(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
29 October 2020 (29.10.2020)

WIPO | PCT

(10) International Publication Number
WO 2020/219905 A1

(51) International Patent Classification:
H01H 33/664 (2006.01)

(21) International Application Number:
PCT/US2020/029850

(22) International Filing Date:
24 April 2020 (24.04.2020)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/839,278 26 April 2019 (26.04.2019) US
62/902,637 19 September 2019 (19.09.2019) US

(71) Applicant: **G & W ELECTRIC COMPANY** [US/US]; 305 West Crossroads Pkwy., Bolingbrook, IL 60440 (US).

(72) Inventors: **DAUKSAS, Arturas**; 9932 S. Kenneth Ave., Oak Lawn, IL 60453 (US). **KIEFER, Alexander**; 2549 Dewhurst St., Naperville, IL 60564 (US). **ACHE, Janet**; 237 St. Andrews Dr., Bolingbrook, IL 60440 (US). **KERR, Blair, S.**; 1049 Grove Street, Downers Grove, IL 60515 (US).

(74) Agent: **MUTH, Jason, P.**; Michael Best & Friedrich LLP, 790 N. Water Street, Suite 2500, Milwaukee, WI 53202 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ,

(54) Title: SWITCHGEAR WITH MANUAL TRIP ASSEMBLY AND MECHANICAL INTERLOCK

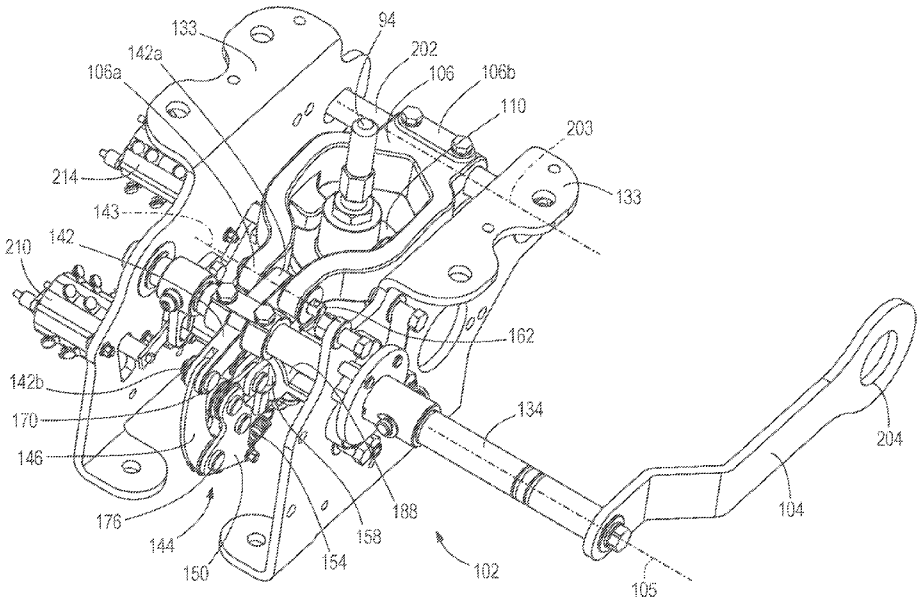


FIG. 6

(57) Abstract: A switchgear apparatus configured for operation at voltages up to 72.5 kV includes a vacuum interrupter assembly having a fixed contact and a movable contact configured to move relative to the fixed contact between a closed position in which the movable contact is in contact with the fixed contact and an open position in which the movable contact is spaced from the fixed contact. The switchgear apparatus also includes an electromagnetic actuator configured to move the movable contact between the open position and the closed position, a manual trip assembly movable from an initial position to an actuated position to move the movable contact from the closed position to the open position, and a mechanical interlock assembly configured to prevent the movable contact from moving from the open position to the closed position when the manual trip assembly is in the actuated position.

WO 2020/219905 A1

[Continued on next page]

OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

SWITCHGEAR WITH MANUAL TRIP ASSEMBLY AND MECHANICAL INTERLOCK

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to co-pending U.S. Provisional Patent Application No. 62/839,278, filed on April 26, 2019, and to co-pending U.S. Provisional Patent Application No. 62/902,637, filed on September 19, 2019, the entire contents of both of which are incorporated herein by reference.

FIELD OF THE DISCLOSURE

[0002] The present disclosure relates to solid dielectric switchgear, and more particularly to reclosers.

BACKGROUND OF THE DISCLOSURE

[0003] Reclosers are switchgear that provide line protection, for example, on overhead electrical power lines and/or substations and serve to segment the circuits into smaller sections, reducing the number of potentially impacted customers in the event of a short circuit. Previously, reclosers were controlled using hydraulics. More recently, solid dielectric reclosers have been developed for use at voltages up to 38 kV. Solid dielectric reclosers may be paired with electronic control devices to provide automation and "smart" recloser functionality.

SUMMARY OF THE DISCLOSURE

[0004] A need exists for fault protection and circuit segmentation in power transmission circuits, which typically operate at higher voltages (e.g., up to 1,100 kV). Reclosers allow for multiple automated attempts to clear temporary faults on overhead lines. A need also exists, however, for a recloser with a manual trip assembly that allows the recloser to be manually operated for servicing or in the event of a failure of the recloser or its controls.

[0005] The present disclosure provides, in one aspect, a switchgear apparatus configured for operation at voltages up to 72.5 kV, including a vacuum interrupter assembly having a fixed contact and a movable contact configured to move relative to the fixed contact between a closed position in which the movable contact is in contact with the fixed contact and an open position in

which the movable contact is spaced from the fixed contact. The switchgear apparatus also includes an electromagnetic actuator configured to move the movable contact between the open position and the closed position, a manual trip assembly movable from an initial position to an actuated position to move the movable contact from the closed position to the open position, and a mechanical interlock assembly configured to prevent the movable contact from moving from the open position to the closed position when the manual trip assembly is in the actuated position.

[0006] The present disclosure provides, in another aspect, a switchgear apparatus configured for operation at voltages up to 72.5 kV, including a vacuum interrupter assembly having a fixed contact and a movable contact configured to move relative to the fixed contact between a closed position in which the movable contact is in contact with the fixed contact and an open position in which the movable contact is spaced from the fixed contact. The switchgear apparatus also includes an electromagnetic actuator configured to move the movable contact between the open position and the closed position, and a manual trip assembly movable from an initial position to an actuated position to move the movable contact from the closed position to the open position. The manual trip assembly includes a first lever and a second lever coupled to the first lever such that the first and second lever provide a compound mechanical advantage.

[0007] Other aspects of the invention will become apparent by consideration of the detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 is a perspective view of a recloser and/or switchgear apparatus ("recloser") according to an embodiment of the present disclosure.

[0009] FIG. 2 is a cross-sectional view of the recloser of FIG. 1.

[0010] FIG. 3 is an exploded perspective view of a housing of the recloser of FIG. 1.

[0011] FIG. 4 is a perspective view of a head casting of the recloser of FIG. 1.

[0012] FIG. 5 is a cross-sectional view of the recloser of FIG. 1, taken through the head casting of FIG. 4.

[0013] FIG. 6 is a perspective view illustrating a manual trip assembly of the recloser of FIG. 1

[0014] FIG. 7 is a cross-sectional view illustrating a portion of the manual trip assembly of FIG. 6 in an initial position.

[0015] FIG. 8 is a cross-sectional view illustrating a portion of the manual trip assembly of FIG. 6 in an intermediate position.

[0016] FIG. 9 is a cross-sectional view illustrating a portion of the manual trip assembly of FIG. 6 in an actuated state.

[0017] FIG. 10 is a side view illustrating actuation of the manual trip assembly.

DETAILED DESCRIPTION

[0018] Before any embodiments of the disclosure are explained in detail, it is to be understood that the disclosure is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The disclosure is capable of supporting other embodiments and of being practiced or of being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. In addition, as used herein and in the appended claims, the terms "upper", "lower", "top", "bottom", "front", "back", and other directional terms are not intended to require any particular orientation, but are instead used for purposes of description only.

[0019] FIG. 1 illustrates a recloser 10 according to an embodiment of the present disclosure. The recloser 10 includes a housing assembly 14, a vacuum interrupter ("VI") assembly 18, a conductor assembly 22, which in some embodiments may be a load-side conductor assembly 22

and in other embodiments may be a source-side conductor assembly 22, and an actuator assembly 26. The VI assembly 18 includes a first terminal 30 extending from the housing assembly 14 along a first longitudinal axis 34, and the conductor assembly 22 includes a second terminal 38 extending from the housing assembly 14 along a second longitudinal axis 42 perpendicular to the first longitudinal axis 34. In other embodiments, the second longitudinal axis 42 may be obliquely oriented relative to the first longitudinal axis 34. The actuator assembly 26 may operate the VI assembly 18 to selectively break and/or reestablish a conductive pathway between the first and second terminals 30, 38. Although the recloser 10 is illustrated individually in FIG. 1, the recloser 10 may be part of a recloser system including a plurality of reclosers 10, each associated with a different phase of a three-phase power transmission system and ganged together such that operation of the plurality of reclosers 10 is synchronized.

[0020] Referring now to FIG. 2, the illustrated housing assembly 14 includes a main housing 46 with an insulating material, such as epoxy, that forms a solid dielectric module 47. The solid dielectric module 47 is preferably made of a silicone or cycloaliphatic epoxy. In other embodiments, the solid dielectric module 47 may be made of a fiberglass molding compound. In other embodiments, the solid dielectric module 47 may be made of other moldable dielectric materials. The main housing 46 may further include a protective layer 48 surrounding the solid dielectric module 47. In some embodiments, the protective layer 48 withstands heavily polluted environments and serves as an additional dielectric material for the recloser 10. In some embodiments, the protective layer 48 is made of silicone rubber that is overmolded onto the solid dielectric module 47. In other embodiments, the protective layer 48 may be made of other moldable (and preferably resilient) dielectric materials, such as polyurethane.

[0021] With continued reference to FIG. 2, the main housing 46 includes a first bushing 50 that surrounds and at least partially encapsulates the VI assembly 18, and a second bushing 54 that surrounds and at least partially encapsulates the conductor assembly 22. The silicone rubber layer 48 includes a plurality of sheds 58 extending radially outward from both bushings 50, 54. In other embodiments, the sheds 58 may be formed as part of the dielectric module 47 and covered by the silicone rubber layer 48. In yet other embodiments, the sheds 58 may be omitted. The first and second bushings 50, 54 may be integrally formed together with the dielectric module 47 of the main housing 46 as a single monolithic structure. Alternatively, the first and

second bushings 50, 54 may be formed separately and coupled to the main housing 46 in a variety of ways (e.g., via a threaded connection, snap-fit, etc.).

[0022] The illustrated VI assembly 18 includes a vacuum bottle 62 at least partially molded within the first bushing 50 of the main housing 46. The vacuum bottle 62 encloses a movable contact 66 and a stationary contact 70 such that the movable contact 66 and the stationary contact 70 are hermetically sealed within the vacuum bottle 62. In some embodiments, the vacuum bottle 62 has an internal absolute pressure of about 1 millipascal or less. The movable contact 66 is movable along the first longitudinal axis 34 between a closed position (illustrated in FIG. 2) and an open position (not shown) to selectively establish or break contact with the stationary contact 70. The vacuum bottle 62 quickly suppresses electrical arcing that may occur when the contacts 66, 70 are opened due to the lack of conductive atmosphere within the bottle 62.

[0023] The conductor assembly 22 may include a conductor 74 and a sensor assembly 78, each at least partially molded within the second bushing 54 of the main housing 46. The sensor assembly 78 may include a current sensor, voltage sensor, partial discharge sensor, voltage indicated sensor, and/or other sensing devices. One end of the conductor 74 is electrically coupled to the movable contact 66 via a current interchange 82. The opposite end of the conductor 74 is electrically coupled to the second terminal 38. The first terminal 30 is electrically coupled to the stationary contact 70. The first terminal 30 and the second terminal 38 are configured for connection to respective electrical power transmission lines.

[0024] With continued reference to FIG. 2, the actuator assembly 26 includes a drive shaft 86 extending through the main housing 46 and coupled at one end to the movable contact 66 of the VI assembly 18. In the illustrated embodiment, the drive shaft 86 is coupled to the movable contact 66 via an encapsulated spring 90 to permit limited relative movement between the drive shaft 86 and the movable contact 66. The encapsulated spring 90 biases the movable contact 66 toward the stationary contact 70. The opposite end of the drive shaft 86 is coupled to an output shaft 94 of an electromagnetic actuator 98. The electromagnetic actuator 98 is operable to move the drive shaft 86 along the first longitudinal axis 34 and thereby move the movable contact 66 relative to the stationary contact 70. In additional or alternative embodiments, the functionality provided by the encapsulated spring 90 may be provided with an external spring and/or a spring

positioned otherwise along the drive shaft 86. For example, the spring may be instead positioned at a first end or at a second end of the drive shaft 86.

[0025] The electromagnetic actuator 98 in the illustrated embodiment includes a coil 99, a permanent magnet 100, a spring 101, and a plunger 103 that is coupled to the output shaft 94. The coil 99 includes one or more copper windings which, when energized, produce a magnetic field that acts on the plunger 103 to move the output shaft 94. The permanent magnet 100 is configured to hold the plunger 103 and the output shaft 94 in a position corresponding with the closed position of the movable contact 66. In some embodiments, the permanent magnet 100 may produce a magnetic holding force on the output shaft 94 of about 10,000 Newtons (N). In other embodiments, the permanent magnet 100 may produce a magnetic holding force on the output shaft 94 between 7,000 N and 13,000 N.

[0026] The spring 101 biases the output shaft 94 in an opening direction (i.e. downward in the orientation of FIG. 2) to facilitate opening the contacts 66, 70, as described in greater detail below. The force exerted by the spring 101 when the contacts 66, 70 are in the closed position is less than the magnetic holding force. For example, in some embodiments, the force exerted by the spring 101 when the contacts 66, 70 are in the closed position may be about 5,000 N. In other embodiments, the force may be between 2,000 N and 6,000 N. Thus, the permanent magnet 100 provides a strong magnetic holding force to maintain the contacts 66, 70 in their closed position against the biasing force of the spring 101, without requiring any current to be supplied through the coil 99.

[0027] In some embodiments, the actuator assembly 26 may include other actuator configurations. For example, in some embodiments, the permanent magnet 100 may be omitted, and the output shaft 94 may be latched in the closed position in other ways. In additional or alternative embodiments, the electromagnetic actuator 98 may be omitted or replaced by any other suitable actuator (e.g., a hydraulic actuator, etc.).

[0028] The actuator assembly 26 includes a controller (not shown) that controls operation of the electromagnetic actuator 98. In some embodiments, the controller receives feedback from the sensor assembly 78 and energizes and/or de-energizes the electromagnetic actuator 98 automatically in response to one or more sensed conditions. For example, the controller may

receive feedback from the sensor assembly 78 indicating that a fault has occurred. In response, the controller may control the electromagnetic actuator 98 to automatically open the VI assembly 18 and break the circuit. The controller may also control the electromagnetic actuator 98 to automatically close the VI assembly 18 once the fault has been cleared (e.g., as indicated by the sensor assembly 78).

[0029] The illustrated housing assembly 14 includes an actuator housing 114 enclosing the electromagnetic actuator 98 and a head casting 118 coupled between the actuator housing 114 and the main housing 46. In the illustrated embodiment, the head casting 118 supports a connector 138 in communication with the sensor assembly 78 such that feedback from the sensor assembly 78 may be obtained by interfacing with the connector 138 (FIG. 3). The head casting 118 is coupled to the main housing 46 by a first plurality of threaded fasteners 122, and the actuator housing 114 is coupled to the head casting 118 opposite the main housing 46 by a second plurality of threaded fasteners 126.

[0030] Referring to FIGS. 4 and 5, the head casting 118 includes a main body 126 and a plurality of mounting bosses 130 spaced along the outer periphery of the main body 126. In the illustrated embodiment, the plurality of mounting bosses 130 includes a first pair of bosses 130a extending from the main body 126 in a first direction, a second pair of bosses 130b extending from the main body 126 in a second direction opposite the first direction, and a third pair of bosses 130c extending from the main body 126 in a third direction orthogonal to the first and second directions. In other embodiments, the head casting 118 may include a different number and/or arrangement of mounting bosses 130.

[0031] The head casting 118 is couplable to the main housing 46 in a plurality of different orientations such that the pairs of bosses 130 (130a, 130b, 130c) may be positioned in a number of different rotational orientations about axis 34 with respect to the main housing 46. That is, the rotational orientation of the pairs of bosses 130 about the circumference of the main housing 46 may be varied as desired by rotating the orientation of the head casting 118 and main housing 46 relative to one another about the axis 34 to a desired position before coupling the head casting 118 and the main housing 46. In some embodiments, the head casting 118 may be coupled to the main housing 46 in at least three different orientations. In other embodiments, the head casting

118 may be coupled to the main housing 46 in at least six different orientations. In other embodiments, the main housing 46, the head casting 118, and the actuator housing 114 may be coupled together in other ways (e.g., via direct threaded connections or the like).

[0032] With reference to FIG. 5, the illustrated actuator assembly 26 includes a manual trip assembly 102 supported by the head casting 118 and that can be used to manually open the VI assembly 18. The manual trip assembly 102 includes a handle 104 accessible from an exterior of the housing assembly 14. In the illustrated embodiment, the handle 104 of the manual trip assembly 102 extends along a side of the main body 126 opposite the third pair of bosses 130c and generally adjacent the connector 138. The handle 104 is preferably at a grounded potential. Because the head casting 118 is couplable to the main housing 46 in different orientations, the position of the handle 104 with respect to the main housing 46 is also variable. As such, the handle 104 may be accessible to an operator when the recloser 10 is in a wide variety of different mounting configurations. As described in greater detail below, the handle 104 is rotatable about a first rotational axis 105 to move a yoke 106 inside the head casting 118. The yoke 106 is engageable with a collar 110 on the output shaft 94 to move the movable contact 66 (FIG. 2) toward the open position.

[0033] Referring to FIGS. 5-6, the illustrated manual trip assembly 102 includes a pair of support brackets 133 fixed inside the head casting 118 and a shaft 134 extending through the main body 126 of the head casting 118 along the first rotational axis 105. The shaft 134 is rotatably supported by the support brackets 133 and is coupled to the handle 104 for co-rotation therewith about the rotational axis 105. The shaft 134 may include a plurality of segments coupled together by one or more fasteners, or the shaft 134 may be formed as a unitary structure. The manual trip assembly 102 also includes a link 142 coupled for co-rotation with the shaft 134 (e.g., by a plurality of fasteners). The link 142 includes a first end 142a pivotally coupled to a first end 106a of the yoke 106 by a first pin 162 for relative pivotal movement about a second rotational axis 143 parallel to the first rotational axis 105. A second end 142b of the link 142 opposite the first end 142a provides an input to a mechanical interlock assembly 144.

[0034] The mechanical interlock assembly 144 includes a lost motion member 146, an actuating member 150, a spring 154, and a blocking plunger 158. As described in greater detail

below, the blocking plunger 158 of the mechanical interlock assembly 144 is movable from a retracted position (FIGS. 7-8) to an extended position (FIG. 9) in which the blocking plunger 158 is engageable with the output shaft 94 to lock the movable contact 66 in its open position, thereby preventing the electromagnetic actuator 98 from reclosing the contacts 66, 70. The lost motion member 146 delays movement of the blocking plunger 158 from the retracted position to the extended position until the contacts 66, 70 have been opened and the collar 110 of the output shaft 94 has moved below the blocking plunger 158.

[0035] Referring to FIG. 7, the lost motion member 146 has an arcuate shape, and a second pin 170 pivotally couples a first end 174 of the lost motion member 146 to the second end 142b of the link 142. A third pin 176 couples a second end 178 of the lost motion member 146 to the actuating member 150. The third pin 176 is slidably received within an arcuate slot 182 in the lost motion member 146. The arcuate slot 182 defines a lost motion region that allows for limited movement of the lost motion member 146 relative to the actuating member 150.

[0036] Referring to FIGS. 6-9, the blocking plunger 158 is received within a plunger housing 188 that is fixed to the support brackets 133. The actuating member 150 is pivotally coupled to the plunger housing 188 by a fourth pin 192. The actuating member 150 is also coupled to the blocking plunger 158 by an intermediate link 196. As such, pivotal movement of the actuating member 150 about the fourth pin 192 imparts movement to the blocking plunger 158. In the illustrated embodiment, a guide pin 200 extends through the blocking plunger 158 and interfaces with the plunger housing 188. The guide pin 200 and the plunger housing 188 constrain movement of the blocking plunger 158 to generally linear movement along the plunger housing 188.

[0037] Referring again to FIG. 6, a second end 106b of the yoke 106 is pivotally coupled to a fifth pin 202 extending between and fixed to the support brackets 133. As such, the yoke 106 is pivotable about a third rotational axis 203 extending centrally through the fifth pin 202. The third rotational axis 203 is parallel to both the first rotational axis 105 and the second rotational axis 143.

[0038] With reference to FIG. 10, the yoke 106 includes a projection 206 that is engageable with the collar 110 on the output shaft 94 to move the output shaft 94 downward (in the direction

of arrow 207 in FIG. 10) and thereby open the contacts 66, 70 in response to actuation of the manual trip assembly 102. The handle 104, the link 142, and the yoke 106 provide a compound lever arrangement to allow the manual trip assembly 102 to overcome the strong magnetic holding force of the permanent magnet 100 when the contacts 66, 70 are closed.

[0039] In the illustrated embodiment, the handle 104 defines a first distance L1 from the center of an aperture 204 in the handle 104 to the first rotational axis 105 (the aperture 204 may be configured to receive a hook to facilitate operating the manual trip assembly 102 when the recloser 10 is mounted on a pole, for example). The link 142 defines a second distance L2 from the first rotational axis 105 to the second rotational axis 143. The yoke 106 defines a third distance L3 from the second rotational axis 143 to the third rotational axis 203. Finally, the yoke 106 also defines a fourth distance L4 from the third rotational axis 203 to the point of engagement between the projection 206 and the collar 110.

[0040] The handle 104 and link 142 define a first, second-class lever, and the yoke 106 and link 142 define a second, second-class lever. The two levers combine their respective mechanical advantages to apply a large axial force to the collar 110 while minimizing the length L1 of the handle 104. It is advantageous to minimize the length L1 of the handle 104 in order to provide the recloser 10 with a compact overall size (i.e. to avoid the handle 104 from protruding significantly beyond the housing assembly 14).

[0041] For example, in some embodiments, the manual trip assembly 102 may apply sufficient force to the collar 110 to overcome a resistance force R of about 5,000 N (e.g., due to the permanent magnet 100) and thereby open the contacts 66, 70 by applying a torque T of about 90 ft-lbs or less via the handle 104. The required torque T is provided by applying a force E on the handle 104 at the aperture 204. The force E can be calculated according to the following equation:

Equation (1): $E = R * L2/L1 * L4/L3$

[0042] Because L2 is much smaller than L1 in the illustrated embodiment, and L4 is smaller than L3, it is evident from Equation (1) that the force E (i.e. the effort force required from the operator) is significantly less than the resistance force R.

[0043] In other embodiments, the manual trip assembly 102 may include other mechanisms for amplifying the force applied on the handle 104 in order to overcome the resistance force R. For example, the manual trip assembly 102 may include one or more hydraulic or pneumatic actuators, pulleys, linkages, or other suitable mechanisms coupled between the handle 104 and the collar 110.

[0044] With reference to FIG. 6, in the illustrated embodiment, the recloser 10 includes first and second state sensors 210, 214 configured to detect the state of the manual trip assembly 102 (i.e. whether the handle 104 is actuated or unactuated) and the state of the VI assembly 18 (i.e. whether the contacts 66, 70 are open or closed). The state sensors 210, 214 may communicate this information to the controller of the recloser 10. In the illustrated embodiment, the state sensors 210, 214 are configured as electrical contacts (e.g., microswitches) responsive to movement of the shaft 134 and the output shaft 94, respectively. In other embodiments, any other types of sensors (e.g., Hall-effect sensors or the like) for determining the state of the manual trip assembly 102 and the VI assembly 18 may be used.

[0045] Exemplary operating sequences of the recloser 10 according to certain embodiments of the present disclosure will now be described.

[0046] With reference to FIG. 2, during operation, the controller of the recloser 10 may receive feedback from the sensor assembly 78 indicating that a fault has occurred. In response to this feedback, the controller may initiate a circuit breaking sequence. In the circuit breaking sequence, the controller automatically energizes the coil 99 of the electromagnetic actuator 98. The resultant magnetic field generated by the coil 99 moves the plunger 103 and the output shaft 94 in an opening direction (i.e. downward in the orientation of FIG. 2). This movement greatly reduces the magnetic holding force of the permanent magnet 100 on the plunger 103. For example, in some embodiments, the plunger 103 may have a resilient construction and retract inwardly and away from the permanent magnet 100 as the plunger 103 moves in the opening direction, thereby creating an air gap between the plunger 103 and the magnet 100. In other embodiments, the width of the plunger 103 may decrease in the opening direction to create an air gap between the plunger 103 and the magnet 100. In yet other embodiments, the plunger 103 may include one or more non-magnetic regions and/or a reduced volume of magnetic material

that may move into proximity with the permanent magnet 100 as the plunger 103 moves in the opening direction.

[0047] With the holding force of the permanent magnet 100 reduced, the spring 101 is able to overcome the holding force of the permanent magnet 100 and accelerate the output shaft 94 in the opening direction. As such, the coil 99 need only be energized momentarily to initiate movement of the output shaft 94, advantageously reducing the power drawn by the electromagnetic actuator 98 and minimizing heating of the coil 99.

[0048] The output shaft 94 moves the drive shaft 86 with it in the opening direction. As the drive shaft 86 moves in the opening direction, the encapsulated spring 90, which is compressed when the contacts 66, 70 are closed, begins to expand. The spring 90 thus initially permits the drive shaft 86 to move in the opening direction relative to the movable contact 66 and maintains the movable contact 66 in fixed electrical contact with the stationary contact 70. As the drive shaft 86 continues to move and accelerate in the opening direction under the influence of the spring 101, the spring 90 reaches a fully expanded state. When the spring 90 reaches its fully expanded state, the downward movement of the drive shaft 86 is abruptly transferred to the movable contact 66. This quickly separates the movable contact 66 from the stationary contact 70 and reduces arcing that may occur upon separating the contacts 66, 70. By quickly separating the contacts 66, 70, degradation of contacts 66, 70 due to arcing is reduced, and the reliability of the VI assembly 18 is improved.

[0049] The controller may then receive feedback from the sensor assembly 78 indicating that the fault has been cleared and initiate a reclosing sequence. In additional and/or alternative embodiments, the controller may initiate the reclosing sequence after waiting a predetermined time period after the fault was originally detected, or in response to receiving a signal from an external controller commanding the controller to initiate the reclosing sequence. In the reclosing sequence, the controller energizes the coil 99 in an opposite current direction. The resultant magnetic field generated by the coil 99 moves the output shaft 94 (and with it, the drive shaft 86 and the movable contact 66) in a closing direction (i.e. upward in the orientation of FIG. 2).

[0050] The movable contact 66 comes into contact with the fixed contact 70, restoring a conductive path between the terminals 34, 38. The output shaft 94 and drive shaft 86 continue to

move in the closing direction, compressing each of the springs 90, 101 to preload the springs 90, 101 for a subsequent circuit breaking sequence. As the output shaft 94 approaches the end of its travel, the plunger 103 of electromagnetic actuator 98 is influenced by the permanent magnet 100, which latches the plunger 103 in its starting position. The coil 99 may then be de-energized. In some embodiments, the coil 99 may be de-energized a predetermined time period after the contacts 66, 70 are closed. This delay may inhibit the movable contact 66 from rebounding back to the open position.

[0051] In some circumstances, an operator may opt to manually initiate a circuit breaking operation to open the contacts 66, 70 using the manual trip assembly 102. To do so, the operator may apply a force E (FIG. 10) to the handle 104, which is conveniently accessible from the exterior of the housing assembly 14 (FIG. 1). In some embodiments, the handle 104 may be a contrasting color from the housing assembly 14. For example, the handle 104 may be a high-visibility color, such as yellow, to allow the handle 104 to be easily visible to the operator.

[0052] As the operator applies the force E, the handle 104, the shaft 134, and the link 142 pivot from an initial or unactuated state, illustrated in FIG. 7, about the first rotational axis 105 generally in the direction of arrow 218. This causes the yoke 106 to pivot downward about the third rotational axis 203, such that the projection 206 bears against the collar 110 on the output shaft 94 (FIG. 10). As discussed above, the compound lever action of the handle 104, link 142, and yoke 106 amplifies the force E. The first end 106a of the yoke 106 moves downward, and the projection 206 bears against the collar 110 on the output shaft 94 with a force sufficient to overcome the holding force of the permanent magnet 100. The drive shaft 94 then begins to move downward in the direction of arrow 207.

[0053] As the operator pivots the handle 104 in the direction of arrow 218, the lost motion member 146 is moved upward by the link 142, and the third pin 176 travels along the slot 182. As such, the actuating member 150 and the plunger 158 remains stationary during an initial travel range of the handle 104. The slot 182 is sized such that the actuating member 150 remains stationary until the handle 104 reaches an intermediate position (FIG. 8). In the illustrated embodiment, the initial travel range is about 27 degrees (i.e. the handle 104 rotates 27 degrees before the third pin 176 reaches the end of the slot 182). In other embodiments, the slot 182 may

be configured to provide different degrees of lost motion to suit a particular configuration of the recloser 10.

[0054] Within the initial travel range of the handle 104, the downward movement of the drive shaft 94 reduces the holding force of the permanent magnet 100 on the plunger 103 as described above. With the holding force of the permanent magnet 100 reduced, the spring 101 is able to overcome the holding force of the permanent magnet 100 and accelerate the output shaft 94 in the opening direction, opening the contacts 66, 70 in the same manner as the circuit breaking sequence described above.

[0055] The lost motion member 146 delays movement of the blocking plunger 158 from the retracted position to the extended position until the contacts 66, 70 have been opened and the collar 110 of the output shaft 94 has moved below the blocking plunger 158. Once the handle 104 has reached the intermediate position and the contacts 66, 70 have been opened, the operator continues to rotate the handle 104 in the direction of arrow 218. With the third pin 176 engaged with the end of the slot 182, the continued rotation of the link 142 with the handle 104 and resultant upward movement of the lost motion member 146 pivots the actuating member 150 about the fourth pin 192. The actuating member 150 in turn drives the blocking plunger 158 forward toward the extended position and into the path of the collar 110 (FIG. 9). With the blocking plunger 158 in the extended position, the blocking plunger 158 is engageable with the output shaft 94 to lock the movable contact 66 in its open position, thereby preventing the electromagnetic actuator 98 from reclosing the contacts 66, 70.

[0056] In addition to the mechanical interlock provided by the blocking plunger 158, in some embodiments, the controller may determine that the manual trip assembly 102 has been actuated based on feedback from the state sensors 210, 214 (FIG. 6). In such embodiments, the state sensors 210, 214 and the controller may act as an electronic interlock assembly to prevent actuation of the electromagnetic actuator 98. For example, the controller may initiate an electronic interlock function to prevent the electromagnetic actuator 98 from reclosing the contacts 66, 70 until the controller determines that the handle 104 of the manual trip assembly 102 has been returned to its initial or unactuated position. By including both electronic and mechanical interlocks, the recloser 10 may be more safely controlled and serviced.

[0057] To disengage the interlock assembly 144, the operator pivots the handle 104 in the opposite direction, returning the plunger 158 to its retracted position (FIGS. 7-8) and lifting the collar 110. Once the controller determines that the handle 104 has been fully returned to its initial or unactuated position (e.g., via the state sensor 210), the controller may disable the electrical interlock. The contacts 66, 70 can then be reclosed via the electromagnetic actuator 98 in the manner described above.

[0058] Although the invention has been described in detail with reference to certain preferred embodiments, variations and modifications exist within the scope and spirit of one or more independent aspects of the invention as described.

[0059] Various features and advantages of the invention are set forth in the following claims.

CLAIMS

What is claimed is:

1. A switchgear apparatus configured for operation at voltages up to 72.5 kV, comprising:

a vacuum interrupter assembly having a fixed contact and a movable contact configured to move relative to the fixed contact between a closed position in which the movable contact is in contact with the fixed contact and an open position in which the movable contact is spaced from the fixed contact;

an electromagnetic actuator configured to move the movable contact between the open position and the closed position;

a manual trip assembly movable from an initial position to an actuated position to move the movable contact from the closed position to the open position; and

a mechanical interlock assembly configured to prevent the movable contact from moving from the open position to the closed position when the manual trip assembly is in the actuated position.

2. The switchgear apparatus of claim 1, wherein the mechanical interlock assembly includes a blocking plunger.

3. The switchgear apparatus of claim 2, wherein the electromagnetic actuator includes an output shaft, and wherein the blocking plunger is configured to inhibit movement of the output shaft to prevent the movable contact from moving from the open position to the closed position.

4. The switchgear apparatus of claim 2, wherein the mechanical interlock assembly includes a handle, and wherein the blocking plunger is movable between a retracted position and an extended position in response to rotation of the handle.

5. The switchgear apparatus of claim 4, wherein the handle is rotatable between a first position and a second position, wherein the handle is coupled to the blocking plunger via a lost motion member such that the blocking plunger remains stationary when the handle is rotated

between the first position and an intermediate position between the first position and the second position.

6. The switchgear apparatus of claim 1, wherein the manual trip assembly includes a first lever and a second lever coupled to the first lever such that the first and second lever provide a compound mechanical advantage.

7. The switchgear apparatus of claim 1, wherein the manual trip assembly includes:

a support bracket,

a handle,

a shaft coupled for co-rotation with the handle relative to the support bracket about a first rotational axis,

a link coupled for co-rotation with the shaft about the first rotational axis, and

a yoke including a first end pivotally coupled to the link and a second end pivotally coupled to the support bracket.

8. The switchgear apparatus of claim 7, wherein the first end of the yoke is pivotally coupled to a first end of the link, and wherein the mechanical interlock assembly is coupled to a second end of the link.

9. The switchgear apparatus of claim 1, further comprising an electronic interlock assembly configured to prevent actuation of the electromagnetic actuator when the manual trip assembly is in the actuated position.

10. A switchgear apparatus configured for operation at voltages up to 72.5 kV, comprising:

a vacuum interrupter assembly having a fixed contact and a movable contact configured to move relative to the fixed contact between a closed position in which the movable contact is in contact with the fixed contact and an open position in which the movable contact is spaced from the fixed contact;

an electromagnetic actuator configured to move the movable contact between the open position and the closed position; and

a manual trip assembly movable from an initial position to an actuated position to move the movable contact from the closed position to the open position,

wherein the manual trip assembly includes a first lever and a second lever coupled to the first lever such that the first and second lever provide a compound mechanical advantage.

11. The switchgear apparatus of claim 10, wherein the manual trip assembly further includes:

a support bracket,

a handle, and

a shaft coupled for co-rotation with the handle relative to the support bracket about a first rotational axis.

12. The switchgear apparatus of claim 11, wherein the manual trip assembly further includes:

a link coupled for co-rotation with the shaft about the first rotational axis, and

a yoke including a first end pivotally coupled to the link and a second end pivotally coupled to the support bracket.

13. The switchgear apparatus of claim 12, wherein the first end of the yoke is pivotally coupled to a first end of the link.

14. The switchgear apparatus of claim 13, further comprising a mechanical interlock assembly configured to prevent the movable contact from moving from the open position to the closed position when the manual trip assembly is in the actuated position.

15. The switchgear apparatus of claim 14, wherein the mechanical interlock assembly is coupled to a second end of the link.

16. The switchgear apparatus of claim 14, wherein the mechanical interlock assembly includes a blocking plunger.

17. The switchgear apparatus of claim 16, wherein the electromagnetic actuator includes an output shaft, and wherein the blocking plunger is configured to inhibit movement of the output

shaft to prevent the movable contact from moving from the open position to the closed position, and wherein the blocking plunger is movable between a retracted position and an extended position in response to rotation of the handle.

18. The switchgear apparatus of claim 17, wherein the handle is rotatable between a first position and a second position, wherein the handle is coupled to the blocking plunger via a lost motion member such that the blocking plunger remains stationary when the handle is rotated between the first position and an intermediate position between the first position and the second position.

19. The switchgear apparatus of claim 11, further comprising a housing enclosing the vacuum interrupter assembly and the electromagnetic actuator, wherein the handle is positioned along an exterior side of the housing, and wherein the handle includes a high-visibility color that contrasts with the housing.

20. The switchgear apparatus of claim 10, further comprising an electronic interlock assembly, wherein the electronic interlock assembly is configured to prevent actuation of the electromagnetic actuator when the manual trip assembly is in the actuated position.

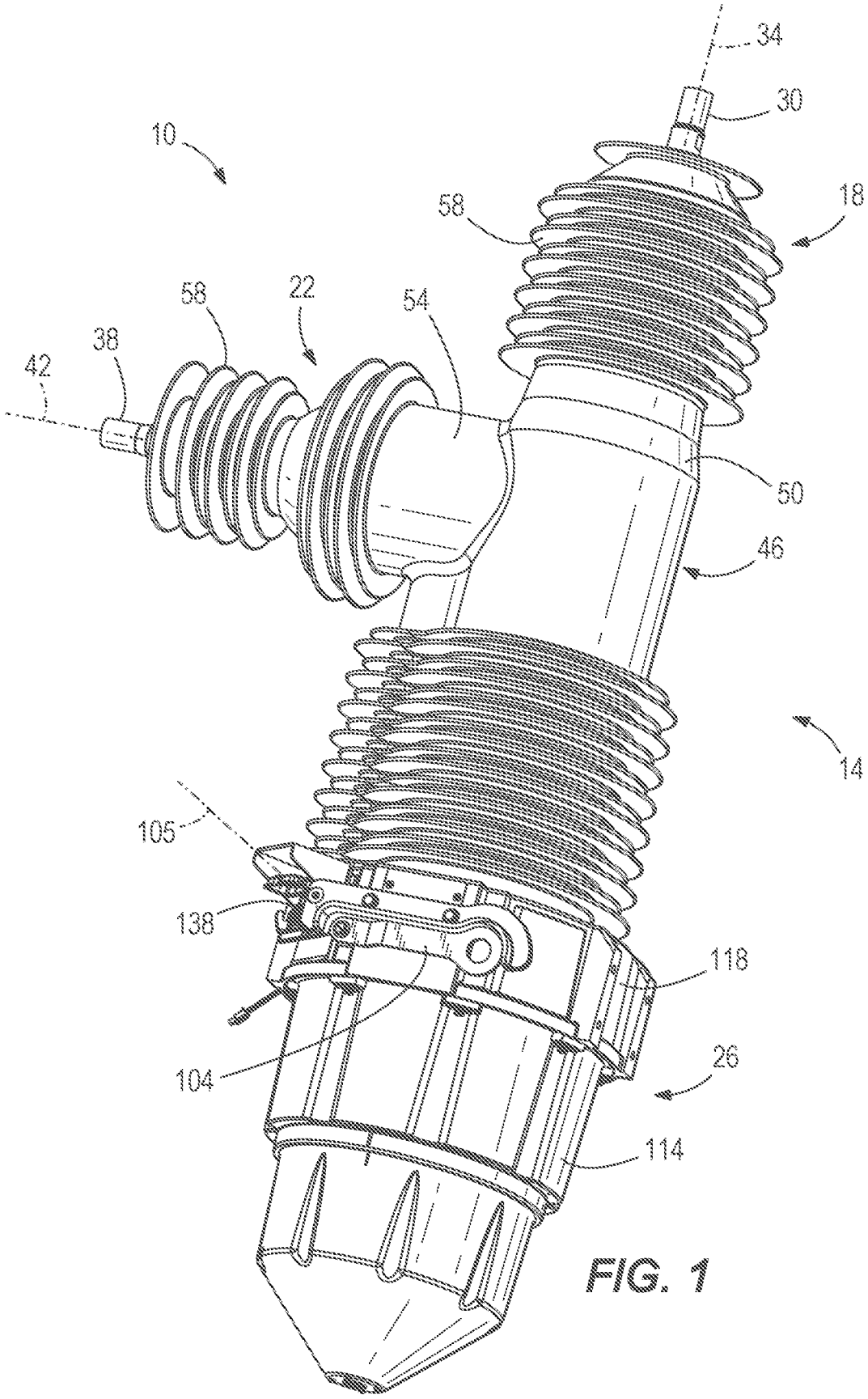


FIG. 1

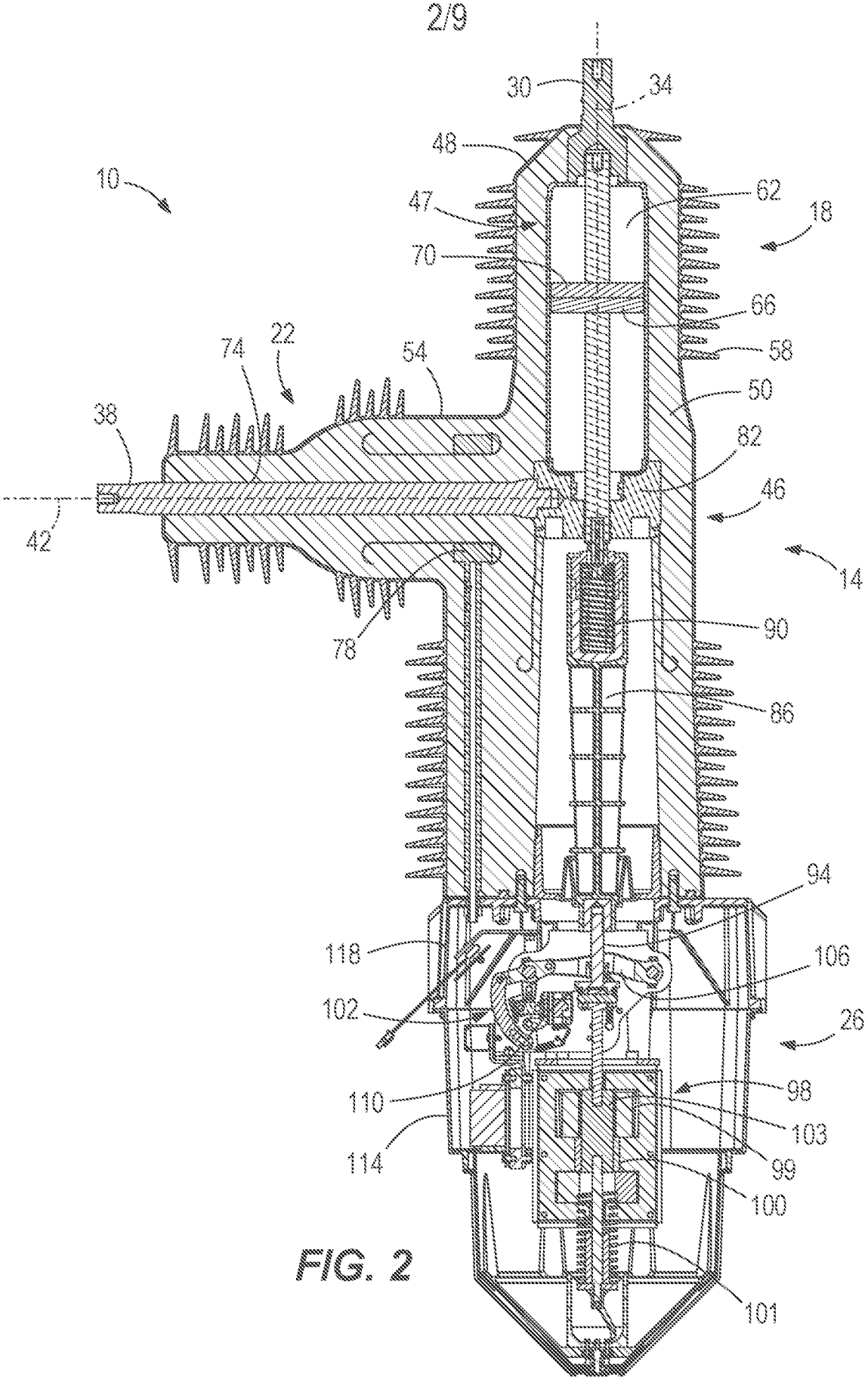

30
34
48
10
47
62
18
70
66
74
22
54
58
50
38
82
46
42
14
78
90
86
94
118
106
102
26
110
98
103
114
99
100
101

FIG. 2

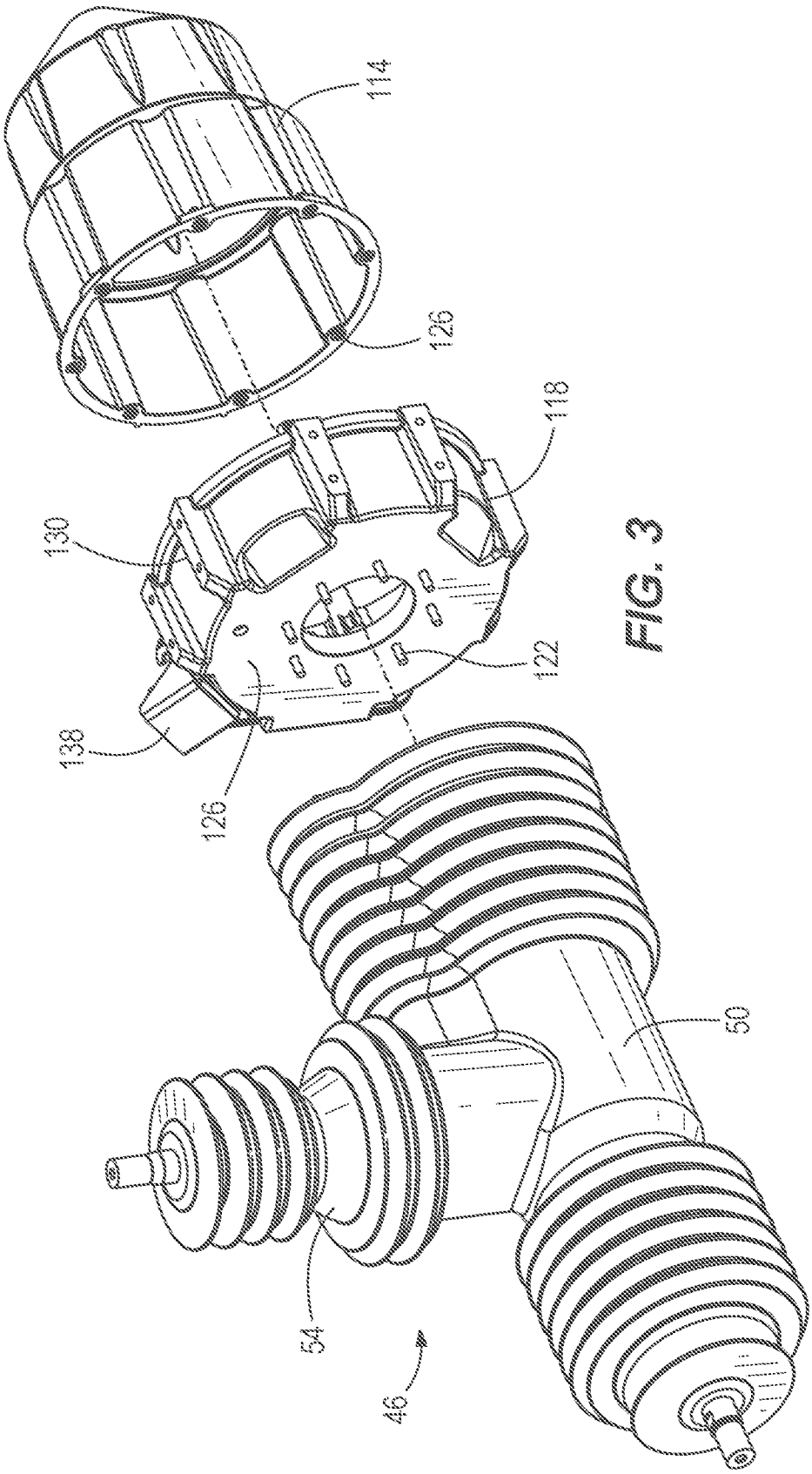


FIG. 3

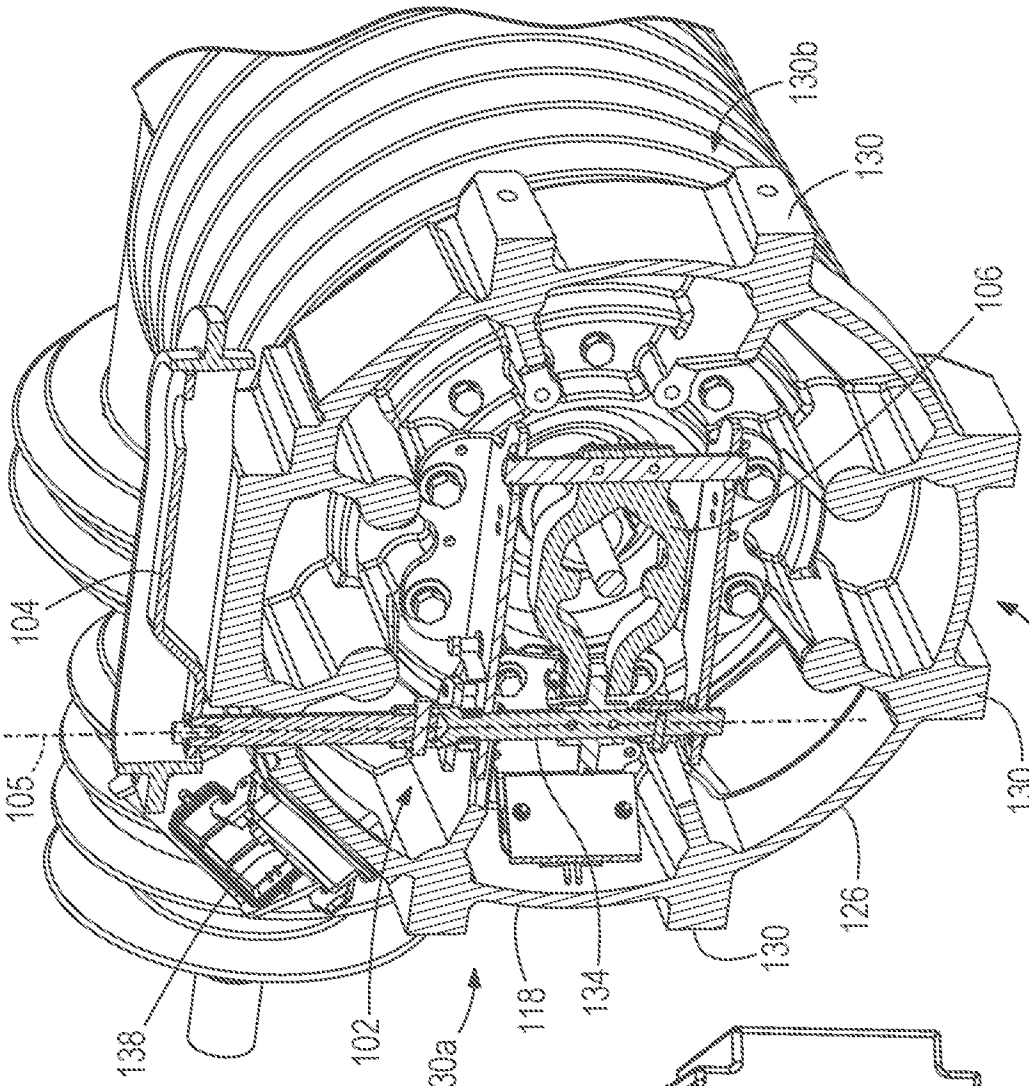

130b
130
106
104
105
130c
130
126
130
138
102
130a
118
134

FIG. 5

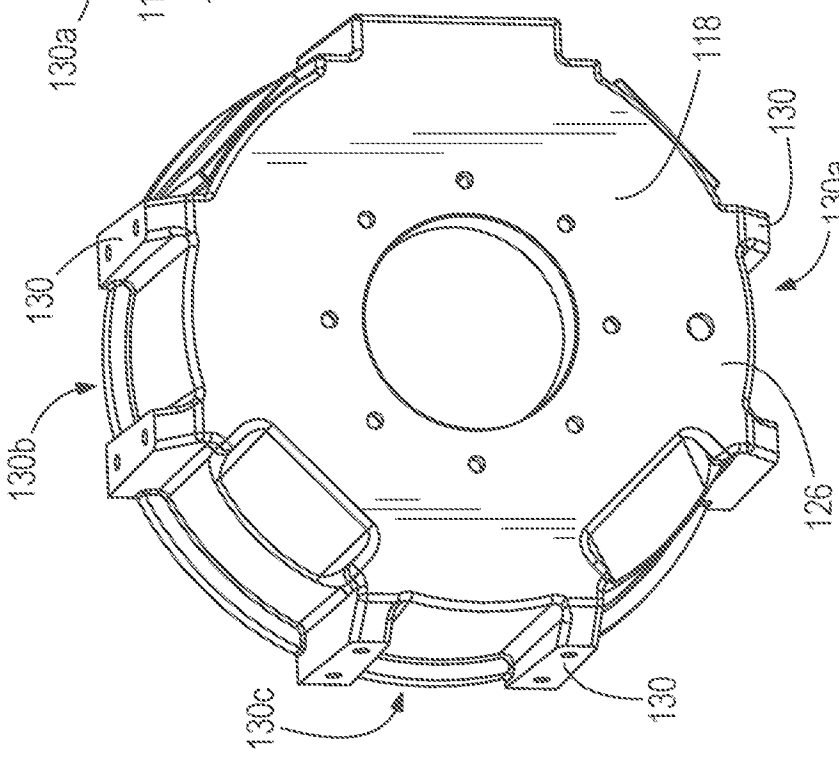

118
130
130a
130
130b
126
130
130c

FIG. 4

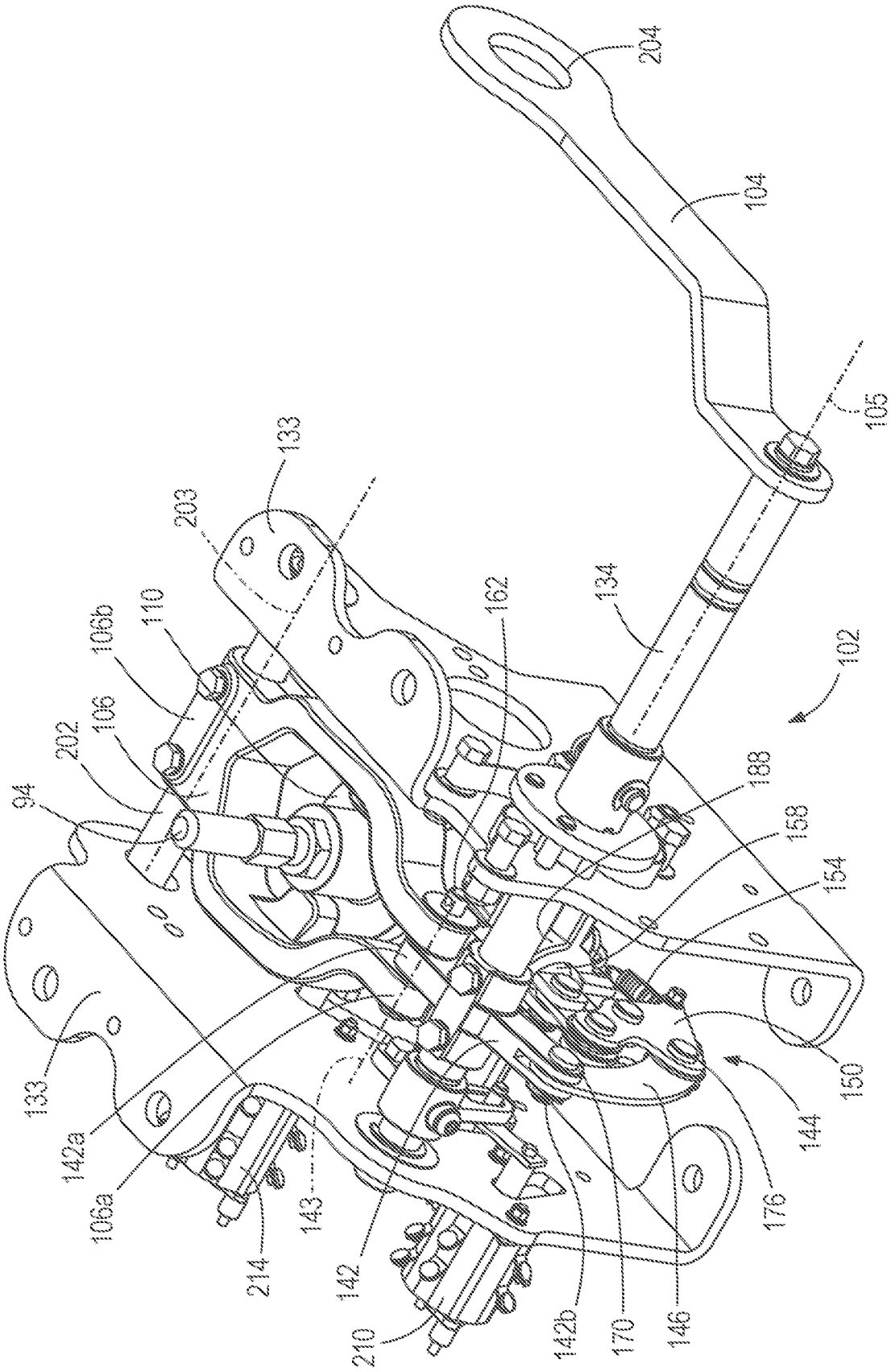

204
104
105
133
203
110
106b
162
134
102
202
106
188
94
158
154
133
142a
106a
214
143
142
210
142b
170
146
144
150
176

FIG. 6

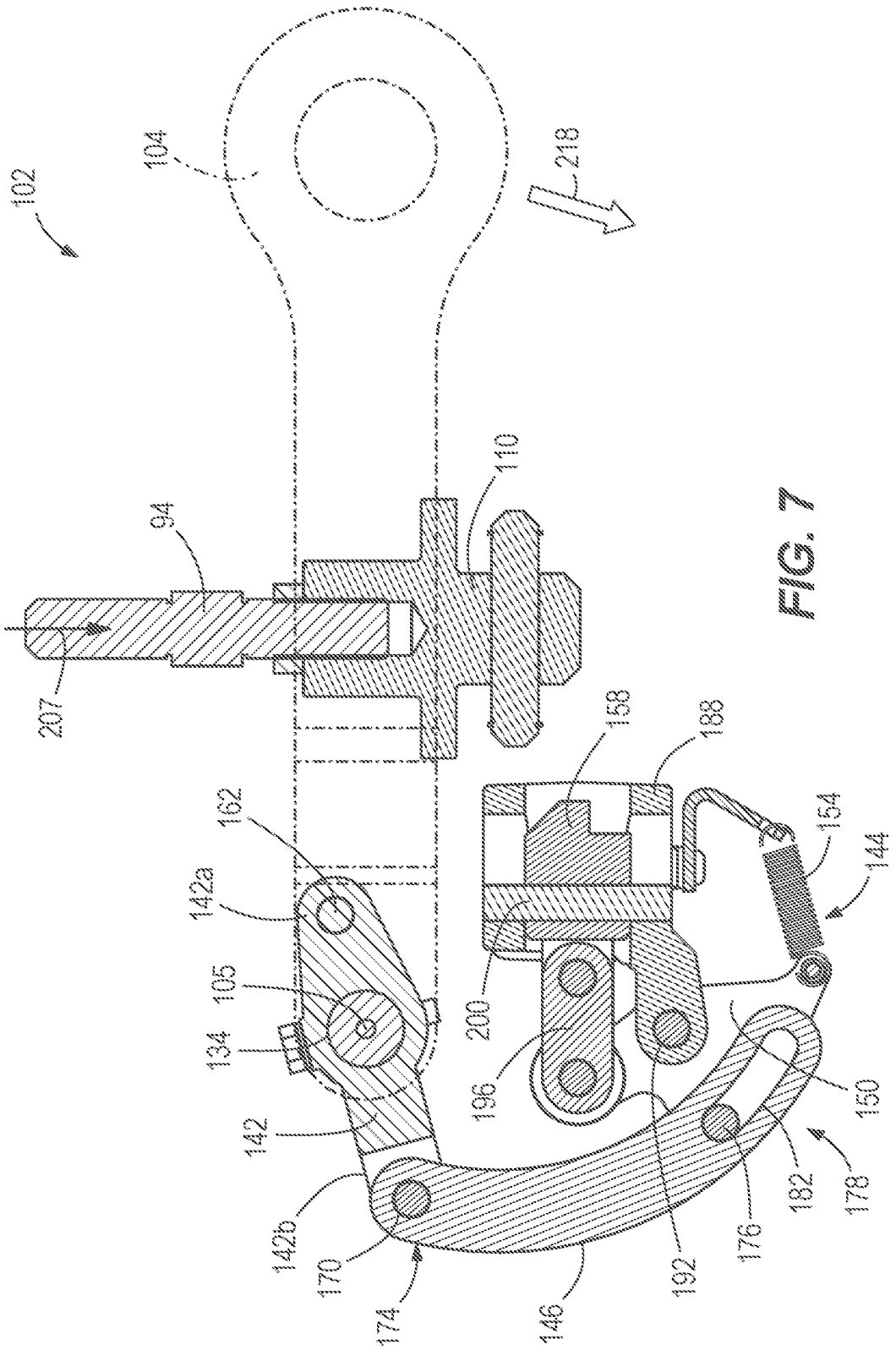

102
104
218
94
110
207
158
188
162
154
144
142a
105
134
200
196
150
142
182
178
142b
170
176
174
192
146

FIG. 7

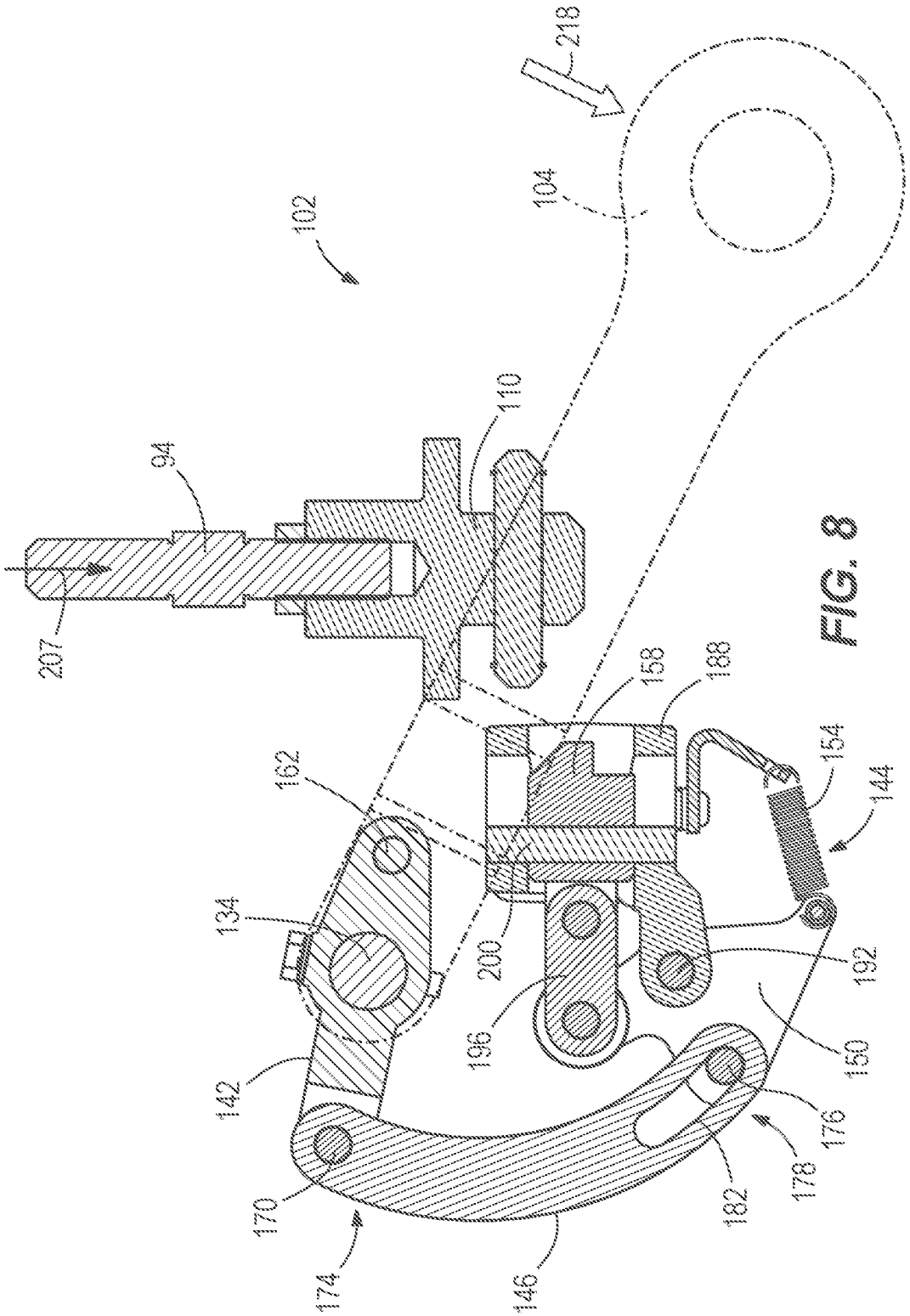

218
104
102
110
94
207
158
188
154
144
162
134
200
192
196
150
142
176
178
170
182
174
146

FIG. 8

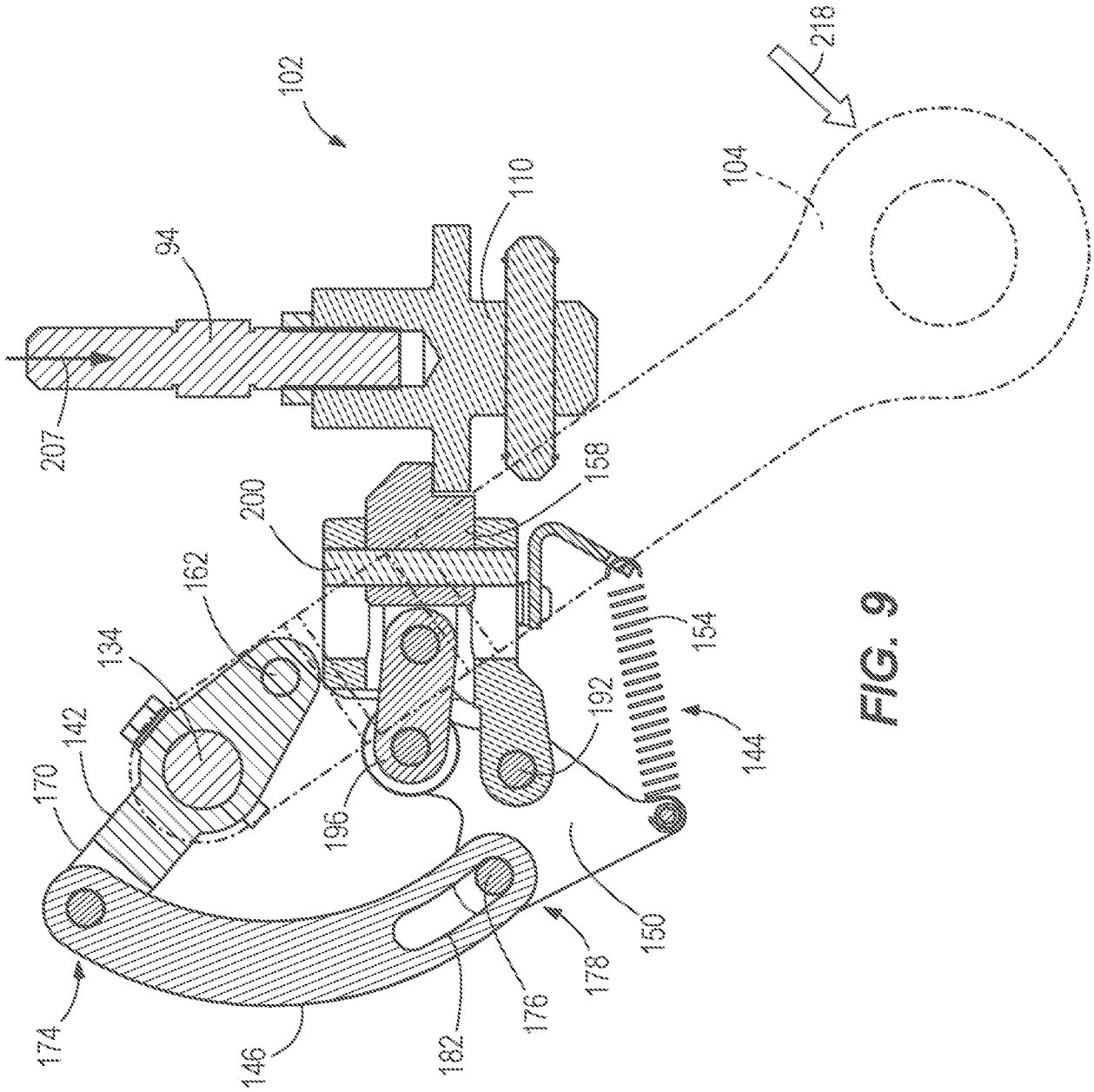

102
218
104
110
94
207
158
200
162
134
154
192
142
144
170
196
150
178
176
174
146
182

FIG. 9

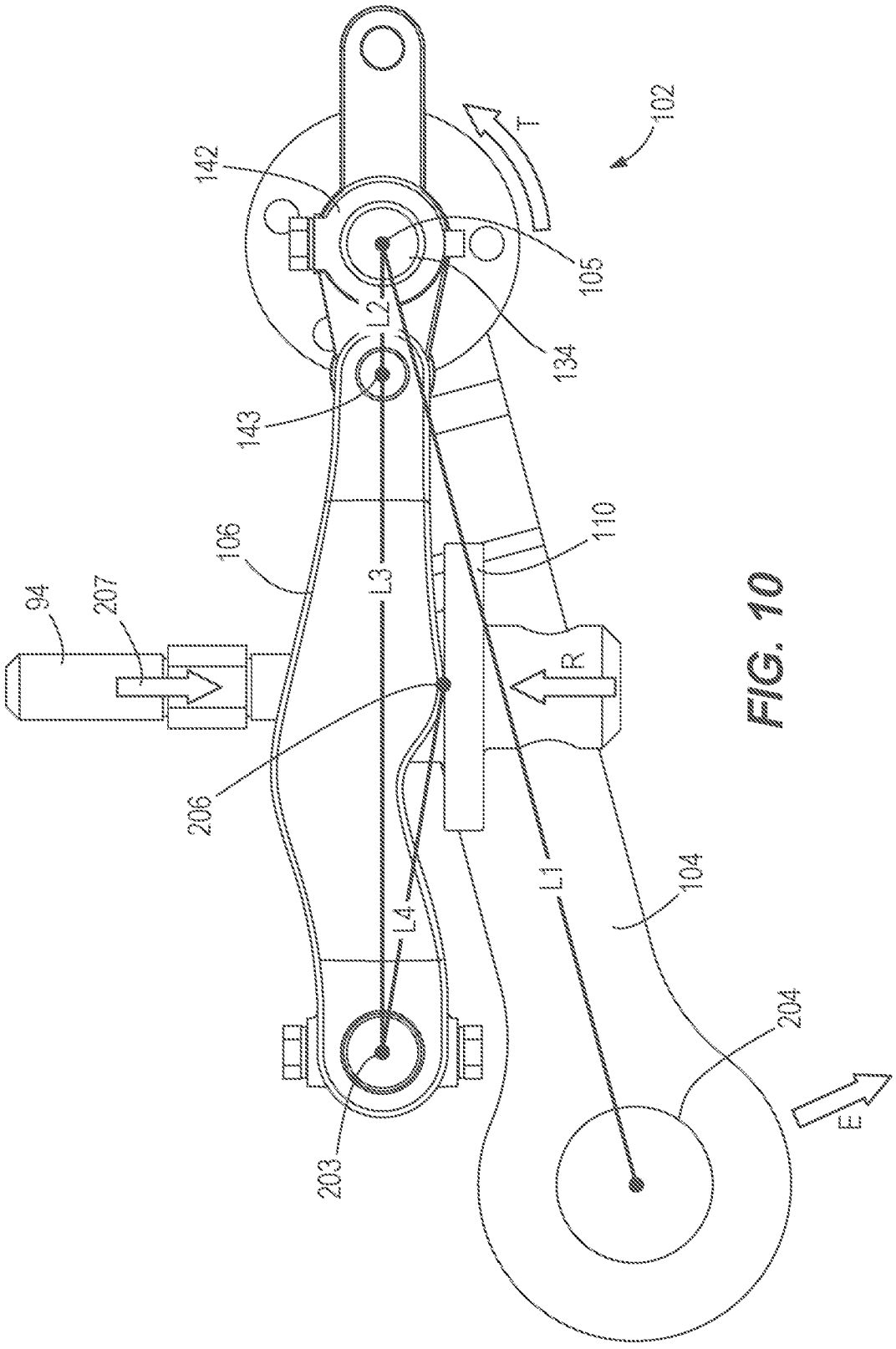


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2020/029850

A. CLASSIFICATION OF SUBJECT MATTER

H01H 33/664(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01H 33/664; H01H 3/00; H01H 33/12; H01H 33/66; H01H 3302; H01H 3342; H01H 71/10; H01H 9/38

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: switchgear, mechanical interlock, manual trip, lever

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2013-0187732 A1 (SCOTT A. BULLOCK et al.) 25 July 2013 See paragraphs [0003], [0027], [0032], [0055]-[0068] and figures 1A, 2-6, 9-10.	1-20
Y	US 6198062 B1 (BRIAN D. MATHER et al.) 06 March 2001 See column 8, lines 20-24, column 11, lines 1-3, column 15, lines 5-26 and figures 5-6, 11-17.	1-20
A	US 4124790 A (DAVID G. KUMBERA et al.) 07 November 1978 See claims 1-14 and figure figures 1-11.	1-20
A	US 2010-0089874 A1 (AYUMU MORITA et al.) 15 April 2010 See claims 1-13 and figures 1-20.	1-20
A	US 4283610 A (KAZUO H. DATE et al.) 11 August 1981 See claims 1-9 and figures 1-15.	1-20

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 August 2020 (14.08.2020)	**14 August 2020 (14.08.2020)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea
Facsimile No. +82-42-481-8578

Authorized officer
KANG MIN JEONG
Telephone No. +82-42-481-8131

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2020/029850

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2013-0187732 A1	25/07/2013	CA 2785215 A1	23/07/2013
		CA 2785215 C	20/10/2015
		MX 2014008848 A	14/10/2014
		US 8729416 B2	20/05/2014
		WO 2013-112524 A1	01/08/2013
US 6198062 B1	06/03/2001	CA 2272200 A1	17/11/2000
		CA 2272200 C	17/08/2004
US 4124790 A	07/11/1978	US 4168414 A	18/09/1979
US 2010-0089874 A1	15/04/2010	CN 101728770 A	09/06/2010
		EP 2178097 A2	21/04/2010
		EP 2178097 A3	16/11/2016
		JP 2010-098776 A	30/04/2010
		JP 5070178 B2	07/11/2012
		KR 10-1285751 B1	19/07/2013
		KR 10-2010-0041680 A	22/04/2010
		SG 161168 A1	27/05/2010
		TW 201025395 A	01/07/2010
		TW I419191 B	11/12/2013
US 4283610 A	11/08/1981	None	