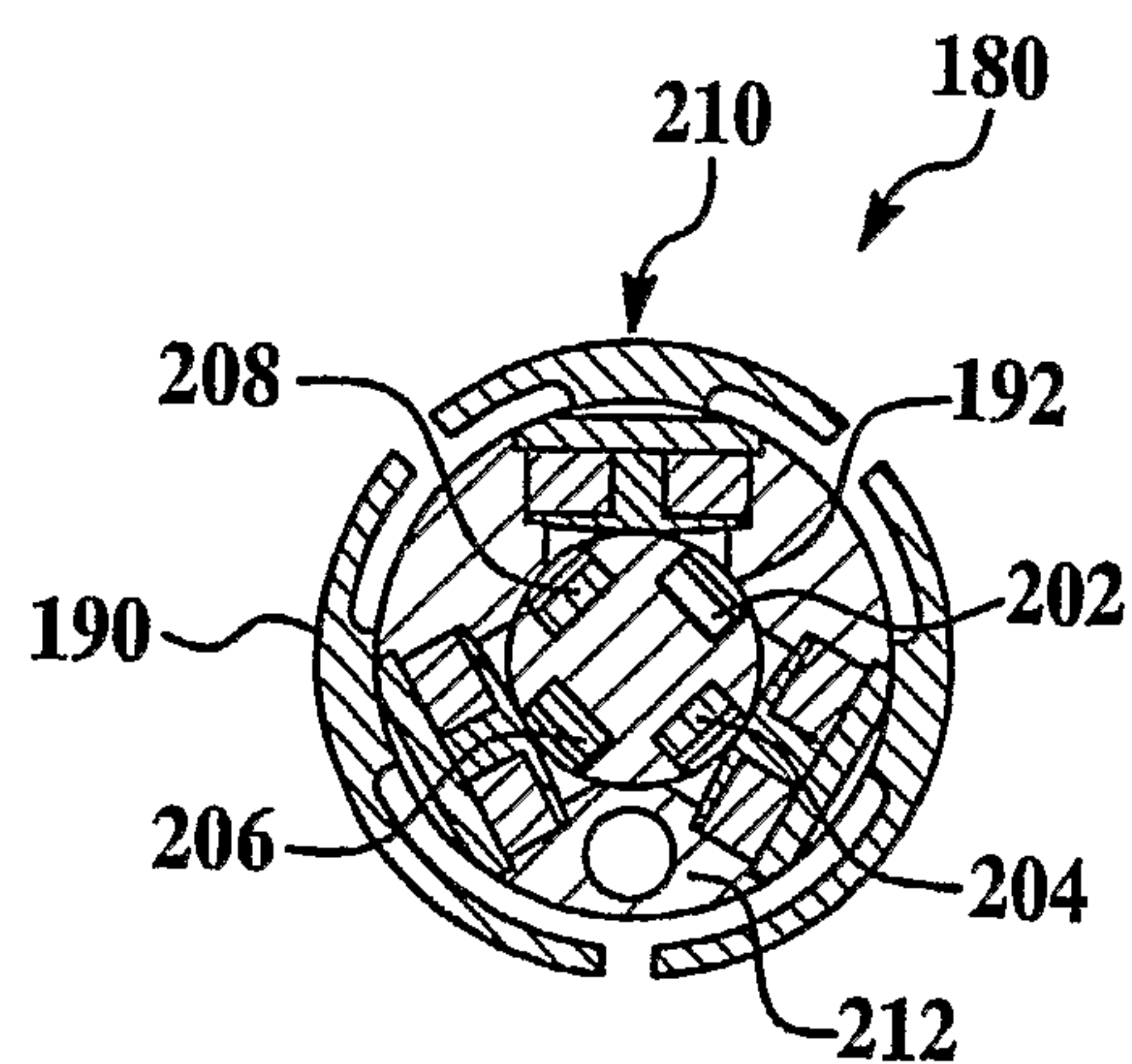


Figure 15

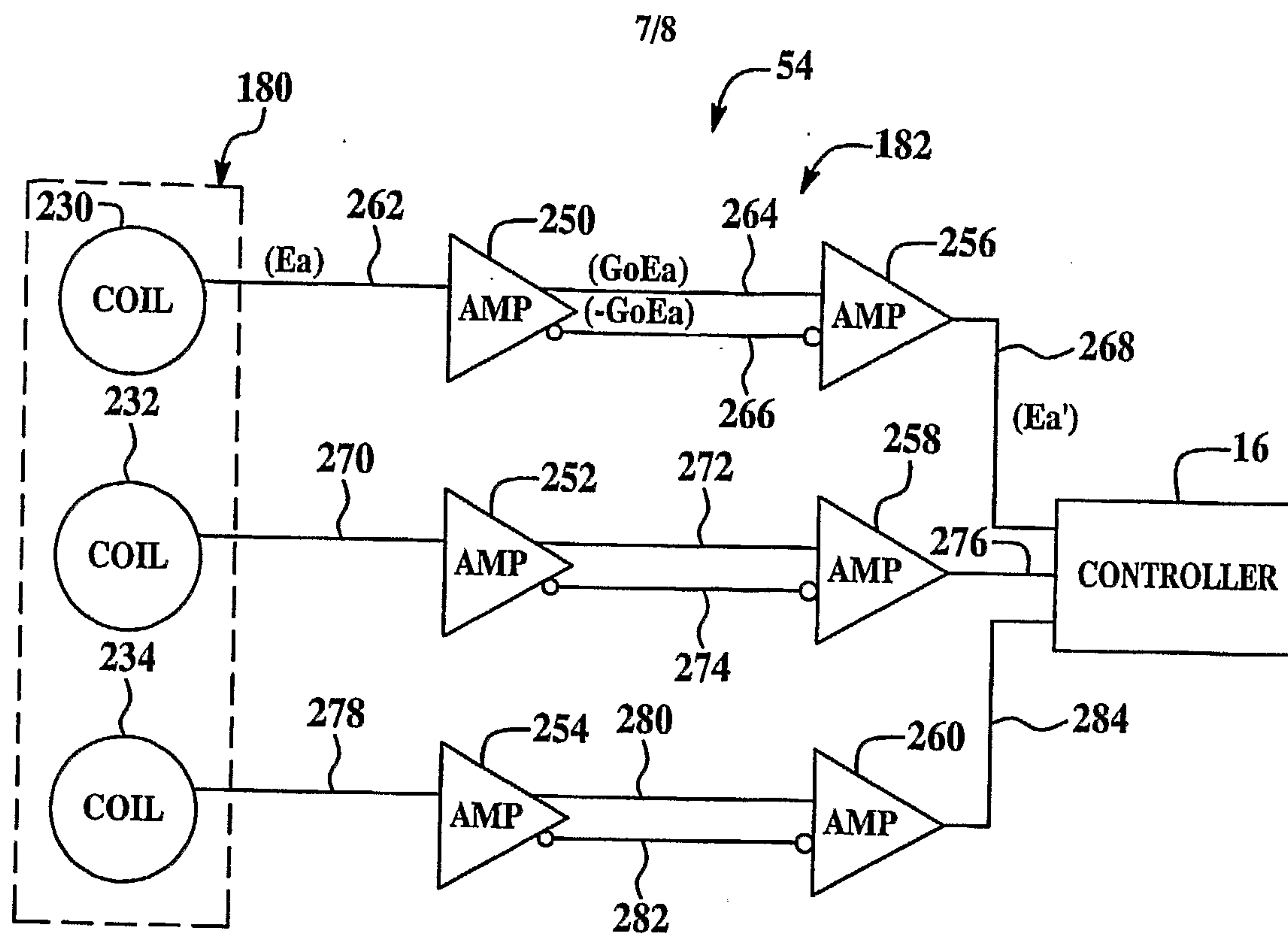


Figure 16

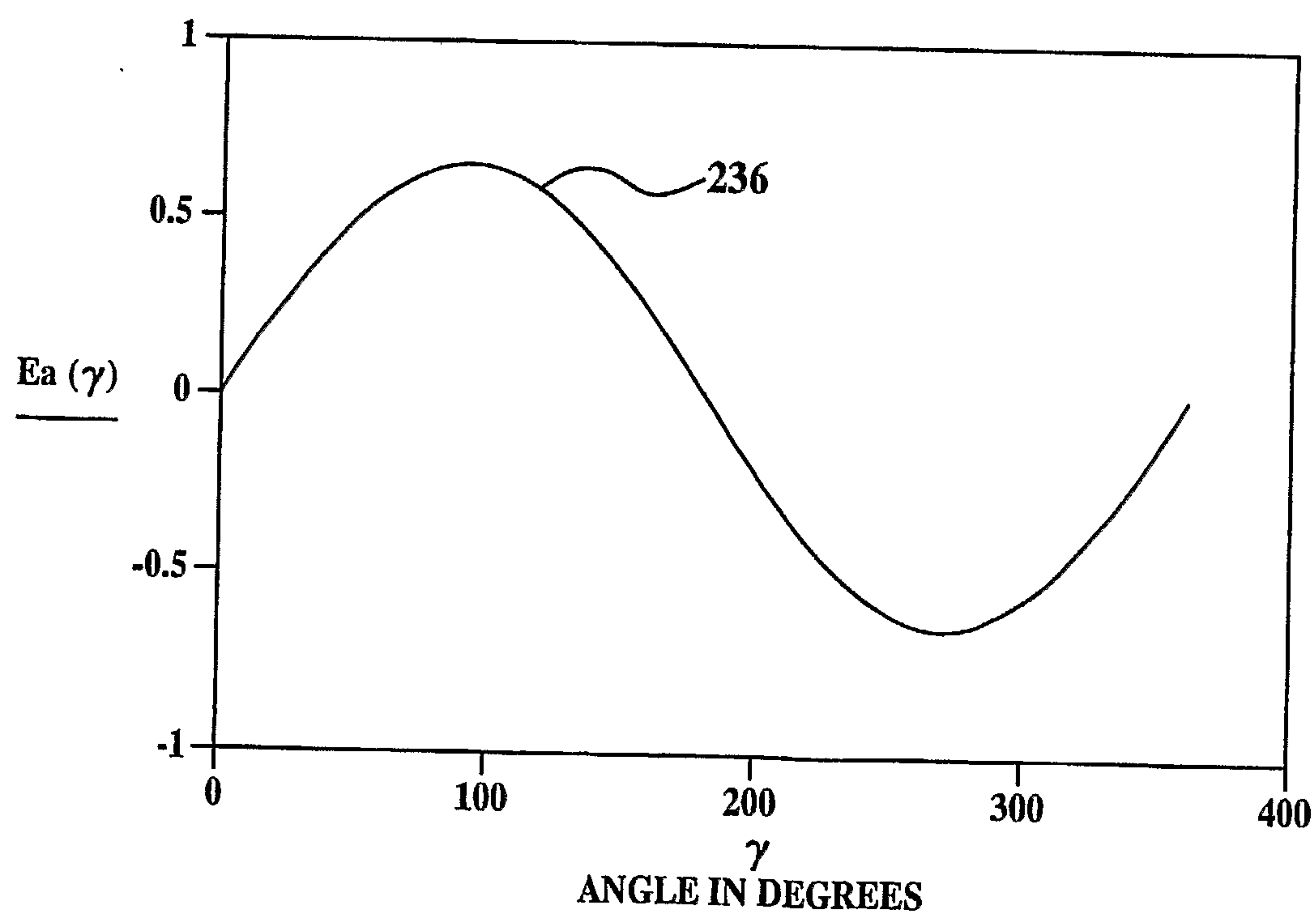
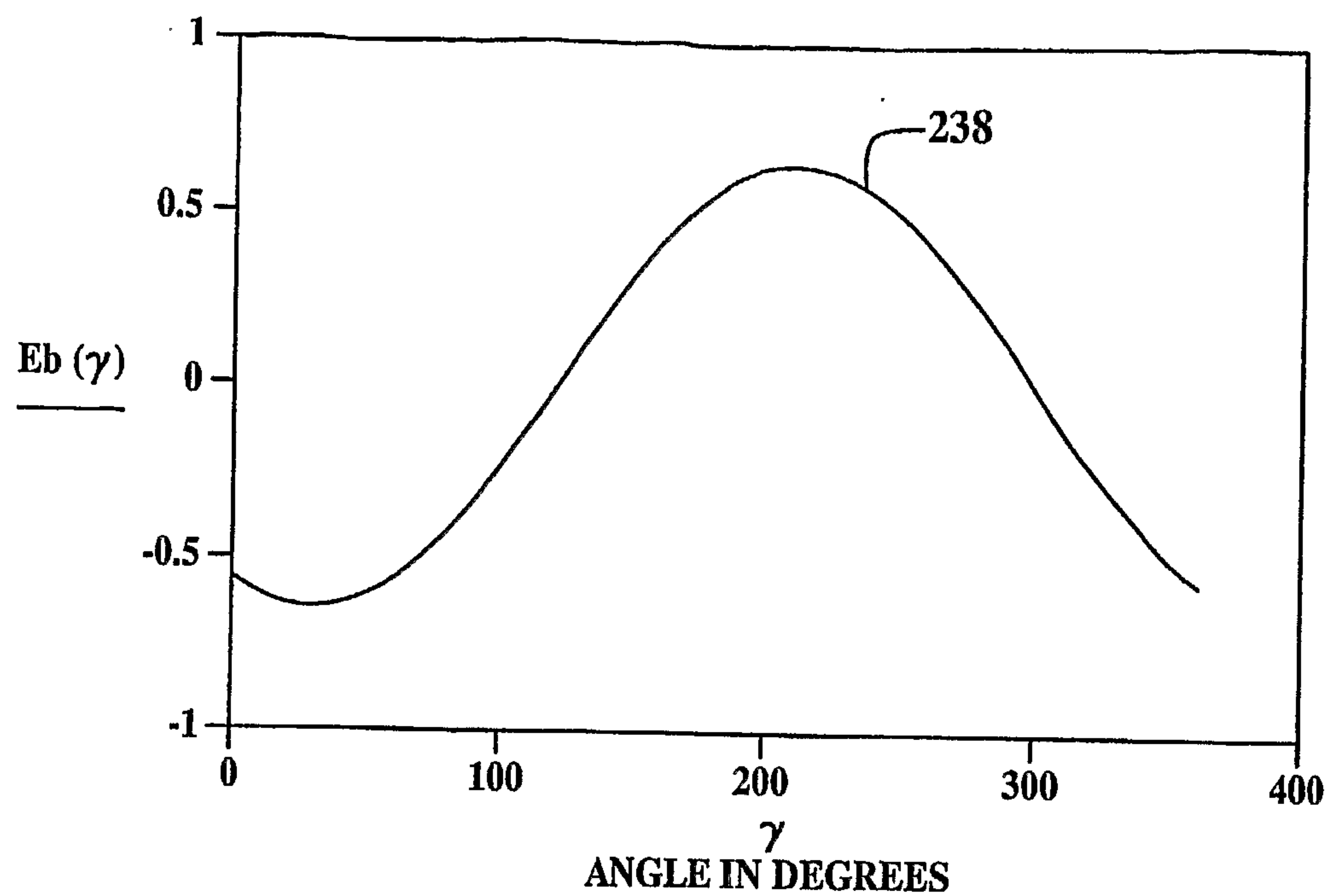
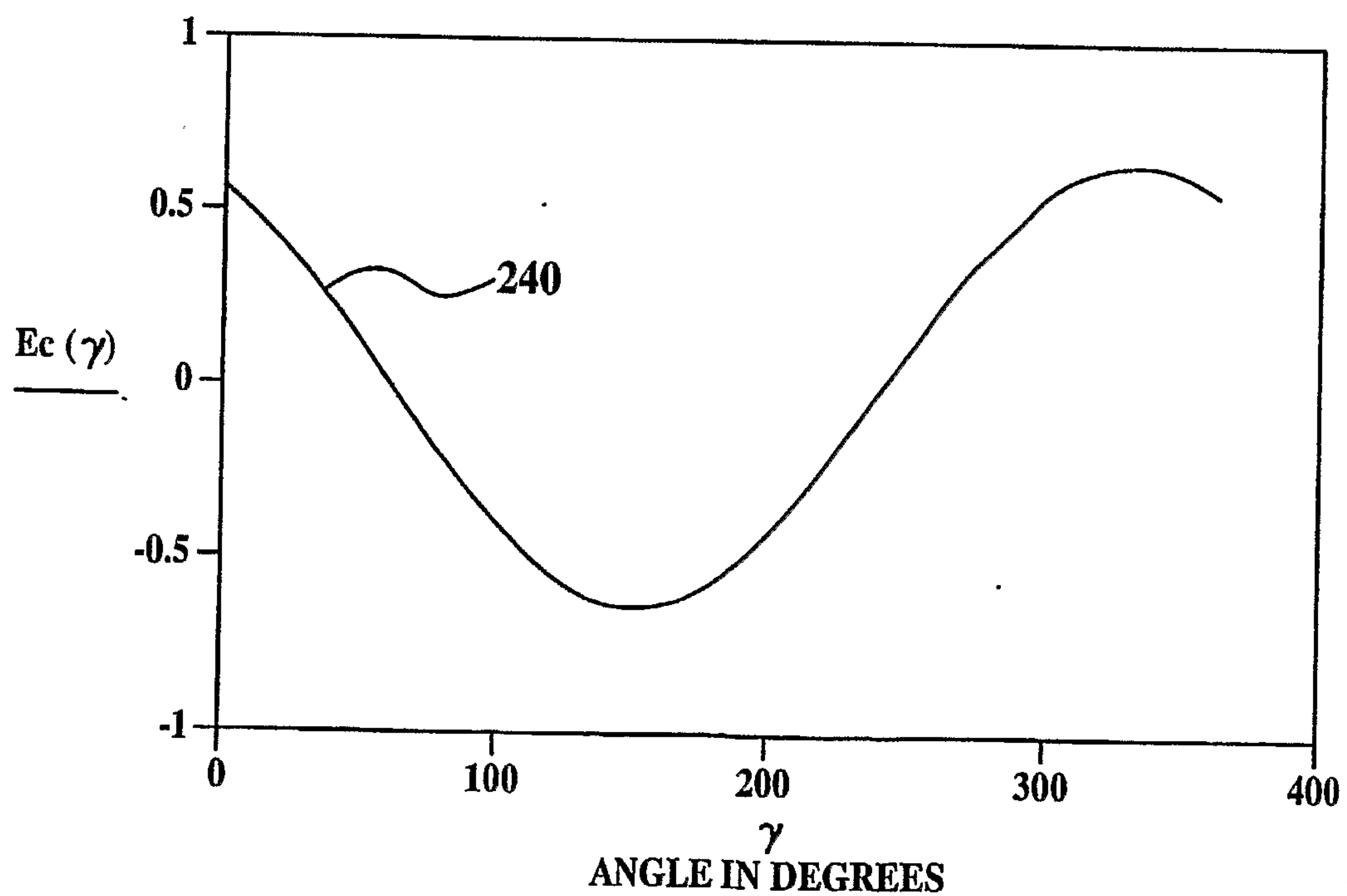


Figure 17

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**Figure 18****Figure 19**

